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What is the effect of macroeconomic news on the VIX?

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Contents

Abstract

This study investigates the impact of different macroeconomic variables on the VIX index. It introduces the index itself, and the global events which have affected it severely. The investigating model builds on empirical observations and expands, firstly to see if an already existing model is significant in other periods of time, and secondly what other variables might have strong explanatory power. The results reveal that the market regard the actions from the Federal Open Market Committee as very important for its outlook on the economy.

1. Introduction

This paper investigates how traditional macroeconomic indicators such as CPI, PPI, GDP, CCI and the employment situation report influence the VIX. It also expands current research on the VIX by investigating the effect of important financial crisis tools and other news[1]. Specifically, the paper examines the influence of FOMC meetings, Quantitative Easing report releases, Federal Reserve's securities held outright, total asset level and 10-year US treasury yield.

The VIX is increasingly important and is often commented by financial media when discussing uncertainty or "fear" in financial markets. The VIX can be viewed as a benchmark of expected volatility implied by the market, or derivatives markets to be specific. The expected volatility measure is a key component of derivatives pricing and the VIX is an index of this measure from a set of selected derivatives. Analysing the behaviour of the VIX could therefore reveal what affects the perceived uncertainty of financial markets.

The paper starts with a thorough introduction to the index itself, before short explanations of significant variables are presented. A theory and methodology section explain the research process of the paper and gives a detailed explanation of the different theories and assumptions the results rely on. Before running the regressions, the models are tested and assessed in order to make sure our results are reliable. The economic rationale behind the final conclusion of the results builds around two hypotheses that is drawn from the research results, and goes as follows:

[1] Where news is defined as new information, not only in the form of announcements, but also as changes in observations

1. VIX is affected by the fundamental macroeconomic indicators employment, CPI, PPI and FOMC

2. The U.S central bank's open market operations after the 2008 financial crisis dominated traditional macroeconomic news in influencing implied market volatility.

Finally, our conclusion is presented and a topic for further research is suggested.

2. Literature Review

Testing the effects of different announcements and news publications on market volatility has been performed several times with different approaches and methods. The more general way is to test the effect that macroeconomic announcements from central banks or common macroeconomic indicators have on the implied volatility, before and after the announcements. Measuring the impact on market volatility requires a good measure of volatility, most research tend to the easily available VIX index for the S&P 500, or some equivalent measure for another market. These measures are of implied volatility, and are not measures of volatility itself, but rather the expected volatility of the underlying market index or stock. Other papers such as Antulio N. Bomfims "Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market" use conditional variance. Bekaert, Hoerova & Lo Duca (2013) has an interesting approach where they divide the implied volatility represented by the VIX into two components, risk aversion and expected stock market volatility. This way they can test the links between different monetary policy stances and investor behaviour.

Nikkinen & Sahlström (2004) focuses on the impact of the scheduled Federal Open Market Committee (FOMC) and the scheduled macroeconomic news releases on stock market uncertainty. The macroeconomic reports they chose were the employment, producer price index (PPI) and consumer price index (CPI). The behaviour of the implied volatility of the VIX is investigated around the FOMC meeting days and on the announcement days of the macroeconomic reports. Gospodinov & Jamali (2012) studies it from another angle, by examine the effects of expected and unexpected changes in Federal funds target rate, while Donders & Vorst (1996) on the other hand focuses on the impact from firm specific news; by studying the behaviour of implied volatility of call options around announcement days of scheduled news. Shaikh & Padhi (2013) used the same base macrovariables

as Nikkinen & Sahlström, but their research was set in Indian markets so the FOMC was naturally not in their model, instead they included variables which were natural for the Indian market. Krieger, Mauck & Vazquez (2015) looks at the federal funds rates, which is one of the more important measures for the economy and is together with the target rate a key measure for how the respective central bank looks at the condition of the economy of the country. Krieger et al tried to examine the responses of U.S. VIX and German VDAX implied volatility indices to the announcement of interest rate policy decisions by the FOMC.

Most of the relevant research on this topic is done on the period 1996 to early 2000. With Krieger et al being the latest paper which looks at 1999-2012 and Kearney & Lombra (2004) looks at the oldest, and maybe most comprehensive timeframe with as early as 1986 until 2002. Most papers therefor hit on the 2001 IT bubble, but few papers include the 2008 financial crisis. The VIX index has been around since 1993, but was not changed to measure the broader S&P 500 from S&P 100 until 2004. It would be very interesting to look at the time after the financial crisis of 2008, since there is little research done during this time. Including more recent data, would make it possible to compare several financial crisis occurrences and its previous and following years.

In efficient markets you expect that stock prices react immediately on new information. Patell & Wolfson (1984) investigated this and found that prices reacted within minutes, but disturbances in the stock price variance persisted for hours. To model variance you often use autoregressive conditional heteroscedasticity (ARCH) models, introduced by Engle (1982), or generalized ARCH (GARCH) models which were introduced by Nelson (1990). One important feature of these models is that in periods of high volatility are assumed to be followed by large movements in prices. This contradicts the efficient market hypothesis imposed by Eugene Fama (1969), which expects uncertainty to decrease after new information is revealed. However, Nikkinen & Sahlström saw, by using ARCH and GARCH models, that implied volatility decreased after news announcements.

Fleming & Remolona (1999) and Donders & Vorst found that macroeconomic announcements not only have an impact on realised volatility at the announcement day, but also have an impact on the market's future expected volatility – both before

and after the announcement day! The market's expectations of future volatility are reflected through the implied volatility of options prices. According to Donders & Vorst the implied volatility rose in the pre-announcement period, had its peak at the moment the news was released, and sharply fell in the aftermath – again, uncertainty decreased after new information, as suggested by the EMH, but the increase before the news release still contradicts the hypothesis.

Nikkinen & Sahlström also found that uncertainty increased prior to the announcement. This suggests that the market is unsure about the content of the announcement and that this uncertainty is affecting the implied volatility substantially. Though, they do not consider what kind of content, and if the news is as expected and not. Gospodinov & Jamali consider this. They add the surprising element to the study, if the outcome from FOMC's meeting is as expected or not. By obtaining futures contracts from the FED they can control for market's expectations. Their findings are interesting; the expected change in FED's rate does not significantly affect the volatility of the market, while a surprising change in monetary policy have a significant increasingly affect. This might suggest that the rising uncertainty that Nikkinen & Sahlström and Fleming & Remolona find is due to an unexpected outcome of the FOMC's meetings.

Shaikh & Padhi expands on the existing research with their investigations of several macroeconomic indicators effect on the Indian VIX. The RBI (Reserve Bank of India) monetary policy statements, the consumer price index, wholesale price index, index of industrial production, the employment rate and gross domestic product (GDP growth rate) are introduced as dummy variables in their model and measures their impact separately. This is in contrast to the study of Nikkinen and Sahlström who treats all macroeconomic announcements as the same. However, even though their research is based on the same macro-variables, the findings of Shaikh & Padhi and Nikkinen & Sahlström are not the same. The latter found that the FOMC meetings were highly significant, while employment report had the largest impact of the macro-variables. But what the results also revealed were that PPI and CPI individually did not have a significant affection, whereas the two together had. This suggests that investors regard the information content of the two as a whole significant. This may be due to the fact that the content is similar. The results from Shaikh & Padhi on the other hand showed that all variables were significant,

individually as well as jointly. This might suggest that there are different drivers for the Indian VIX than for the US. Maybe not surprising, but nevertheless a valuable discovery.

Shaikh & Padhi finds that especially announcements related to the GDP had a larger effect on the Indian VIX. Their research shows that for most news announcements on macroeconomic indicators, the VIX increases before and up until the announcement, but returns to normal levels after the announcements, this is explained by the removal of uncertainty in the market. The opposite effect is found in monthly inflation rates announcements where the VIX increases after scheduled announcements. They therefore argue that there is a predictable pattern in the Indian VIX related to scheduled announcements, and they suggest opening for more financial instruments based on the Indian VIX to further improve the liquidity and transparency in the market.

Krieger et al further builds on the research from other countries than the US by looking at the difference and similarities between the effect of announcements in US and Europe. Their paper reveals that the effect of interest rate announcements in the US have a negative effect on the VIX, uncertainty is removed, but in Europe it is only removed if the announcement was in line with the market expectations. There is also a big difference in how the two volatility indexes respond to the other countries announcements, while the European VDAX responds to US interest rate announcements by declining, the VIX does not get effected by the European central bank (ECB) interest rate announcements. This has important implications for the ECB as they must consider other countries monetary policy when resolving domestic uncertainty, especially announcements from the US. FOMC announcements also seem to impact both uncertainty and risk taking in the market, by decreasing uncertainty and risk aversion, but the spillover effect to Europe is only short lived and does not seem to impact risk aversion.

3. Data

Our dataset spans from January 1990 to December 2016. It will be divided up in samples according to our analysis and hypothesis. It is explained in further detail below.

3.1 The Chicago Board Options Exchange Volatility Index (VIX)

The VIX index is considered one of the most important measures of market volatility expectations and has been nicknamed the “Fear index” (Whaley, The Investor Fear Gauge, 2000). The Chicago Board Options Exchange (CBOE) first created the index back in 1993, as an index over 30-day volatility of the Standard & Poor’s (S&P) 100 Index options prices, but in 2004 the underlying index was changed to S&P 500 to better reflect the current market structure and development. Back when the index was first created the OEX (S&P 100 Index Options ticker) was 75% of the total index option volume (Whaley, Derivatives on Market Volatility: Hedging Tools Long Overdue, 1993), but this changed over the years as SPX (S&P 500 index options ticker) replaced OEX as the most traded option. The marked for options, and especially out-of-the-money options has increased substantially over the years, and CBOE also increased the amount of options included in the calculations of the VIX (CBOE White Paper, 2018) Trading volume and debt is important to ensure correct and efficient prices, with lower chance of manipulation.

3.1.1 Uses

The VIX is most appreaciated for two main features. First of all it makes it possible to measure market anxiety almost in real time, and compare it to other historical levels to get a better understanding of the different market conditions and sentiment. Secondly, it opens up the possibility to write futures and options contract on expected volatility. This has made trading volatility much easier then the old straddle and strangle teqniques and over past 15 years there has been a large increase in trading of these products, mainly for risk management and hedging purposes, but speculation in volatily has become quite common.

3.1.2 The Fear Index

The VIX index has been nicked named “The Fear Index” or “The Fear Gauge” as it is believed that the index is a measure of how much the market thinks the S&P 500 will move. If people are afraid of risky events occurring that will affect the index valuation, option prices will increase as the volatility measure increase, there will also be a demand effect on the options as the SPX market is dominated by hedgers and as investors get more afraid, they will buy more options. VIX is an

indicator that reflects the price of portfolio insurance (Whaley, Understanding VIX, 2008).

3.1.3 OEX or SPX

In our study we have chosen not to differentiate between the two different methodologies and underlying index change of the VIX calculations. This is due to the high share of equal contents and shared characteristics. Both the S&P 100 and the S&P 500 are market capitalization-weighted stock indexes. As of October 31, 2008, all S&P 100 stocks are contained within the S&P 500 index portfolio and account for 62.46% of the S&P 500's total market capitalization. The 34 highest market cap stocks in the S&P 500 are also the 34 highest market cap stocks in the S&P 100. Of the 100 highest market cap stocks in the S&P 500, 70 are from the S&P 100 (Whaley, Understanding VIX, 2008). This is also proved by comparing mean returns and standard deviations, which also are almost identical.

3.1.4 VIX Analysis: 1990-2003

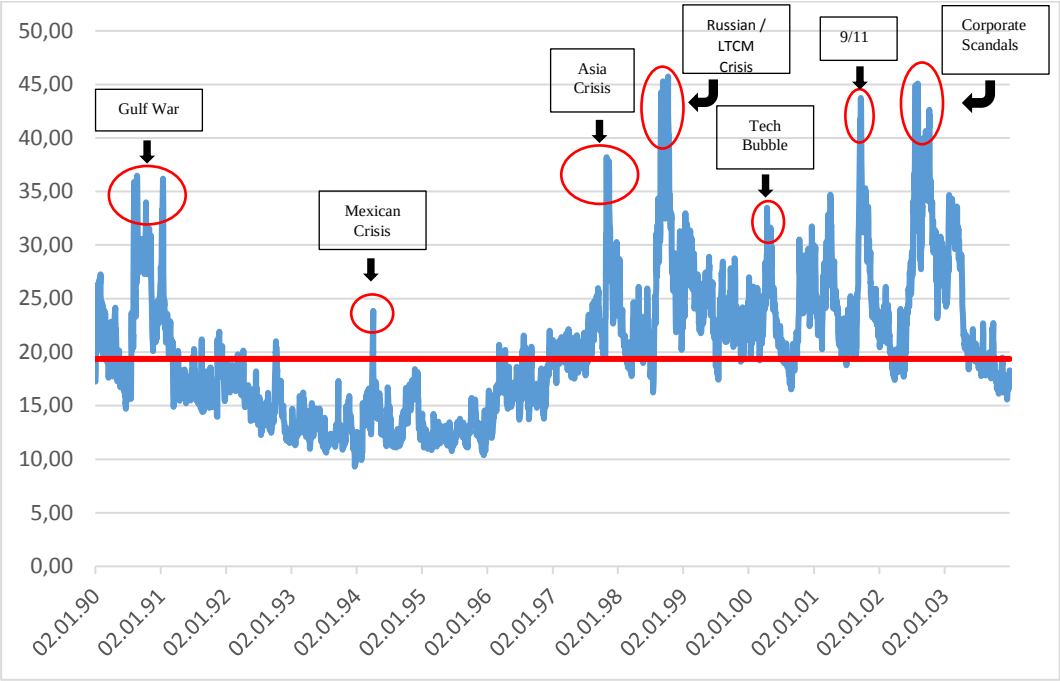


Figure 1: VIX Based on S&P 100

The first period from 1990-2003 the VIX index had a mean of 20.2 with maximum value of 45.74 and minimum value of 9.31. The period saw considerable financial distress with 7 larger financial crises. Beginning with Operation Desert Storm, or the Gulf War from 1990-1991, when an US lead international coalition attacked Iraq. After which the VIX entered a period of below average implied volatility, only

interrupted by the Pesos crisis in Mexico, after their central bank removed its peg on US. Dollars and let their currency float freely, leading to hyperinflation and capital flight. From 1997-1998 the Asian financial crisis was a major source of risk and uncertainty and kept the VIX at high levels before the famous hedge fund Long Term Capital Management went bust in late 1998. At the same time the Russian economy, brought in extra financial uncertainty. The tech bubble hit other indexes harder, but still caused a major spillover in other assets and caused the VIX to spike. In the end of the period we saw the terrorist attacks on 9/11 and several corporate scandals as significant contributors to high VIX values. (Bekaerta et al, 2013)

3.1.5 VIX Analysis: 2003-2017

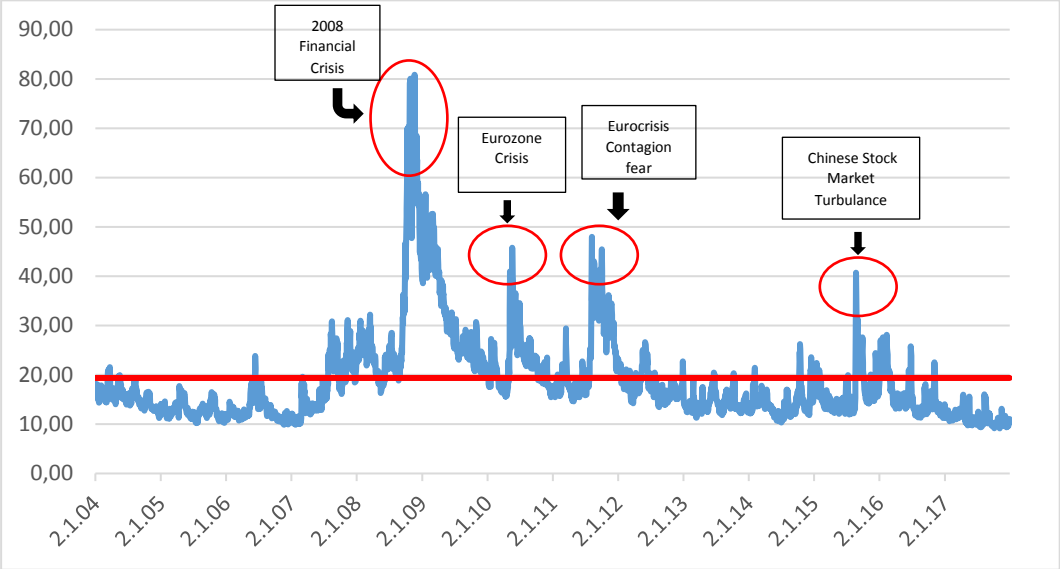


Figure 2: VIX Based on S&P 500

The period from 2003 until 2017 are less volatile overall, but has larger and more severe jumps in implied volatility. The periods mean was 18.53 (20,20 for 90-03) with a maximum value of 80.6 after the Lehman Brother collapse during the 2008 financial crisis (Bekaerta et al, 2013) The American financial crisis started by the sub-prime mortgage craze spread to Europe, igniting the latent debt crisis, especially in the PIGS (Portugal, Ireland, Greece and Spain) countries. The problems continued in Europe and fear of contagion of the financial troubles to other European countries started to get a foothold, which lead to a spike in the VIX index, before several years of low values started, only interrupted by the Chinese stock market turbulence in late 2015. (Bekaerta et al, 2013)

3.1.6 Source

Our data is downloaded from the Chicago Board Options Exchange website where spreadsheets with historical price data is available for the two periods VIX Daily Data for 2004 to Present (CBOE Data Source 1, 2018) and VIX Daily Data for 1990 – 2003 (CBOE Data Source 2, 2018) the historical data we have used is the daily closing prices. The two files, and time periods are separated when CBOE changed from S&P 100 to S&P 500 index options as a basis for their VIX calculations.

3.1.7 Characteristics

The two periods are quite different, this is as stated before mainly because of the different market characteristics during the different time periods and not the constituency of the index.

	1990-2003	2004-2017	1990-2017
Average	20.20	18.53	19.37
Max	45.74	80.86	80.86
Min	9.31	9.14	9.14
Observations	3532	3524	7056
Skewness	0.825197	2.626343	2.086079
Kurtosis	0.573969	9.285016	7.615817

3.1.8 Implied Volatility versus Realised Volatility

It is important to understand the difference between the implied volatility that the VIX measures and indexes and the realized volatility experienced by the investors of the S&P 500 index. The VIX is based on a basket of options prices, which is heavily dependent of an expected volatility to get the correct price. These options are used for speculation or hedging on the S&P 500, buyers are therefore comfortable with paying a premium above the true value to get this exposure. Option sellers on the other hand, rarely take the other side of the trade, they rather hedge their positions with different hedging strategies and charge a premium for the option to cover the hedging cost and their fee. As a result we see that the 30 day realized volatility of the S&P 500 is consistently higher than the VIX for most periods, with a few exemptions where option sellers have underestimated volatility.

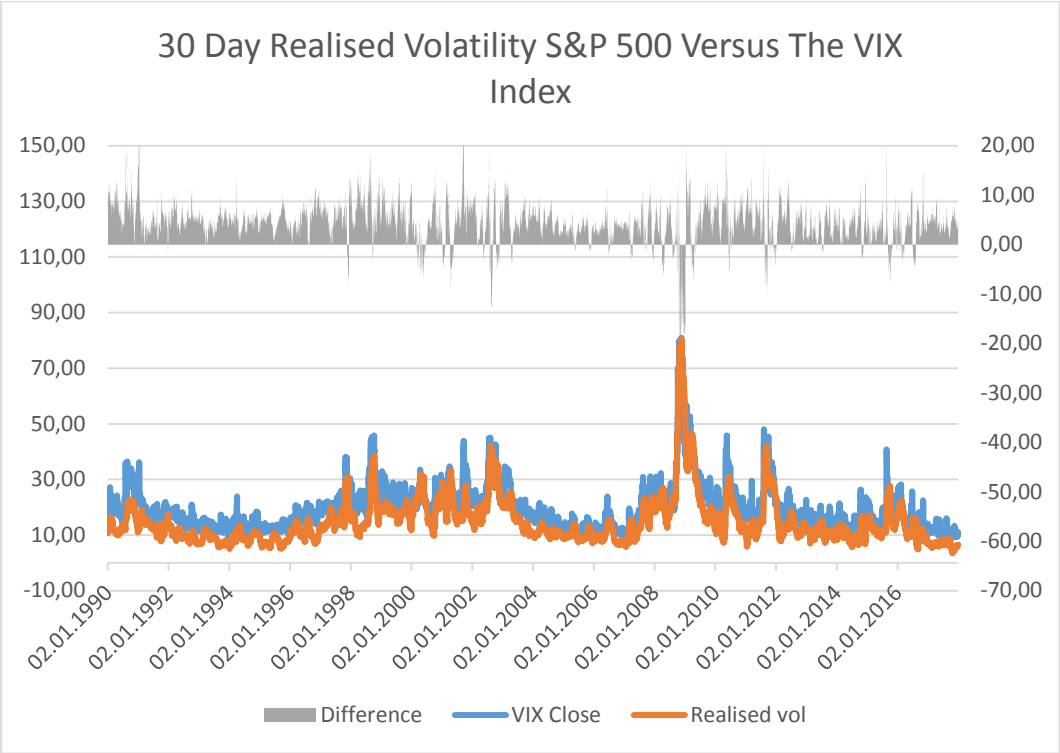


Figure 3: Risk Premium Illustrated

This is important to understand, since in our model we do not try to explain the effect of different variables on actual volatility. The model tries to explain what affects the market's expectations of volatility over the next 30 days, by measuring the effect of the release of new information about macroeconomic conditions.

3.2 The Consumer Price Index (CPI)

The CPI measures the average change in prices that domestic consumers faces over time. The prices are collected for a basket of consumer goods and services, which is determined by surveying and gathering consumption habits from more than 24 000 consumers. The data consists of weekly consumer spending diaries that is recorded over a two-year period, before being used to update the basket. The basket's goods and services therefore have a lag of 2-3 years, i.e. the CPI for 2016 was based on data from 2013. The Bureau of Labor Statistics gather the price data with a carefully decided strategy on geographic areas, retail establishments, commodities and services and assigns appropriate weights for all items. (BLS, 2018)

The CPI has several important uses, it is used to deflate economic time series and adjust dollar values for income and benefits for consumers, but more importantly it

is used as an important economic indicator for price movements for consumers and is the most frequently measurement used to quote inflation. It is therefore used as an important guiding indicator for the United States President, Congress, and the Federal Reserve when they formulate fiscal and monetary policies. It is these characteristics that are of most interest to us, as certainty about the CPI should influence the level of uncertainty or volatility in the market.

