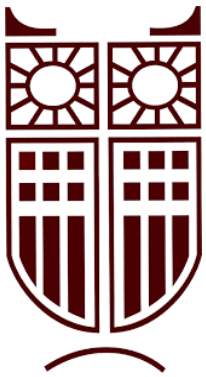

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"Measures of uncertainty and economic policy"

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Η παρούσα διπλωματική εργασία εκπονήθηκε στο πλαίσιο του μεταπτυχιακού προγράμματος «Εφαρμοσμένων Οικονομικών & Διοίκησης», του τμήματος Οικονομικής και Περιφερειακής Ανάπτυξης του Πάντειου Πανεπιστημίου Οικονομικών και Πολιτικών Επιστημών. Την τριμελή εξεταστική επιτροπή αποτελούν οι κάτωθι:

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Contents

Tables

Figures

Abstract

The purpose of this thesis is to examine the effects of monetary policy on risk measures such as VIX and TYVIX indices, as it's been applied by the Federal Reserve Bank after 2008. We use a bivariate GARCH model in order to extract the dynamic correlation of the aforementioned variables. We search for possible regime changes in correlation of VIX and TYVIX by applying a simple switch regime model before and after the implementation of quantitative easing (QE). We find a weak regime transition between high and low correlation level, with the exception of the period 2007 – 2011 when a high regime reveals a high correlation both in boom and bust cycles. FED's intervention could have contributed to the reduction of volatility in both stock and bond markets during the period when QE1 and QE2 were in effect but after 2012 this impact diminished. The effects of monetary policy on "fear" indices co-movement is an interesting feature in the financial markets and could be useful information for various investment strategies.

Keywords : *Quantitative easing, uncertainty, volatility, bivariate GARCH model, switch regime model*

Introduction

In the aftermath of the 2008 economic crisis, central banks all over the world applied expansionist monetary policies with the aim to help global economies recover. The main monetary tools used by central banks in order to achieve their goals were quantitative easing (henceforth QE) and forward guidance. QE is the process in which large amounts of new money created by central banks are used to buy large quantities of financial assets such as government bonds and private securities. Forward guidance is the verbal assurance of a central bank that it will keep the existing monetary policy unchanged and that future changes won't be unexpected and will be made at a specific timeline. Until 2008, the most used tool of central banks to stimulate the economy was the fixing of the basic interest rate, either by fixing the discount rate or by buying and selling short-term government bonds. By the end of 2008, the basic interest rate had reached the zero low bound in almost all of the biggest economies. The monetary regulations of several central banks, like the Federal Reserve banks (Henceforth FED) in USA, prohibit the setting of a negative rate, so a more aggressive expansionist policy was needed. In order to increase liquidity on financial markets central banks all over the world began purchasing financial assets in exchange for deposits. By the year 2018, the combined amounts of new money issued by the monetary authorities in the four major world economies (USA, JAPAN, E.U. and CHINA) was more than 10 trillion US dollars (usd $).

The appraisal of monetary policies is not easy, because their total integration in economic life may take several years. Since the magnitude of the unconventional monetary policies applied from 2008 and thereafter has no historical precedent, we can rely only on theoretical perspectives for any consequences. However a research about the conditions in the economy as a result of monetary policies is worthwhile to be done. In this thesis, we examine the time-varying correlation of risk measures such as VIX and TYVIX indices during the QE period.

Some views recognize only positive results from the unconventional monetary policy implementation, which can already be measured. Increases on corporate investments in fixed capital, lower yield payments for governments and businesses, and increasing rates of growth output are partly attributed to QE. To find out if these views make sense, we must reckon what exactly the central banks intended to do and how they tried to accomplish it. The main purpose of assets purchase is to reduce the yields' term premium in order to reduce the cost of lending and benefit borrowers (at the expense of lenders), pushing output to grow both by increasing investments and consumption. Another goal of QE

is to raise asset prices like stocks, so the holders of these assets get their wealth boosted and start spending more. QE also intended to bring stability to the economy by providing liquidity through the banking system.

On the other side, there is a growing number of individual who consider unconventional monetary policy as the cause of malfunctions in the economy despite the seemingly good economic performance, mainly after 2012. The main argument of the critics is that by lowering the prevailing yield curve central banks cause an exogenous increase in asset prices and a decrease in risk perception which leads financial stakeholders to illogical economic behavior and act with complacency. If this becomes the prevailing feature in the financial markets might lead to the creation of the next crisis, which would be much worse than the crisis which led to the implementation of the unconventional measures.

As for the impact of QE in real variables, the opponents of QE claim that it would be negative or insignificant, since the way QE was applied favors mostly the financial sector and could increase speculation and unproductive investments. Moreover, this economic policy prohibits the liquidation of the existing bad assets that have been accumulated in various sectors in past years. As a result, zombie-corporations have the opportunity to continue their function, due to low-yielding borrowing costs, which doesn't allow new and more productive investments to install and the economy stalls. For example some analysts have expressed the opinion that the low yields between 2003 and 2007 have played a crucial role for the advent of the 2008 financial crisis. The result of QE, according to its critics, would be the therapy to kill the patient.

In this thesis, we examine if the FED policy had any effects on USA bond and stock volatility indices. Of course, in order to study the consequences of a monetary policy, a bunch of factors both domestic and foreign must be taken into account. The contemporaneous exercise of monetary policy in all the major economies, the rising of Asian economies which provided cheap labor-intensive products with deflationary effects all over the world, and the growing capital flows between various sovereign states, requires a very accurate and thorough research.

The difference of our approach related to the existing literature, as far as we are concerned, is that it focuses on the correlation of the implied volatilities in the stock and bond markets and how much it has been affected by the implementation of QE. We use a multivariate GARCH model to extract the time-varying correlation of the two volatility variables. The correlation series becomes our new variable, in which we implement a Markov switch regime model to explore if QE had an impact in the correlation of stock-bond volatilities. We try to find out if there are any crucial changes around QE

announcements and the periods between them. A very important moment is that of 2013, a period widely known as the “taper tantrum”, when the FED decided to reverse the QE program as well as the period after February of 2018, when FED started to sell bonds with the aim to reduce its balance sheet.

The importance of time varying correlations in financial assets is something that is commonly admissible by modern portfolio theories. We think that the bond-stock correlation is an important factor for monetary policy decisions. Mallick et al. (2017) use VIX as proxy of stock market volatility and MOVE index for bonds volatility in order to examine the determination of term structure in government bonds. They use both bond and stock implied volatilities because investors diversify their portfolios mainly among these assets. Also, the gradually growing importance of volatility trading strategies such as risk parity funds and CTAs makes assets’ volatility an important variable to observe. Even if these financial strategies use realised volatility as an input in their models there is a constant relationship with implied volatility indices which can be used as a proxy. There are a couple of stocks and bonds volatility measures but the difficulty in obtaining their data leads us in the use VIX and TYVIX indices, since they are more accessible to obtain.

Our findings suggest that monetary intervention can play an important role in easing the volatility of both stock and bond markets for a quite long time after a financial turbulence. But after this period its impact eases and VIX and TYVIX time-varying correlation is mostly affected by other exogenous factors.

First we consider a part of the existing literature and its findings about what interactions of monetary policies with the economy and financial markets are.

Chapter 1. Literature review

In the economic research, there are two financial assets that are commonly examined, stocks and bonds. Bond price movements and the implicit price of their yield, affect a variety of other financial assets since the bond yield is used as the discounting factor in their price calculation. For example, the stock price valuation methods have a benchmark interest rate as parameter in their calculation formula which is used as a discounting factor. A common rate used for stock valuation is the yield of short-term US government bonds. Some papers examine the stock-bond correlation and try to find out its transmission patterns which are important due to the increasing degree of interdependence among financial markets (i.e. Stivers et al., 2002; Campbell, J., Taksler, G., 2002). In addition, stocks and bonds represent the largest portion of total investment positions together with real estate and commodities, so it is useful to examine their interactions.

There is enough relative literature about monetary policy and how it affects financial markets, part of which focuses on the impact that monetary policies, such as the FED´s quantitative easing or the ECBs corresponding program, have on assets prices and on volatilities. Bekaert et al. (2013) after decomposing VIX in two components, risk aversion and uncertainty, assert that a loosening monetary policy reduces both of them, but more strongly affects risk aversion. That effect lasts for more than 2 years, and the fact that the three QE programs were spaced apart about 2 years possibly is not a coincidence. Rompolis (2017) applying a structural vector auto-regression (S-VAR) model finds out that an expansion in ECB balance sheet decreases in the medium term, both uncertainty and risk aversion as measured by the VSTOXX index which is the implied volatility of EURO STOXX50 stock market. Mallick et al. (2017) provide similar findings of the interaction between monetary policy and uncertainty in US markets. Using a var model, they show that a monetary loosening policy either with a cut in the fed rate before 2007, or an increase in assets buying after 2008 crisis, resulted in the decline in both bond and stock volatility. The impact was higher for stock volatility index relative to bond volatility as measured by the MOVE index. Tan and Kohli (2011) examined the consequences of FED assets purchasing on VIX index and on realized volatility of S&P500 index the period between 2008 and 2011. Their results indicate that the first two stages of QE (QE1 and QE2) kept stock market volatility low. A jump of volatility occurred in the period before the beginning of QE and also in the intermediate period between QE1 and QE2.

Another group of research aims to find the impact on volatility from central banks' statements and decisions on basic rate, especially the period before basic interest rate reaching the zero low bound. Krieger et al. (2015) find that VIX declines in an average percentage of 2.78% on scheduled meetings of Federal Open market Committee (henceforth FOMC), a clear indication of risk aversion or uncertainty resolving. This decline comes regardless of the content of the policy decision and the announcements that accompany it. They also show that during FED meeting days, the German stock market volatility index (VDAX) had the same declining course with VIX. The European Central Bank meetings did not have an impact on VIX index, probably depicting the importance of US rates for the entire world, due to the usage of US dollar as the main financial currency in global markets. The changes on rate can affect the value of the dollar as well as the London Interbank Bank Rate, which is the rate of the dollar-dominated worldwide lending activity. Vähämaa and Äijö (2011) show that stock market uncertainty as measured by the implied volatility VIX index, tends to decrease after FOMC meetings and mostly after downward negative surprises for the federal fund rate decision. The data period of their research is between 1994 and 2007, a period in which global economy had positive growth rates with the exception of 2001-2002.

The effects of monetary policy can be seen not only on stock, but also on bond and interest rates volatility. Chang and Feunou (2013) examine the effects of central bank of Canada monetary actions on implied and realized volatility of interbank lending rate futures and report that the implied volatility of interest rates in Canada has been reduced, as the central bank of Canada was committed to keep interest rates unchanged or reduce them. They also provide evidence that uncertainty decreases after central banks' announcements. An important conclusion of their work is that the termination of central banks' commitment for future interest rate changes increased uncertainty. Gospodinov and Jamali (2012) find that implied volatility responded positively when there was a surprise in rate decision, but had no response when the interest rate decision was expected. This inference was observed for both daily and monthly data during 1994 - 2007.

Except from the decisions of central banks on interest rate and assets purchasing, another factor that affects volatility and asset price movements is investors' expectations about monetary authorities' announcements. Some researchers find important changes on volatility indices around central bank meeting days and examine the impact of both expected and unexpected monetary meetings in volatility. Bomfim (2003) examines stock returns and volatility movements the day before and the same day of FOMC policy announcements for the period 1989-1998. His findings show that volatility was low on days prior to the monetary policy announcement and was boosted the day when the decision was taken.

This “calm before the storm” effect is more intense the period after 1994 when FOMC changed the way it communicates its rate policy decision and started issuing formal press releases the day of the rate announcement. Additionally he finds out that volatility is more affected when a decision for an increase in fed rate is greater than it is expected. Farka (2009) ends up in the same conclusion examining the impact of FOMC statements the period 1994-2005, but in addition she notes that there is a significant drop in volatility after the announcement day where volatility returns are substantially low. She studied high frequency data of S&P500 futures prices and used a garch model for the calculation of volatility.

There is another part of the literature that examines the impact of changes in monetary policies not, on volatility measures, but in tail risk perception. Hattori et al. (2013) examine how forward guidance affect investors’ tail risk expectations for both bonds and stocks and find out that the option-implied stock and interest rates tail risk reduces after FEDs’ announcements. Roache and Rousset (2013) conclude that FED's QE program had a diminishing effect on tail risk of stock prices distribution constructed by at the money option prices, especially after QE1 and QE3.

Another question researchers often pose is what the results of central banks’ decisions on assets price changes are. Some papers support the idea that an expansionary monetary policy can increase the stock market index value in a significant extent. (Bernanke and Kuttner, 2005; Bhar et al., 2015). The impact of monetary policy is more direct on financial markets than on real economy variables like growth or unemployment. Bhar et al. (2015) assert that QE had a smaller positive impact on interest rates and unemployment than on stock market. Bernanke and Kuttner (2005) find out that a decrease in federal fund rate by 0,25% increase stock index by 1%. A different view expressed by Gali and Gambetti (2015) who report that an exogenous tightening of monetary policy contributes to an increase in stock prices, after a short-run decline during the period from 1960 to 2011. Farka (2009) asserts that a surprise 1% increase in policy rates causes a decline in stock returns by around 5.6%, and points out that losses on stock market are bigger when FED cuts interest rate more than expected, than when it raises it more than expected.

From all the above, we can assume that central banks decisions could have a significant impact on financial markets and on real economic variables, and we try to examine FED’s policy impact on measures of uncertainty such as VIX and TYVIX

Chapter 2. Theoretical Concepts

2.1 Risk measures

Risk or uncertainty is a very important factor in the economy and the measurement and forecasting of risk provides some very crucial benefits. Risk has a different notion from uncertainty as it incorporates estimated probabilities of a final outcome, while uncertainty is the fear of possible changes in these probabilities. However, the two concepts are both used to express volatility, so we can use them as being identical. According to Haddow et al. (2013), uncertainty cannot be directly observed since it relates to individuals subjective beliefs about the economy, but it can be observed indirectly using a proxy variable. They summarize several indicators that can be used as proxies for uncertainty mainly financial markets and survey data based indicators and create from them an uncertainty index using principal components analysis method.

Moore (2016) quotes some candidate uncertainty measures, and divides them in three categories. Newspaper - based, finance - based and forecast disagreement measures. Among finance-base measures, he stands out stock market prices volatility, because it's available in real time and it can be used to compare economic conditions in different countries. Realized and forward-looking volatility can be two other measures of stocks volatility. Realised volatility measures volatility of past stock returns. Forward-looking volatility is an implied volatility constructed from stock index options and it is a good measure of uncertainty for the reason that uncertainty has a future time-dependent nature. Bong Soo and Doojin (2013) support the view that implied volatility is more appropriate for economic research than realised or historical volatility, because it can gauge investors' expectations and sentiments. Historical and realized volatility do not contain such information because they are backward-looking measures.

Chang and Feunou (2013) examining the impact of monetary policies in interest rates, use both realized and implied volatility. They assert that the latter is important, because it is a forward-looking gauge of expectations about futures rates contracts (ex-ante), and the former because it allows the observation of interest rates futures volatility after an important economic event has taken place (ex-post). They conclude that by taking into account both measures of volatility, a more complete picture of the impact of central banks decisions could be drawn.

A well known gauge of stock market uncertainty is the Chicago Board of Options Exchange

(CBOE) market volatility index, known with the ticker symbol "VIX". It is a risk measure of the US stock market and represents the expected risk-neutral volatility of the stock market over the next 30 days. CBOE publishes the quotes of VIX index every 15 seconds, so VIX just like stock indices it is computed on a real-time basis throughout each trading day (Whaley, 2009). It is calculated from out of the money call and put options on the S&P 500 index, which are european style options (i.e. they are exercisable only at expiration). The maturity range of these options is 24 days (near term options) and 31 days (next term options) from the calculation day. It is called implied volatility index because it is derived from traded options prices and in contrast to others implied volatility measures like the Black and Scholes model does not have parameters in its calculation, so it is a model free index. VIX is calculated by a standard formula equation founded by Robert Whaley with CBOE contribution, (Whaley, 2009) as a weighted average number. Chicago Board Options Exchange (2014) white paper presents a step-by-step calculation of VIX index and provides the mathematical formula that is used for quoting VIX prices. Bong Soo and Doojin (2013) assert that model-free implied volatility measures like VIX have a better explanatory power than option-dependent models like Black-Scholes or Heston model. In addition, the use of an index computed only from out-of-the-money options, especially put options, contains important information due to portfolio insurance demand that investors seek in bad times (Whaley, 2009).

An interesting feature of the VIX index according to Whaley (2009) is that it often spikes upward but in the aftermath of each spike returns to normal levels. The same mean-return behavior is observed when VIX is in low levels and finally moves upward to its long-run mean, so we can assert that VIX index is a mean-reverting variable. Also, VIX and the S&P 500 index move most times in opposite directions, even if sometimes rising stock prices co-move with an upward VIX index price. Negative stock returns have greater impact on volatility than positive ones, creating an asymmetric relation between S&P500 returns and VIX. This can be attributed to two factors, the leverage effect and the volatility feedback effect (Bong Soo and Doojin, 2013). Leverage effect explains the asymmetric co-movement between VIX and stock returns, based on the fact that the equity value of a firm relative to its debt becomes smaller after a decrease in its stock price. In this case, the firm becomes more risky as it has a greater relative debt burden (a.k.a increased leverage). This may lead to increased future interest rate payments because it will be difficult for the firm to obtain low cost loans. The result is an increase on stock volatility, and investors further sell off. If this trend coincides in many stocks, the S&P500 index falls. Then, investors buy more S&P500 index put options as a hedge against further market declines and as a consequence VIX rises. There are occasions when VIX and stock market

prices increase at the same time, for example the period between 1995 and 1999 and this is an indication that investors become nervous even if stock price rise. In the case of a rising market, a profit-taking selling trend takes place but it's not as big in magnitude as in the case when stock prices falls. Increment stock prices lead investors to purchase less put and call options. An investor who is optimistic about future stock prices will probably buy directly the equity shares and not call options on stocks, unless the purchase of call options aims to leverage investors' financial position taking. In addition, when prices go up, put options purchases diminish, as they become less important for portfolio protection strategies. Of all the above we can assume that when market prices increase, purchases of options are diminishing and as a consequence VIX falls. But the crucial inference is that, if expected volatility as measured by the VIX index increases, then investors will demand higher returns for holding stocks and as a result their prices fall.

The volatility feedback effect in contrast to leverage effect, explains the impact of volatility surprises to stock prices returns. If volatility is priced, an anticipated increase in volatility would raise the required rate of return, in turn necessitating an immediate stock-price decline to allow for higher future returns (Bollerslev et al., 2006) and this explains the asymmetric relationship between VIX and S&P500 indices.

How good is VIX as a gauge of fear in markets? The fact that VIX index spikes during periods of market turmoil is the reason why many investors consider it a "fear index". We can assert that VIX is indeed a barometer of investor "fear", from the asymmetric relation between S&P 500 rates and VIX. Changes in the VIX rates reflect the demand for portfolio insurance and that's why the relation with the stock market is asymmetric. VIX index also can work as a predictor of stock indices movements (Whaley, 2009). Bekaert et al. (2013) decompose VIX in two parts, risk aversion and uncertainty. They show that monetary policy reduces both components of VIX but mostly affects risk aversion, so VIX can measure satisfactorily changes in volatility by exogenous events. Shaikh, I., Padhi, P. (2015) corroborate that Indian stock market VIX index, which is calculated in the same way as S&P 500 VIX, can be assumed as investors' "fear" index and as an unbiased estimator of future stock market volatility.

A question that arises is whether VIX is quoted fairly and whether it's trading in a liquidity market environment. According to Whaley (2009) the use of several option series in calculation methodology makes VIX less sensitive to any single option price change and less susceptible to manipulation. But a drawback of VIX index is that it has become the underline index for several financial products, so there is the incentive of being manipulated. Griffin and Shams (2018) explore if there is manipulation in the VIX index settlement with the aim of speculation in VIX futures, and find

out evidence of this might be happening.

The bond market volatility respectively can be measured by TYVIX index, which is provided like VIX by the CBOE. We can be well informed about this bond volatility index from the Chicago Board Options Exchange (2015) white paper, which is a practical guide explaining how it is constructed. TYVIX is calculated every 15 seconds from 7:00 am to 3:15 and just like VIX can be considered as a non-parametric model-free index. It measures the 30-day expected volatility of the interest rates market and it is calculated from the prices of options on 10-year Treasury note futures, which is a derivative exchange-traded product for the USA government bonds provided by Chicago Board OF Trade (CBOT). From the moment the TYVIX price is an estimate of the expected volatility of Ten-Year Treasury futures, by extension is an estimate of the volatility of Ten-Year Treasury Notes. The historical series from 2003 to 2014 shows that the TYVIX index reacts strongly to sudden and extreme variations in 10-year treasury bonds yield and may depict markets' expectations about future bond price changes. The more uncertainty about changes on interest rates, the higher the TYVIX index tends to be.

Mele et al. (2015) examining the combined behavior of VIX with the swap rate volatility index (SRVX) which is a similar to TYVIX index, they claim that it provides sufficient information on diversification of portfolios for hedging methods. The motivation for their research was the increasing importance of interest rates volatility for investor decisions.

Changes in VIX and TYVIX indices prices could have interesting interpretations and inferences. This is the notion of volatility of volatility (vol-of-vol), which can be estimated not only for implied volatility but also for realised volatility or for option-based parametric models. Baltusen et al. (2012) use the volatility of option-implied volatility as a proxy for uncertainty and find out that the higher vol-of-vol signals higher uncertainty for expected stock returns in investor perceptions. A reason for assets price uncertainty is that investors need time to learn about the probabilities of potential outcomes ("known unknowns") or they do not observe them at all ("unknown unknowns"). Using volatility of options as a proxy for uncertainty can be a good forecasting tool for future stock performance, as stocks with high vol-of-vol underperform compared with the stocks with low vol-of-vol ones. Park (2013) builds a tail risk measure, using a risk-neutral measure of volatility of the volatility, the VVIX index, which is calculated from options on the VIX index. He supports the idea that VVIX index is associated with tail risk because volatility of volatility is a critical determinant of the likelihood of extremely low returns. His research suggests that a high level of the VVIX index predicts lower tail risk hedge returns (put options, VIX call options) three to four weeks ahead.

The importance of using volatility measures as variables in the study of economy is accepted by a vast number of researchers. There are many research papers which use VIX as a measure of volatility and as a proxy variable for financial stress in the economy (Rompolis, 2017, Mallick et al. 2017, Bekaert et al., 2013). Bekaert et al. (2013) show that VIX co-moves strongly with measures of monetary policy so it is a useful variable to examine how central bank actions affect volatility. As for interest rates volatility indices, Mele et al. (2015) examine the SRVX index in relation with VIX, in order to observe stock and bond volatility co-movement behavior. SRVX is a model-free index provided by CBOE like TYVIX, and it is constructed by forward swap rate out-of-money options. Chang and Feunou (2013) use interest rates futures to calculate the realized volatility of interest rates and prices of options on interest rate futures, to compute an implied volatility measure. They find out that both realised and implied volatility are useful indicators of uncertainty about future interest rates.

Uncertainty affects economic activity in various ways and could cause violent changes in financial variables. Although central banks have no implicit goal to tame volatility, we guess that they take volatility into account when they must decide about policy changes. Haddow et al. (2013) support the idea that Bank of England must take into account for its policy decisions, both future and current state of uncertainty in the economy. Of course, central bank decisions affect volatility and vice-versa, so there is an endogeneity problem (Farka, 2009) between uncertainty and monetary policy.

Moore (2016) mentions that uncertainty is negative for economy for two main reasons. Firstly, households saving ratio increases following an uncertainty shock, as a precautionary measure against future difficulties. This reaction has an immediate impact on consumption and negative effects in most sectors of the economy. The second reason is that firms may decide to delay investments which would be costly to reverse after their implementation if the future economic environment proves to be unfavorable. This behavior has a demand-side effect for consumption as firms will cease their purchases, but mainly affects the supply channel, because when investments are postponed the future productivity of the economy won't grow. According to Bekaert et al. (2013) increased uncertainty as represented by VIX index leads to lower industrial production growth. Also, uncertainty about future conditions increases assets' risk premium and consequently the cost of credit for firms and households swell. This may negatively affect the consumption and investments that are vulnerable in a high yield environment (Haddow et al., 2013).

In addition to these demand-side effects, Haddow et al. (2013) point out two supply side dysfunctions that uncertainty causes in the economy. The first is the lower labor productivity, which is caused by unwillingness of households to leave their jobs and search for more productive ones and by

the unwillingness of firms to hire new and possibly more productive workers. Secondly is the deterrence of firms from entering new markets including export ones, which affects mostly the more productive firms that have a lot to gain from the increased competition and delaying this decision keeps their productivity stagnated.

So how can central banks handle and affect uncertainty and economic slowdowns and especially the FED?

2.2 Quantitative easing

Quantitative easing has been the main monetary tool that central banks all over the world have used to stimulate the economy after the 2008 economic crisis. The urgent necessity of a quick response to a flattened economic system made unconventional policies the best case solution. The reducing of short term interest to the zero low bound by the end of 2008 seem to have no effect in helping the economy recover as the malfunctioning of financial system continued. The whole system was in the verge of collapse. The interbank rate had fallen from 5,25 percent in September 2007 to virtually zero in December 2008 just a few months after the Lehman brothers bankruptcy, but economic conditions were worsening. The first concern of the FED was to stabilize the collapsing financial system by providing liquidity to the institutions that had been plagued by the ramifications of the crisis. The launch of liquidity facilities to financial institutions (i.e. banks, money market funds) led to an increase of FEDs' balance sheet, from 925,7 billion usd in 3 September of 2008 to 2,212 trillion usd in November 2008. These amounts were gradually replaced by the large bond purchase program which was launched within the expansionist policy.