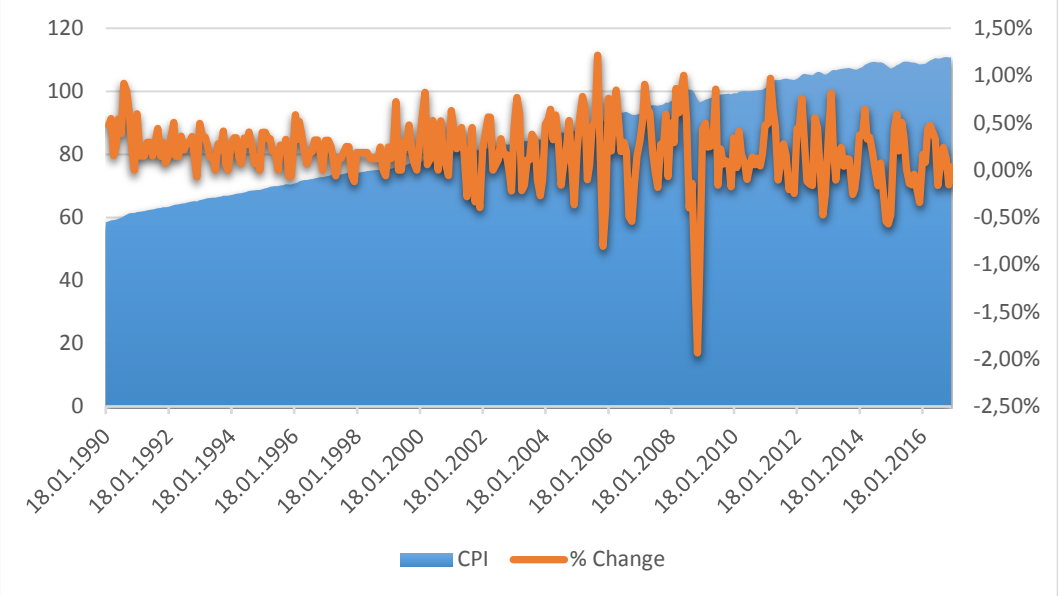


Figure 4: CPI total and first differences

3.3 The Producer Price Index (PPI)

The PPI measures the average change in prices US producers achieves for their produced products and services. It is an important macroeconomic tool, because it takes the view on price changes from the producer's standpoint. The PPI is the oldest continuous statistical series of the Federal Government (BLS, 2018) and is together with the CPI an important measurements of inflation.

PPI's main uses is very similar to the CPI, it is used as an economic indicator, as an economic series deflator and as the basis of contract adjustments. While all of these uses are important, our interest is in the PPI are mainly as an economic indicator. The PPI changes are a major indicator for the overall health and drive in the economy, it is also used by the United States President, Congress, and the Federal Reserve when they formulate fiscal and monetary policies (BLS, 2018). It is therefore both an important lagging economic variable and an influencer on future economic conditions, and hence certainty of the PPI should have implication for market uncertainty and volatility.

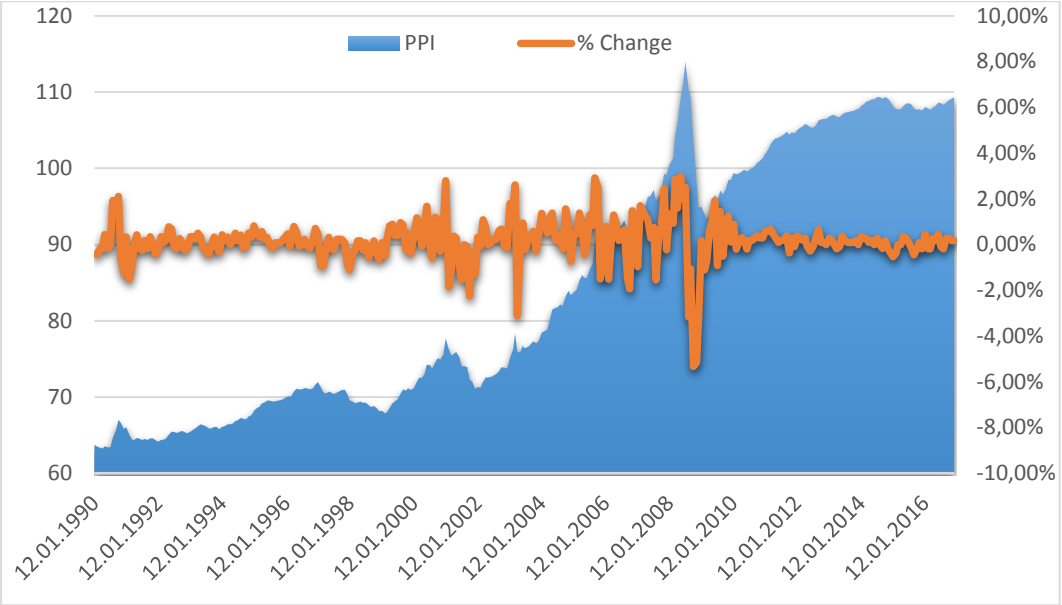


Figure 5: PPI Total, and first differences

PPI is calculated by comparing the base period revenue level with the current period revenue for a fixed set of products.

$$PPI_i = \left(\frac{(\sum Q_o \; P_o \, (\frac{P_i}{P_o}))}{\sum Q_o \; P_o} \right) * 100$$

The index is the weighted average of price relatives where:

$\boldsymbol{P_i}$ = The price of a commodity in the current period

$\boldsymbol{P_0}$ = The price of a commodity in the base period.

$\boldsymbol{Q_O}$ = The quantity of the commodity shipped during the base period

(BLS, 2018)

Both CPI and PPI data are downloaded from the US Bureau of Labor Statistics online web. From the graph above we clearly see a statistical trend in the unlogged time series data.

3.4 Gross Domestic Product (GDP)

A country's GDP is the total value of all goods and services produced within its borders. The formula for GDP is:

$$GDP = C + I + G + (X - M)$$

C = Consumption **I** = Investment **G** = Government spending **(X-M)** = Net exports

GDP is considered one of the more important measures of the country's economic size and health. The change in GDP tells if the country's economy is expanding or contracting and hence if it is in an economic recession or boom. Our GDP data stretches from first quarter of 1991 until last quarter of 2016. The average growth of US. GDP is 1.11% a quarter and the largest one quarter expansion in GDP was in the second quarter of the year 2000. While the largest contraction was unsurprisingly during the US financial crisis in 2008. The fourth quarter of 2008 saw a 1.98% drop in overall GDP from the previous quarter (Appendix 1). Our GDP data was obtained from the World Bank Data Catalog, which is published online. Our data is quarterly and dollar denominated. (World Bank Data Catalog, 2018)

3.5 Consumer Confidence Index (CCI)

The CCI is a macroeconomic lead-indicator, as it tries to give a numerical picture of consumers' confidence in their economic future, and hence gives information about where we are going. It does so by surveying consumers about their current economic plans and their expectations about their immediate economic future. The answers are sorted into grades of positive or negative answers which forms the index of economic conditions and confidence. (OECD , 2018). The CCI is categorized as a leading indicator since it is supposed to indicate future economic conditions, based on consumers own beliefs. It is therefore interesting to see whether these leading properties applies to the VIX as well. Our data is downloaded from the OECD data homepage, OECD is a huge data collector and a trusted source for high quality data on the CCI.

3.6 Employment Situation Report

The Employment Situation report is produced by the Bureau of Labor Statistics on a monthly basis, it contains several surveys about employment and is produces to monitor the labour market. The most important parts of the report are the unemployment rate, non-farm payroll employment, average workweek and average hourly earnings. These numbers have significant macroeconomic implications and

is viewed to have significant implications for inflations and hence the Federal Reserve key interest rate decision.

The unemployment rate is measured as a percentage of people classified as unemployed of the people in the labour force. People are classified as unemployed if they meet all the criteria set by the bureau, which is of the sort “no employment, but available for work” and “made specific efforts to find employment” (U.S. Bureau of Labor Statistics, 1990-2018). The unemployment rate is seasonally adjusted. It is one of the more interesting inputs, and as the graphical illustration of the two times series show, the VIX and of unemployment are somewhat correlated.

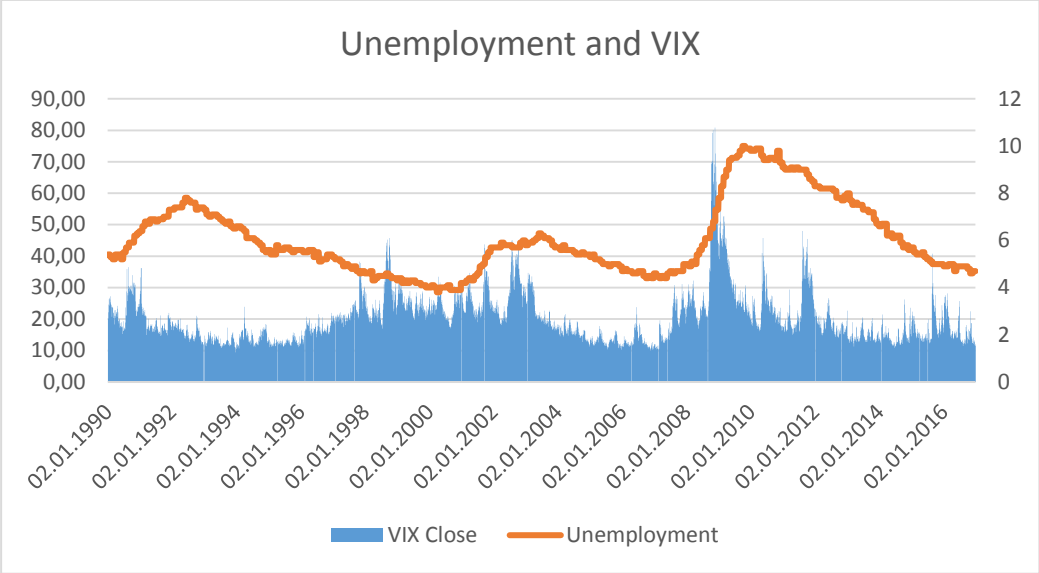


Figure 6: VIX compared to Unemployment

The unemployment rate during the same period as the VIX index has been recorded has a mean of 6.05% with a minimum value of 3.8% during the spring of 2000 and a maximum rate of 10% reached in December 2009 in the period after the financial crisis. The period has seen three periods with relative high unemployment, the early 90, during the IT bubble and after the financial crisis of 2008.

3.7 The Federal Open Market Committee Meetings

The Federal Open Market Committee (FOMC) is a committee under the US central bank, the Federal Reserve and is responsible for open market operations. The committee consist of twelve members that meet eight times a year. In these meetings, the economic and financial conditions of the United States are discussed and reviewed and used as a basis for the FOMC open market operations. The

FOMC are authorized, by law, to perform open market operations mainly in the form of purchasing or selling securities, U.S. agency securities, banker's acceptances, bills of exchange, cable transfers, bonds, notes, warrants, debentures, and other obligations to accomplish both its long and short-term goals of keeping the federal funds rate at a level that ensures price stability and sustainable economic growth. During our period of study there has been a significant downwards trend in the funds rate, with an average value of 2.97%, the funds rate has a maximum value of 8.29% in the beginning of the 90's at the start of our dataset to a minimum 0.07% recorded in late 2011 during the low interest rate environment seen after 2008 financial crisis (Appendix 2).

3.8 Quantitative Easing

Quantitative easing (QE) is a tool that central banks use to "ease" markets that are in distress. It can take several forms, but its main characteristics are direct market interventions like the purchase of one or more types of financial securities. The quantitative easing program of the Federal Reserve was initiated after the financial crisis in 2008 and its termination was announced in October 2014.

The Federal Reserve's goal with its QE programs was to push interest rates down and increase the money supply. The QE program focused especially on longer dated interest rates because they are harder to move with the federal funds rate, which is the rate of interbank system that the bank use to lend from each other. Companies typically lend long term, while financial institutions fund themselves short term. Lowering the federal funds rate lowered the cost of short term lending, but since everybody believed the financial crisis to be temporarily, longer dated rates was still high. To lower the interest rate of companies the federal reserved had to push longer dated rates down, they did this by purchasing a large amount longer dated government bonds and other interest-bearing securities from the market. The increased demand for these securities that the Federal Reserve created pushed yields down, lowering the funding cost of companies. This was believed to have a calming effect on markets as it was believed to ease the cost of companies, lower the cost of new investments and hence stimulate the economy.

We have created a variable that represent the dates of important announcements concerning the QE program. This variable is built from a mix of press releases and

analyses of the FOMC meeting notes. The announcements concern everything from direct purchase information, where the Federal Reserve announces both amount and security type they will purchase to FOMC considerations about the program. The FOMC evaluation of the program gave markets an indication of whether the program would continue as before, be stepped up or stopped, which again could influence market conditions and hence implied volatility as it removes uncertainty about the direct market interventions of the central bank. The announcements and their content are attached in the appendix in its entirety. (Appendix 3)

3.9 The Federal Reserve Total Assets

One of the apparent consequences of the QE market interventions is the large increase in the Fed's assets. The Fed's balance sheet reached USD 4 500 000 000 000 (4. 5 trillion USD) in January 2015, and started to decline as the Fed slowly stopped their rollover program for reinvestments of interest payments.

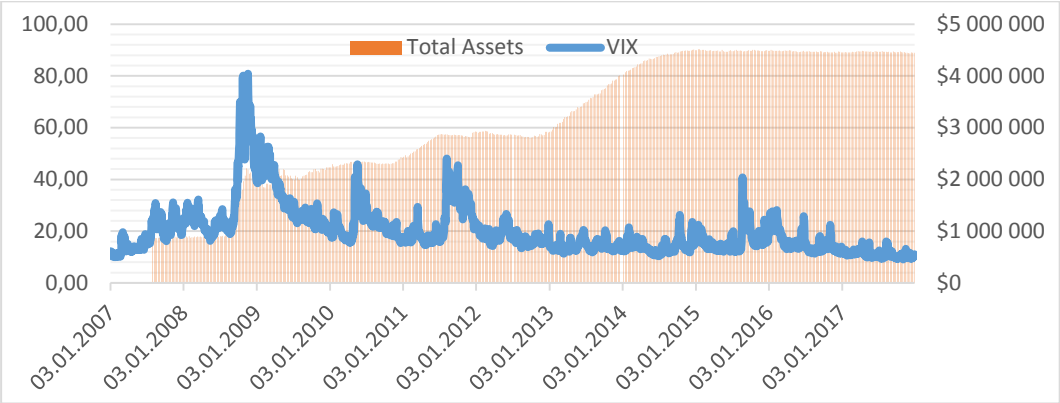


Figure 7: Federal Reserve's Total Assets compared to VIX

The graph clearly reveals the downward move in the VIX, as the Feds balance sheet grew larger.

3.10 The Federal Reserve Securities Held Outright

The Federal Reserve total assets include a large range of financial products, from central bank liquidity swaps to foreign currency reserves, but even though many of them are instrumental in steering the economy, some are more influential than others. We find some of the more interesting balance sheet accounts under the securities held outright. An example of these items can be viewed in the Federal

Reserve Board's published financial report from November 18, 2016 which included an overview of the Feds total assets. As can be seen from the table below Securities held outright is the largest balance sheet account. With US treasuries and mortgage-backed securities as the largest accounts, with 2.464 and 1.736 trillion dollars respectively. (Federal Reserve, 2016) This is almost four times as much as in May 2009 for both accounts.

				May 2009	November 2016
Total assets				2.082	4.454
	Selected Assets				
		Securities held outright		1.107	4.218
			U.S. Treasury Securities	600	2.464
			Federal agency debt securities	80	18
			Mortgage-backed securities	428	1.736
			Overnight securities lending	-	20
			Net commitments to purchase mortgage-backed securities	-	38
		Unamortized premiums on securities held outright		-	176
		Unamortized discounts on securities held outright		-	-15
		Central bank liquidity swaps		182	4
		Net portfolio holdings of Maiden Lane LLC		-	2
		Foreign currency denominated assets		-	21

3.11 10 Year US treasury Yield

The 10 Year US Treasury Yield is one of the most important measures of long term interest rates in the world. It is often used as a benchmark for riskless long term debt and measures the rate at which the US government can fund itself with a majority of 10 year. Over the VIX total history, 1990-2018 it has been averaging 4.64% with a minimum value of 1.37% and maximum value of 9.09%. The yield has followed a downward slope from 1990 until today, as low rate regimes has dominated the western part of the world. The 10year yield is fairly stable, with absolute average moves of less than 0.072 basis points a day. The yield has however, historically seen absolute moves of up to 51 basis points (Appendix 4). The data for the yield was provided by the U.S. Department of Treasury (U.S. Treasury, 2018).

4. Theory

4.1 VIX

The VIX is calculated in a different way than other typical indices, such as the S&P 500 which is calculated using the prices of its included stocks. Each index has certain rules that govern the selection of which securities to include and a formula to calculate its values. The VIX Index is a volatility index comprised of options rather than stocks, with the price of each option reflecting the market's expectation of future volatility. Though, like conventional indexes, the VIX calculation procedure follows certain rules for selecting which options to include and a formula to calculate its values. The generalized formula used in the VIX calculation is:

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2$$

Where…

σ is VIX/100 → VIX = σ * 100

T is time to expiration

F is forward index level desired from index option prices

K_0 is the first strike below the forward index level

K_i is the strike price of the i*th* out-of-the-money option

ΔK_i is the interval between strike prices

R is the risk-free rate

Q(K_i) is the midpoint of the bid-ask spread for each option with strike K_i

It is constructed by taking a weighted average of implied volatilities of the two OEX calls and two puts that will expire next, but has 8 or more calendar days to expiry. An average of those call and put options' implied volatility is then calculated, the strike prices of the options must be just above the index price. Similarly, an average is again calculated using the same procedure as above, but with a strike price just below the price of the index. Further, these averages are used to interpolate at-the-money implied volatilities, where the at-the-money implied volatilities are calculated similarly as the put and call option, from the series of the following

contract month. Therefore, considering that two option series are used, there are two interpolated at-the-money implied volatilities. Finally, these volatilities are finally weighted to obtain a single volatility that always has 30 calendar (22 trading) days to expiry. As a consequence of this, the VIX represents the 30-day implied volatility for an index option (CBOE White Paper, 2018).

4.2 Macroeconomic News

The classical asset pricing models express that prices should only reflect the sum of its discounted expected future cash flows divided by its number of shares outstanding, given available information. Gikas A.Hardouvelis (1987) found that stock prices primarily react to monetary news, but also to other news as well.

$$P_t = \left(\frac{E\left(\sum_{\tau=1}^{\infty} \frac{cf_{t+\tau}}{1 + r_{t+\tau}}\right)}{\#\ shares\ outstanding} \middle| \Omega_t \right)$$

Where…

Pt is the price of the stock at time t

cft+τ is the cash flow at time t+τ

r is the discount factor for the cash flows at time t+τ

Ωt is the information set at time t.

The news is captured by the difference between Ωt+1 and Ωt for each period. On any given point in time, the expected news in time t+1 also includes all the previous known information. Under the assumptions of market efficiency and rational investors, stock prices should solely respond to, and immediately adjust to, *new* information.

Financial theory suggests that stock prices follow a random walk and news shocks are uncorrelated over time, we can extract the effect on prices from macroeconomic events by looking at the daily stock price changes at the announcement day of macroeconomic news. The news will affect the prices and thus the volatility since

investors will act according to their interpretation of those news, some will buy and some will sell. If the market feels the newly revealed information changes its expectations to future cash flows, to the discount rate or to the number of shares outstanding, or all, the prices will move.

4.3 GARCH

When working with financial data, it is important to know that some time periods are riskier than others; meaning, the expected value of the magnitude of error terms is at some times greater than at others – often referred to as heteroscedastic error terms. Moreover, these risky periods are not spread randomly across quarterly or annual data. Instead, there is a degree of autocorrelation in the riskiness of financial returns. In plots of daily returns, the amplitude of the returns varies over time and describe this as "volatility clustering". The ARCH and GARCH models are designed to deal with just this set of issues. They have become common tools for dealing with time series heteroskedastic models. The goal of such models is to provide a volatility measure, like a standard deviation, that can be used in financial decisions (Engle, 2001).

To test whether or not our regression exhibit heteroscedasticity, we conduct an Engel's ARCH test with the optimal number of lags specified by comparing log likelihood values for different choices of lags. We use Akaike and Bayesian information criteria (AIC/BIC) to compare log likelihood values, where we look for the one which gives us the lowest AIC/BIC value for a given lag. We estimate the GARCH model by fitting the residuals from the regression based on a maximum likelihood function, with the number of lags specified above.

5. Methodology

To study which factors that drive the change in the VIX we will build a model. We will use the daily log-change in the VIX, with dates from the announcement day of macroeconomic reports as dummy variables, and log-changed values of important macroeconomic measures.

We base our model on several previous academic papers which amongst others are: Nikkinen & Sahlström (2004), Gospodinov & Jamali (2012), Donders & Vorst (1996), Shaikh & Padhi (2013), Chen & Clements (2007). As a basis for factors to investigate, we will exploit the knowledge of previous paper's empirical results,

and our own considerations of important macroeconomic variables that we presume have an impact on the VIX. We then test all variables for their level of significance using conventional cut-off levels.

Isolating the impact on VIX from new information can be done in different ways. Nikkinen & Sahlström implement a simple regression model,

$$\ln(\mathrm{VIX}_t/\mathrm{VIX}_{t-1}) = \alpha + \beta D_{0,t}^{\mathrm{Emp}} + \delta D_{0,t}^{\mathrm{PPI}} + \gamma D_{0,t}^{\mathrm{CPI}} + \lambda D_{0,t}^{\mathrm{FOMC}} + \varepsilon_t,$$

where the explanatory variables are dummy variables that takes the value 1 at the announcement day of employment report, producer price index (PPI), consumer price index (CPI) and Federal Open Market Committee (FOMC) respectively. By taking the value 1 on the days where the reports are reviled, the dummy variables capture the behaviour of the VIX on that day. We use a similar model, but also investigate variables mentioned in other papers and the ones we believe have an effect on the VIX. For instance, Shaikh & Padhi (2013) used monetary credit information review of central bank of India (MCIR), gross domestic product (GDP) and wholesale price index (WPI), and we consider announcements of quantitative easing (QE) as interesting to look at – a factor which we so far have not seen been investigated. Variables tend to correlate with each other and between observations in the same time series data (autocorrelation). To adjust for this, the variance of the error term, ε, is based on a general autoregressive conditional heteroscedasticity model.

5.1 Initial model

Nikkinen & Sahlström's model is significant on all levels in its given time slot, which makes it a good starting point for our model. At first, we wanted to see if it is valid in other time periods as well. The methodology is standard least square method with a GARCH error term to adjust for heteroscedasticity. We used the daily log-changes of the index values as the depended variable.

$$VIX = \alpha + EMP_t\beta_1 + PPI_t\beta_2 + CPI_t\beta_3 + FOMC_t\beta_4 + \varepsilon_t$$

Where VIX is the logarithmic change from the close price on business day t-1 to t[2]. α is the intercept. *EMP*, *PPI*, *CPI* and *FOMC* are dummy variables at time t, and β their coefficients. ε_t is the error term at time t.

5.1 Expanded model

After looking at the results from the initial model, we saw that not all of Nikkinen & Sahlström's variables were significant in different periods in time. We explored further options and expanded the model with new variables. To ensure that the economic rationale behind their inclusion is intact and fit for the new model, we analysed the different economic and statistical features of the variables (Appendix 5). When looking at the core data, all variables seem to have a trend and this observation is further enhanced from the results we got from the Auto-Correlation Function (ACF). The plot suggests that the series are non-stationary. In particular, the first lags of the ACF are very close to one. In addition, the ACF plots show a very slow decay which suggests that the "memory" of the DGP is very long; long memory is indicative of non-stationarity. In order to use an autoregressive model, we transformed the data. Since the dummy variables we use rely on the VIX-dataset being log-change of the VIX-levels, we must take the log-change of the other variables to keep consistency. We tried taking the first differences of the variables, but the conclusions from the results did not change. After the examination and transformation of the variables of interest, we included them in the model to test if they had a significant impact on the VIX.

We looked for macroeconomic variables, not necessarily news in form of reports, but as in new information that might have an impact on the U.S. market; such as changes in GDP, sovereign debt and tax-levels. We began to search for suitable macroeconomic factors at the websites of U.S. Bureau of Labor Statistics, Federal Reserve, OECD, IMF, CBOE and Statista. These are highly recognised sites where we could trust the data source. The factors that we believed could have a significant impact were: Quantitative Easing (announcement days), Total assets of FED's balance sheet (*TotAssFed*), the level of securities held outright by the FED (*SecHeldOut*), Support to Specific Institutions[3] from the FED, FED's Debt level, industrial production, American GDP, U.S. taxes on corporate income, the level of

[2] $ln(VIX_t/VIX_{t-1})$

[3] Support to Specific Institutions includes: Maiden Lane LLC; Maiden Lane II LLC; Maiden Lane III LLC; and support to AIG

the Consumer Confidence Index, Treasury Yield Curve Rates and number of options traded on the VIX (see appendix 5 for further details). After regressing all variables, we removed the ones that were not significant at a 5% level, regressed again and continued this process until we only had variables that were significant at a 5% level.

After extensive testing in different time periods, with different combination of the variables mentioned above, we concluded with this base model:

$$\Delta VIX = \alpha + EMP_t\beta_1 + PPI_t\beta_2 + CPI_t\beta_3 + FOMC_t\beta_4 + QE_t\beta_5 + TotAssFed_t\beta_6 + SecHeldOut_t\beta_7 + Yield_t\beta_8 + GDP_t\beta_9 + CCI_t\beta_{10} + \varepsilon_t$$

QE, TotAssFed and SecHeldOut will not be included in the period before 2008 since the data set is from August 2007. Meaning that we did not find Support to Specific Institutions from the FED, FED's Debt level, industrial production, U.S. taxes on corporate income or number of options traded on the VIX to have a significant effect on the VIX index. The base model is used as the initial model in the periods we want to test. Next, we exclude variables that are not significant in the given time slot, this results in the final model for each time period. Even though TotAssFed was not significant at a 5% level we include it because it correlates with SecHeldOut and thus, by holding it out, our estimate would suffer from omitted variable bias, and would be in direct conflict with the 3rd assumption of OLS ($E[\boldsymbol{\epsilon}|\boldsymbol{X}] = \mathbf{0}$). Its presence sorts out the noise and makes SecHeldOut cleaner, making SecHeldOut significant at a 5% level compared to at a 10% level if we exclude it.

6. Model Assessment

Our model is a linear OLS model, with the following assumptions:

1. The data-generating-process is linear.
2. No perfect linear relationship amongst columns of $\boldsymbol{X}$.
3. Strong-form: $\boldsymbol{X}$ is non-stochastic; or weak-form: $E[\boldsymbol{\epsilon}|\boldsymbol{X}] = \mathbf{0}$ and $\boldsymbol{X}$ is exogenous.
4. Constant variance of residuals.
5. No time series dependence of residuals.

6. Normally distributed residuals.

Together, the first three assumptions imply that linear regression is the right way to model the relationship between the *y*-variable and the *x*-variables. The last three assumptions enable straight-forward statistical testing of the parameter estimates and the overall model (Stock & Watson, Introduction to Econometrics, 2014).

1. We can ensure our model is consistent with this assumption by careful analysis of the residuals and consideration of other possible models.

2. None of the regressors can be a linear combination of another regressor. High correlation between them can lead to unstable estimates and inaccurate p-values (Sharpe, De Veaux, & Velleman, 2015). Variance Inflation Factor (VIF) is a measure for this, and a VIF-value < 10 is considered acceptable.

3. This is a gross simplification (most *x*-variables vary randomly in some sense). But within most modelling contexts it is a reasonable starting position. Both strong and weak forms imply "$\boldsymbol{X}$ has no useful information about $\boldsymbol{\epsilon}$". And it would be sufficient for most purposes to assume the weak-form that $E[\boldsymbol{\epsilon}|\boldsymbol{X}] = \mathbf{0}$ (Stock & Watson, Introduction to Econometrics, 2014)

    I. There are two main corollaries to 3:

        i. By the law of iterated expectations $E[\epsilon t]=EX[E[\epsilon t|X]]=0$.

        ii. $cov[\epsilon t,X] = 0$.

The point of the first three assumptions is that a linear regression model is reasonable. This means that $E[\boldsymbol{y}|\boldsymbol{X}] = \boldsymbol{X\beta}$ is correct. In words, this means that the mean of the *y*-variable, conditional on the observed $\boldsymbol{X}$ matrix, is $\boldsymbol{X\beta}$.

4. In other words, $var(\epsilon t) = \sigma 2$ for all *t*. This is an assumption that simplifies the variance formula for ***β_hat***. It may not be true, and we will test it with an Engle's ARCH Test.

5. In other words, $cov(\epsilon i, \epsilon j) = 0$ for all *i* and *j*. This is also an assumption that simplifies the variance formula for ***β_hat***. It may not be true, and we well check whether the residuals are independent and identically distributed or not with a Durbin-Watson test. The test statistic is always between 0 and 4, with values above 3 of below 1 been problematic, and a value of 2 indicating no autocorrelation (University of Notre Dame, 2018).

6. This is a strong but convenient assumption. The convenience is that we can directly deduce analytic probability distributions applicable to parameter estimates. Which, for example, provides a quick step to the proverbial "significance tests" on parameters and overall models. We will draw a histogram and examine it.

6.1 Initial model

Our first model is a replication of Nikkinen & Sahlström's model from 2004. It consists of four dummy variables which ought to explain the change in the VIX index. The period is from 01.01.1996 to 31.12.2000 and the results from the model assessment are:

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon$$

1. After using the included application for model optimisation in MatLab we did not find a significantly better model. The Root Mean Squared Error was approximately the same for all models and since a linear model is easier to interpret than a non-linear model we will continue with the linear model.

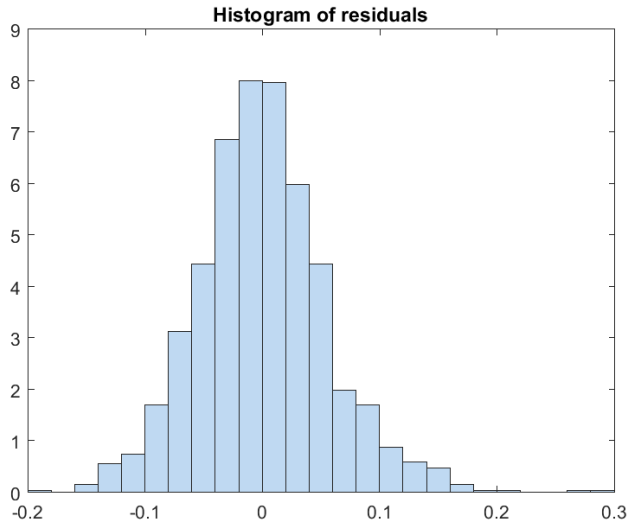
2. By removing and adding the explanatory variables we can clearly see that their estimates and p-values are stable, this indicates that there is low correlation between them. The Variance Inflation Factor supports this claim with a value of 1.0067, 1.0053, 1.0071 and 1.0035, respectively.

3. This is a subjective analysis where we must think of other variables that correlate both with the VIX and one or more of the regressors, and if so, we must include it in the regression to not get a biased estimate from the omitted variable. We included industrial production to test for biasedness, but it was not significant. This is possibly a non-exhaustive exercise, but to our knowledge there are no other variables to test.

4. Conducting a test for conditional heteroscedasticity on the residual series, using optimal number of lags specified by a GARCH model. The Engle's ARCH Test concludes that the residuals are homoscedastic, and with a p-value of 0.8923, test statistic of 0.0183 and critical value of 3.8415 we can conclude that the results strongly indicate that heteroscedasticity is not present.

5. We get a Durbin-Watson value of 2.0618 which is close to the optimal value and strongly indicates that the error term is I.I.D.

6.



The histogram clearly illustrates residuals close to being normally distributed. There are some outliers in the right tale, but nothing critical enough to investigate further.

We changed the sample to test if this regression is valid during other time periods. We looked at 1990-1996, 2000-2005, 2003-2008, 2008-2012 and 1996-2016. The results led to the same conclusions about our assumptions as above, except point 4, regarding the heteroscedasticity, where we exhibit significant volatility clustering in the residual series. To deal with this problem we include a GARCH term in the regressions as the error term. The results can be seen in its entirety in the appendix (Appendix 6).

6.2 Extended model

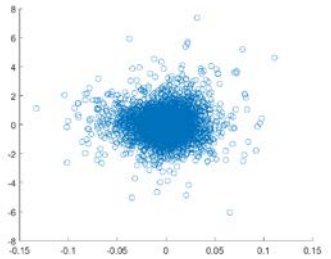
We extended our model with several variables, depending on the time period. For the period 1.1.2000 – 31.12.2007 we included Yield, GDP and CCI, and for the period 1.1.2008-31.12.2016 we further included QE, TotAssFed and SecHeldOut. Finally we will include all variables for the period after Nikkinen & Sahlström's research up until 2000-2016.

The results for period 2000-2016 are:

Linear regression model:

VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield + ε

1. We repeated the procedure from the initial model, but found no significant improvement by having a non-linear model. Analysing the residuals further gives us a confirmation that a linear process is valid. The residuals show no pattern and are symmetrically distributed and clustered around zero.



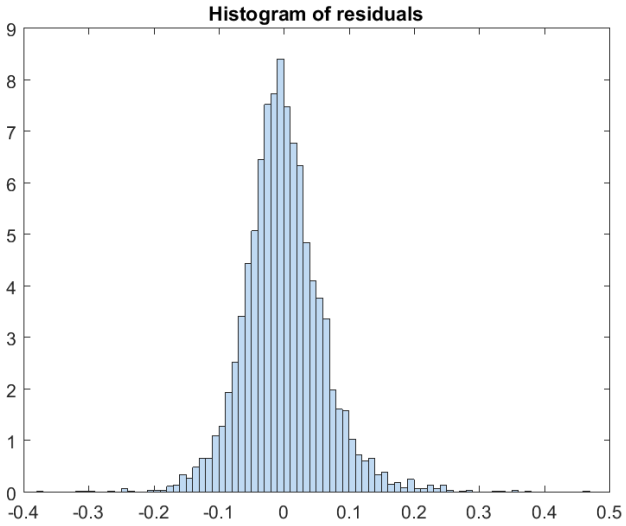
2. We were worried that TotAssFed and SecHeldOut correlated too much, and the VIF indicator shows notable higher values for those variables, but they are still satisfactorily below the critical measure of 10. The results are: 1.0021 1.0545 1.0463 1.1262 1.1351 1.0047, respectively according to the regressors in the above regression.

3. We have tested for omitted variable bias and are confident that the explanatory variables in our final model have a low correlation with the error term.

4. Conducting a test for conditional heteroscedasticity on the residual series, using optimal number of lags specified by a GARCH model. The Engle's ARCH Test concludes that the residuals are heteroscedastic, and with a p-value of 0, test statistic of 228.5095 and critical value of 3.8415, the results strongly indicate that heteroscedasticity is present. To adjust our model, we create a GARCH term from the calculated residuals and add it as the error term in the regression.

5. We get a Durbin-Watson value of 2.1504 which is close to the optimal value and strongly indicates that the error term is I.I.D.

6. The histogram clearly illustrates residuals close to being normally distributed. It is closer than the initial model, probably due to that there are substantially more observations in the extended model.



We changed the model slightly and broke the time periods down to 2000-2007 and 2008-2016. The regressions are VIX ~ 1 + EMP + PPI + FOMC + GDP + Yield + CCI + ε and VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield + ε, respectively. Analysing the results from the same exercises as above, we came to the same conclusions with no further need for elaboration. The results can be seen in its entirety in the appendix (Appendix 6).

6.3 Model Specification Bias

An unwanted feature with the model is that it might have specification error. This means that the independent variable is to some degree correlated with the error term, which in our case is other macroeconomic news that we have not included in the model. This bias may be triggered by a number of causes; i) The functional form may be incorrect, ii) omitted-variable bias, iii) errors-in-variables, iv) bad sample selection, and v) simultaneity-equation bias (Stock & Watson, Introduction to Econometrics, 2014). If we find evidence of specification bias, we will need to take action according to what kind of obstacle we meet.

i) We believe that the linear form we chose captures the observations in a good way. We have tested different forms without any sign of significant improvement and the residuals seem to look fine.

ii) For a regression to exhibit an omitted variable bias, the variable has to: 1) be a part of the error term and affect the dependent variable and 2) correlate with one or more of the regressors. We cannot say our regression does not have an omitted variable, it most likely does, but we are confident that the variables we have tested make up the majority of what could be a natural explanatory variable with a significant effect on both the VIX-index and the other variables in the regression. We discussed including an instrument variable, but did not find a suitable one.

iii & iv) Said a little different, we are looking at if we have included irrelevant or insufficient variables. Screening the data we could not see any missing observations and the irrelevant variables were excluded when we discovered that they were not significant.

v) Indirectly we could argue that changes in the VIX-index affects some of the regressors. For instance, if the VIX spikes, meaning that the market is in a turmoil, other forces will start to unravel and affect e.g. the outcome of FOMC's meetings. However, this is happening because of a snowball-effect, hence we do not believe that there is any strong direct causality, i.e. Y causes X.

7. Hypothesis 1

VIX is affected by the fundamental macroeconomic indicators employment, CPI, PPI and FOMC

Uncertainty is a source for marked volatility and several researchers have studied the effect of important announcements of market sensitive information. Especially interesting are the so-called lagging indicators that measure an economy's current health. FOMC meeting days, employment, PPI and CPI are such indicators and was studied by Nikkinen & Sahlström 2004 report. They found that implied volatility represented by the VIX increases prior to the scheduled news releases and decreases after. This indicates that the release of new data on macroeconomic indicators removes uncertainty about the state of the economy. Our hypothesis is that Nikkinen & Sahlström's results are correct, and still applicable to the VIX index for larger datasets. We tested our hypothesis by replicating their study with their own model on the same dataset.

We started this process by comparing datasets. We chose the exact same dates and observations from the available CBOE VIX close dataset. It is important to notice that their values are slightly different for the VIX level and change. They have higher maximum and mean values, but also higher minimum value for the VIX Close level quotes (See table below). As a consequence their data is less skewed, with slightly higher standard deviation and kurtosis. The data from the change in VIX closing quotes is however indistinguishable. We observe the same mean and small differences in maximum, minimum and median values. The data is close to equal in skewness and kurtosis. We view the overall differences as negligible and are comfortable to proceed with the research with the data at hand.

	VIX Level Close			VIX Change Close		
	P&O	**Nikk&Sahl**	**Difference**	**P&O**	**Nikk&Sahl**	**Difference**
Nb of Observations	1261	1261.00	0.00	1260	1260	0
Mean	22.40998	23.71	1.30	0.06 %	0.06 %	0
Median	21.7	23.07	1.37	-0.05 %	-0.01 %	0.0004
Minimum	12	12.74	0.74	-19.38 %	-27.14 %	-0.0776
Maximum	45.74	48.56	2.82	29.50 %	42.78 %	0.1328
Standard Deviation	5.258971	5.39	0.13	5.71 %	6.46 %	0.0075
Skewness	1.099512	1.08	-0.02	0.255273	0.41	0.154727
Kurtosis	2.223951	2.48	0.26	1.069185	2.84	1.770815

7.1 Replication results (1996-2000)

Our replication of Nikkinen & Sahlström 2004 research confirms their findings. The VIX seem to be affected by the fundamental macroeconomic indicators employment, CPI, PPI and FOMC for the period 1996 until 2000. We replicated their result using their linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC$$

	Estimate		Probability of t statistics	
Estimated Coefficients:	**P&O**	**Nikk&Sahl**	**P&O**	**Nikk&Sahl**
(Intercept)	0.0057994	00.48	0.00075907	0.003
EMP	-0.055912	-0.0471	1.8652e-13	0.000
PPI	-0.019434	-0.0144	0.0081433	0.078
CPI	-0.013134	-0.0094	0.073756	0.205
FOMC	-0.029581	-0.0307	0.00099943	0.003

7.2 The Extended dataset (1996-2016)

To build on the understanding of the effect employment, CPI, PPI and FOMC have on the VIX we extend our dataset to include data up until 2016. This is more than

four times as many years as Nikkinen & Sahlström, including two major stock market turmoil's and one of the largest financial crisis the S&P 500 has encountered; the 2008 financial crisis. During this period the VIX index reached its all-time high with a recorded maximum index value of over 80 (See figure below), indicating average daily movies in the S&P 500 of more than +-5%, which is extreme. The period ends in a sustained period of below average implied volatility and the longest recorded period of sustained stock market price increases. The central bank increases its market operations and unemployment decrease to historical low levels, CPI, PPI and other inflationary indicators remain low and inflation remains below the central bank's target of 2%. There seem to be a disconnect in the Philips Curve, indicating a decoupling between traditional inflationary measures and unemployment.

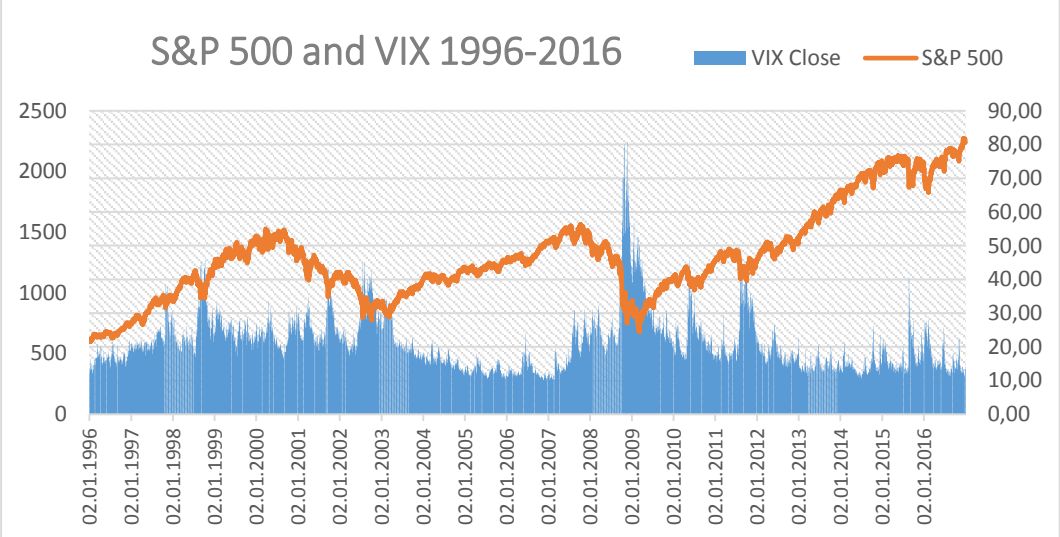


Figure 8: VIX' and S&P's historical values

7.3 Results extended dataset (1996-2016)

Linear regression model: VIX ~ 1 + EMP + PPI + CPI + FOMC				
Estimated Coefficients:	**Estimate**	**SE**	**T Stat**	**P Value**
(Intercept)	0.0030556	0.00097098	3.1469	0.0016592
EMP	-0.023275	0.00419	-5.5549	2.9134e-08
PPI	-0.0089288	0.0041624	-2.1451	0.031991
CPI	-0.011339	0.0041644	-2.7228	0.0064952
FOMC	-0.030162	0.0050596	-5.9613	2.665e-09

All our estimates for the period 96-16 are negative, and significant at 5% level. This is in accordance with our previous result from the period 96-00 and our own intuition, the implied volatility decreases as these macroeconomic indicators are

released and uncertainty about the conditions of the economy removed. The dataset is large, with significantly different periods of investor sentiment and market conditions. To test whether there are periods where these indicators act differently than other periods. We continue our research by splitting the time series data into different regimes.

7.4 Period (1990-1996)

Our dataset stretches from 1990 to 2017, but Nikkinen & Sahlström only focused on the period 1996-2000. We therefore conducted a regression on the same variables for the period before Nikkinen & Sahlström's study. The result was different from our previous findings. The employment situation report and FOMC meetings where not significant on any level and PPI significant at10% level with its 6.8%. The estimates are negative, indicating that their publication decreases uncertainty. These results provide evidence that indicate that different time regimes give different results in our estimated macroeconomic variables.