The short credit facilities provided in the first months of the crisis, even if they hindered the short-term collapse, were not enough to reverse the bad atmosphere in global economies. The only solution for monetary authorities was to inject liquidity in the economy on a permanent and stable basis, with the aim to increase production and output growth. The biggest fear after the worst has passed was deflation. Deflation is an undesirable economic condition that can trigger a spiral of falling assets and goods prices and is created when households and corporations slowdown their consumption in anticipation of even lower prices in the future. The example of Japan's "lost" decade scared the monetary committee. The way for the central bank to confront this malfunction, was by reducing the long term rates and promote the wealth effect by appreciating assets prices. Implementing the QE, FED

had bought a total of around 3,6 trillion usd of medium and long-term securities by the end of 2014, and issued an equal amount of short-term liabilities in the form of bank reserves.

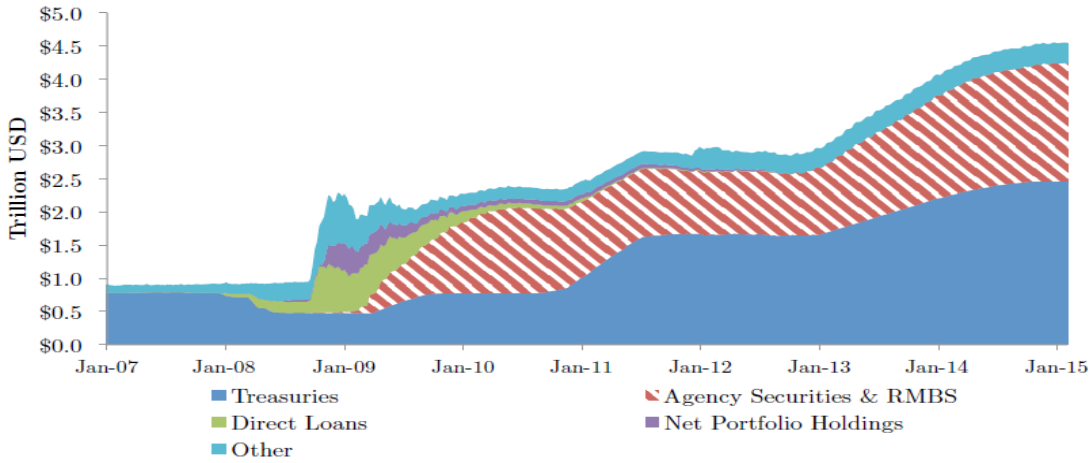
Di Maggio et al. (2016) and Fawley and Neely (2013) describe the whole monetary procedure from the starting year of 2008 to 2014 when the program ended (Figure 1 and Figure 2). The first round of QE began in December 2008, after it was announced on 25 November, with the purchase of large amounts of government sponsored enterprises (GSEs) bonds (i.e. Fannie Mae, Freddie Mac), especially those struck by the 2008 crisis and the subprime loan turmoil**.** In March of 2009, Fed announced the expansion of the QE1 targeting the total amount of $1.725 trillion, adding to GSEs bonds the purchase of long-term Treasury bonds. This stage lasted until March 2010.

The first announcement about an imminent QE2 was made in August 2010. The procedure of QE2 was initiated in 03 November 2010 and lasted until June 2011. This time, asset purchases were focused exclusive on Treasuries bonds ($600 billion in purchases). After three months in September 2011, Fed proceeded with the Maturity Extension Program (MEP) aiming to purchase long-term and sell short-term Treasury securities in an effort to reduce the supply of bonds with longer maturities. Within the MEP, the Fed sold $667 billion of short-term securities and the proceeds were used to purchase an equal amount of long term ones. MEP or "operation twist" as had been named, lasted until December of 2012, and did not result in the expansion of the monetary base because it was just a duration assets swap rather than new money creation. As of the end of 2012, the Federal Reserve had bought $1.567 trillion in long-term government bonds, $1.41 trillion in MBS, and $175 million in GSE debt, for a total of $3.152 trillion in purchases. The announcement of QE3 was on 13 September 2012 in the same month along with MEP and the proportion of assets that Fed intended to purchase was equally weighted between Treasuries and MBS. The Fed eventually bought over $1.6 trillion in net new MBS ($823bn) and Treasury ($790bn) debt during QE3. In October of 2014 Fed announced the end of QE program and its balance sheet assets peaked in January 2015 to 4,516 trillion usd. The termination of QE was decided after the economy was considered to have entered the development phase. From that point on, the central bank would reinvest the proceeds from the bonds that matured into new bonds with the same characteristics. The main tool of Feds' policy would be again the adjusting of basic interest rate. The first interest rate increase decided in December 2015 when the FOMC settled it to around 0.5 percent. By May 2018 the effective federal fund rate after several increases reached the level of 1,70 percent and balance sheet assets were at 4,327 trillion usd .

McLeay et al. (2014) provide a good description of QE procedure. With QE a central bank creates new money in the form of bank reserves and uses them to buy financial assets from non-bank financial

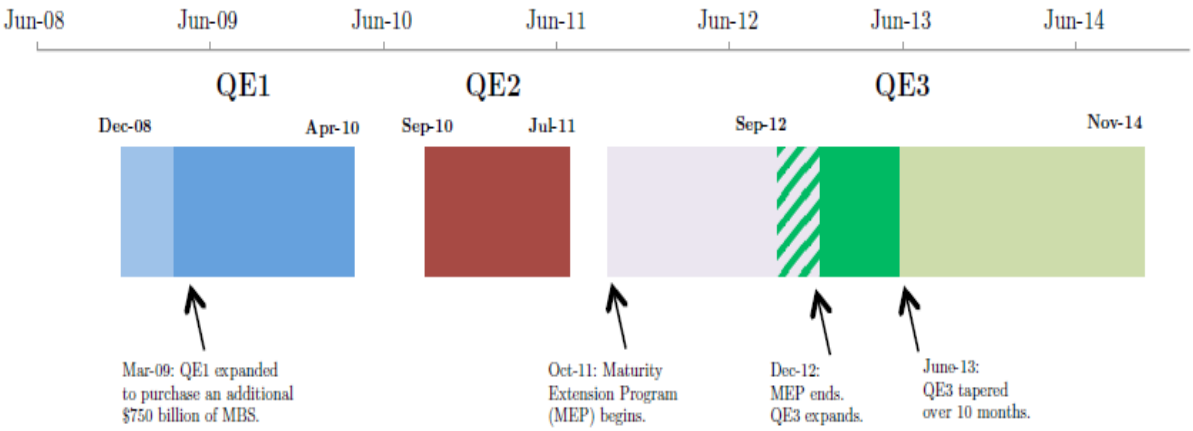
companies or institutions like pension funds, insurance companies, investments funds etc. The expectation of monetary authorities is that receivers of these bank reserves will increase the purchases of financial assets with higher yields than bank deposits, such as long term bonds or corporate stocks. This belief is based on the expectation that the financial institutions may not want to hold their funds in the form of a bank account with low interest, but they will probably look for better returns. The ultimate goal is that the purchases of financial assets from the institutions will lead to an increase in assets price and a decrease in yields. As a consequence of the long term bonds purchases, the long term interest as well as the cost of lending will fall. The lower lending costs stimulate spending and investing activity. When the central bank purchases corporate or commercial assets directly from the issuer, it has a direct impact on lending costs for firms. The reason is that the exchanged securities will be more liquid and attractive for investors to buy, because it would be easy to resell it as long as the central bank is a possible buyer. This reduces the risk of holding corporate bonds and promotes further purchase of these bonds with their interest rates falling respectively.

Figure 1: The evolution of QE



Source: Fed H4.1 weekly reports – Extracted from Di Maggio et all(2016)

Figure 2: Timeline of QE



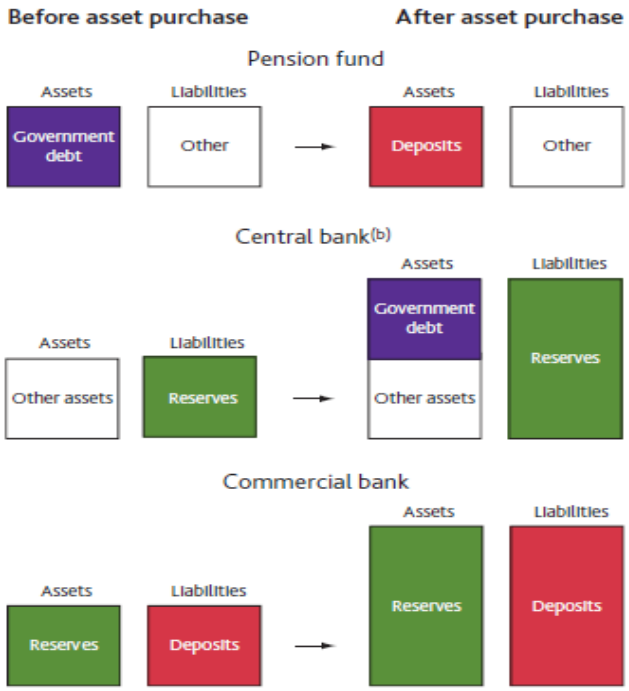
Source: Di Maggio et all (2016)

As we can see in McLeay et al. (2014), the exact transaction that takes place during QE, includes three counterparts. The central bank, the financial institution that holds the financial asset that will be purchased by the central bank and the commercial bank that will process the transaction. The central bank cannot buy bonds directly from financial institutions so the transaction must be handled through the banking system. For example, if the central bank wants to buy 1 billion US dollars of government or mortgage bonds from an insurance company or a pension fund, it would have to print money in exchange for these bonds. But the transfer of money in the modern banking system takes place in an electronic form and not with physical money like banknotes. Also, financial institutions do not have a reserve account with the central bank as commercial banks have. Financial institutions hold bank accounts in commercial banks for their daily operations or their borrowing activity. The transfer of the 1 billion USD will take the form of an electronic credit payment in the bank's reserve account with the central bank. After that, the commercial bank will credit the money to the insurance company's bank account and its deposits will swell by 1 billion usd. The purchased bond is recorded on the assets side of the central bank's balance sheet and the 1 billion usd on the liabilities side. Also, the commercial bank will record the 1 billion usd on both assets and liabilities sides of the balance sheet. The result as seen in Figure 3 is an increase of 1 billion usd in the monetary base (or "narrow money') and an equal amount increase in broad money in the form of bank deposits (Benford et al., 2009).

The increase in money supply and especially in broad money is the first step for a successful monetary policy in the process of transmitting the newly created central banks' money to the economy

through the banking system. If the new deposits become new loans, the realization of the monetary plan would be achieved. The commercial banks' interaction is crucial due to their role as the conductive pass and administrators of money supply. If banks can find ways to transform the new deposits into loans for productive investments, economy will benefit. The central bank pays interest to commercial banks for their reserves, but usually this interest rate is lower in relation to interest banks paying for their clients' deposits. Banks are therefore forced to find investments that will generate a higher interest than the one they pay for deposits.

Figure 3: Impact of QE on balance sheets



Source: **McLeay et al. (2014)**

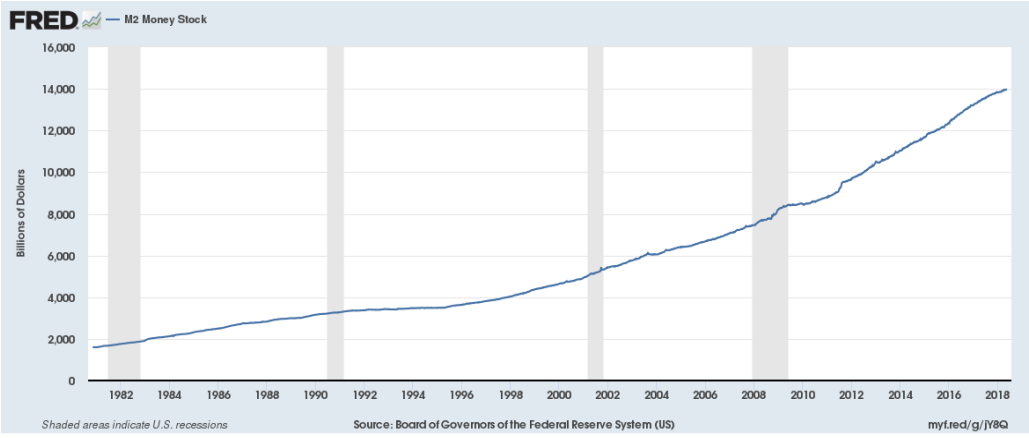
A prerequisite for new loan generation is that banks which receive the extra deposits have sufficient reserves in the central bank's account to meet a possible higher withdrawal of deposits, although in the modern banking system there is not such a problem (McLeay et al., 2014). Interbank lending assures that funds can flow between banks in the form of short-time swap transfers of reserves, when necessary. The bank which lends another bank will receive an interest rate for the borrowed funds. When the interest paid by the central bank for banks' reserves is high, the interbank lending may cease because banks prefer to hold their money in their account instead of lending and transfer their reserves to another bank for a lower yield. This can be a constraint for banks to generate loans although

under normal conditions they don't face such a problem. The main exogenous constraint on credit expansion is the minimum capital requirements imposed by the central bank, which may reduce the desire of banks to issue new loans. Uncertainty about economy is also a crucial factor for lending and money supply, because under uncertain conditions banks are scared to grant new loans to firms, households or other banks.

A suspension of monetary policy would occur if firms, with the extra money they receive in return of their assets, repay their debts and as a consequence the net lending in the economy would reduce. The same happens if the deposits leave the country, either for foreign goods or asset purchases. The best scenario is the new central bank money to flow into the economy through further asset buying (i.e. stocks, bonds, houses), and the sellers of these assets to increase their spending and investing.

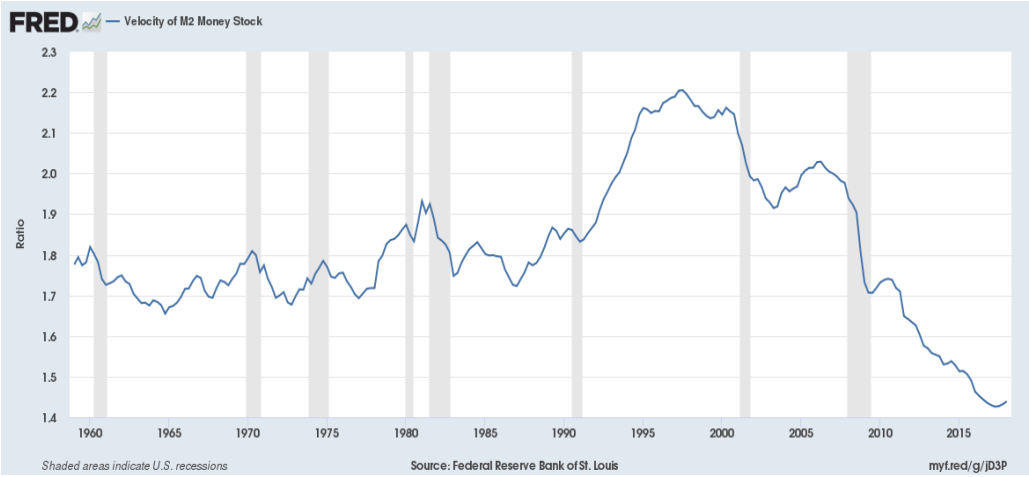
For GDP and inflation growth, which is the main goals of the central bank, an increase in money supply is important but not sufficient. At the same time, the velocity of money has to remain stable or increase. If velocity of money gets reduced, the impact of QE will be negligible since the money printed by the central bank won't be channeled in the economy. An increase in money supply with a simultaneous drop in velocity of money might be an indication that the money created by the central bank did not end up in loans for productive investments, which will raise the GDP in the long run, but to risky financial instruments that can lead to financial turmoil. In figures illustrative below, we see that the increased money supply as measured by M2 in the USA from 2008 onwards (Figure 4) coincides with a drop in the velocity of money (Figure 5).

Figure 4: M2 Money Stock 1980-2018



Source: Federal Reserve Bank of Saint Louis

Figure 5: Velocity of M2 Money Stock 1973-2018



Source: Federal Reserve Bank of Saint Louis

We can assume that a portion of new bank credit as depicted in figure 6 is likely to have ended up in non-productive investments, since the increase in M2 money supply (figure 4) is proportional to the decrease in velocity of money (figure 5).

Figure 6: Loans and Leases in Bank Credit, All Commercial Banks 1973-2018

Source: Federal Reserve Bank of Saint Louis

Increased bank lending was the first goal of QE in order to help economic advances since rising bank lending stimulates output growth and stabilizes inflation rate. In the USA, a large portion of the capital funding is not channeled through the banking system but through bond markets. The main benchmark rate for bonds and banks loans is usually a long-term interest rate, provided that a vast part of borrowing activity is of long duration. Hence, the main objective of the central bank asset purchase program was to reduce long-term interest rates as well as the term premium and not the increase in money supply. According to Mallick et al. (2017) term premium is an important factor of general financial conditions and real economic activity, mainly by reducing borrowing costs.

A way to reduce the term premium is through the portfolio-balancing channel through which the central bank reduces the relative supply of safer financial assets to reduce their yields. (Di Maggio et al., 2016). The drop in yields motivates financial institutions to invest in higher-yield assets, leading benchmark rates to drop. Risk aversion and uncertainty about financial assets prices returns could be an inhibitor for portfolio-balancing activation as investors would demand higher compensation for holding longer duration assets so, decreasing uncertainty is another channel of monetary transmission.

There are 3 factors that guarantee that QE will successfully be implemented and that FED would achieve the goal of reducing the term premium. The first factor is expectations hypothesis, second is segmented markets and third is the lower duration risks (Yu, 2016). Expectations hypothesis asserts that long term rates are determined by investor's beliefs regarding the future short term rate (fed interest rate) level. The central bank, in order to succeed in reducing the term premium, has to convince investors that will not raise short rates in the coming years. And that's because, all else equal, there is no reason for short maturity bonds to differ from long term ones in investors preferences, expect if they are assured that the central bank will change in the future, the short term interest rates. If investors expect raises in the short term rate in the future, they will demand higher rates for keeping long term bonds they hold and as a result term premium will rise. Assuring investors that no changes in interest rates will take place in the future, central banks should declare their commitment to keep interest rates in a specific range for a long period. This policy is called "forward guidance" and is part of the "signaling mechanism" that central banks use.

A necessary prerequisite for the central bank in order to reduce the term premium, is the absence of arbitrageurs which could take opposite positions especially if they have large amounts of money to invest. But bond market-segmentation and portfolios balances render bonds with different maturities imperfect substitutes. An example of this segmentation is insurance firms that invest mostly on long term bonds to match their proceeds with liabilities derived from insurance contracts and payout

annuities. Since short term bonds don't match the financial institutions' investing profile, in contrast with long term ones, their demand is moderate. The central bank, by purchasing long term bonds limits further their supply, leading to a reduction in term premium. If arbitrageurs have ample funding, they would sell long-term bonds and buy short terms bonds and the term premium would rise again. Since arbitrageurs have a capital constraint on the money they invest, it's not possible for them to take large inverse positions and buy the amounts that insurance companies and the central bank purchase and as a result they can't take opposite positions with the policy of the central bank.

Duration risk channel is the third factor for an effective implementation of QE. This channel works through the reduction of the investor's risk of holding long bond maturities in their portfolio. Investors would require an extra compensation incorporated in the bond yield, for holding a long term bond instead of a short term bond, which is the second reason for the existence of the term premium. By reducing the supply of riskier long maturity bonds, QE leads to an increase in safer assets such as bank deposits and, as a consequence, investor's total portfolio risk is reduced. This renders risk-aversion investors more tolerance to risk, as their portfolios become safer and they demand a lower compensation to hold long term bonds. This, results in the drop of long term bonds yields and consequently in the term premium.

Central banks have been using various tools in the frame of their monetary policies, with some of them being not only unconventional but also quite extreme. One of these tools is the imposition of negative interest rates on interbank lending and on reserves held by commercial banks in the central bank's accounts. The first goal of this policy is to punish commercial banks for the maintenance of idle reserves in the central banks' balance sheet and to force them to increase the lending activity. The second is to motivate consumers and firms to increase their consumption and spending either by lowering their deposits or by taking low cost loans. After imposing negative interest rates on banks reserves, banks charge their clients with higher than usual fees in order to cover their increased expenses and make it costly for depositors to keep money in their bank accounts. So they could probably use their deposits for purchases of various goods or financial products such as stocks and bonds that could offer a higher yield.

Another ambiguous and controversial policy that central banks, such as the Bank of Swiss (SNB) and the Bank of Japan (BOJ), intensively use is the purchase of assets like stocks or exchange trade funds (ETF), in order to increase their prices or to affect the exchange rate. This direct intervention of central banks on financial markets may distort their constitutional role as stabilizers of economic function and make them a source of imminent financial disturbances. The fact that central banks use

proprietary trading in Chicago Mercantile Exchange & Chicago Board of Trade (Chicago Mercantile Exchange Group Inc, 2017) makes us assume that this intervention may be more profound and more risky than it is known.

The most extreme policy tool that has been proposed is "helicopter money", under which central banks have the discretion of channeling money directly to household's or other economic agent's bank accounts, either directly or by using intermediates like government agencies. This measure, in contrast to QE, which targets the term premium, could lead to rapid inflation advances in a pace that is not desirable for monetary authorities. This policy, though not yet imposed, may be the ultimate resort for central banks if all other monetary tools fail.

The scope of all the above unconventional measures is to promote growth in the economy. According to Bernanke and Kuttner (2005), by affecting prices and assets returns central banks try to change economic behavior in ways that will help them to achieve their ultimate objectives like raise in output, unemployment, and inflation. This is what is broadly known as the wealth effect. Of course by lowering the yield channel or else the basic interest rates, doesn't necessarily lead to wealth effects. That's why the central bank has to intervene directly, to fuel money in the economy and immediately reduce the term premium.

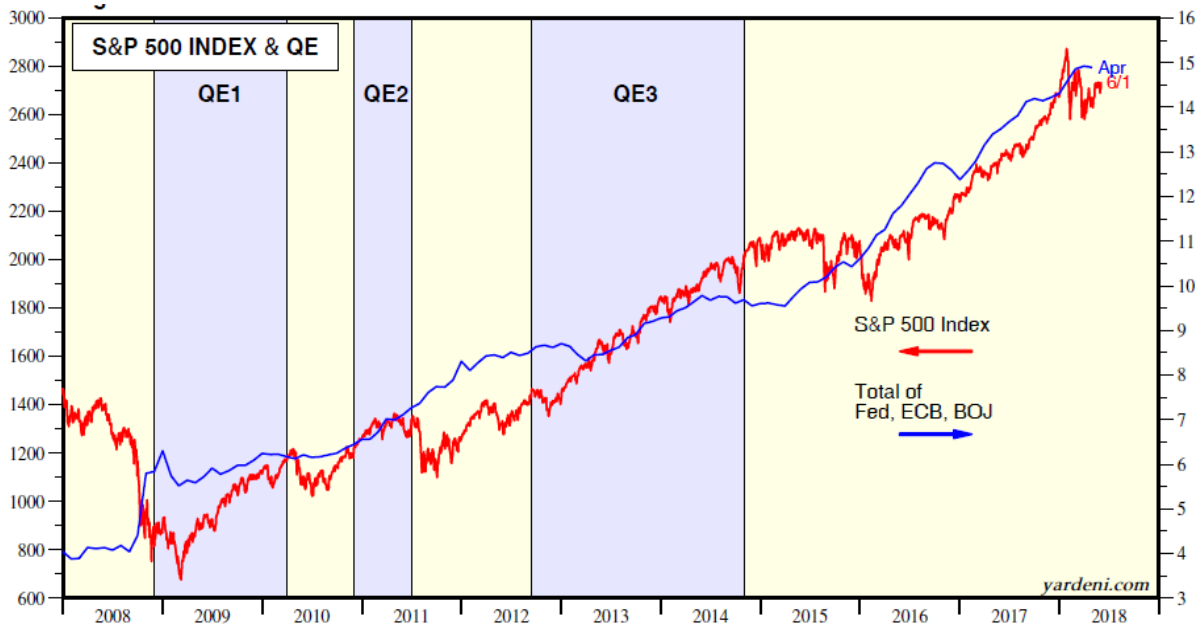
About the achievements of QE, Di Maggio et al. (2016) report that interest on mortgage loans fell 100 basis point after QE1 implementation. The period between QE2 and QE3 interest rates recorded a slower reduction, and after the 2013 tapering decision, interest rates increased by 25 basis points. Regarding the financial institutions activity they assert that during the QE evolution, they had tripled the monthly issues of mortgages loans, especially for loans that were eligible for purchase by the FED program. More intense lending activity was observed around QE1 and QE3. The reduction of interest payments as a result of QE led to the refinancing of over 600 billion dollars of mortgage loans, which led to an increase in household wealth as they saved money due to lower interest payments and the equity of their houses rose. This led mortgagors to increase their consumption by 76 billion usd. Bauer and Rudebusch (2014) also support the idea that QE reduced interest rates, with the larger effect being in QE1. He attributes this to the "signaling effect" that changes the investors' expectations regarding the future path of fed rate, which is the result of the central bank's commitment to keep interest rates unchanged.

QE not only reduced long term treasury rates but also reduced borrowing costs for households and firms mainly during the first phase of QE. This reduction was more beneficial for corporations because they tend to match the maturity of their assets with the obligations they undertake. As Yu (2016)

indicates, firms issued more long-term debt to fund capital investments, as the monetary program has been evolving.

About the results of monetary policy for wealth effect creation Bhar et al. (2015) examined the effects of QE in the SP500 index and found that QE1 increased the index by 18%, QE2 by 11% and QE3 by 26%. In figure 7 we can see the time-variant stock market price during the QE program.

Figure 7: QE and S&P 500 Index 2008-2018



Source: Federal Reserve Board, Standard & Poor's and Haver Analytics. Extracted from: Yardeni Research Inc., Global Economic Briefing: Central Bank Balance Sheets June 1, 2018

From the above we assume that monetary intervention has indeed helped the economy recover after the 2008 crisis and set the foundations for future growth. But could there be negative consequences of the unconventional policies that central banks have implemented?