Linear regression model: VIX ~ 1 + EMP + PPI + CPI + FOMC				
Estimated Coefficients:	**Estimate**	**SE**	**T Stat**	**P Value**
(Intercept)	0.0015666	0.0016334	0.95908	0.33767
EMP	-0.0043112	0.0070206	-0.61409	0.53925
PPI	-0.012839	0.0070244	-1.8277	0.067788
CPI	-0.015184	0.0070188	-2.1633	0.030675
FOMC	-0.0076419	0.0085129	-0.89768	0.3695

7.5 Period (2001-2005)

The period after Nikkinen & Sahlström initial research has several spikes in volatility, especially the terrorist attacks of 9/11 and corporate crisis that followed some years after. Over the five-year period the S&P 500 saw an overall decline of nearly 6%. As markets started to recover from the turbulence in the early 2003, market implied volatility started declining, ending the period with the VIX around 11.

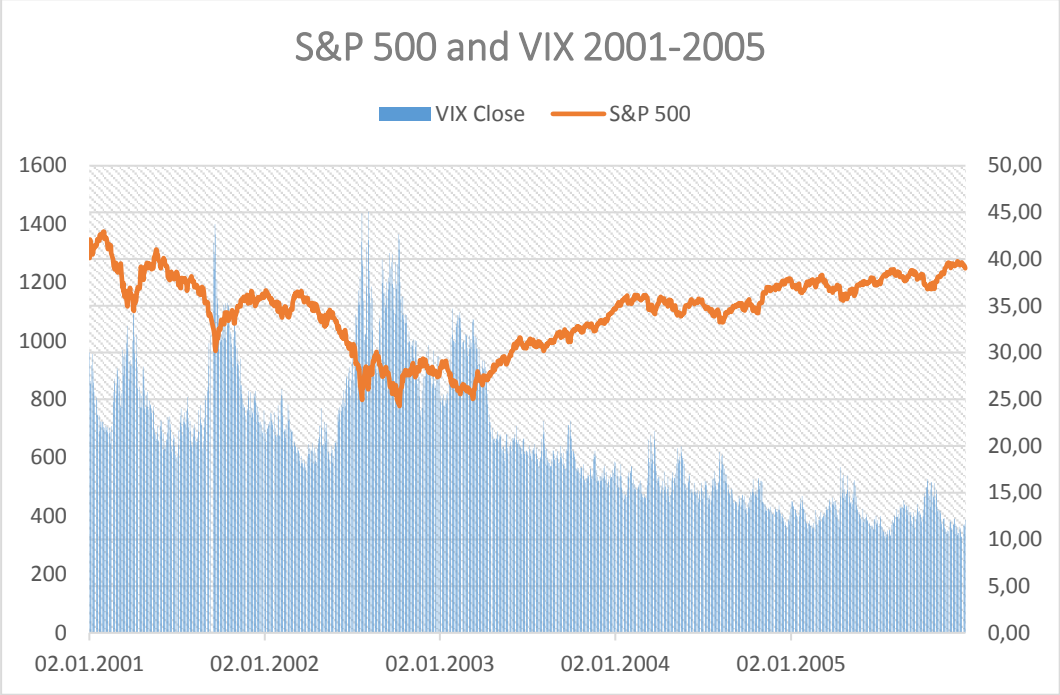


Figure 9: VIX' and S&P's values

The period after the dotcom bubble saw a steady decline in the VIX, from the level of 20+ to below 15. The employment situation report is still not significant, with PPI between the 10% and 5% significant levels. Most of the significant estimates have are negative, but the employment situation report have turned slightly positive.

Linear regression model:	**VIX ~ 1 + EMP + PPI + CPI + FOMC**			
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.001427	0.0015623	0.91343	0.36119
EMP	0.00043789	0.0065947	0.0664	0.94707
PPI	-0.012216	0.0067417	-1.8119	0.070235
CPI	-0.018271	0.0066883	-2.7317	0.0063887
FOMC	-0.020123	0.0081172	-2.4791	0.013304

7.6 Pre 2008 Crisis (2003-2007)

From 2003 until 2008, our macroeconomic variables improved substantially, both PPI and CPI increased, unemployment decreased and average hour earnings increased. Things looked good in the economy, though some started to warn about bubble tendencies in some asset classes in the end of the period. Our significant variables have a negative estimate.

Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0024423	0.001791	1.3636	0.17293
EMP	-0.0036181	0.0076887	-0.47058	0.63802
PPI	-0.017126	0.0076222	-2.2469	0.02482
CPI	-0.012508	0.0076838	-1.6279	0.1038
FOMC	-0.031968	0.0093161	-3.4314	0.00061987

7.7 Post 2008 crisis (2008-2012)

The period after the 2008 crisis is one of the more volatile in our dataset, with a substantial increase in the unemployment rate and decreasing PPI and CPI levels.

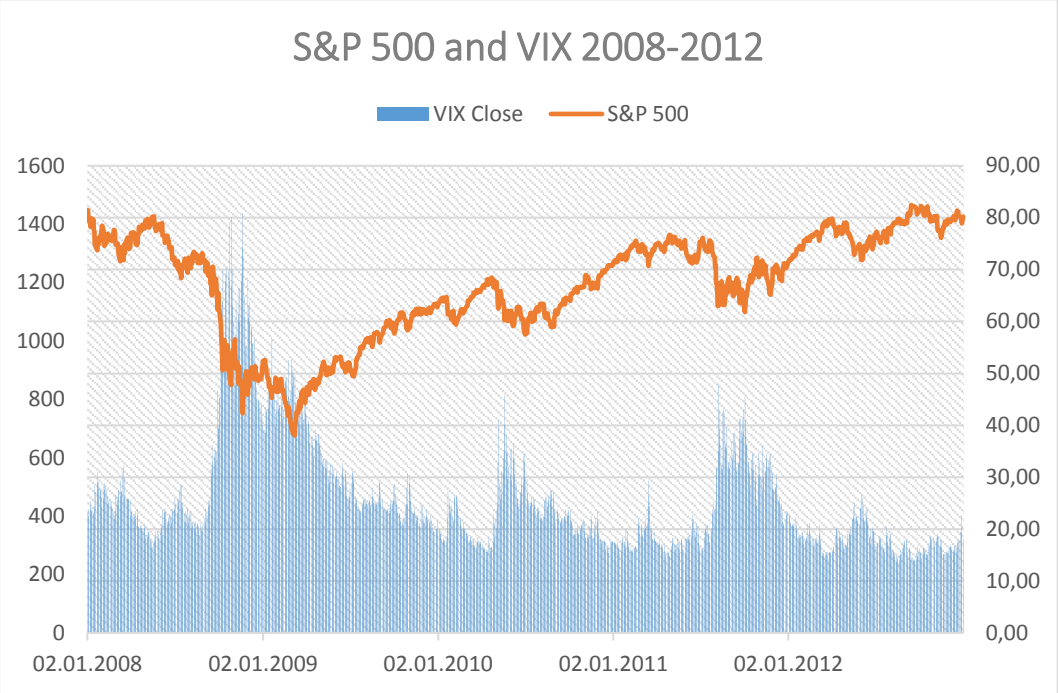


Figure 10: VIX' and S&P's values

During this period only FOMC meetings are significant, our estimate for FOMC is also the lowest we have found out of all time regimes, indicating that the FOMC meetings where instrumental in removing market uncertainty and lowering market implied volatility. The other macroeconomic estimates are neither significant at 10% level, nor at 5% level.

Linear regression model:	**VIX ~ 1 + EMP + PPI + CPI + FOMC**			
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0022705	0.0021827	1.0402	0.29843
EMP	-0.012911	0.009555	-1.3512	0.17688
PPI	-0.0061482	0.009399	-0.65413	0.51315
CPI	-0.0077025	0.0094054	-0.81895	0.41297
FOMC	-0.037518	0.011406	-3.2892	0.0010324

8. Conclusion Hypothesis 1

Estimated Coefficients:	1990-1996	1996-2000	2000-2005	2003-2007	2008-2012	1996-2016
(Intercept)	0.0015666	0.0057994	0.001427	0.0024423	0.0022705	0.0030556
EMP	-0.0043112	-0.055912	0.00043789	-0.0036181	-0.012911	-0.023275
PPI	-0.012839	-0.019434	-0.012216	-0.017126	-0.0061482	-0.0089288
CPI	-0.015184	-0.013134	-0.018271	-0.012508	-0.0077025	-0.011339
FOMC	-0.0076419	-0.029581	-0.020123	-0.031968	-0.037518	-0.030162

This table illustrates the different estimates for the dummy variables Employment Situation Report, Producer Price Index, Consumer Price Index and Federal Open Market Committee for the different time regimes tested in the analyses above. Red represents estimates with significance level lower than 10%, orange represents estimates significant at 10% level and green represents estimates significant at above 5% level.

8.1 Employment Situation Report

The employment situation report estimates performance poorly in our study of separate periods except for 96-00 where it is significant at a 5% level and for 96-16 where it also is significant at 5%. The report is large with several important measures on the employment situation. However, several seem to be lagging the VIX index, especially the unemployment rate which increases after financial and economic turmoil. This is clearly illustrated in the graph bellow. This can mean that in the short run, and in shorter time frames, the employment situation report is not especially important to reduce short term implied volatility. Over time however, as the period 96-16 shows, the employment situation is one of the key drivers of inflation and therefore influence monetary policy and implied volatility.

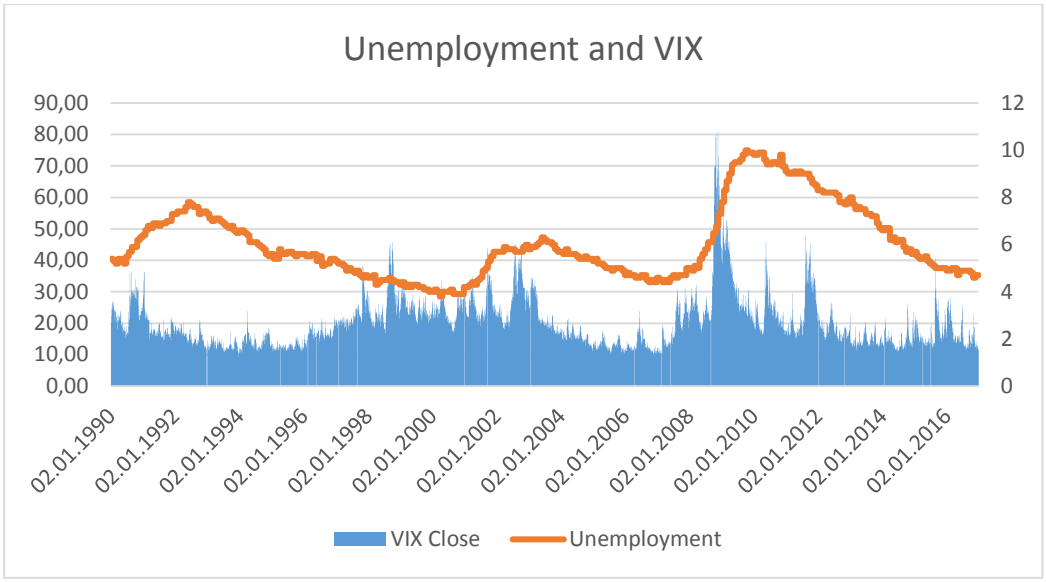


Figure 11: VIX compared to Unemployment

8.2 PPI and CPI

The PPI estimates are significant on at least 10% for all but the period after the 2008 financial crisis. The PPI estimates seem to produce higher p-values and estimates for periods before a crisis. The estimates are negative for all periods, meaning that the PPI has a negative impact on the VIX on the day it is published. The CPI estimates are significant on a 5% level for the time regimes 90-96, 00-05, 96-16 and 10% significant in 96-00, but produce less extreme p-values at the 03-07 and 08-12 making them outside our cut-offs of 5% and 10%. The CPI estimates are negative for all periods. This is in line with our previous assumptions and complementary research on the PPI and CPI. Making the current PPI and CPI measurement public reduces uncertainty about the overall state of the economy, and hence reduces implied volatility measured by the VIX. Due to the fact that important market operators use the PPI and the CPI in their decision-making about future economic and monetary policy, these indicators also reveal important indicative information on future key policy stances and action.

8.3 FOMC Conclusion

The FOMC meetings seem to have become more important over time, but not significant before 1996. This could be explained by the poor information and explanation provided by the FOMC at this time. The Central Bank, and FOMC in particular, has changed its behaviour towards the public significantly since our time series start in 1990. They have increased transparency by including more material from their discussions and their market view in the report. The FOMC did not announce its rational on policy statements before February 1994, and it was not before January 2000 that the committee decided to issue a statement after each scheduled meeting. The Green book started off with around 50 pages in 1964, but grew to over 100 pages in 2002. Beginning from October 2007, the FOMC participants that take part in policy decisions submitted their individual summery of economic projections which in 2011 where expanded to a more advanced version. (Federal Reserve, u.d.) This could be the explanation for why the FOMC has little effect on market implied volatility and uncertainty before 1996 and increases its influence towards 2016. Some of the more active years of the FOMC is after the 2008 financial crisis, where we see the highest estimate of FOMC meeting influence on implied volatility.

8.4 End Remarks

We notice that most of our variables are outside the 5% and 10% thresholds in the period after the financial crisis, but within the cut-off during the whole period. This could indicate that while these important macroeconomic indicators are crucial indicators on the overall economic health, they are less important in financial turmoil where other indicators could be viewed as more important. The FOMC meetings stand out as an increasingly important event for markets, which is in line with the increased market activity of the U.S. central bank in its efforts of securing financial stability and its overall increase in transparency and published material. This is why we thought it would be interesting to further break down the U.S. central banks publications and market operations to investigate their impact on market implied volatility expressed as the VIX.

9. Hypothesis 2

Hypothesis 2: *The U.S central bank's open market operations after the 2008 financial crisis dominated traditional macroeconomic news in influencing implied market volatility.*

Our results from hypothesis one indicate that macroeconomic indicators have an inconsistent influence on the VIX in the different periods we studied. Especially the period after the 2008 financial crisis, where the FOMC meetings where the only one that showed significance. We wanted to test whether the different open market interventions from the FED influenced the VIX, and if so, to what degree. We also wanted to include other macroeconomic factors that had a key role in the recovery process after the crisis. We have expressed these factors as variables of the federal debt, Consumer Confidence Index and 10 year U.S. treasury yields. To compare our results, we conducted the same test on the period preceding the 2008 crisis, however, several of our post crisis variables do not have any observations during this period as these were solely implemented as measures to improve economic recovery.

9.1 Period 2000-2016

The table beneath shows the remaining variables after our model optimisation process for the whole period.

Linear regression model: VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield				
Estimated Coefficients:	Estimate	SE	t-Stat	p-Value
(Intercept)	0.0015403	0.0010029	1.5358	0.12465
EMP	-0.016316	0.0045318	-3.6004	0.00032137
FOMC	-0.028454	0.0056204	-5.0627	4.3086e-07
QE	-0.037015	0.014771	-2.5059	0.012251
TotAssFed	0.29708	0.15414	1.9273	0.054008
SecHeldOut	-0.4021	0.16549	-2.4298	0.015148
Yield	-1.0657	0.049514	-21.523	1.2225e-97

It is important to have in mind that the QE only has entries after 2008, while total assets and securities held outright have substantially lower total values. Most of the variables have a negative estimate during the period, which support their intended purpose of a calming effect on markets.

9.2 Period 2000-2007

Regression on the period from 2000-2007 changed the results to some degree. After our model optimisation process we were left with the variables FOMC, 10 year US Treasury Yields, employment situation report, PPI, GDP, and CCI. In contrast to the whole period, PPI and CCI where significant at both 10% and 5% level, this provides some evidence that in normal conditions, the traditional macroeconomic variables influence the VIX.

Linear regression model: VIX ~ 1 + EMP + PPI + FOMC + GDP + Yield + CCI				
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0021744	0.0013364	1.6271	0.10388
EMP	-0.011602	0.0058358	-1.9881	0.046936
PPI	-0.013919	0.0058302	-2.3874	0.017061
FOMC	-0.02733	0.007083	-3.8585	0.00011767
GDP	-2.2594	0.75771	-2.9819	0.0028989
Yield	-0.92706	0.09817	-9.4435	9.6526e-21
CCI	-4.8698	2.4059	-2.0241	0.043089

In our model for the period before 2008, both Treasury Yields and FOMC came back significant on 5% level, with a large margin. We have tested both with and without federal debt, but its estimates failed our p-value cut offs of 5% and 10% level with a p-value of 0.63657. After the model assessment revealed that debt resulted in a negligible change in the other estimates, mainly for FOMC meetings and 10 Year Yield, we decided to remove it from the final regression. The FOMC result is in line with our previous results, but we are surprised by the negative estimate of the treasury yields. Yields tend to increase when prices fall, which they typically do when investors demand a larger risk premium as a result of a conceived riskier environment for their counterparty, and hence also their investment. Yields also increase when prices are moved down because of interest rates increases, which they also tend to do when the economy is improving. These factors should contribute to different directions of the VIX. Interest rates should encourage a negative correlation with the VIX and risk premiums a positive correlation with the VIX. We expected the premium to dominate the interest rate effect in the long run.

10 Year Treasury Yields					
Interest Rates	↑	**Yield**	↑	**VIX**	↓
Risk Premium	↑	**Yield**	↑	**VIX**	↑

9.3 Period 2008-2016:

For our post crisis model, the optimisation process concluded with three new variables; a dummy variable for the QE announcement dates, change in total asset value of the Fed and securities held outright. These are variables which represent the efforts of the Fed to stabilise the US economy, and bring about economic recovery and growth after the 2008 crisis.

Linear regression model: VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield				
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0019248	0.0015037	1.28	0.20066
EMP	-0.021433	0.0068126	-3.1461	0.0016764
FOMC	-0.028569	0.0086193	-3.3145	0.00093262
QE	-0.037251	0.016463	-2.2627	0.023748
TotAssFed	0.29476	0.16981	1.7358	0.082733
SecHeldOut	-0.41459	0.18165	-2.2824	0.022561
Yield	-1.0968	0.060287	-18.192	4.013e-69

During our model assessment, debt again came back with a p-value higher than our cut-off levels of 5% and 10%. But this time we expected the debt to be significant,

as the federal debt rose sharply after the financial crisis to finance different countercyclical initiatives by the federal government. The graph below illustrates the sharp shift upwards in the federal debt.

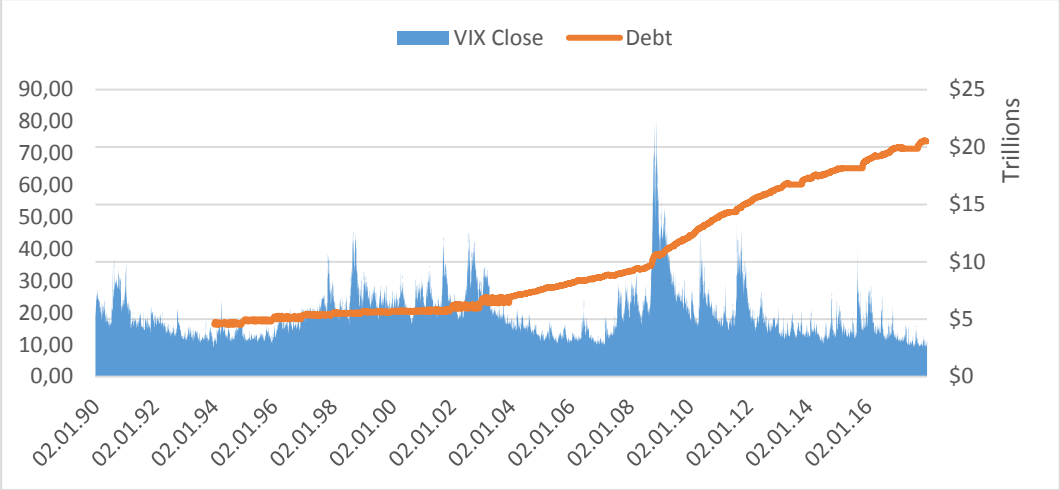


Figure 12: VIX and U.S. Debt values

An explanation for this result, could be that federal income from both corporations and private individuals fell sharply as a result of failing sales as demand fell and increased unemployment and lower wages. According to the US Congressional Budget Office *"The recent increase in debt has been the result of three sets of factors: an imbalance between federal revenues and spending that predates the recession and the recent turmoil in financial markets, sharply lower revenues and elevated spending that derive directly from those economic conditions, and the costs of various federal policies implemented in response to the conditions."* (CBO, 2010) If most of the debt where used to dam up for lower income, it would only bring about the status quo for government spending and hence not give as much of the countercyclical effects we first expected. Removing debt from the equation still gives negligible changes in the other estimates.

9.3.1 Quantitative Easing

The effect of quantitative easing announcements is negative and significant at both 5% and 10% level with a p-value of 0.023748. In the aftermath of the 2008 financial crisis, there was increased concerns of both liquidity shortages and credit defaults of critical financial institutions. The VIX spiked to above 80, and the S&P saw intraday moves of up to 10%. On the day of the announcement of the QE-1 program the VIX fell 6%. This QE-initiative was focused on clearing distressed assets from

large lenders so that they could continue to provide liquidity to financial markets. The content of the programs where unknown, though the market had its expectations, hence, aiding the market and revealing the strategy to do so removed significant uncertainty in from financial markets and especially the stock market.

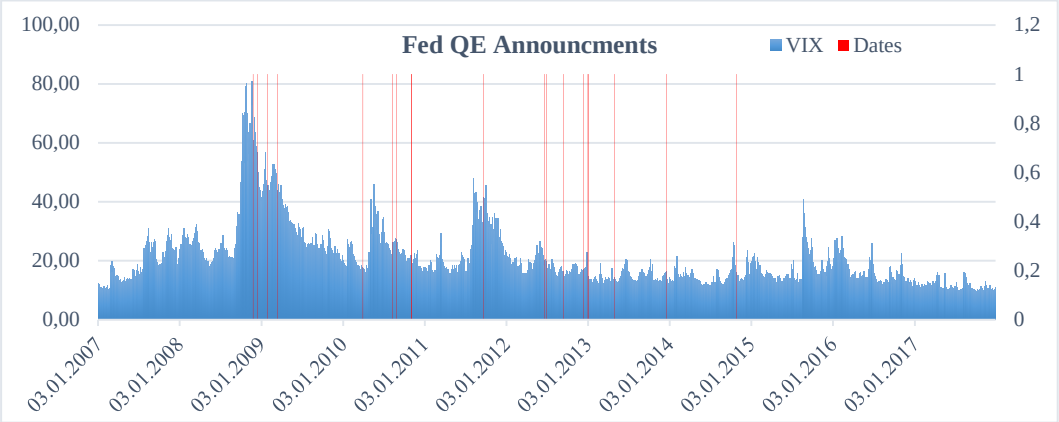


Figure 13: FED QE announcement history

As the graph above shows, the periods after the different announcement dates are significantly lower than before. Especially in the short term, the VIX shows large movements in the subsequent period before QE relevant announcements. For a more detailed explanation of the different QE programs, relevant announcements and their implications and justifications, see Fed's Quantitative Easing History attached in the appendix (Appendix 3).