2.3 Risks in the economy

The effects of monetary policy in the economy over the past decades raise the question of whether central bank interventions are favorable to economic progress or not. Some consider that the accommodation policy of central banks is the cause of investors' complacency and risk-taking behavior that could lead to financial disruptions. An argument that often central banks use to justify the

accommodative monetary policies they follow is that low fed rates and the quantitative easing programs are the best response to the prevailing low inflation environment. The reason of low inflation the decade after the 2008 recession is questionable, with some economists blaming the low population growth or the reduction in energy costs and others focusing on the high leverage in the financial system that prohibits the growth of consumption. But even if expansionary policies have the goal of confronting low inflation, its indirect consequences could prove much worse than the problems they are trying to solve.

We examine risks in the economy from two perspectives. First we try to observe the risk incorporated in the activities of systemically important financial institutions and intermediaries with leveraged positions. From the other side, we examine the subdued levered institutions and retail investors which are not supervised by the regulatory authorities. A major concern among economic researchers, especially the post 2008 period, is the effectiveness of market regulation in confronting the risk behavior. Rajan (2005) describes how changes in financial markets due to technology, deregulation and other institutional transition can increase risks in the economy. These changes have been observable in various forms over the last decades, ranging from the conservative banking activities in the 1950s, to speculation strategies of hedge funds in the 1990s. By the same token, Borio and Zhu (2012) argue that changes in the financial system and prudential regulation may have increased the importance of the risk taking channel and that prevailing macroeconomic paradigms and associated models are not well suited in capturing it. Feroli et al. (2014) propose that better communication from FED, helped bond markets improve their performance after December 2013, when the FED made it clear that it will not start tapering the bond purchases. Instead, macroprudential tools such as bank capital ratios, bank liquidity requirements, haircut regulation on repurchase agreements, or loan to value ratios were not enough to tame bond market flows, so clear monetary policy intentions can help the financial system to function better.

According to Borio and Zhu (2012), low interest rates can lead to imbalances in financial markets and affect financial managers' and retail investors' perceptions regarding risk aversion. They refer to this monetary transmission mechanism as the risk-taking channel, which is activated when the reduced interest rates cause the increase of investors' risk-tolerance and affect their risk assessment. A possible source of risk taking channel is the investing behavior of financial institutions' managers, which often lead to negative results. Rajan (2005) attaches great importance to investment managers' behavior and points out that managers are prone in taking more risks, as long as their compensation is based on their performance in relation to their peers. Due to the fact that investors are being attracted by higher

returns, managers in a race to attract more clients are trying to increase returns from their investments by any means. This is the main reason for the increase in herding or "momentum" chasing investment strategies. When asset prices are on an upward trend, managers are more willing to bear the low probability of "tail" risk of steep falling prices, as they are assured that their competitors will do the same. So, they take long positions on financial markets trying not to underperform in relation to their peers, risking losing their job, and they don't care about the possibility of falling prices since they know that their competitors will also lose out on their investments when markets fall. The herding behavior can push prices upward especially in a low interest rates environment, where the search for higher yield is the main objective. This situation can be violently reverse if an unexpected event triggers a market drop. The herding behavior will exacerbate the downfall as the majority of investors will sell their assets at the same time.

The risk taking behavior can be amplified by the poor communication of the central banks' policies, especially when financial agents have the perception that central bank's policy favors asset price increases. As Altanubas et al. (2010) point out, when managers believe that the monetary authority will follow a loosen policy whenever there is a temporary drop in asset returns, the perceived down-side risk probabilities are further reduced, since monetary policies reduce investors' uncertainty. This is a typical moral hazard problem that can lead to steep price increases when the monetary policy is expansionary, or to a drastic decrease in asset returns when it turns out to be restrictive.

Some financial institutions and their administrative managers are motivated to operate with the sole aim of achieving positive returns in order to come up with their commitments. For example, pension funds need a high return to pay their members′ pensions and mutual funds to pay their clients' share. When interest rates drop, the search for riskier but higher yielding investments is imperative for these institutions to have a chance to survive. Rajan (2005) names the above as "risk shifting", which will be amplified when the prevailing economic conditions induce managers to ignore downside risks and focus on upward outcomes. Risk shifting behavior could be reduced if interest rates were high enough for financial institutions to earn the yields they need, making insurance companies and pension funds managers more conservatives in their investment choices as long as they meet their obligations. Another negative impact of low interest rates in managers' behavior is that the reduced cost of borrowing could lead managers to take more leveraged positions as long as it gives them higher returns with less owned funds. By the same token, Altanubas et al. (2010) point out the dangers of yield search race and the sequential feedback loop that emerges. Low interest rates reduce financial institutions' cash flows leading to an increase in their overall risk, and force their manager to further risky

investments in order to replenish the reduced proceeds.

On the contrary, Chodorow-Reich (2014) points out the positive side of an unconventional policy, suggesting that lower rates permit the implementation of risky and low-yield projects that lead to higher consumption. In addition to the above, the delinquency and default rates drop and because of this several companies keep operating and hiring and improve their output. The improvements in economic output swell asset prices, which permits financial institutions' to ameliorate their balance sheets and improve their solvency.

A crucial question in financial research is whether the risks have passed from financial intermediaries to retail investors and subdued-leveraged non-finance institutions. Some researches highlight the risks that may have been incorporated in leveraged institutions activities, but the regulations that have been enacted since the 2008 crisis have reduced these concerns, especially for banks. Feroli et al. (2014) show that financial instability is not associated with the insolvency of financial institutions. They emphasize on subdued leveraged investors as possible causes of systemic risk in financial sector. These non-systemically important investors don't become insolvent in the way the financial institutions do, and in contrast to banks or insurance companies they don't have regulatory oversight. Moreover, their investment decisions may, in certain circumstances, result in a demand in risk premiums with multiple negative ramifications. They examine "tantrums" periods such as the summer of 2013 and find that risk shifting and herding investment strategy of non-bank market participants such as mutual fund could cause negative price outcomes that can be strengthen by redemptions from ultimate retail investors.

Subdued leveraged investors often follow "momentum" chasing strategies and pour their money to "winning" assets leading their prices upward and amplify a positive feedback loop. High flows lead to rising prices, which attract more flows, which further raise prices. Then, if return chasing reverses abruptly, a negative feedback loop emerges. Monetary policy, especially badly communicated forward guidance, can affect this behavior. Also, monetary authorities often overlook the risks of unlevered institutions actions or do not treat them as a potential hazard for financial stability. Silva (2015) reaches to the opposite conclusion asserting that leveraged institutions reduce their concentration of risk as a consequence of unconventional policy. He points out that leveraged institutions are more sensitive to low returns and when prices fall, even if they are more risk tolerant, they tend to sell their assets to the central bank, thus reducing their exposure relative to risk-averse non-leveraged investors.

The importance of levered financial institutions and intermediaries in the financial world, is indisputable and their role in the economy non-substitutable. Monetary policies can have a direct

impact on their operations, either positive or negative since the central bank's policy rate is a determinant factor of the term premium that affects banks' financing costs and profits. When the interest rates are low, the banking sector may prove to be a source of economic malfunction through the risk-taking channel, as the search for profits may lead them to issue high yielding risky loans fueled to unproductive projects (Bruno and Shin, 2015). Chodorow-Reich (2014) shows that unconventional monetary reduced solvency of banks and insurance companies as it helped to the recapitalization of these institutions the first years after 2008 crisis. The value of their assets that had been crushed by the recession increased as a consequence of low rates and the value of balance sheet improved. Also, banks have increased their leverage as their collaterals value increased and thus could provide liquidity and more loans. Bruno and Shin (2015) support the idea of a positive feedback loop in bank leverage driven by lower rates and they highlight bank leverage as the linchpin of the risk-taking channel. Accommodative policies lead to a reduction in risk, which help banks sign more loans, as financial conditions improve and uncertainty drops. From this perspective, the risk-taking behavior of levered financial institutions has a positive contribution in the economy, as the increased credit supply can stimulate growth even if it incorporates possible dangers. The economic growth creates a stable financial environment and is likely to compress risk spreads and the volatility. Banks use volatility as a parameter in their value-at-risk models and when volatility is reduced, banks' risk falls. This allows them to further expand their lending activity and allows a positive feedback loop to emerge, as leverage reduces risks and promotes further leverage. On the contrary, an increase in bank funding costs will result in a decline in bank leverage promoting a negative feedback loop.

The feedback loop effect in financial institutions' leverage can also be triggered by the appreciation of assets prices. Hattori et al. (2013) assert that the confidence that the central bank will keep rates low could reduce financial institutions value-at-risk constraints. Leveraged institutions avoid hedging against possible assets' drops and as a consequence, out-of-money options prices fall. When options prices fall, the implied volatilities that are used in VaR models are reduced and the overall risk is coming down further inducing financial institutions to take additional assets purchases either using leverage or their own funds, leading to increases in asset values. A positive feedback loop emerges as long as increased assets prices will further reduce the VaR constraints which in turn will boost further demand for asset purchases. Altanubas et al. (2010) assert that when volatility is low, the reduction of value at risk makes financial firms more generous and prompts them to increase position take. Changes in measured risk lead to adjustments in bank balance sheets and leverage conditions, which in turn amplifies business cycle movements. Banks balance sheets get swelled because of the appreciation of

their assets, but there always is the danger of being sharply downgraded if interest rates rise. Banks with lower profit margins may, in this case, need extra capital to absorb possible losses and that will constrain lending. A great concern of the impact of low yields in the bank managers' actions is that the non-performing loans prices are boosted and this may cause future problems in the economy as long as bank managers aren't motivated to confront bad loans, due to the fact that the bank balance sheet assets side is improving.

Gilchrist and Zakrajsek (2013) assert that even if FED's loose policy lowered the overall level of credit risk in the economy, this is not observed in the financial sector credit risks and that's because the flattened yield curve reduces bank profits. Banks and other financial institutions are balancing across maturities, as their assets have long term durations and their liabilities short. When short term interest rates increase and long term ones stay steady, banks cannot easily transfer the increased interest bear to their lenders and consequently must record loses

Rajan (2006) points out, that financial institutions are required to reach a benchmark rate of return and when prevailing interest rates are low, they could succumb to high yielding risk assets purchases. For example, a number of insurance companies and pension funds have entered into the credit derivatives' market to sell guarantees against a company defaulting to collect the premia. He refers to the pre-crisis 2008 period when the recession in the economy resulted in problems for insurance companies that were selling CDS. Respectively, in the post crisis of 2008 period, we can observe the same behavior as volatility selling is a common strategy among unlevered institutions, in order to collect options premiums. If interest rates start moving upward, insurance companies will have enough proceeds to meet their obligations without taking undue risk. A negative effect of monetary policy in financial institutions is that in a low yield environment the promised return on pensioner's fund is high enough to make the fund insolvent in the long term, as they cannot match their income with their expenses.

An accommodative policy is a possible source of malfunctions in various economic sectors**.** Mallick et al. (2017) find out that unconventional monetary policy doesn't have a significant impact on economic activity advances, although it may lead to a decline in the term premium of bond yields. As a result, various economic agents like households and financial institutions are punished with lower yields in exchange for negligible rise in the output. Altanubas et al. (2010) assert that loosen monetary policy reduces default risk and helps consumption and investments. On the other hand there is the fear that increased liquidity will lead to highly inflation rates with detrimental consequences in the economy**.** If banks start intense lending, economy will start to grow faster and uncontrollably more than

central banks can handle. The possible responses, like raising policy interest rates or selling bonds, in order to keep inflation in check, would have a negative impact on the economy (Yu, 2016). The past two decades, FED tried to respond proactively to tame inflation and control the rate of growth which contributed in moderate fluctuations in asset prices. The predictable and systematic reactions to economic data, kept inflation steadier and as a result the economy avoided large swings in interest rates. Subsequently, volatility in housing prices has been reduced leading to the rise of excessive or speculative investments in the residential sector. The period prior to the 2007 crisis, the FED settled for low federal fund rates, amplifying the initial increases in real estate prices. Subsequently increases in housing prices further led to an upward spiral that resulted in even higher housing prices. When the FED finally increased the basic rate, to match the prevailing economic conditions, it did not take long for a crush to occur. Taylor (2007) asserts that short term interest deviation from monetary policy rules has been an important factor for the problems in housing market over the period 2003-2007. Respectively, Bekaert et al. (2013) report that the "Greenspan put" (a.k.a. the Feds' liquidity provision during the 2000 recession) is considered by many researchers to be an important factor contributed to the 2007 bubble. According to Yu (2016) QE program has prompted financial agents to support particular sectors such as real estate at the expense of others, resulting in unilateral economic growth. The consequences of this investing behavior could prove disastrous and endanger the collapse of financial markets in case where the overinvested sectors represent for a large portion of the economy.