9.3.2 Total Asset

Our estimates for the Fed's change in assets are around 0.3 and significant at 10% level with a p-value of 0.082733. This is the opposite of what one would expect, as one would think that Fed's purchases would lower VIX. We believe the results could be explain by two things. 1) The increase in Feds asset was viewed as negative by some market participants as they knew that the assets would have to be wined down sooner or later, creating a situation with larger outflows of cash, some also argued that it would not be enough, creating a jump in the VIX from the disappointment. 2) It could also be explained with the correlation between the source of volatility and the Fed's increased holdings of assets. When the Fed and the rest of the market started to get anxious about situations in the market, implied volatility would rise and the Fed would increase purchases to stabilise the market, in line with the conditions of the QE programs, hence a positive correlation of 0.036

in the change in VIX and total assets of the Fed. We tried to exclude this variable as a result of lacking economic rational of its influence on the VIX. However, this resulted in a larger move in the estimate for securities held outright, and made it only significant at a 10% level, from previously at a 5% level. We therefore kept the variable for total assets in the model.

9.3.3 Securities Held Outright

Testing the securities held outright returns an estimate of -0.41459 and p-value of 0.022561, significant on both 10% and 5% level. When the Fed became an active purchaser of US treasuries and mortgage-backed securities it subdued market implied volatility as the books increased. This relationship can also be seen in the graph below where we see the large increases in securities held outright with the downward push in the VIX.

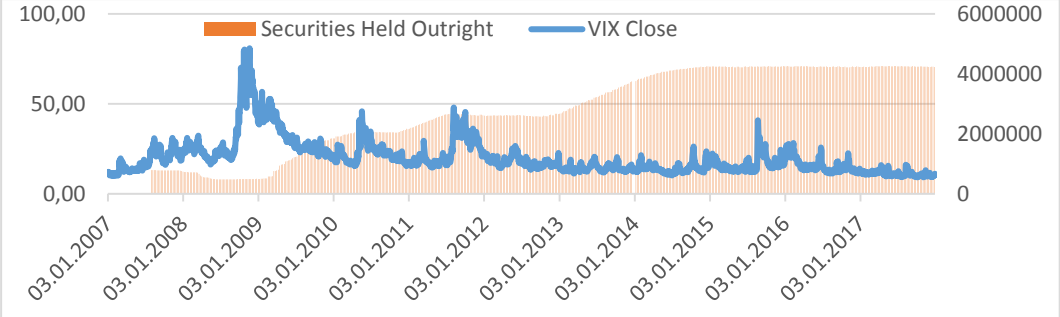


Figure 14: Securities Held Outright compared to VIX

Even though the Fed did not outright by shares in the S&P 500, the influence on implied volatility was indirectly from buying distressed assets that large credit institutions, banks and insurance companies where overexposed to. These are companies such as Goldman Sachs, American International Group (AIG), JP Morgan, Citigroup, Bank of New York Mellon, Bank of America and Ambac Financial, just to mention a few and where all listen in the S&P 500. The fear of insolvency in these "too big to fail" institutions rocked implied volatility, and also the actual volatility in the S&P 500 during trading hours. Lehman Brothers was one of the major banks that did not receive government support during the crisis. Reuters wrote on September 15th 2008: "*Lehman filed for Chapter 11 protection for creditors in the largest U.S. bankruptcy ever, after taking on too much exposure to deteriorating mortgage and real estate markets, and after a last-ditch effort to find a buyer over the weekend failed.*" As a consequence, the company was removed

from the S&P 500 (Reuters, 2008). Before being removed, it contributed significantly to S&P volatility as its share price plummeted.

9.3.4 10 Year US treasury Yield

The 10 year US treasury yield is still significant with an estimate of -1.1 and a p-value of 2.8929e-69. The p-value is extremely low, and indicates that an upward move in yields have on average a negative effect on the VIX. Earlier we discussed the different effect of interest rate and risk premium changes on yields. In the graph below we illustrate the federal funds rate and 10 year US treasuries. The federal funds rate are of a very short maturity date, this is the rate at which bank often lend and pay for overnight deposits from other institutional market participants, usually other banks and credit unions. This is also the rate depository institutions receive from the central bank for depositing their required reserves. Even though the overnight deposit are uncollateralised, it is maybe the closest one gets a riskless loan. This rate is an important part of the yield of the 10 year Treasury bill, but as the graph illustrates, risk premium and majority term play an important role in the yield as well. The negative impact of yield on VIX is illustrated inside the red circle; when the financial crisis was imminent, and market turbulence was at its highest, the central bank dropped the FED's rate dramatically. This brought down the yield and as the volatility spiked the risk premium started to rise as markets slowly calmed and the interest rate spread between Federal funds rate and the 10 year yield started to narrow.

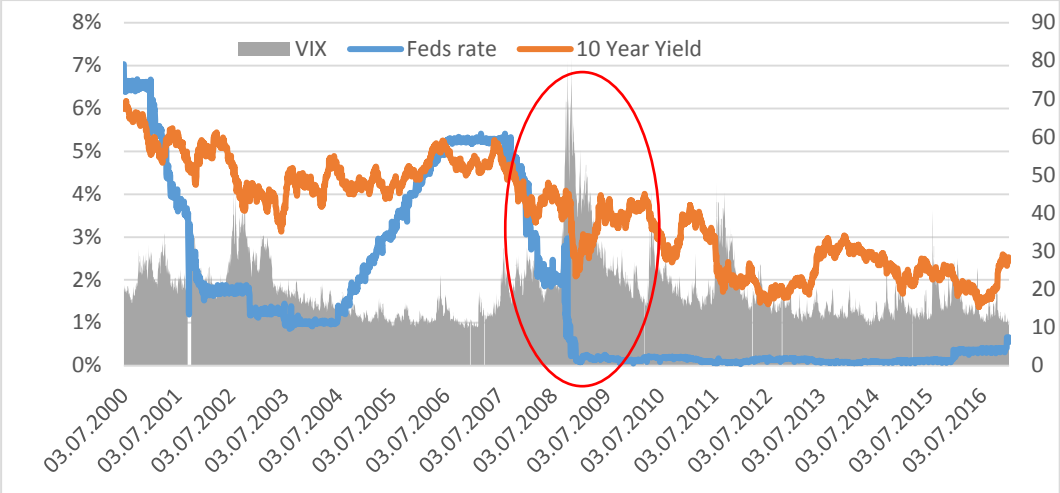


Figure 15: Federal funds rate and 10-year treasury yield

9.3.5 CCI

The CCI failed to stay within our cut off levels of 10% and 5% significance level for the whole period, 2000-2016, and the period after the financial crisis, 2008-2016. However, it was significant at a 5% level for the period preceding the financial crisis, 2000-2007. This was not as expected as we though the CCI would have leading characteristics and influence on implied volatility. The VIX is a proxy for 30 days volatility, and CCI is a proxy for economic view of consumer's immediate future. A graphical representation of the two time series clearly illustrates our view on the CCI. We have circled some of the more interesting periods with red.

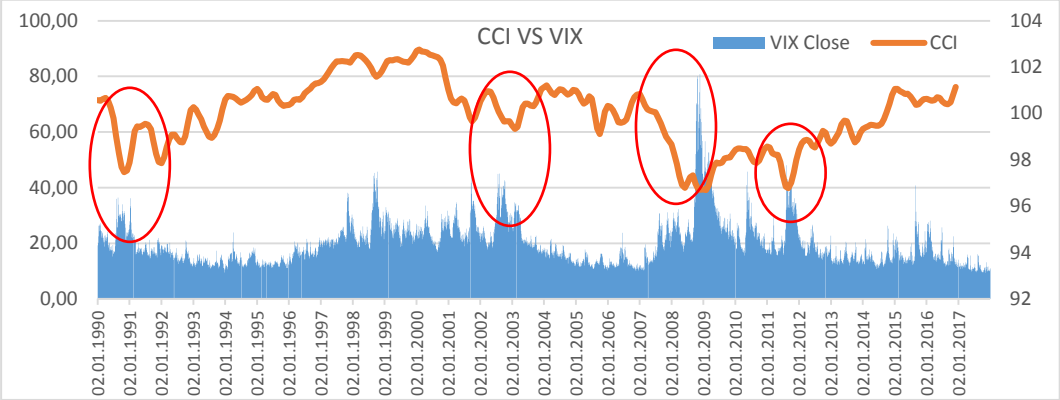


Figure 16: VIX compared with highlighted events

The two time series show a clear tendency to move in the opposite direction. We can however see a small disconnect in the period after 2008. We have tested CCI's leading characteristics with lags of 12, 18 and 24 months without convincing results, though 18 months where significant at 10% level (Appendix 7).

9.4 Conclusion Hypothesis 2

We have found evidence that support our second hypothesis; during financial turmoil and instability, news about traditional macroeconomic variables seem less important than during normal conditions. While other news, especially related to the U.S central bank's open market interventions, prove more important. PPI, GDP and CCI ended up totally excluded from the model, the treasury yield decreased its negative estimate with 18.31%, the employment situation report decreased its negative estimate with 84.74%, and the FOMC meetings decreased its negative estimate with 4.5%, meaning they all got a stronger effect.

10. Conclusion

This paper study how uncertainty in the S&P 500 is affected by the release of new information about macroeconomic data and actions. This is done by investigating the behaviour of The Chicago Board Options Exchange Volatility Index (VIX), commonly referred to as “the fear index”.

The results of the study support the hypothesis that the VIX is affected by the fundamental macroeconomic indicators employment, CPI, PPI and FOMC. This is in line with previous research and indicates that the scheduled release of macroeconomic data and actions around these indicators are important factors that affect the implied market volatility and the perceived uncertainty in financial markets towards the overall condition of the S&P 500. However, the paper also found different time regimes where these indicators lacked evidence of such effects, especially in the period after the 2008 financial crisis. These results support the hypothesis that The U.S central bank’s open market operations after the 2008 financial crisis dominated traditional macroeconomic news in influencing implied market volatility.

The study presents evidence that when markets are on high alert, when uncertainty is high, short term Federal Reserve actions are more important than the traditional macroeconomic indicators. The large increase in uncertainty during these conditions are due to short term risks of illiquidity and system failure, which is exactly what these Federal Reserve’s interventions focus to correct. During the 2008 financial crisis, the risk of market failure rose and hence information about Quantitative Easing and the Federal Reserve’s increased holdings of distressed assets were more important.

In this study the information connected to the FOMC meetings was the most important and a highly significant factor in the removal of uncertainty about the expected value of the S&P 500, regardless of whether the market was in a time of crisis or under normal conditions. A more thorough understanding and in depth analysis of FOMC meetings would be an interesting topic for future research.

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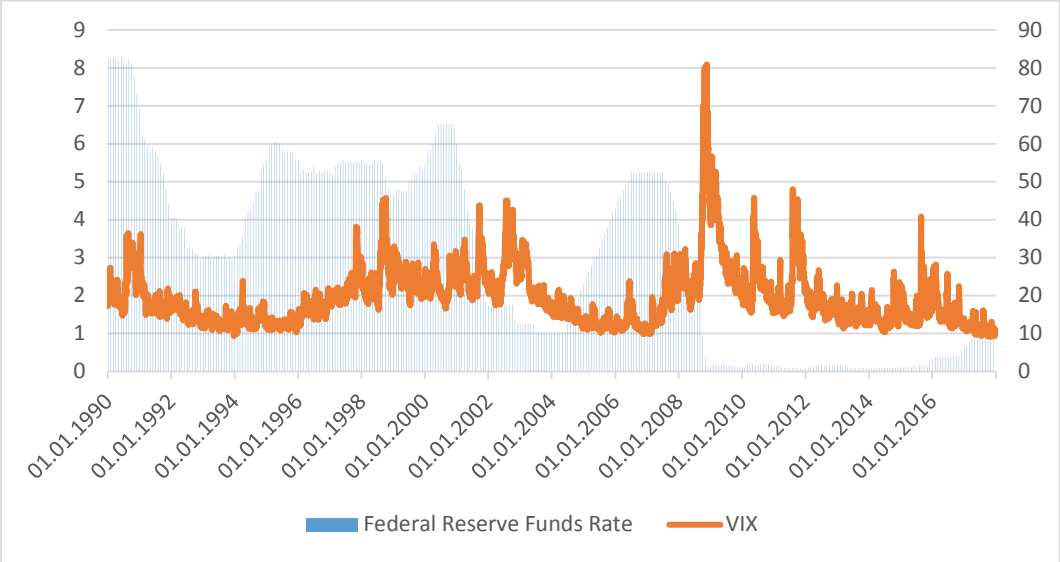
12. Appendix

Appendix 1: GDP

Appendix 2: The Federal Reserve's Funds Rate



Appendix 3: Fed's Quantitative Easing History

Oct 29, 2014 Fed Terminates QE-3

FOMC statement announces termination of QE-3. "The Committee judges that there has been a substantial improvement in the outlook for the labor market since the inception of its current asset purchase program. Moreover, the Committee continues to see sufficient underlying strength in the broader economy to support ongoing progress toward maximum employment in a context of price stability. Accordingly, the Committee decided to conclude its asset purchase program this month. The Committee is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities and of rolling over maturing Treasury securities at auction. This policy, by keeping the Committee's holdings of longer-term securities at sizable levels, should help maintain accommodative financial conditions."

Dec 18, 2013 QE-3 Tapering Begins

FOMC statement announces start of QE tapering: "In light of the cumulative progress toward maximum employment and the improvement in the outlook for labor market conditions, the Committee decided to modestly reduce the pace of its asset purchases. Beginning in January, the Committee will add to its holdings of

agency mortgage-backed securities at a pace of $35 billion per month rather than $40 billion per month, and will add to its holdings of longer-term Treasury securities at a pace of $40 billion per month rather than $45 billion per month. The Committee is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities and of rolling over maturing Treasury securities at auction. The Committee's sizable and still-increasing holdings of longer-term securities should maintain downward pressure on longer-term interest rates, support mortgage markets, and help to make broader financial conditions more accommodative, which in turn should promote a stronger economic recovery and help to ensure that inflation, over time, is at the rate most consistent with the Committee's dual mandate."

Jun 19, 2013 QE-3 Tapering Discussed

In his press conference, Fed Chairman Ben Bernanke said, "If the incoming data are broadly consistent with this forecast, the Committee currently anticipates that it would be appropriate to moderate the monthly pace of purchases later this year. And if the subsequent data remain broadly aligned with our current expectations for the economy, we would continue to reduce the pace of purchases in measured steps through the first half of next year, ending purchases around midyear. In this scenario, when asset purchases ultimately come to an end, the unemployment rate would likely be in the vicinity of 7 percent, with solid economic growth supporting further job gains, a substantial improvement from the 8.1 percent unemployment rate that prevailed when the Committee announced this program.

"I would like to emphasize once more the point that our policy is in no way predetermined and will depend on the incoming data and the evolution of the outlook as well as on the cumulative progress toward our objectives. If conditions improve faster than expected, the pace of asset purchases could be reduced somewhat more quickly. If the outlook becomes less favorable, on the other hand, or if financial conditions are judged to be inconsistent with further progress in the labor markets, reductions in the pace of purchases could be delayed. Indeed, should it be needed, the Committee would be prepared to employ all of its tools, including an increase in the pace of purchases for a time, to promote a return to maximum employment in a context of price stability.

"It's also worth noting here that, even if a modest reduction in the pace of asset purchases occurs, we would not be shrinking the Federal Reserve's portfolio of securities, but only slowing the pace at which we are adding to the portfolio while continuing to reinvest principal payments and proceeds from maturing holdings as well. These large and growing holdings will continue to put downward pressure on longer-term interest rates. To use the analogy of driving an automobile, any slowing in the pace of purchases will be akin to letting up a bit on the gas pedal as the car picks up speed, not to beginning to apply the brakes."

May 1, 2013 QE-3 Modified

FOMC Statement included the following new language about QE-3: "The Committee is prepared to increase or reduce the pace of its purchases to maintain appropriate policy accommodation as the outlook for the labor market or inflation changes."

Jan 2, 2013 QE-3 Initiated

Fed starts latest bond buying program.

Dec 12, 2012 QE-3 Expanded

FOMC Statement announces Treasury bond buying program to replace Operation Twist at the beginning of 2013: "To support a stronger economic recovery and to help ensure that inflation, over time, is at the rate most consistent with its dual mandate, the Committee will continue purchasing additional agency mortgage-backed securities at a pace of $40 billion per month. The Committee also will purchase longer-term Treasury securities after its program to extend the average maturity of its holdings of Treasury securities is completed at the end of the year, initially at a pace of $45 billion per month. The Committee is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities and, in January, will resume rolling over maturing Treasury securities at auction.

"The Committee will closely monitor incoming information on economic and financial developments in coming months. If the outlook for the labor market does not improve substantially, the Committee will continue its purchases of Treasury and agency mortgage-backed securities, and employ its other policy tools as appropriate, until such improvement is achieved in a context of price stability. In determining the size, pace, and composition of its asset purchases, the Committee

will, as always, take appropriate account of the likely efficacy and costs of such purchases."

Sep 13, 2012 QE-3 Announced and Initiated

FOMC Statement announces latest bond buying program. "To support a stronger economic recovery and to help ensure that inflation, over time, is at the rate most consistent with its dual mandate, the Committee agreed today to increase policy accommodation by purchasing additional agency mortgage-backed securities at a pace of $40 billion per month. The Committee also will continue through the end of the year its program to extend the average maturity of its holdings of securities as announced in June, and it is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency mortgage-backed securities. These actions, which together will increase the Committee's holdings of longer-term securities by about $85 billion each month through the end of the year, should put downward pressure on longer-term interest rates, support mortgage markets, and help to make broader financial conditions more accommodative."

Dec 31, 2012 Operation Twist Terminated

Operation Twist terminated.

Jun 29, 2012 QE-2 Terminated

QE-2 terminated. Under the program, the Fed purchased $827 billion in US Treasuries, while its holdings of US Agency debt and MBS declined $247 billion as securities matured.

Jun 20, 2012 Operation Twist Extended

FOMC Statement announces extension of Operation Twist: "The Committee also decided to continue through the end of the year its program to extend the average maturity of its holdings of securities. Specifically, the Committee intends to purchase Treasury securities with remaining maturities of 6 years to 30 years at the current pace and to sell or redeem an equal amount of Treasury securities with remaining maturities of approximately 3 years or less. This continuation of the maturity extension program should put downward pressure on longer-term interest rates and help to make broader financial conditions more accommodative. The Committee is maintaining its existing policy of reinvesting principal payments from its holdings of agency debt and agency mortgage-backed securities in agency

mortgage-backed securities. The Committee is prepared to take further action as appropriate to promote a stronger economic recovery and sustained improvement in labor market conditions in a context of price stability."

Sep 21, 2011 Operation Twist Announced

FOMC Statement announces Operation Twist: "To support a stronger economic recovery and to help ensure that inflation, over time, is at levels consistent with the dual mandate, the Committee decided today to extend the average maturity of its holdings of securities. The Committee intends to purchase, by the end of June 2012, $400 billion of Treasury securities with remaining maturities of 6 years to 30 years and to sell an equal amount of Treasury securities with remaining maturities of 3 years or less. This program should put downward pressure on longer-term interest rates and help make broader financial conditions more accommodative."

Nov 4, 2010 QE-2 Explained

Washington Post publishes Ben Bernanke's op-ed titled, "What the Fed did and why: supporting the recovery and sustaining price stability." He wrote: "The FOMC decided this week that, with unemployment high and inflation very low, further support to the economy is needed. With short-term interest rates already about as low as they can go, the FOMC agreed to deliver that support by purchasing additional longer-term securities, as it did in 2008 and 2009. The FOMC intends to buy an additional $600 billion of longer-term Treasury securities by mid-2011 and will continue to reinvest repayments of principal on its holdings of securities, as it has been doing since August. This approach eased financial conditions in the past and, so far, looks to be effective again. Stock prices rose and long-term interest rates fell when investors began to anticipate the most recent action. Easier financial conditions will promote economic growth. For example, lower mortgage rates will make housing more affordable and allow more homeowners to refinance. Lower corporate bond rates will encourage investment. And higher stock prices will boost consumer wealth and help increase confidence, which can also spur spending. Increased spending will lead to higher incomes and profits that, in a virtuous circle, will further support economic expansion."

Nov 3, 2010 QE-2 Announced

FOMC Statement announces QE-2: "To promote a stronger pace of economic recovery and to help ensure that inflation, over time, is at levels consistent with its mandate, the Committee decided today to expand its holdings of securities. The

Committee will maintain its existing policy of reinvesting principal payments from its securities holdings. In addition, the Committee intends to purchase a further $600 billion of longer-term Treasury securities by the end of the second quarter of 2011, a pace of about $75 billion per month."

Aug 27, 2010 QE-2 Hinted

Fed Chairman Ben Bernanke hints at QE-2 in Jackson Hole speech: "A first option for providing additional monetary accommodation, if necessary, is to expand the Federal Reserve's holdings of longer-term securities. As I noted earlier, the evidence suggests that the Fed's earlier program of purchases was effective in bringing down term premiums and lowering the costs of borrowing in a number of private credit markets. I regard the program (which was significantly expanded in March 2009) as having made an important contribution to the economic stabilization and recovery that began in the spring of 2009. Likewise, the FOMC's recent decision to stabilize the Federal Reserve's securities holdings should promote financial conditions supportive of recovery."

Aug 10, 2010 QE-1 Rollover

FOMC Statement announces rollover program: "To help support the economic recovery in a context of price stability, the Committee will keep constant the Federal Reserve's holdings of securities at their current level by reinvesting principal payments from agency debt and agency mortgage-backed securities in longer-term Treasury securities.1 The Committee will continue to roll over the Federal Reserve's holdings of Treasury securities as they mature."

Mar 31, 2010 QE-1 Terminated

QE-1 terminated. Under the program, the Fed purchased $1.5trillion in bonds, including $1.2 trillion in US Agency debt and MBS and $300 billion in US Treasuries.