Theoretically, the diversification in investing strategies and increased financial interactions create a greater capacity for the economy to absorb risks hidden on financial markets. But competition and managers' compensation may induce more correlation in financial assets than is desirable. (Rajan, 2006). Altanubas et al. (2010) claim that the economic expansion that began in 2002 was characterized in many cases by the coexistence of low monetary policy rates, financial innovation and booming asset prices, three conditions that may have amplified the effectiveness of the risk-taking channel. We can find some analogies in the recent period, with the advent of algorithmic trading at the same time when interest rates are low and assets prices like bonds and stock are high. Herding and "momentum" chasing mentality could have negative implications in combination with the increasing correlation between financial assets. Feroli et al. (2014) support the idea that herding and momentum chasing is only observed in fixed asset securities and not in stocks, because market mechanisms can prevent investing malfunctions. In contrast to their point of view, herding investment strategies can be observed in stock market as long as in various financial assets. In recent years, a growing amount of money has been poured into passive funds which invest in stock market indices, favoring stocks that have a large

weight in index calculation. The cultivation of "momentum" behavior on financial markets is amplified by the yield chasing race which is the result of low interest rates. Investors favor low-fee passive investments products such as exchange traded funds (ETF), where herding especially in heavy index weighed stocks like technology is very intense. On the other hand, active management is losing shares in invested funds and their contribution to price discovery mechanisms is diminishing. Caginalp et al. (2014) show that prices of highly liquid ETFs can significantly deviate from their daily net asset values. If value based investors trade ETFs more than the stocks which underlay them, then this illiquidity condition may have negative implications to market stability. In the case of a declining market, active managers who are buy-side investors will be absent, so the herding behavior would be more violent and the feedback loop will be more intense. In addition, the high frequency algorithmic trading could cause flash crushes, which will rapidly exacerbate a potential sell-off. Therefore, financial risks could be in the core financial markets than in risky and financial products.

Corporate stock buybacks may be a possible source of systemic risk due to the fact that they could amplify herding and "momentum" investing mentality and could contribute to the creation of dangerous positive feedback loops. In addition, a large portion of corporate buybacks is based on leverage, as firms issue loans in order to exploit the low borrowing cost and buyback their stock to avoid giving expensive dividends. This behavior can promote capital misallocations and wealth transfers from bondholders to shareholders as well as boost managers' compensation, giving them the incentive to continue stock buybacks.

An environment of low interest rates favors the accumulation of debt in a wide range of economic sector. A good example of the dispersion of debt in the economy is student loans in USA, as well as the auto loans, can also be a source of risk. Because of the accumulation of debt, households may decrease their consumption which will have negative effects in the economy. From the other side, firms take advantage of low yields and issue debt with low covenants as yield-seeking investors are willing to buy them despite the risk such an invest incorporates. The junk bond market has been boosted after 2008, and the bond term premium is at historically low levels. If rates reverse, these firms will have the risk of default and holders of these bonds will face steep discounts on their positions

In a race for high yields, new volatility investment strategies like VIX-based financial products have emerged. Volatility selling has been a common way for many investors to find returns, even if the premium they receive is very low. The low volatility financial environment assures them that their positions will not reverse. In the first months of 2018 there was a temporary unwinding of volatility

selling conditions, especially in USA which coincided with the launch of the FED's balance sheet reduction within the quantitative tightening Fed's policy.

Another example of volatility based strategies are risk parity funds. Risk-parity portfolios allocate funds to assets based on their longer-term volatility, as well as their cross asset correlations. In order to be successful, risk parity strategies depend on negative or even low correlations between assets. A cause that could change this condition would be an inflation spike and the consequent increase in interest rates, which would affect the valuation of both stocks and bonds, as well as their volatilities. When cross assets correlations are low or negative, volatility strategies are profitable, but if volatilities turn positive for a long period, the performance of risk parity funds and other volatility-based investments deteriorates. In the case of rising correlations, managers or algorithms of volatility-based investment funds, they will begin to sell their assets and that can exacerbate markets drops.

A potential negative impact of low interest rates in advanced economies could be the transfer of funds, from safer assets to risk adjusted investments such as emerging markets assets, given the fact that these assets can generate higher returns. This transfer of capital can help poor countries to improve their economies and find cheap capital, but there is a danger for a violent reverse, if interest rates in advanced economies rise. The capital flight to advanced economies may cause problems in emerging markets due to the rising cost of borrowing for both households and firms, which may have difficulty paying their debts. The FEDs' actions have implications not only domestically in U.S, but all over the world, as dollar is the global funding and trading currency. Kroencke et al. (2015) find out that downward shifts in the front end of the U.S. yield curve are associated with reallocations from U.S. assets into foreign, higher-yielding assets. Their results show that funds relocations are positively related to lag returns in advanced markets and are consistent with a channel where fund investors chase equity and bond returns internationally. Manager's risk-shifting and herding behavior can amplify the capital reallocation. Baba et al. (2009) shows how money market funds managers' behavior has contributed to an increase in global financial risks during the financial crisis of 2008. Until September 2008 non-US banks funded their dollar-denominated liabilities with funds they borrowed from US based financial institutions such as money market investments funds. During this period, European banks have been overleveraged with many dollar-denominated loans and seeking dollar funding in order to refinance their liabilities. Traditionally, money market funds invested in US assets, but due to the competition among managers for higher yields they begun to invest in non-US headquartered assets and harvest the "Yankee premium". Hence, European banks found in money market funds a cheap source of dollar funding in order to continue their relentless non-euro denominated lending activity.

But the deterioration of European conditions led money market funds to allocate their investments to safer assets and especially in US government bonds and as a consequence European banks lost their dollar funding source. This forced the FED to launch swap lines with the European Central Bank in order to provide the dollars that European commercial banks would need or else the solvency of European banking system would be endangered. After the implementation of QE program, large amount of dollars have come to the markets, and the liquidity problems all over the world have diminished. A QE unwinding would put this status in peril, and the world might face again liquidity shortages amid growing dollar- denominated funding.

The 2013 "taper tantrum" was a sign of what could happen when monetary policy changes are not coordinated among global economies. In the summer of 2013 interest rates jumped, following the remarks of the Fed Chairman Ben Bernanke, for an imminent tapering of asset purchases by the Federal Reserve. This caused turbulence in emerging markets bonds and currencies and threatened the stability of the whole world financial system. The turmoil on the financial markets lasted until the FED announced that the decision for the tapering of assets buying was postponed. According to Bruno and Shin (2015) this incident shows that a contractionary shock to US monetary policy leads to a decrease in the cross-border capital flows in the banking sector, which causes problems in emerging market economies. In addition, the risk-taking managers' stand plays a negative role exacerbating the problem. Feroli et al. (2014) document that yield-seeking investment flows across the border, driven by both external and domestic factors, have driven to a decline in local emerging markets bond yields. The importance of relative ranking among managers, injects spillover effects across asset manager's behavior and an endogenous coordination element in their portfolio choice. The cost of being last generates a behavior that has the outward appearance of shifts in preferences (Morris and Shin, 2014).

Interest rate changes can have serious implications for various sectors of the global economy and affect a wide range of countries. If low interest rates can lead to low volatility and reduced asset yields, the risk has a possibility to increase as a reverse condition. The time-varying spillovers among assets and countries could have long term implications that can be difficult to prevent in case of bust on financial markets. The importance of volatility behavior and the correlation between assets has grown up in recent years. Can monetary policy affect this behavior?

Chapter 3. Data – Methodology

The sample period covers the period spanning the time interval from January 2004 to May 2018. During this period, economy had various cycles ranging from the calm period after the 2000-2001 recession to the turbulent years around the 2008 crisis, after Lehman bankruptcy. After the central bank's intervention in 2009, a dreaded period followed where the economic recovery was an ambiguous perspective. But with the passage of time the conditions improved, and economic instability moved away. By the end of 2014, FED decided to remove the loosening policy and started tapering the assets purchases in addition with increases in the policy rate. At the beginning of 2018 was the first selling of the purchased bonds.

We try to examine if there was significant changes in the pattern of the time-variant correlation of VIX and TYVIX indices, and if these changes coincided with the Fed's policy implementation. The initial sample period in 2004 was chosen due to the fact that TYVIX data started quotes that year.

3.1 Multivariate garch model

Multivariate GARCH models are widely used to provide information about time-varying co-variances and correlations between financial variables. A common used GARCH model is the Diag-VECH model, initially proposed by Bollerslev et al. (1988), which we apply in order to obtain the time-variant correlation of VIX and TYVIX indices. We find very informative examples of multivariate-garch models in Brooks, C. (2002), and in Xekalaki and Degiannakis (2010). The specification of our model is:

$$\mathbf{y}_t = \boldsymbol{\mu} + \mathbf{e}_t$$

$$e_t / \Omega_{t-1} \sim N(0, \boldsymbol{H}_t)$$

$$\mathbf{H}t = g\,(\mathbf{H}_{t-1}, \mathbf{H}_{t-2}, \dots, \mathbf{e}_{t-1}, \mathbf{e}_{t-2\dots})$$

$$\mathbf{e}_t = \mathbf{H}_t^{\frac{1}{2}} z$$

$$\text{Vech}\,(\mathbf{H}_t) = \mathbf{C} + \sum_{i=1}^{p} \mathbf{A}_j \text{Vech}(\mathbf{e}_{t-i}, \mathbf{e}'_{t-i}) + \sum_{j=1}^{q} \mathbf{B}_j \text{Vech}(\mathbf{H}_{t-j})$$

where $\mathbf{y}_t$ =(VIX, TYVIX) is a (2x1) vector containing the VIX index and TYVIX index prices, $\mathbf{H}_t$ is a (2x2) conditional variance - covariance matrix, $\boldsymbol{\mu}$ is a (2x1) parameter vector (constant) and $\boldsymbol{\varepsilon}_t$ is the innovation process. $\boldsymbol{\Omega}_{t-1}$ denotes the information available through time t, and **z** is an (n x 1) independently and identically distributed (iid) vector process. **C** is a 3 x 1 parameter vector, p = q= 1, **A** and **B** are (3x3) parameter diagonal matrices, and vech (.) is the column stacking operator that stacks the lower triangular portion of a symmetric matrix where:

$$Vech(\boldsymbol{H}_t) = \begin{bmatrix} h_{1,t} \\ h_{2,t} \\ h_{1,2,t} \end{bmatrix}$$

and :

$$\boldsymbol{H}_t = \begin{pmatrix} h_{1,1,t} & h_{1,2,t} \\ h_{2,1,t} & h_{2,2,t} \end{pmatrix}$$

The conditional variances at time t of the two variables are:

$$h_{i,i,t} = c_{1,1} + a_{i,i} e^2_{i,t-1} + b_{i,i} h_{i,i,t-1}$$

for i,j = 1,2

$$h_{j,j,t} = c_{2,1} + a_{j,j,t} e^2_{j,t-1} + b_{j,j,t} h_{j,j,t-1}$$

The conditional covariance of the 2 variables is:

$$h_{i,j,t} = c_{3,1} + a_{i,j} e_{i,t} e_{j,t-1} + b_{i,j} h_{i,j,t-1} \qquad \text{for i,j} = 1,2$$

And the time-varying correlation is:

$$\rho = {h_{i,j,t}}/{h_{i,i,t} h_{j,j,t}}$$

3.2 Markov switch regime model

To examine whether monetary policy has influenced the correlation of VIX and TYVIX volatility indices we apply on the correlation series we extracted from the GARCH model, a Markov switch regime model (Hamilton, 1989). In each period *t* the regime is denoted by s_t. There can be *m* possible regimes: $s_t = 1,..., m$. We have a simple model with $m = 2$ regimes. The variable ρ_t is the correlation series of VIX and TYVIX.

$\rho_t = \mu_1 + e_t$ when $s_t = 1$

$\rho_t = \mu_2 + e_t$ when $s_t = 2$

$e_t \sim$ i.i.d. N $(0, s^2)$

The probability of the mean (μ) to be in a state regime s_t is depended only in the closest previous regime s_{t-1}, without take into account the past values. Probability of moving from state *i* to state *j* is :

$$p_{i,j} = P[s_t = j \mid s_{t-1} = i]$$

Switching (or conditional) probabilities between the two states are:

$$\text{Prob}\,[s_t = 1 \mid s_{t-1} = 1] = p_{11}$$
$$\text{Prob}\,[s_t = 2 \mid s_{t-1} = 1] = 1 - p_{11}$$

$$\text{Prob}\,[s_t = 2 \mid s_{t-1} = 2] = p_{22}$$
$$\text{Prob}\,[s_t = 1 \mid s_{t-1} = 2] = 1 - p_{22}$$

Chapter 4. Results

For the estimation of our models we used the econometric package E-views. The graphs of both the two variables show a time-varying behavior and a spike around the financial crisis of 2008 (Figure 8, Figure 9). Mele and Obayashi (2013) assert that the volatilities of Treasury markets and stock market co-move quite heterogeneously over time and their correlation range from negative to positive marked by periods of rapid movements. We can visual identify a mean reversing feature of the implied volatilities of bonds and stocks market, as sharp spikes are followed by a quite fast drop in their price . Despite the jumps during turmoil periods in financial markets, they turn to the long term mean after a quite short period. The unit root test shows that VIX is a stationary variable at level with intercept, for all the critical values level (Table 1). TYVIX is stationary with intercept, expect for the 1% significance level (Table 2).

Figure 8: VIX index quotes 2004-2018

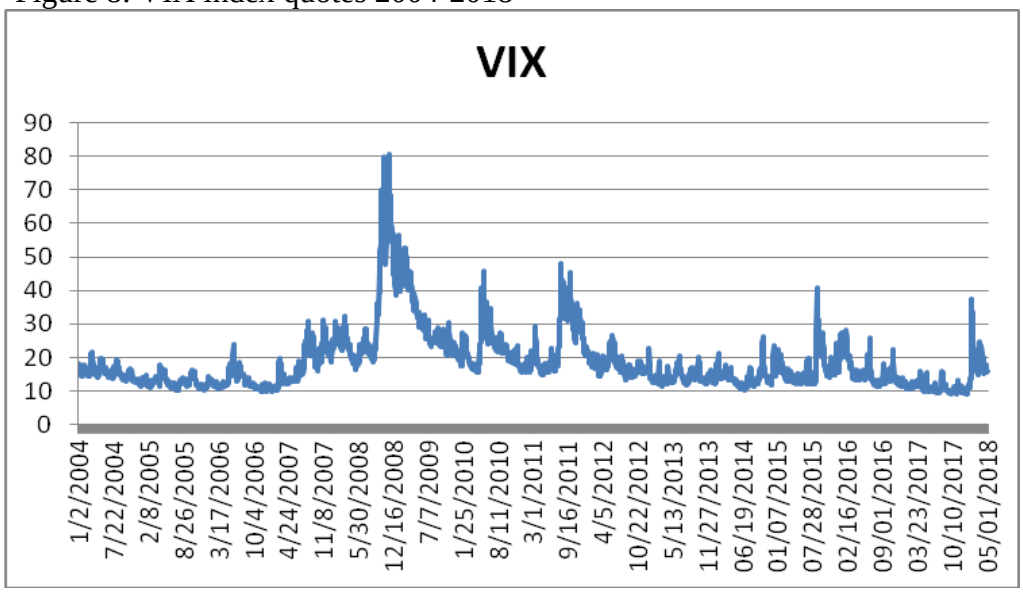


Figure 9: TYVIX index quotes 2004-2018

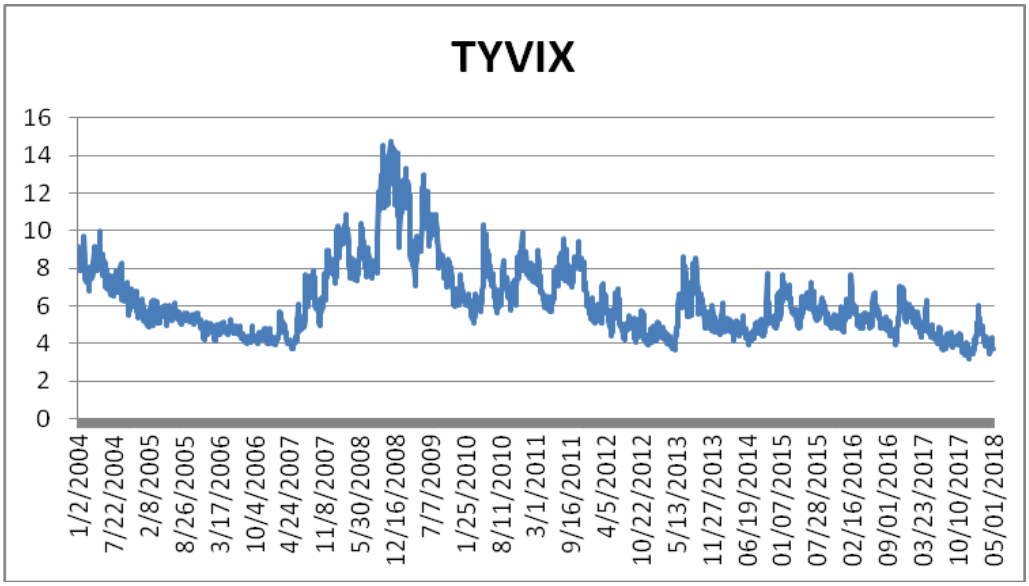


Table 1: Augmented Dickey-Fuller test for VIX

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.247384	0.0006
Test critical values:	1% level	-3.431974	
	5% level	-2.862143	
	10% level	-2.567134	

Table 2: Augmented Dickey-Fuller test for TYVIX

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.397480	0.0111
Test critical values:	1% level	-3.431975	
	5% level	-2.862143	
	10% level	-2.567135	

In table 3 we see the results of the Diag-Vech (1,1) model for the two volatility indices. Figure 10 depicts the time-variant correlation of VIX and TYVIX.

Table 3: Diag-Vech(1,1) MGARCH Results

System: UNTITLED
Estimation Method: ARCH Maximum Likelihood (BFGS / Marquardt steps)
Covariance specification: Diagonal VECH
Date: 05/22/18 Time: 02:16
Sample: 1 3617
Included observations: 3617
Total system (balanced) observations 7234
Presample covariance: backcast (parameter =0.7)
Convergence achieved after 63 iterations
Coefficient covariance computed using outer product of gradients

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	13.18740	0.034962	377.1919	0.0000
C(2)	4.998113	0.010638	469.8394	0.0000
	Variance Equation Coefficients			
C(3)	0.454206	0.017118	26.53348	0.0000
C(4)	0.040183	0.004715	8.522596	0.0000
C(5)	0.038896	0.002116	18.37958	0.0000
C(6)	0.853268	0.052709	16.18815	0.0000
C(7)	0.839413	0.053461	15.70133	0.0000
C(8)	0.847696	0.054351	15.59678	0.0000
C(9)	0.162498	0.013604	11.94483	0.0000
C(10)	0.164348	0.013988	11.74932	0.0000
C(11)	0.157764	0.014514	10.86974	0.0000

Log likelihood	-11609.34	Schwarz criterion	6.444236
Avg. log likelihood	-1.604830	Hannan-Quinn criter.	6.432112
Akaike info criterion	6.425401		

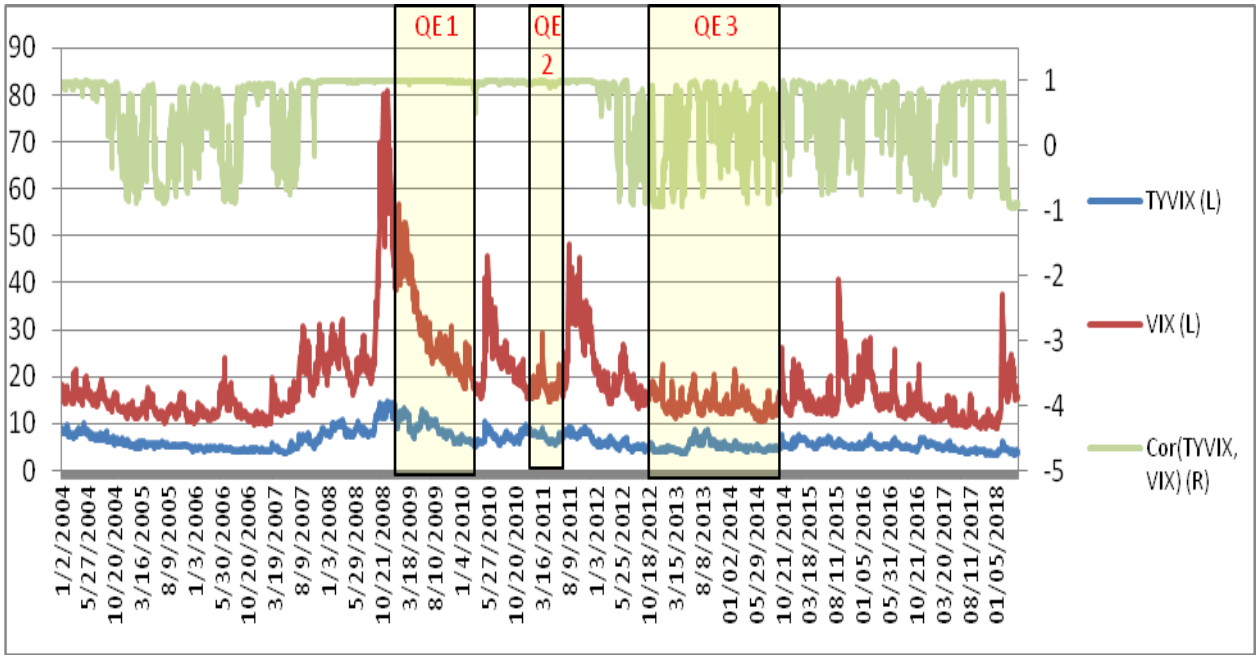
Equation: VIX = C(1)			
R-squared	-0.355181	Mean dependent var	18.50780
Adjusted R-squared	-0.355181	S.D. dependent var	8.928529
S.E. of regression	10.39390	Sum squared resid	390647.9
Durbin-Watson stat	0.028626		

Equation: TYVIX = C(2)			
R-squared	-0.397277	Mean dependent var	6.242701
Adjusted R-squared	-0.397277	S.D. dependent var	1.974873
S.E. of regression	2.334427	Sum squared resid	19705.58
Durbin-Watson stat	0.017919		

Covariance specification: Diagonal VECH
GARCH = M + A1.*RESID(-1)*RESID(-1)' + B1.*GARCH(-1)
M is an indefinite matrix
A1 is an indefinite matrix
B1 is an indefinite matrix*

	Transformed Variance Coefficients			
	Coefficient	Std. Error	z-Statistic	Prob.
M(1,1)	0.454206	0.017118	26.53348	0.0000
M(1,2)	0.040183	0.004715	8.522596	0.0000
M(2,2)	0.038896	0.002116	18.37958	0.0000
A1(1,1)	0.853268	0.052709	16.18815	0.0000
A1(1,2)	0.839413	0.053461	15.70133	0.0000
A1(2,2)	0.847696	0.054351	15.59678	0.0000
B1(1,1)	0.162498	0.013604	11.94483	0.0000
B1(1,2)	0.164348	0.013988	11.74932	0.0000
B1(2,2)	0.157764	0.014514	10.86974	0.0000

Figure 10: Conditional correlation of VIX and TYVIX 2004-2018



We examine the correlation series for possible regime switches. Bhar et al. (2015) investigate the hypotheses that QE has an impact on interest rates, on unemployment and on stock market using a markov switch regime model. Table 4 shows the results of the 2 states switch model for the mean of the correlation, with a low mean equal to 0.18 in regime 1 and a high mean equal to 0,97 in regime 2.

Table 4: Maximum likelihood estimates for the daily correlation 2004-2018

Dependent Variable: CORRDVVIXTYVIX
Method: Markov Switching Regression (BFGS / Marquardt steps)
Date: 06/16/18 Time: 16:59
Sample (adjusted): 1 3589
Included observations: 3589 after adjustments
Number of states: 2
Initial probabilities obtained from ergodic solution
Standard errors & covariance computed using observed Hessian
Random search: 25 starting values with 10 iterations using 1 standard deviation (rng=kn, seed=1588193148)
Convergence achieved after 9 iterations

Variable	Coefficient	Std. Error	z-Statistic	Prob.
		Regime 1		
C	0.183833	0.015688	11.71784	0.0000
LOG(SIGMA)	-0.471227	0.016297	-28.91479	0.0000
		Regime 2		
C	0.971594	0.000719	1351.592	0.0000
LOG(SIGMA)	-3.893346	0.035489	-109.7064	0.0000
		Transition Matrix Parameters		
P11-C	3.809381	0.168401	22.62089	0.0000
P21-C	-3.683262	0.164809	-22.34863	0.0000

Mean dependent var	0.553117	S.D. dependent var	0.601525
S.E. of regression	0.456291	Sum squared resid	746.4036
Durbin-Watson stat	0.301581	Log likelihood	2021.411
Akaike info criterion	-1.123105	Schwarz criterion	-1.112764
Hannan-Quinn criter.	-1.119419		