Mar 16, 2009 QE-1 Expanded

FOMC Statement expands MBS program to $1.25 trillion, buy up to $300 billion of longer-term Treasury securities: "To provide greater support to mortgage lending and housing markets, the Committee decided today to increase the size of the Federal Reserve's balance sheet further by purchasing up to an additional $750 billion of agency mortgage-backed securities, bringing its total purchases of these securities to up to $1.25 trillion this year, and to increase its purchases of agency

debt this year by up to $100 billion to a total of up to $200 billion. Moreover, to help improve conditions in private credit markets, the Committee decided to purchase up to $300 billion of longer-term Treasury securities over the next six months."

Jan 28, 2009 QE-1 Evaluated

FOMC Statement discusses expanding program: "The Federal Reserve continues to purchase large quantities of agency debt and mortgage-backed securities to provide support to the mortgage and housing markets, and it stands ready to expand the quantity of such purchases and the duration of the purchase program as conditions warrant. The Committee also is prepared to purchase longer-term Treasury securities if evolving circumstances indicate that such transactions would be particularly effective in improving conditions in private credit markets."

Dec 16, 2008 QE-1 Evaluated

FOMC Statement evaluates benefits of purchasing longer-term Treasury Securities: "As previously announced, over the next few quarters the Federal Reserve will purchase large quantities of agency debt and mortgage-backed securities to provide support to the mortgage and housing markets, and it stands ready to expand its purchases of agency debt and mortgage-backed securities as conditions warrant. The Committee is also evaluating the potential benefits of purchasing longer-term Treasury securities."

Nov 25, 2008 QE-1 Announced

The Federal Reserve press release announced "the purchase of the direct obligations of housing-related government-sponsored enterprises (GSEs)–Fannie Mae, Freddie Mac, and the Federal Home Loan Banks–and mortgage-backed securities (MBS) backed by Fannie Mae, Freddie Mac, and Ginnie Mae….Purchases of up to $100 billion in GSE direct obligations under the program will be conducted with the Federal Reserve's primary dealers through a series of competitive auctions and will begin next week. Purchases of up to $500 billion in MBS will be conducted by asset managers selected via a competitive process with a goal of beginning these purchases before year-end. Purchases of both direct obligations and MBS are expected to take place over several quarters."

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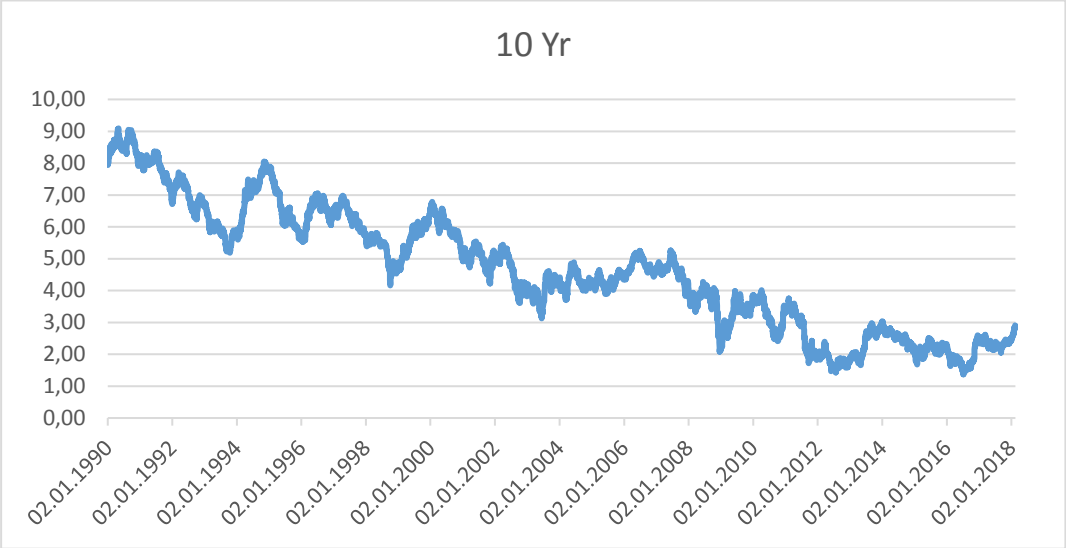
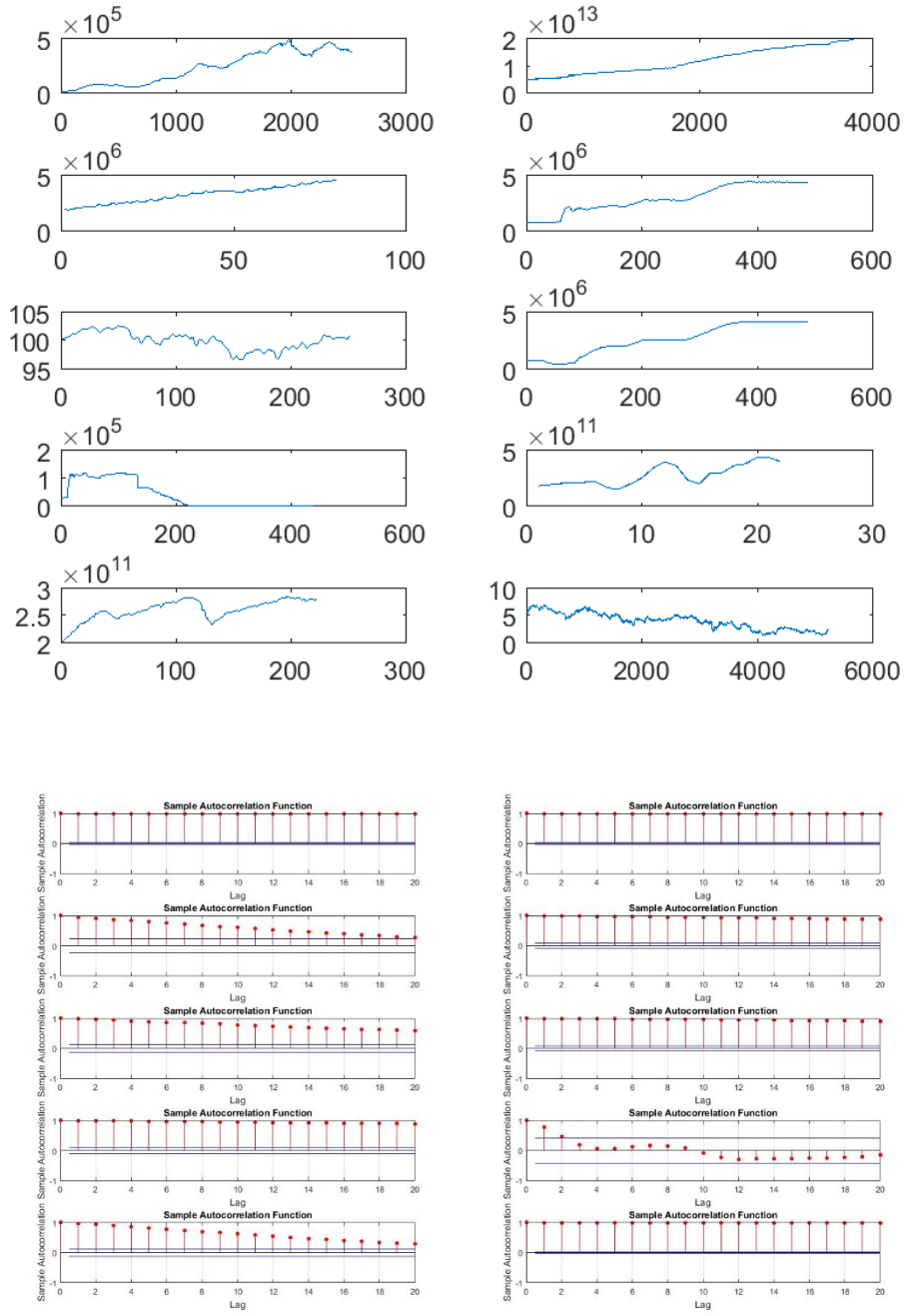
Appendix 4: 10 Year US Treasury Yield

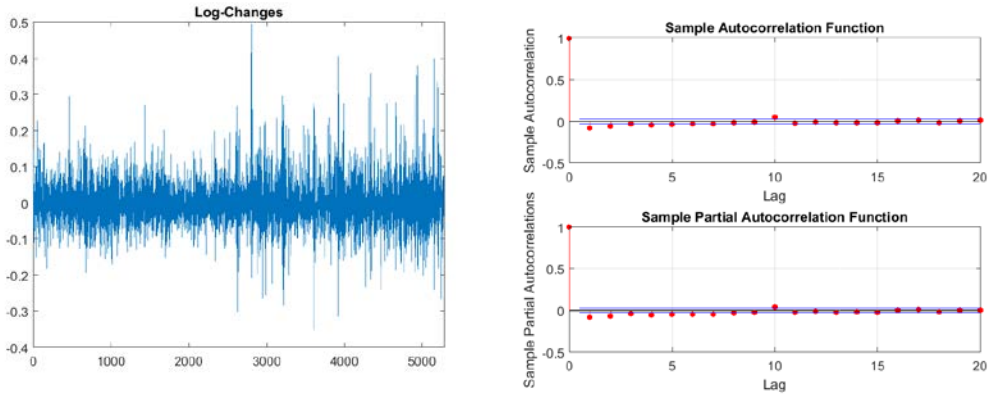


Appendix 5: Variable Analysis



All variables seem to have a trend and this observation is further enhanced from the results we got from the Auto-Correlation Function (ACF). The plot suggests that the series are non-stationary. In particular, the first lags of the ACF are very close to one. In addition, the ACF plots show a very slow decay which suggests that the "memory" of the DGP is very long; long memory is indicative of non-stationarity. Thus, in order to use an autoregressive model, we have to transform the data. Since the dummy variables we use rely on that the VIX-dataset is the log-change of the VIX-levels (this to be able to capture the percent change in the index at the day

when news is announced), we decided to take the log-change of the other variables as well to keep consistency. We also tried taking the first differences of the variables, but the conclusions from the results were the same.



VIX

The series seem to have a mean-reverting effect with a mean around zero, i.e. the series apprears to be trend-stationary, and the Dickey-Fuller test supports this claim. For us to have a consistent regression, we want the regressors to be trend-stationary as well; meaning that the series' properties do not depend on the time at which the series is observed.

Augmented Dickey-Fuller Test; H1: unit root, H2: trend-stationarity, α=0.05

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (H=1 → no unit root, data likely stationary)

The sample ACF and PACF exhibit significant autocorrelation. Both samples seems to have a significant, but decreasing autocorrelation from 1 to 10 lags. The data appear to fluctuate around a constant mean, hence no data transformation is needed before conducting a Ljung-Box Q-test. The test is conducted with 5, 10 and 15 lags. From the results below we conclude that there is significant autocorrelation in the series.

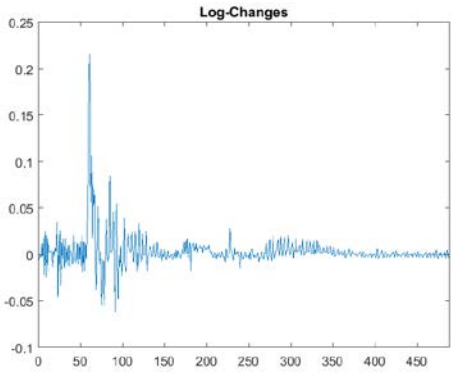
Ljung-Box Q-Test; H1: no autocorrelation, H2: autocorrelation, α=0.05

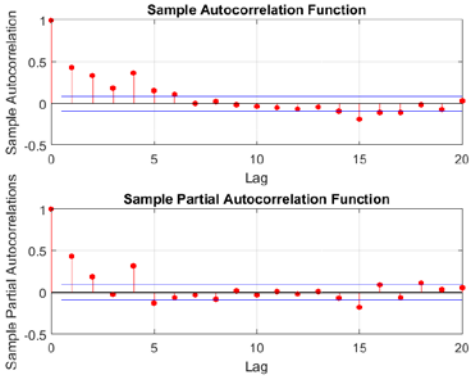
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

H=1 → significant autocorrelation in the series

TotAssFed

The series appear to fluctuate around a constant level, but exhibit volatility clustering. Large changes in the asset-values tend to cluster together, and small changes tend to cluster together.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

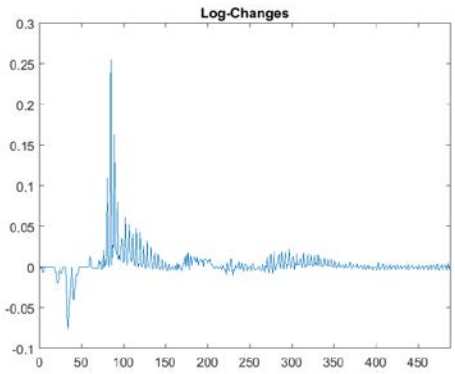
Ljung-Box Q-Test

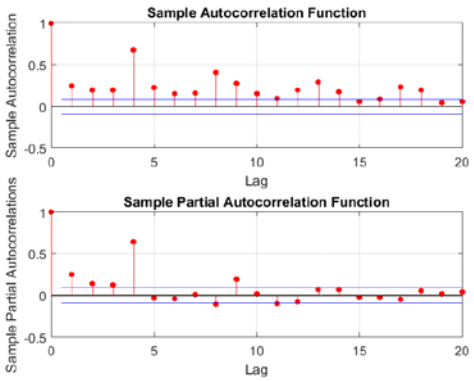
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

SecHeldOut

The series appear to fluctuate around a constant level, but exhibit volatility clustering. Large changes in the security-values tend to cluster together, and small anges tend to cluster together.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

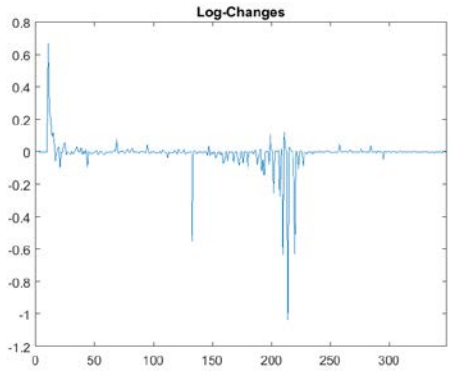
Ljung-Box Q-Test

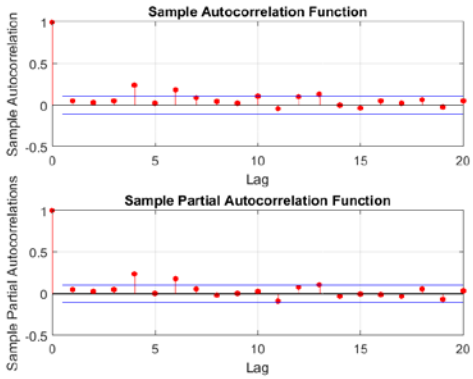
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

Support

The series appear to fluctuate around a constant level, but exhibit volatility clustering in the beginning and in the midle. Large changes in the support-values tend to cluster together, and small changes tend to cluster together.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

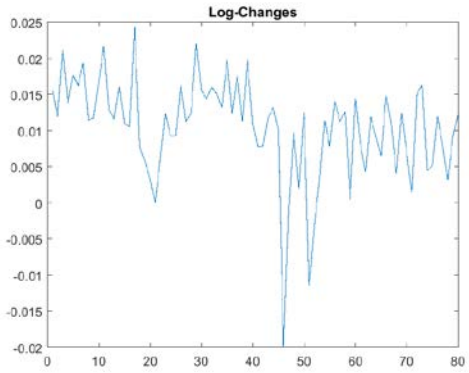
Ljung-Box Q-Test

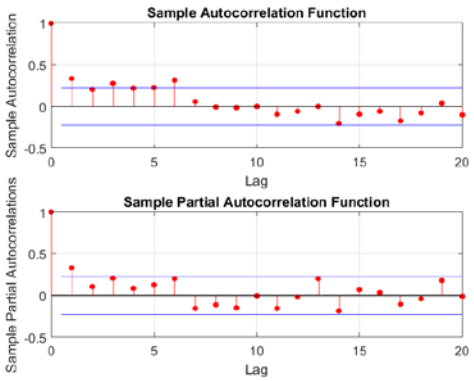
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

GDP

The mean is 0.0105, we can see that it pretty constant around its mean.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	0	0	0

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

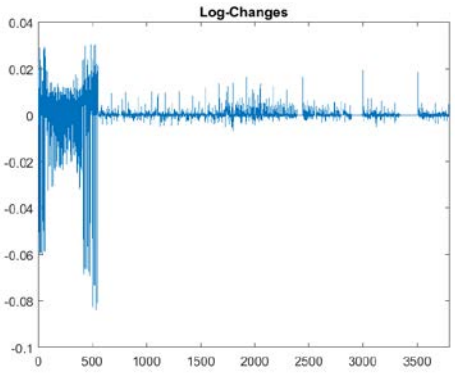
Ljung-Box Q-Test

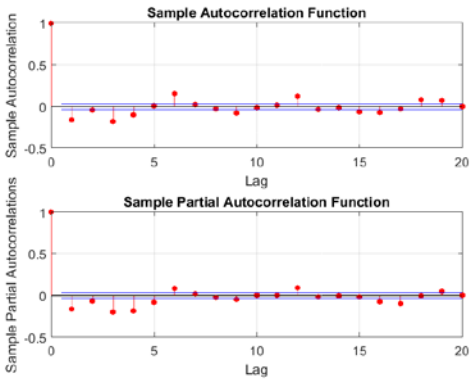
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	

h=1 → significant autocorrelation in the series

Debt

The data seems to fluctuate around a constant mean and looks stationary, however it seems to exibit heavy volatility clustering in the beginning of the series.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

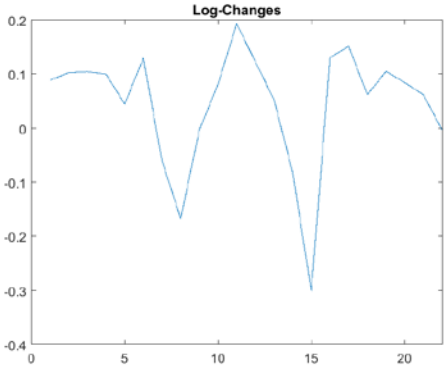
Ljung-Box Q-Test

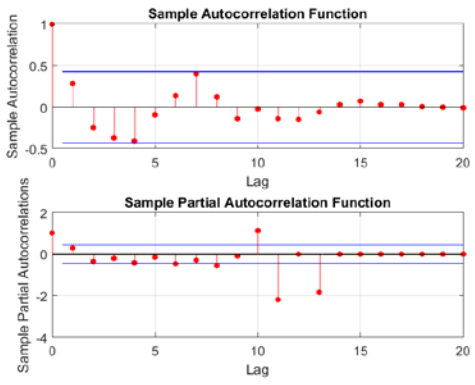
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

Tax

The data is very infrequent and even though it looks to have a mean-reverting effect, it does not seem to be usable. Neverthenless, we will test it to see.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	0	0	0	0	0

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

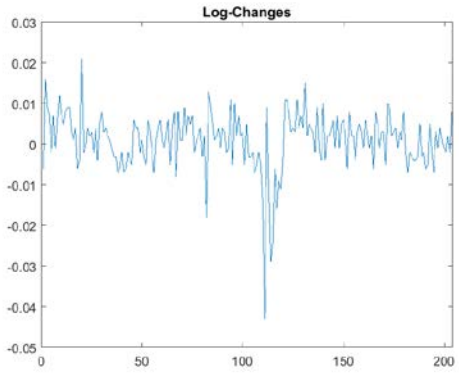
Ljung-Box Q-Test

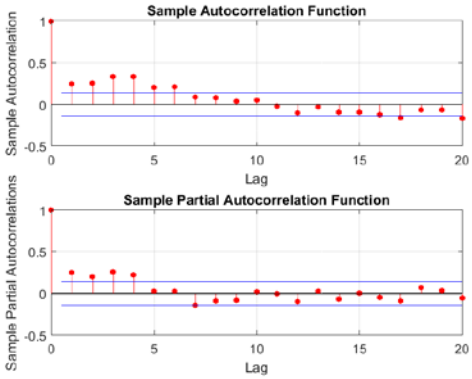
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

IP

The data seems to fluctuate around a constant mean and looks stationary.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	0	0

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

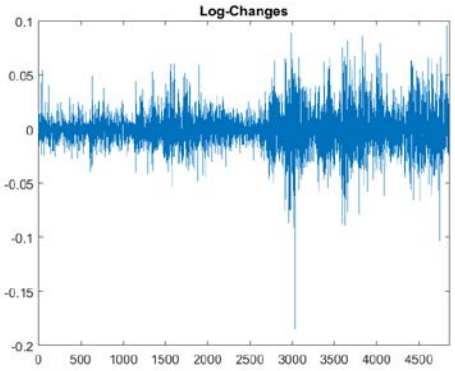
Ljung-Box Q-Test

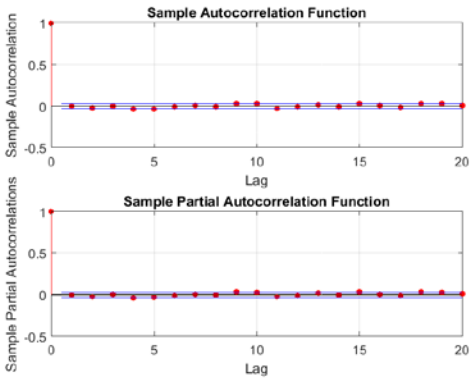
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

Yield

The series seem to have a mean-reverting effect with a mean around zero, i.e. the series apprears to be trend-stationary, and the Dickey-Fuller test supports this claim.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	0	0

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

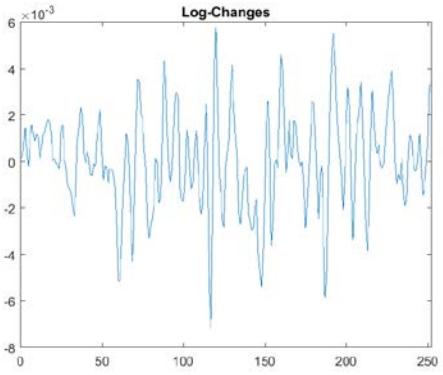
Ljung-Box Q-Test

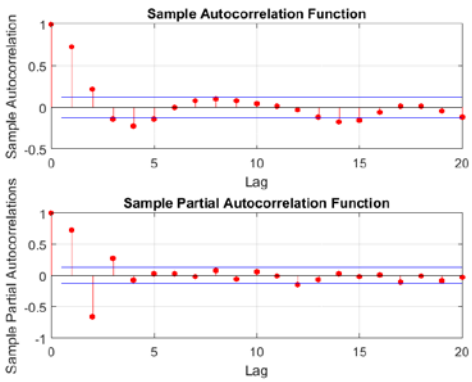
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

CCI

The data seems to fluctuate around a constant mean and looks stationary.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

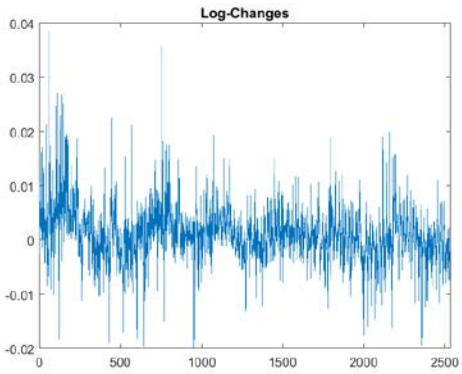
Ljung-Box Q-Test

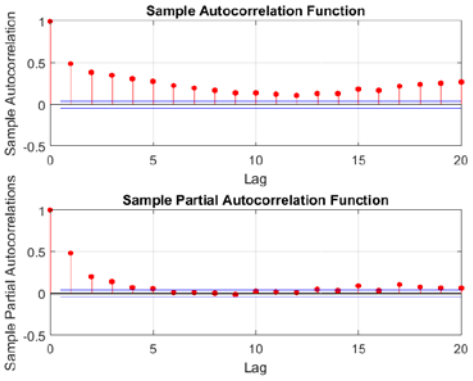
Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

#Options

The data seems to fluctuate around a constant mean and looks stationary.