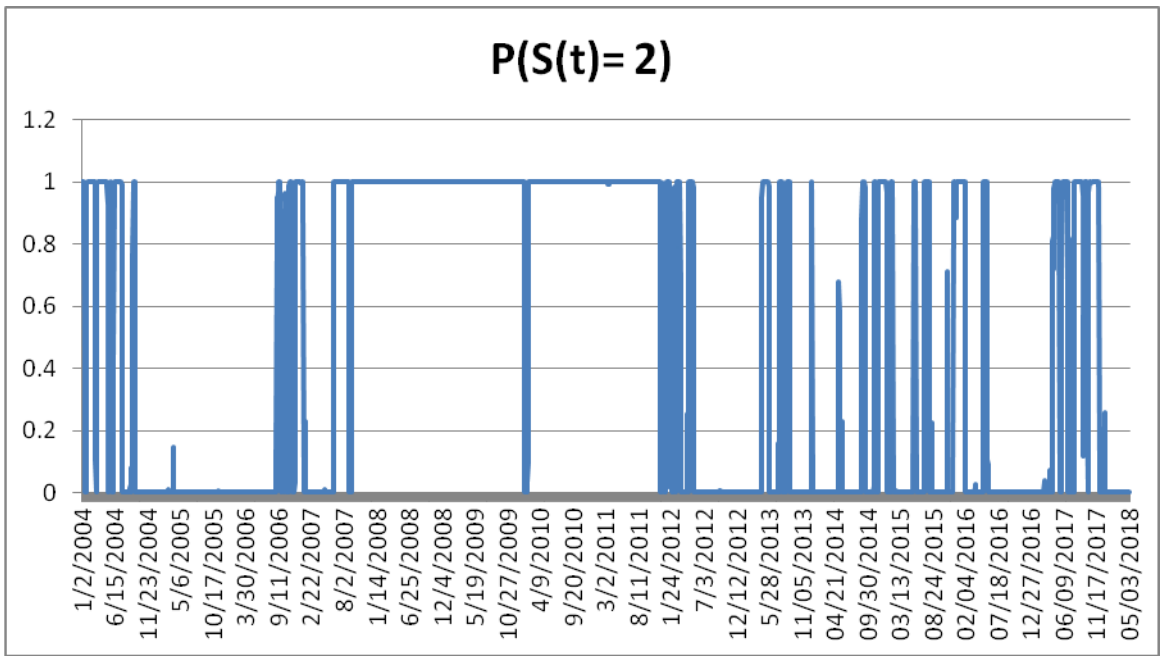
As depicted in table 5, the probability that correlation stays in the low regime 1 is 97,8%, and in the high regime 97,5%

Table 5: Transition probability matrix

	1	2
1	0.978319	0.021681
2	0.024524	0.975476

Looking at smooth probability (Figure 11) which estimates for the regime probabilities in period t using the information set up to t-1, we can observe how the two regimes have evolved over time. With a visual observation of the Figure 11 we can discern a high mean regime ranging between observations 934 to 2000 which represent the period between September 2007 and December 2011. The high correlation of the VIX and TYVIX the period before and short after the Lehman bankruptcy (September 2007) can attributed to investors' fears which led volatility measures to move upward. We can assume that after 2009, the existence of a high correlation regime was partly affected by the FED's intervention, which managed to cease investor's fears and led volatility measures to co-move downward. After 2012 the graph displays sharp spikes at irregular intervals, indicating that the transition from the low to the high mean regime occurs for a very short period of time. These sharp spikes suggest that the correlation of VIX and TYVIX shows weak regimes and therefore we cannot infer if there is any impact of QE on correlation.

Figure 11: Smoothed probability for regime 2, 2004-2018



Chapter 5. Conclusion

Examining the effects of monetary policies on volatility indices correlation, we assume that monetary policy had a short-term impact in reducing uncertainty in the economy the first period after the financial crisis of 2008. Correlation remained in a high regime both in the recession and recovery, indicating that VIX and TYVIX co-movement was proportionate either when their prices spiked the period after Lehman bankruptcy in 2007 or when they reduced within the economy recovery after 2009. The period after 2012, correlation didn't have a stable relation and this may reflect exogenous factors that have affected the volatility indices, mainly TYVIX, due to the worldwide importance of USA markets as safe resorts, in times of turbulences.

The analysis of the time-varying correlation between implied volatilities may not provide the same information value as the correlation of returns, nevertheless, observing changes in volatilities we have a better perception of uncertainty in economic functioning.

References

Altunbas, Y., Gambacorta, L. and Ibanez, D. M. (2010), "Does Monetary Policy Affect Bank Risk-Taking?", *ECB Working Paper Series No 1166*

Baba, N., McCauley, R. N. and Ramaswamy, S. (2009), "US dollar money market funds and non-US banks", BIS Quarterly Review, part 5

Baltussen, G., Van Bekkum, S., and Van der Grient, B. (2012), "Unknown Unknowns: Vol-of-Vol and the cross section of stock returns", *Erasmus University Working Paper.*

Bauer, M. and Rudebusch, G. (2014), "The Signaling Channel for Federal Reserve Bond Purchases*",* *International Journal of Central Banking*, vol.10, Issue 3, pp. 233–289.

Bekaert, G., Hoerova, M. and Lo Duca, M. (2013) "Risk, uncertainty and monetary policy", *European Central Bank Working Paper No. 1565*

Benford, J., Berry, S., Nikolov, K., Young, C. and Robson, M. (2009), "Quantitative easing", *Bank of England Quarterly Bulletin Q2*, pp. 90-100

Bernanke, B. and Kuttner K. (2005), "What Explains the Stock Market's Reaction to Federal Reserve Policy?", *The journal of finance*, Vol. 19, Issue 3, pp. 1221-257

Bhar, R., Malliaris, A. and Malliaris, M. (2015), "The Impact of Large-Scale Asset Purchases on the S&P 500 Index, Long-Term Interest Rates and Unemployment" , J*ournal of applied economics*, Vol. 47, Issue 55, pp. 6010-6018

Bollerslev, T., Engle, R.F. and Wooldridge, J.M. (1988), "A capital asset pricing model with time-varying covariances", Journal *of Political Economy*, Vol. 96, pp. 116–131

Bollerslev, T., Litvinova, J. and Tauchen, G. (2006), "Leverage and Volatility Feedback Effects in High-Frequency Data", *Journal of Financial Econometrics*, Vol. 4, Issue 3, 353–384

Bomfim, A. (2003). "Pre-announcement effects, news effects, and volatility: Monetary policy and the stock market", *Journal of Banking and Finance*, Vol. 27, pp. 133–151

Bong Soo, L. and Doojin, R. (2013), "Stock returns and implied volatility : A new VAR approach", *The Open-Access, Open-Assessment E-Journal*, Vol. 7, Issue 3, pp. 1-20 , http://hdl.handle.net/10419/70097

Borio C. and Zhu H. (2012), "Capital Regulation, Risk-Taking and Monetary Policy: A Missing Link in the Transmission Mechanism?", *Journal of Financial Stability,*Vol.8, Issue 4, pp. 236-251

Brooks, C. (2002), *Introductory econometrics for finance*. Cambridge: Cambridge University Press.

Bruno, V. and Shin, H. (2015), "Capital flows and the risk-taking channel", *Journal of Monetary Economics*, Vol. 71, pp.119 - 132

Caginalp, G., Mark DeSantis, M. and Sayrak, A. (2014), "The nonlinear price dynamics of U.S. equity ETFs", *Journal of Econometrics*, Vol. 183, Issue 2, pp. 193-201

Campbell, J. and Taksler, G. (2002), "Equity volatility and corporate bond yields", *NBER Working Paper No. 8961*, http://www.nber.org/papers/w8961

Chang, Y. and Feunou, B. (2013), "Measuring Uncertainty in Monetary Policy Using Implied Volatility and Realized Volatility", *Bank of Canada working paper No. 2013-37*

Chicago Board Options Exchange (2014), "The CBOE Volatility Index" – *Chicago Board Options Exchange White Paper*

Chicago Board Options Exchange (2015), "Guide to the CBOE / CBOT 10 Year Treasury Note Volatility Index (TYVIX^{SM}Index)", *Chicago Board Options Exchange White Paper*

Chicago Mercantile Exchange Group Inc (2017), "Central Bank Incentive Program Questions & Answers", *Chicago Mercantile Exchange & Chicago Board of Trade FAQ*

Chodorow - Reich, G. (2014), "Effects of Unconventional Monetary Policy on Financial Institutions", *Brookings Papers on Economic Activity*, Vol. 45, Issue 1, pp. 155-227

Di Maggio, M., Kermani, A. and Palme, C. (2016), "How quantitative easing works: Evidence on the refinancing channel", *NBER Working Paper*, No. 22638 *http://www.nber.org/papers/w22638*

Farka, M. (2009), "The effect of monetary policy shocks on stock prices accounting for endogeneity and omitted variable biases". *Review of Financial Economics*, Vol. 18, pp. 47-55.

Fawley, B. and Neely, C. J. (2013), "Four Stories of Quantitative Easing", *Federal Reserve Bank of St. Louis Review*, Vol. 95, No. 1, pp. 51-88

Feroli M., Kashyap, A. K., Schoenholtz, K. and Shin, H. S. (2014), "Market Tantrums and Monetary Policy", *Chicago Booth Paper*, No. 14-09

Gali, J. and Gambetti, L. (2015), "The Effects of Monetary Policy on Stock Market Bubbles: Some Evidence", *American Economic Journal: Macroeconomics*, Vol. 7, Issue 1, pp. 233-257

Gilchrist, S. and Zakrajsek, E. (2013), "The Impact of the Federal Reserve's Large-Scale Asset Purchase Programs on Corporate Credit Risk", *Journal of Money, Credit and Banking*, Vol. 45, Issue 2, pp. 29-57

Gospodinov, N. and Jamali, I. (2012), "The effects of Federal funds rate surprises on S&P 500 volatility and volatility risk premium", *Journal of Empirical Finance*, Vol. 19, Issue 3, pp. 497-510

Griffin, J. M. and Shams, A. (2018), "Manipulation In the VIX?", *The Review of Financial Studies*, Vol. 31, Issue 4, pp. 1377-1417

Haddow, A., Chris H., Hare, J. and Shakir, T. (2013), "Macroeconomic uncertainty: what is it, how can we measure it and why does it matter?", *Bank of England Quarterly Bulletin*, Vol. 52, No 2, pp. 100-109

Hamilton, J. (1989), "A new approach to the economic analysis of nonstationary time series and the business cycle", *Econometrica*, Vol. 57, pp.357-38

Hattori, M., Schrimpf, A. and Sushko V. (2013), "The Response of Tail Risk Perceptions to Unconventional Monetary Policy", *BIS Working Papers*, No. 425

Krieger, K., Mauck, N. and Vazquez, J. (2015), "Comparing U.S. and European market volatility responses to interest rate policy announcements", *International review of financial analysis*, Vol. 39, pp. 127-136

Kroencke, T. A., Schmeling, M. and Schrimpf, A. (2015), "A Global Asset Allocation Shifts*", BIS Working Papers*, No 497

Mallick, S., Mohanty, M. and Zampolli, F. (2017), "Market volatility, monetary policy and the term premium", *BIS Working Papers*, No. 606

McLeay, M., Radia, A. and Thomas, R. (2014), "Money creation in the modern economy", *Bank of England Quarterly Bulletin*, Vol. 54, No 1, pp. 14-27

Mele, A. and Obayashi, Y. (2013), "Volatility Indexes and Contracts for Government Bonds and Time Deposits", *Swiss Finance Institute Research Paper,* No. 13-26

Mele, A., Obayashi, Y. and Shalen, C. (2015), "Rate fears gauges and the dynamics of fixed income and equity volatilities", *Journal of Banking and Finance*, Vol. 52, pp. 256-265

Moore, A. (2016), "Measuring Economic Uncertainty and Its Effects," *Reserve Bank of Australia Research Discussion Paper*, No. 1

Morris, S. and Shin, H. S. (2014), "Risk-taking channel of monetary policy: a global game approach", Princeton University

Park, Y., (2013), "Volatility of Volatility and Tail Risk Premiums", *Federal Reserve Board Washington Working paper,* No. 2013-54

Rajan, R. G. (2005), "Has financial development made the world riskier?" *Proceedings – Economic Policy Symposium – Jackson Hole. Federal Reserve Bank of Kansas City*, Issue Aug, pages 313-369.

Roache, S. and Rousset, M. (2013), "Unconventional Monetary Policy and Asset Price Risk", *IMF working paper* No. 13/190

Rompolis, L. (2017), "The effectiveness of unconventional monetary policy on risk aversion and uncertainty", *European Central Bank Working Paper No. 231*

Shaikh, I. and Padhi, P. (2015), "The implied volatility index: Is 'investor fear gauge' or 'forward-

looking'?", *Borsa Istanbul Review*, Vol. 15. Issue 1, Pages 44-52

Silva, D. (2015), "The Risk Channel of Unconventional Monetary Policy", *Job Market Paper, MIT,* available at http://economics.mit.edu/files/10982)

Stivers, C., Sun, L. and Connolly, R. (2002), "Stock implied volatility, stock turnover, and the stock-bond relation", *Federal Reserve Bank of Atlanta Working Paper, No. 2002-3a*

Tan, J. and Kohli, V. (2011), "The Effect of Fed's Quantitative Easing on Stock Volatility", Electronic copy available at: http://ssrn.com/abstract=2215423

Taylor, J. (2007), "Housing and Monetary Policy," *NBER Working Paper,* No. 13682 , Paper Presented at a Symposium Sponsored by the Federal Reserve Bank of Kansas City at Jackson Hole WY.

Vähämaa, S. and Äijö, J. (2011), "The Fed's policy decisions and implied volatility", *Journal of Futures Markets*, Vol. 31, No.10, pp. 995-1009.

Whaley, R. E. (2009), "Understanding the VIX", *The Journal of Portfolio Management*, Vol. 35, Issue 3, pp. 98-105

Xekalaki, E and Degiannakis, S.(2010), "*ARCH models for financial applications*", Chichester: Wiley.

Yu, E. (2016), "Did Quantitative Easing Work?', *Federal Reserve Bank of Philadelphia Economic Insights*, Vol.1, Issue 1, pp. 5-13