Augmented Dickey-Fuller Test

Lags	1	2	3	4	5
Hypothesis	1	1	1	1	1

Test for a unit root against a trend-stationary alternative (h=1 → no unit root, data likely stationary)

Ljung-Box Q-Test

Lags	5	10	15
Hypothesis	1	1	1
P-value	0	0	0

h=1 → significant autocorrelation in the series

Summary

Looking at the features of the other variables, we can clearly see that they fall in line with the VIX. All seem to fluctuate alround a constant mean and do not exibit a unit root from 0-2 lags. However, TotAssFed, SecHeldOut and Debt seem to have structural break in the beginning of the time series, neverthenless we will keep all the data because we are trying to explain the movement in the VIX and we cannot afford to cut out that amount of observations. All variables show various tendencies of autocorrelation, but due to that we have very frequent data it is expected. If heteroscedacistyis present in the rediduals when performing the regression, a GARCH(1,1) term will be added to controll for this issue.

Appendix 6: Model Assessment

Initial model

Results

1.1.1990-31.12.1995

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon$$

EstimatedCoefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0015666	0.0016334	0.95908	0.33767
EMP	-0.0043112	0.0070206	-0.61409	0.53925
PPI	-0.012839	0.0070244	-1.8277	0.067788
CPI	-0.015184	0.0070188	-2.1633	0.030675
FOMC	-0.0076419	0.0085129	-0.89768	0.3695

Number of observations: 1516, Error degrees of freedom: 1511

Root Mean Squared Error: 0.058

R-squared: 0.0056, Adjusted R-Squared 0.00296

F-statistic vs. constant model: 2.13, p-value = 0.0753

'EMP' 'PPI' 'CPI' 'FOMC'

VIF = 1.0061 1.0092 1.0085 1.0029

Engle's ARCH Test[4]

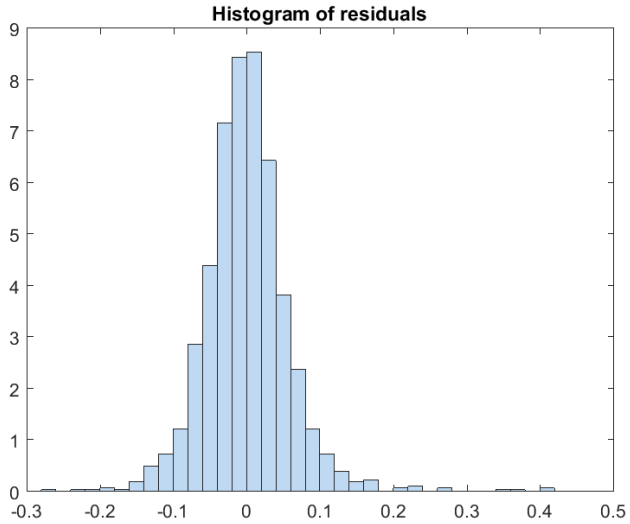
lags = 1

h = 1

pValue = 3.0600e-10

stat = 39.6360

cValue = 3.8415



Durbin Watson

p = 1.8374e-04

DW = 2.1981

GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.179134	0.0143768	12.4599
GARCH{1}	0.695183	0.0204223	34.0404
ARCH{1}	0.128646	0.0132327	9.72177

1.1.2001-31.12.2005

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon$$

[4] The result h = 1 indicates that you should reject null hypothesis of no conditional heteroscedasticity and conclude that there are significant ARCH effects in the return series

Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0014053	0.0015627	0.89932	0.36866
EMP	-0.0034945	0.0067024	-0.52139	0.60219
PPI	-0.0074913	0.0066931	-1.1193	0.26324
CPI	-0.018326	0.0066931	-2.7381	0.0062673
FOMC	-0.020218	0.008123	-2.489	0.01294

Number of observations: 1258, Error degrees of freedom: 1253

Root Mean Squared Error: 0.0505

R-squared: 0.0114, Adjusted R-Squared 0.0082

F-statistic vs. constant model: 3.6, p-value = 0.00634

'EMP' 'PPI' 'CPI' 'FOMC'

VIF = 1.0073 1.0053 1.0103 1.0076

Engle's ARCH Test

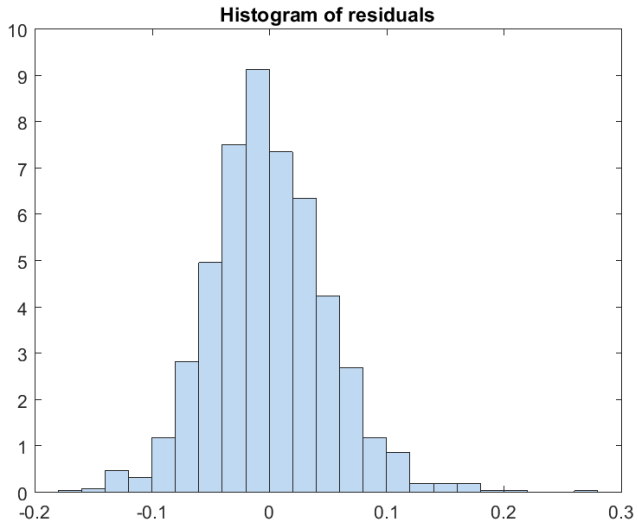
lags = 1

h = 1

pValue = 0.0011

stat = 10.6139

cValue = 3.8415



Durbin Watson

p = 0.0841

DW = 2.1058

GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic

Constant	0.068745	0.0210841	3.26051
GARCH{1}	0.846742	0.0317646	26.6567
ARCH{1}	0.0848273	0.0178932	4.74076

1.1.2003-31.12.2007

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon_3$$

Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0025948	0.001791	jan.87	0.14766
EMP	-0.0066129	0.0076887	-0.86009	0.38991
PPI	-0.017841	0.007682	-2.3224	0.020369
CPI	-0.012659	0.0076838	-1.6475	0.099708
FOMC	-0.032081	0.0093163	-3.4435	0.0005931

Number of observations: 1260, Error degrees of freedom: 1255

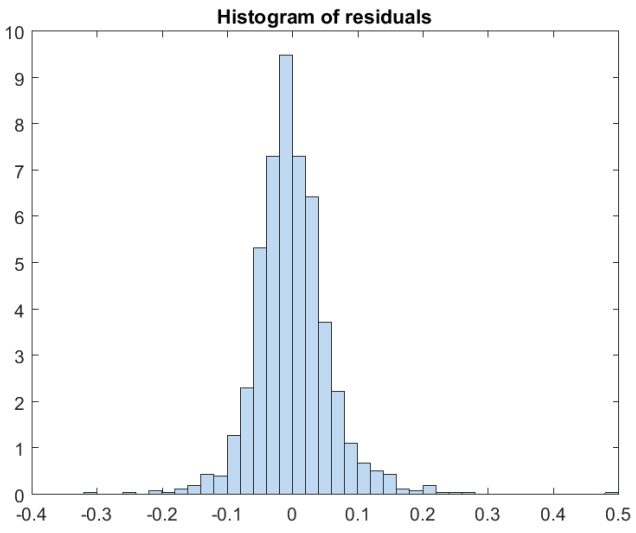
Root Mean Squared Error: 0.0579

R-squared: 0.0154, Adjusted R-Squared 0.0123

F-statistic vs. constant model: 4.91, p-value = 0.00063

'EMP' 'PPI' 'CPI' 'FOMC'

VIF = 1.0076 1.0096



Engle's ARCH Test

lags = 1

h = 1

pValue = 2.7350e-05

stat = 17.5937

cValue = 3.8415

Durbin Watson

p = 2.4104e-05

DW = 2.2444

GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.048064	0.0106314	4.52095
GARCH{1}	0.862252	0.0214969	40.1105
ARCH{1}	0.0918329	0.0153592	5.979

1.1.2008-31.12.2012

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon$$

Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0022974	0.0021836	1.0521	0.29294
EMP	-0.0132	0.0094777	-1.3927	0.16396
PPI	-0.006174	0.0093988	-0.65689	0.51137
CPI	-0.007728	0.0094052	-0.82167	0.41142
FOMC	-0.037541	0.011406	-3.2913	0.0010249

Number of observations: 1259, Error degrees of freedom: 1254

Root Mean Squared Error: 0.0708

R-squared: 0.0108, Adjusted R-Squared 0.00762

F-statistic vs. constant model: 3.41, p-value = 0.00872

	'EMP'	'PPI'	'CPI'	'FOMC'
VIF =	1.0081	1.0062	1.0077	1.0127

Engle's ARCH Test

lags = 1

h = 1

pValue = 3.4114e-10

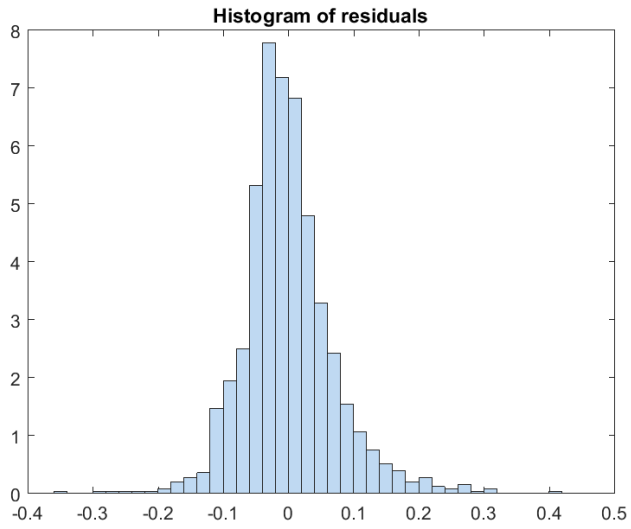
stat = 39.4236

cValue = 3.8415

Durbin Watson

p = 4.8048e-04

DW = 2.2038



GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.0779168	0.016066	4.84981
GARCH{1}	0.797401	0.0286719	27.8112
ARCH{1}	0.123386	0.0171809	7.18161

1.1.1996 - 31.12.2016

Linear regression model:

$$VIX \sim 1 + EMP + PPI + CPI + FOMC + \varepsilon$$

Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0030418	0.00097066	3.1337	0.0017354
EMP	-0.024175	0.0041899	-5.7698	8.3858e-09
PPI	-0.0079019	0.0041702	-1.8949	0.058166
CPI	-0.011355	0.0041713	-2.7221	0.0065082
FOMC	-0.030202	0.0050586	-5.9704	2.5205e-09

Number of observations: 5288, Error degrees of freedom: 5283

Root Mean Squared Error: 0.0644

R-squared: 0.0141, Adjusted R-Squared 0.0133

F-statistic vs. constant model: 18.8, p-value = 2.22e-15

	'EMP'	'PPI'	'CPI'	'FOMC'
VIF =	1.0068	1.0049	1.0054	1.0022

Engle's ARCH Test

lags = 1

h = 1

pValue = 0

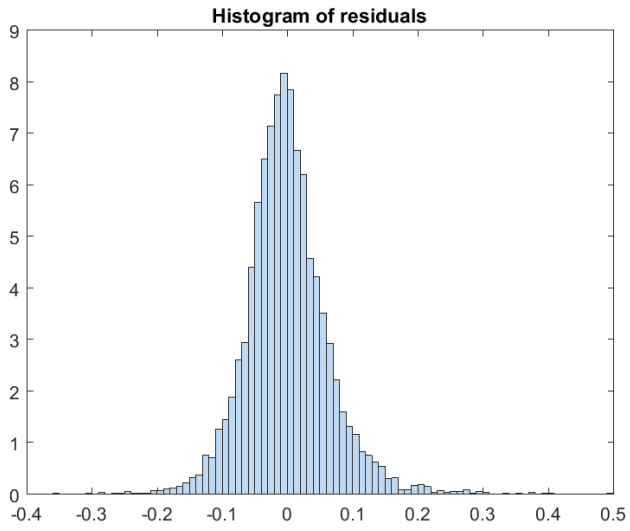
stat = 199.9493

cValue = 3.8415

Durbin Watson

p = 7.6058e-08

DW = 2.1497



GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.0753093	0.00700868	10.7452
GARCH{1}	0.808669	0.0120978	66.844
ARCH{1}	0.116992	0.00754434	15.5072

Extended model

1.1.2000 - 31.12.2007

Linear regression model:

VIX ~ 1 + EMP + PPI + FOMC + GDP + Yield + CCI

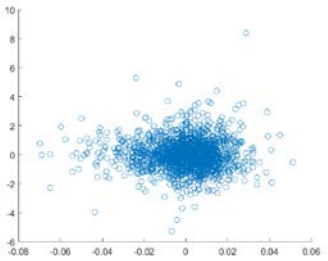
Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0021744	0.0013364	2E+06	0.10388
EMP	-0.011602	0.0058358	-1.9881	0.046936
PPI	-0.013919	0.0058302	-2.3874	0.017061
FOMC	-0.02733	0.007083	-3.8585	0.00011767
GDP	-2.2594	0.75771	-2.9819	0.0028989
Yield	-0.92706	0.09817	-9.4435	9.6526e-21
CCI	-4.8698	2.4059	-2.0241	0.043089

Number of observations: 2012, Error degrees of freedom: 2005

Root Mean Squared Error: 0.0556

R-squared: 0.0601, Adjusted R-Squared 0.0573

F-statistic vs. constant model: 21.4, p-value = 1.97e-24



Residuals plotted against fitted values for assessing if a linear model is suitable

	'EMP'	'PPI'	'FOMC'	'GDP'	'Yield'	'CCI'
VIF =	1.0055	1.0036	1.0040	1.0032	1.0013	1.0014

Engle's ARCH Test

lags = 1

h = 1

pValue = 7.3433e-06

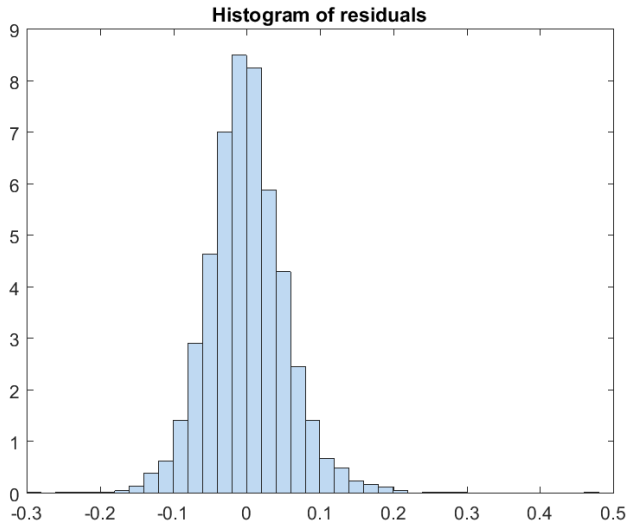
stat = 20.1017

cValue = 3.8415

Durbin Watson

p = 1.4216e-04

DW = 2.1766



GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.0538629	0.0121211	4.44372
GARCH{1}	0.879269	0.0191158	45.997
ARCH{1}	0.0665668	0.00977941	6.80683

1.1.2008 - 31.12.2016

Linear regression model:

VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield

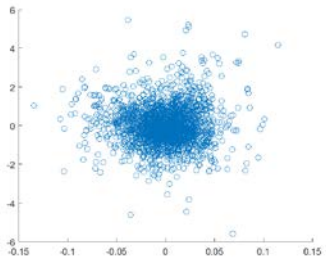
Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0019248	0.0015037	1.28	0.20066
EMP	-0.021433	0.0068126	-3.1461	0.0016764
FOMC	-0.028569	0.0086193	-3.3145	0.00093262
QE	-0.037251	0.016463	-2.2627	0.023748
TotAssFed	0.29476	0.16981	1.7358	0.082733
SecHeldOut	-0.41459	0.18165	-2.2824	0.022561
Yield	-1.0968	0.060287	-18.192	4.013e-69

Number of observations: 2267, Error degrees of freedom: 2260

Root Mean Squared Error: 0.0684

R-squared: 0.141, Adjusted R-Squared 0.138

F-statistic vs. constant model: 61.6, p-value = 5.43e-71



Residuals plotted against fitted values for assessing if a linear model is suitable

	'EMP'	'FOMC'	'QE'	'TotAssFed'	'SecHeldOut'	'Yield'
VIF =	1.0024	1.1070	1.0915	1.1286	1.1446	1.0058

Engle's ARCH Test

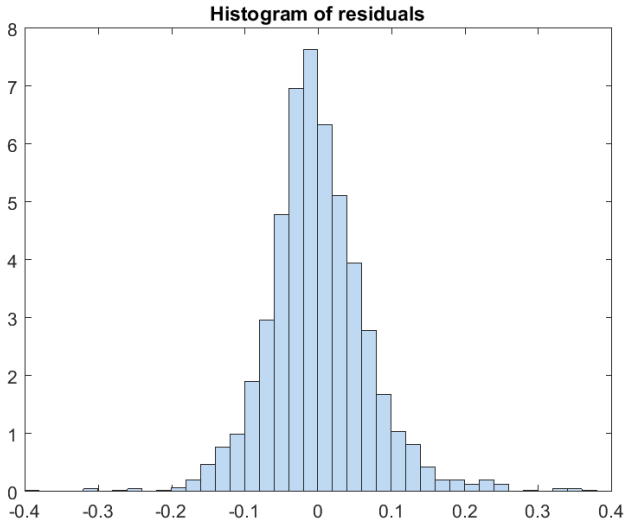
lags = 1

h = 1

pValue = 0

stat = 190.3373

cValue = 3.8415



Durbin Watson

p = 0.0019

DW = 2.1370

GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic

Constant	0.17626	0.0201965	8.72725
GARCH{1}	0.6443	0.0315964	20.3915
ARCH{1}	0.177115	0.0182952	9.68095

1.1.2000 - 31.12.2016

Linear regression model:

VIX ~ 1 + EMP + FOMC + QE + TotAssFed + SecHeldOut + Yield

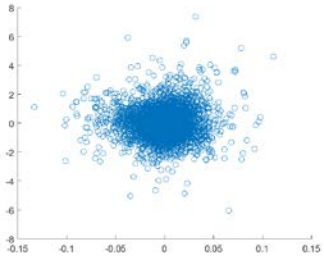
Estimated Coefficients:				
	Estimate	SE	tStat	pValue
(Intercept)	0.0015403	0.0010029	1.5358	0.12465
EMP	-0.016316	0.0045318	-3.6004	0.00032137
FOMC	-0.028454	0.0056204	-5.0627	4.3086e-07
QE	-0.037015	0.014771	-2.5059	0.012251
TotAssFed	0.29708	0.15414	1.9273	0.054008
SecHeldOut	-0.4021	0.16549	-2.4298	0.015148
Yield	-1.0657	0.049514	-21.523	1.2225e-97

Number of observations: 4279, Error degrees of freedom: 4272

Root Mean Squared Error: 0.0628

R-squared: 0.109, Adjusted R-Squared 0.108

F-statistic vs. constant model: 87, p-value = 3.52e-103



Residuals plotted against fitted values for assessing if a linear model is suitable

	'EMP'	'FOMC'	'QE'	'TotAssFed'	'SecHeldOut'	'Yield'
VIF =	1.0021	1.0545	1.0463	1.1262	1.1351	1.0047

Engle's ARCH Test

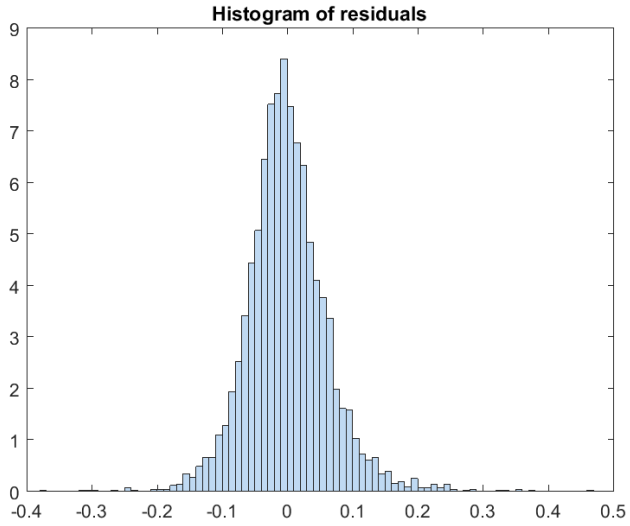
lags = 1

h = 1

pValue = 0

stat = 228.5095

cValue = 3.8415



Durbin Watson

p = 1.5149e-06

DW = 2.1504

GARCH(1,1) Conditional Variance Model:

Conditional Probability Distribution: Gaussian

Parameter	Value	Standard Error	t-Statistic
Constant	0.10715	0.0122173	8.77037
GARCH{1}	0.7698	0.0197217	39.0332
ARCH{1}	0.121769	0.00979203	12.4355

Appendix 7: CCI lag behaviour test

Lag CCI				
1 year lag				
Linear regression model: VIX ~ 1 + EMP + PPI + CPI + FOMC + QE + TotAssFed + SecHoldOut + Yield + CCI				
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0023407	0.0010526	2.2237	0.02622
EMP	-0.017326	0.0045471	-3.8104	0.0001407
PPI	-0.0074173	0.0045169	-1.6421	0.10064
CPI	-0.0087625	0.0045361	-1.9317	0.053459
FOMC	-0.028423	0.0056192	-5.0582	4.4105e-07
QE	-0.036662	0.014771	-2.482	0.013103
TotAssFed	0.29387	0.15425	1.9051	0.056829
SecHoldOut	-0.37027	0.16611	-2.2291	0.02586
Yield	-1.0654	0.049518	-21.515	1.4301e-97
CCI	**-1.7806**	**1.9177**	**-0.92852**	**0.35319**
1.5year lag				
Linear regression model: VIX ~ 1 + EMP + PPI + CPI + FOMC + QE + TotAssFed + SecHoldOut + Yield + CCI				
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0023134	0.0010524	2.1982	0.027985
EMP	-0.016926	0.0045413	-3.7271	0.00019622
PPI	-0.0074617	0.0045157	-1.6524	0.098525
CPI	-0.008739	0.0045351	-1.927	0.054048
FOMC	-0.028194	0.0056175	-5.019	5.4049e-07
QE	-0.037376	0.014762	-2.5319	0.01138
TotAssFed	0.29386	0.15412	1.9067	0.056621
SecHoldOut	-0.37178	0.16607	-2.2387	0.025225
Yield	-1.0667	0.049485	-21.557	6.3592e-98
CCI	**-3.1792**	**1.9075**	**-1.6667**	**0.095644**
2year lag				
Linear regression model: VIX ~ 1 + EMP + PPI + CPI + FOMC + QE + TotAssFed + SecHoldOut + Yield + CCI				
Estimated Coefficients:	Estimate	SE	tStat	pValue
(Intercept)	0.0023456	0.0010527	2.2283	0.025913
EMP	-0.017159	0.0045414	-3.7784	0.00015998
PPI	-0.0074641	0.0045167	-1.6525	0.098499
CPI	-0.0087748	0.0045361	-1.9344	0.053128
FOMC	-0.028335	0.0056183	-5.0434	4.7636e-07
QE	-0.037198	0.014765	-2.5193	0.011795
TotAssFed	0.28992	0.15455	1.8759	0.060734
SecHoldOut	-0.36696	0.16618	-2.2082	0.027282
Yield	-1.066	0.049504	-21.533	1.0093e-97
CCI	**1.684**	**1.914**	**0.87983**	**0.379**

Appendix 8: Preliminary Report

- Study Programme

MSc in Business/QTEM – Major in Finance

- Title

What is the effect of macroeconomic news on the VIX?

- Name of supervisor

Chunyu (Ben) Yang

Abstract

We study the behaviour of the VIX Index from impacts of macroeconomic news.

In the preliminary thesis we introduce the topic and some of the theory behind it, we discuss the content of academic journals written on the issue, we describe what we have done so far and the way ahead.

Introduction

The VIX index was introduced in 1993 by the Chicago Board Options Exchange (CBOE), in 2004 they introduced futures trading in the index and in 2006 they opened for options trading in the index. Since then there has been an explosion in trading in the index, on some periods there is more trading in VIX futures than in actual S&P 500 options, this makes it an interesting index with high variance. We would like to look into how macroeconomic factors affect the volatility of the market, where the VIX represents the volatility of the S&P500, i.e. more or less the US Equity market, which again is known to be a proxy for the market as a whole.

Using the VIX as a proxy for the market's volatility is advantageous considering that it mitigates problems associated with measuring implied volatility, such as transaction cost and time-varying stochastic volatilities. Hull & White (1987) found that the VIX minimises the magnitude of stochastic volatilities since the index represents at-the-money implied volatilities. While Day & Lewis (1988) found that the extent to which the estimates of implied volatility are affected by noise from

illiquid assets or large bid-ask spreads is minimised due to the use of at-the-money options in the VIX.

It is well known that monetary policy has a lot to say for everything from investor's sentiment, to governments' and corporations' strategy and corporate action. All this has immense implication for the financial sector and how asset prices move.

Several studies have investigated the movement in the VIX due to changes in monetary policy or other macroeconomic news, nevertheless, we want to look into this with more up-to-date data and by adding explanatory variables which may unveil new discoveries and add statistical power to the output. Our motivation for choosing this topic is that divided. For once, we wanted to do something original, or as original as a thesis can be considering all the papers that have been made, and we wanted to do something which is interesting and an up-to-date issue. The VIX has figured regularly in international media, thus we wanted to learn more about how it really works and what drives it. And out of the results of our search for master theses in the archives, we believe that this topic is one of the less investigated ones.

Problem/objective

In our initial thesis proposal we form the research question "*What is the effect of VIX futures and options trading on the VIX*". After looking deeper into this issue, and after discussing it with academics and getting feedback from our supervisor, we decided to change the question slightly. We now want to investigate the impact of macroeconomic news on the VIX. We all know that macroeconomic factors affect asset prices, but how does the uncertainty in the market become affected? For instance, will good and bad news have equally effect? I.e. that investors buy equally more in terms of good news, as they sell in terms of bad news, and thus the volatility of those actions is the same. We have found some academic papers on this issue in general, but the topic is by far not exhausted; new variables can be added and newer data can be investigated, and, as mentioned, this is to our knowledge one of the less examined topics.

Objective: *What is the effect of macroeconomic news on the VIX?*

Literature Review

Testing the effects of different announcements and news publications on market volatility has been performed several times with different approaches and methods. The more general way is to test the effect that macroeconomic announcements from central banks or common macroeconomic indicators have on the implied volatility, before and after the announcements. Measuring the impact on market volatility requires a good measure of volatility, most research tend to the easily available VIX index for the S&P 500, or some equivalent measure for another market. These measures are of implied volatility, and are not measures of volatility itself, but rather the expected volatility of the underlying market index or stock. Other papers like Antulio N. Bomfims "Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market" use conditional variance. Bekaert, Hoerova & Lo Duca (2013) has an interesting approach where they divide the implied volatility represented by the VIX into two components, risk aversion and expected stock market volatility. This way they can test the links between different monetary policy stances and investor behaviour.

Nikkinen & Sahlström (2004) focuses on the impact of the scheduled Federal Open Market Committee (FOMC) and the scheduled macroeconomic news releases on stock market uncertainty. The macroeconomic reports they chose were the employment, producer price index (PPI) and consumer price index (CPI). The behaviour of the implied volatility of the VIX is investigated around the FOMC meeting days and on the announcement days of the macroeconomic reports. Gospodinov & Jamali (2012) studies it from another angle, by examine the effects of expected and unexpected changes in Federal funds target rate, while Donders & Vorst (1996) on the other hand focuses on the impact from firm specific news; by studying the behaviour of implied volatility of call options around announcement days of scheduled news. Shaikh & Padhi (2013) used the same base macro-variables as Nikkinen & Sahlström, but their research was set in Indian markets so the FOMC was naturally not in their model, instead they included variables which were natural for the Indian market. Krieger, Mauck & Vazquez (2015) looks at the federal funds rates, which is one of the more important measures for the economy and is together with the target rate a key measure for how the respective central bank looks at the condition of the economy of the country. Krieger et al tried to examine the

responses of U.S. VIX and German VDAX implied volatility indices to the announcement of interest rate policy decisions by the FOMC.

Most of the relevant research on this topic is done on the period 1996 to early 2000. With Krieger et al being the latest paper which looks at 1999-2012 and Kearney & Lombra (2004) looks at the oldest, and maybe most comprehensive timeframe with as early as 1986 until 2002. Most papers therefor hit on the 2001 IT bubble, but few papers include the 2008 financial crisis. The VIX index has been around since 1993, but was not changed to measure the broader S&P 500 from S&P 100 until 2004. It would be very interesting to look at the time after the financial crisis of 2008, since there is little research done during this time. Including more recent data, would make it possible to compare several financial crisis occurrences and its previous and following years.

In efficient markets you expect that stock prices react immediately on new information. Patell & Wolfson (1984) investigated this and found that prices reacted within minutes, but disturbances in the stock price variance persisted for hours. To model variance you often use autoregressive conditional heteroscedasticity (ARCH) models, introduced by Engle (1982), or generalized ARCH (GARCH) models which were introduced by Nelson (1990). One important feature of these models is that in periods of high volatility are assumed to be followed by large movements in prices. This contradicts the efficient market hypothesis imposed by Eugene Fama (1969), which expects uncertainty to decrease after new information is revealed. However, Nikkinen & Sahlström saw, by using ARCH and GARCH models, that implied volatility decreased after news announcements.

Fleming & Remolona (1999) and Donders & Vorst found that macroeconomic announcements not only have an impact on realised volatility at the announcement day, but also have an impact on the market's future expected volatility – both before and after the announcement day! The market's expectations of future volatility are reflected through the implied volatility of options prices. According to Donders & Vorst the implied volatility rose in the pre-announcement period, had its peak at the moment the news was released, and sharply fell in the aftermath – again, uncertainty decreased after new information, as suggested by the EMH, but the increase before the news release still contradicts the hypothesis.

Nikkinen & Sahlström also found that uncertainty increased prior to the announcement. This suggests that the market is unsure about the content of the announcement and that this uncertainty is affecting the implied volatility substantially. Though, they do not consider what kind of content, and if the news is as expected and not. Gospodinov & Jamali consider this. They add the surprising element to the study, if the outcome from FOMC's meeting is as expected or not. By obtaining futures contracts from the FED they can control for market's expectations. Their findings are interesting; the expected change in FED's rate does not significantly affect the volatility of the market, while a surprising change in monetary policy have a significant increasingly affect. This might suggest that the rising uncertainty that Nikkinen & Sahlström and Fleming & Remolona find is due to an unexpected outcome of the FOMC's meetings.

Shaikh & Padhi expands on the existing research with their investigations of several macroeconomic indicators effect on the Indian VIX. The RBI (reserve bank of India) monetary policy statements, the consumer price index, wholesale price index, index of industrial production, the employment rate and gross domestic product (GDP growth rate) are introduced as dummy variables in their model and measures their impact separately. This is in contrast to the study of Nikkinen and Sahlström who treats all macroeconomic announcements as the same. However, even though their research is based on the same macro-variables, the findings of Shaikh & Padhi and Nikkinen & Sahlström are not the same. The latter found that the FOMC meetings were highly significant, while employment report had the largest impact of the macro-variables. But what the results also revealed were that PPI and CPI individually did not have a significant affection, whereas the two together had. This suggests that investors regard the information content of the two as a whole significant. This may be due to the fact that the content is similar. The results from Shaikh & Padhi on the other hand showed that all variables were significant, individually as well as jointly. This might suggest that there are different drivers for the Indian VIX than for the US. Maybe not surprising, but nevertheless a valuable discovery.

Shaikh & Padhi finds that especially announcements related to the GDP had a larger effect on the Indian VIX. Their research shows that for most news announcements on macroeconomic indicators, the VIX increases before and up until the announcement, but returns to normal levels after the announcements, this is

explained by the removal of uncertainty in the market. The opposite effect is found in monthly inflation rates announcements where the VIX increases after scheduled announcements. They therefore argue that there is a predictable pattern in the Indian VIX related to scheduled announcements, and they suggest opening for more financial instruments based on the Indian VIX to further improve the liquidity and transparency in the market.

Krieger et al further builds on the research from other countries than the US by looking at the difference and similarities between the effect of announcements in US and Europe. Their paper reveals that the effect of interest rate announcements in the US have a negative effect on the VIX, uncertainty is removed, but in Europe it is only removed if the announcement was in line with the market expectations. There is also a big difference in how the two volatility indexes respond to the other countries announcements, while the European VDAX responds to US interest rate announcements by declining, the VIX does not get effected by the European central bank (ECB) interest rate announcements. This has important implications for the ECB as they must consider other countries monetary policy when resolving domestic uncertainty, especially announcements from the US. FOMC announcements also seem to impact both uncertainty and risk taking in the market, by decreasing uncertainty and risk aversion, but the spill over effect to Europe is only short lived and does not seem to impact risk aversion.

Theory

The VIX is calculated in a different way than other typical indices, such as the S&P 500, which is calculated using the prices of its included stocks. Each index has certain rules that govern the selection of which securities to include and a formula to calculate its values. The VIX Index is a volatility index comprised of options rather than stocks, with the price of each option reflecting the market's expectation of future volatility. Though, like conventional indexes, the VIX calculation procedure follows certain rules for selecting which options to include and a formula to calculate its values. The generalized formula used in the VIX calculation is:

$$\sigma^2 = \frac{2}{T}\sum_i \frac{\Delta K_i}{K_i^2} e^{RT} Q(K_i) - \frac{1}{T}\left[\frac{F}{K_0} - 1\right]^2$$

Where…

σ is VIX/100 → VIX = σ * 100

T is time to expiration

F is forward index level desired from index option prices

K_0 is the first strike below the forward index level

K_i is the strike price of the i*th* out-of-the-money option

ΔK_i is the interval between strike prices

R is the risk-free rate

$Q(K_i)$ is the midpoint of the bid-ask spread for each option with strike K_i

It is constructed by taking a weighted average of implied volatilities of the two OEX calls and two puts that will expire next, but has 8 or more calendar days to expiry. An average of those call and put options' implied volatility is then calculated, the strike prices of the options must be just above the index price. Similarly, an average is again calculated using the same procedure as above, but with a strike price just below the price of the index. Further, these averages are used to interpolate at-the-money implied volatilities, where the at-the-money implied volatilities are calculated similarly as the put and call option, from the series of the following contract month. Therefore, considering that two option series are used, there are two interpolated at-the-money implied volatilities. Finally, these volatilities are finally weighted to obtain a single volatility that always has 30 calendar (22 trading) days to expiry. As a consequence of this, the VIX represents the 30-day implied volatility for an index option (The CBOE Volatility Index - White Paper).

Methodology and model

We base our study on several previous academic papers. I mention amongst others: Nikkinen & Sahlström (2004), Gospodinov & Jamali (2012), Donders & Vorst (1996), Shaikh & Padhi (2013), Chen & Clements (2007). By examining their models we get a good understanding of how to build our own model and which variables that are interesting.

When studying how asset prices react to new information, returns are traditionally divided into expected returns and abnormal returns. When examining equity returns, an asset pricing model is used to compute the expected returns which again is used to determine if the returns are abnormal or not. In the context of implied volatility, the return on the VIX, there are no obvious asset pricing model to explain these returns. A possible solution, at least from a statistical point of view, is to account for the expected change in VIX in a mean-reverting framework, meaning that we expect its value to converge towards its mean when diverging from it. By doing so, it is not necessary to assume a constant expected return.

To study which factors that drive the change in the VIX we need a model. The daily log-change in prices is what that should be used, and to implement macroeconomic factors in the model, dates from the announcement day of macroeconomic reports could be used. Then the discussion of which factors to use arises. There is not one answer to this, and it is something we will look into and test to find the most significant variables. Though, we will exploit the knowledge previous papers gives us.

Isolating the impact in VIX from new information can be done in different ways. Nikkinen & Sahlström (2004) implement a simple regression model,

$$\ln(\mathrm{VIX}_t/\mathrm{VIX}_{t-1}) = \alpha + \beta D_{0,t}^{\mathrm{Emp}} + \delta D_{0,t}^{\mathrm{PPI}} + \gamma D_{0,t}^{\mathrm{CPI}} + \lambda D_{0,t}^{\mathrm{FOMC}} + \varepsilon_t,$$

where the explanatory variables are dummy variables that takes the value 1 at the announcement day of employment report, producer price index (PPI), consumer price index (CPI) and Federal Open Market Committee (FOMC) respectively. By taking the value 1 on the days where the reports are reviled, the dummy variables capture the behaviour of the VIX on that day. Variables tend to correlate with each other and itself over time (autocorrelation), to adjust for this the variance of the error term, ε, is based on general autoregressive conditional heteroscedasticity model (GARCH). The model we will use will be similar to this, but we will consider the variables used in other papers as well. For instance, Shaikh & Padhi (2013) used monetary credit information review of central bank of India (MCIR), gross domestic product (GDP) and wholesale price index (WPI), and we believe

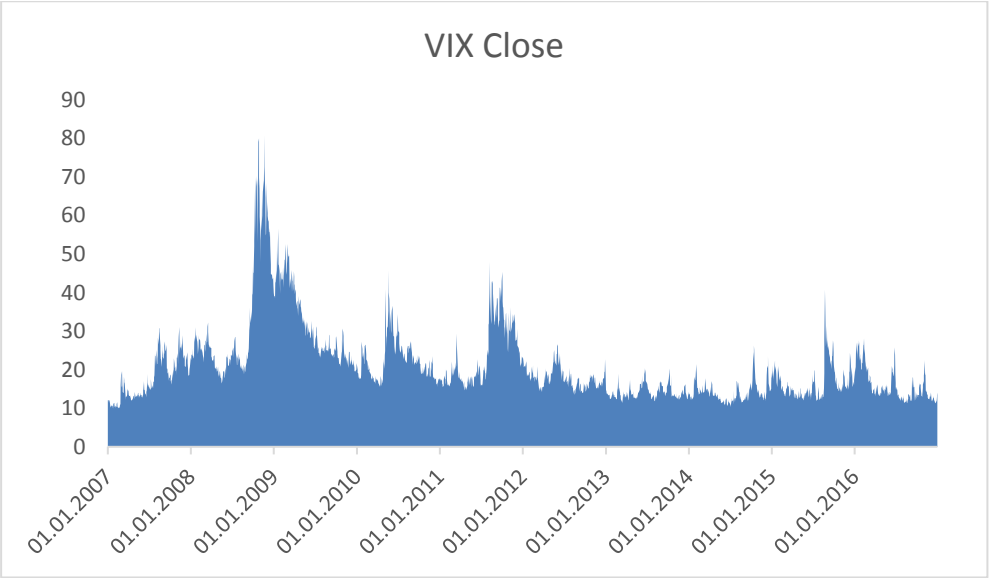
announcements of quantitative easing (QE) could be interesting to look at – a factor which we so far have not seen been used.

Data

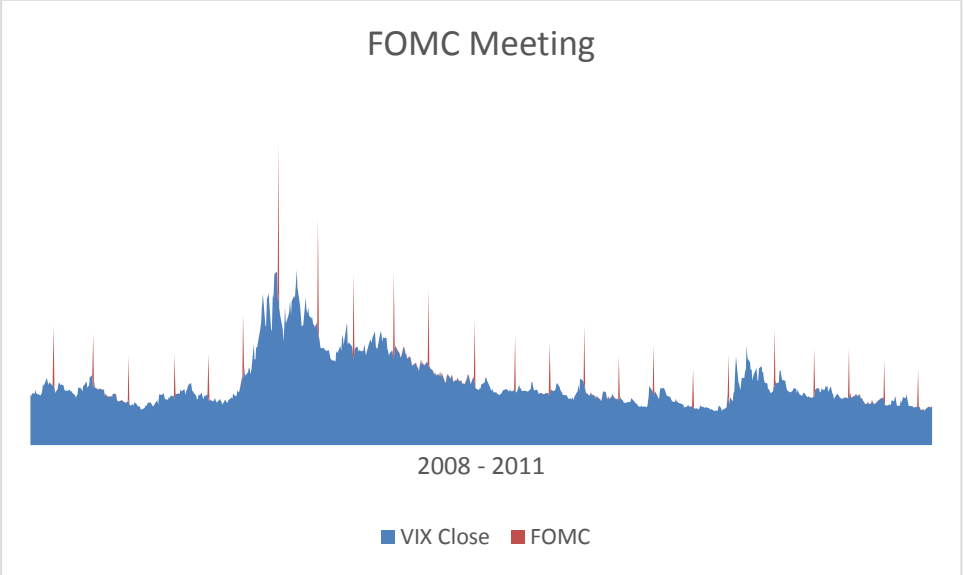
For our study we need data on the VIX and on announcement dates for macroeconomic news. Our sample consist of daily data on the VIX, while the macroeconomic reports for CPI, PPI and employment rate are published monthly and the FOMC's meetings are held eight times a year. The announcements of QE can be divided up in three, QE1, QE2 and QE3. The 25th of November 2008 was the first time FED announced that they would purchase mortgage-backed securities (MBS) and agency debt. QE2 was reviled the 3rd of November 2010 and QE3 on the 13th of September 2012 (Quantitative Easing - Federal Reserve Bank of Boston).

Implied volatility data can be downloaded from the CBOE website[5], the exact dates for when the macroeconomic reports were released can found in the actual reports provided by the Bureau of Labor Statistics[6] and the dates for when the meetings held by the FOMC can be found at the FED's website[7]. The sample period we are looking at is from 1st of January 2007 to 1st of January 2017. Then we will capture the up-run to the financial crises and the aftermath. In this period there were held 80 FOMC meetings and we will have 120 reports from each macroeconomic variable we choose.

[5] VIX Options and Futures Historical Data (The daily volatility implied by the VIX can be calculated when recognising that the VIX quote is equivalent to 100 times the annualised return standard deviation. Hence (VIX/(100√252))2 represents the daily volatility measure (see CBOE, 2003).
[6] Archived News Releases - Bureau of Labor Statistics
[7] Meeting calendars of the Federal Open Market Committee



Figur 17: VIX from January 2007 to January 2017



Figur 18: VIX from January 2008 to January 2011 with FOMC meetings

As we can see in figure 1 there are a lot of spikes which will be very interesting to investigate and see if our variables have any explanatory power. Figure 2 shows us a sample from the beginning of 2008 and out 2010, which was period where the VIX spiked the most, and when the FOMC's meetings took place. It is hard to say anything from these graphs, but we clearly see a downward trend in figure 2 which will be very interesting to see if we can find any correlation between the trend and the strategy FED made to handle the financial crisis.

Process to complete the thesis

Our thesis is very theoretical and there is no part of it which needs us to conduct a survey or interview individuals or groups. Hence, the time will be spent at our academic institution where we have great facilities. Structure and planning is essential for a good outcome; since both of us are working part-time two days a week, we have designated days each week solely for working on the thesis – we also expect to work in the weekends. The workload will be divided between the two persons in the group and the different tasks will be allocated based on each person's strengths, if not applicable the group will work together. In the coming weeks we will continue to gather relevant information and immerse ourselves in the literature. Some of the data is already gathered, we will retrieve the rest and start to look into it in detail before deciding on a statistical program to process the data and which quantitative techniques to use to calculate the implied volatility of the index.

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