Radboud University

Master Thesis

The effect of Quantitative Easing on stock indices in the US and the Eurozone and the relation between the EUR/USD and stock indices

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Abstract

This thesis examines the effect of the quantitative easing (QE) policy of the European Central Bank (ECB) on the comovement among stock markets in the US and Eurozone. In addition, it also examines the relation between the EUR/USD and the US and Eurozone stock market indices in the time period as of July 1st 2014 (as of this date the euro depreciated sharply). The ECB announced their QE program in January 2015 and implemented it in March 2015. By testing the existence of comovement, a distinction has been made between the announcement and implementation date. Weekly data of the S&P 500, AEX, DAX, CAC40, IBEX and FTSE MIB has been used to perform the empirical analysis. The statistical models that are used for analyzing the existence of comovement are the augmented Dickey-Fuller test and the Johansen test. The Granger causality test is performed to test whether there exist a causal relation between stock markets. In addition, the Granger causality test is also used to analyse the relation between the EUR/USD and the stock market indices. With regard to the results on comovement, in general, there are not many results who show comovement among the stock market indices. There only exist comovement between the DAX and the AEX during the time period as the announcement, which implies that the announcement of a QE program influences the existence of comovement. The results of the Granger causality test imply that the Eurozone has a small influence on the US after the implementation of the QE program. To conclude on the relation between the EUR/USD and stock markets, all stock markets within this thesis influenced the EUR/USD in the time period as of July 1st 2014.

Table of contents

1. Introduction

In 2008 the global financial crisis started in the US by the collapse of the US housing market. Diamond and Rajan (2009, p.1-2) describe the consensus on the causes of the financial crisis: (1) the US financial sector misallocated resources to real estate, financed through the issuance of exotic new financial instruments; (2) a significant portion of these instruments found their way, directly or indirectly, into commercial and investment bank balance sheets; (3) these investments were largely financed with short-term debt. The global financial crisis had a devastating impact on almost all countries in the world because it started in the US. The US is the largest and central economy in the world and is the home country of the US dollar, the most global and dominant currency in the world. This financial crisis was different from other financial crises and not only in its breadth and magnitude, but also in its origin. Therefore the 2008 global financial crisis is marked as the worst since the Great Depression in the 1930s (Kawai, 2009). This resulted in a stagnation of economic growth, unemployment rates increased heavily and banks needed to be saved by their governments.

As a response to the financial crisis, central banks implemented several measures to counteract the financial crisis. Usually central banks use conventional monetary polies to stimulate the economy. Conventional monetary policies encompasses changing interest rates and minimum reserve requirements for banks. Blinder (2010) states that the central banks conventional policy instrument, the overnight interest rate, is the most powerful instrument during normal circumstances. During the financial crisis, central banks lowered their interest rates, resulting in interest rates near to zero in 2009. Despite the decreased interest rates central banks were still unable to sufficiently stimulate the economy. In a situation in which the nominal interest rate hits its zero lower bound, conventional monetary measures has no longer any effect. This situation is called a liquidity trap. Consequently, the quantity of money becomes irrelevant because money and bonds are essentially perfect substitutes (Krugman 1998, p.137). Blinder (2010) states that real interest rates matter for the aggregate demand. A low real interest rate makes it less interesting for savings and more interesting to borrow money, which will finally benefit the economy. The other way around, a higher real interest rate will harm the economy. Blinder (2010) argues that policymakers should push real interest rates into a negative rates when a country faces a recession. A negative real interest rate arises when the inflation exceeds the nominal interest rate. But when the nominal interest rate is zero, central banks cannot further decrease the nominal interest rate and the real interest rate will be stuck at minus the inflation rate. When the inflation rate will fall, this could be a dangerous situation for a country. A nominal interest rate of zero and a fall of the inflation rate, will increase the real interest rate which will harm the economy even more. To obtain a lower short-term interest rate, central banks can commit to keep the overnight interest rate at zero for, say, an extended period, until inflation rates rise above a certain level (Blinder, 2010). On the other hand, to lower the long-term interest rate, central banks can decide to purchase long-term government bonds. An increase in the demand for long-term government bonds, makes long-term government bonds more expensive. Consequently, the long-term interest rate will decrease.

When a situation arises where there is no room for conventional monetary policies, central banks can use unconventional monetary policies to stimulate the economy. A common known form of unconventional monetary policy is quantitative easing (QE). QE could be a useful policy to implement when interest rates cannot be lowered any further. Fawley and Neely (2013, p.52) have a comprehensive definition of QE: ''QE policies are those that unusually increase the monetary base, including asset purchases and lending programs''. Japan was the first country who implemented a QE policy. In the 1990s, the real estate bubble burst in Japan. Consequently, the Japan's economy suffered from deflation that followed in the 1990s. Therefore, Japan implemented QE in 2001 because they were stuck in a liquidity trap. Their interest rates were at their zero lower bound, therefore the Bank of Japan aimed at purchasing government securities from banks to boost the level of cash reserves the banks held in the system. The idea of targeting a high enough level of reserves, would eventually spill over into lending to the broader economy and helping asset prices to increase and counteract deflation (Joyce et al. 2012, p.274).

The major central banks, Federal Reserve (Fed), Bank of Japan (BOJ), Bank of England (BOE) and the European Central Bank (ECB) implemented unconventional monetary policies as a response to the aftermath of the financial crisis. The Fed was the first central bank who started their QE policy as a response to the financial crisis. On November 25th 2008, the Fed

announced to start with their purchasing program. In March 2009 the Fed announced to expand their purchasing program. These two asset purchase programs were commonly called QE1 (Fawley and Neely, 2013). In May 2009, the ECB announced their Covered Bond Purchase Program (CBPP). Jean-Claude Trichet, former president of the ECB, explicitly mentioned that this was not QE and it would not increase the size of the balance sheet of the ECB. Trichet stated that the program was a credit easing program, which needed to revive the financial markets, which suffered because of the financial crisis. The unconventional monetary policies which were announced by former president of the ECB, Jean-Claude Trichet, were not mentioned as QE, only as credit easing. However, the current president of the ECB, Mario Draghi, has implemented QE in order to support the economy.
The main goal of the CBPP was to improve the spreads, depth and the liquidity of the market. In the years that followed after the first unconventional policies, the Fed and the ECB have introduced several unconventional monetary policies. The unconventional monetary policy programs of the Fed and the ECB differ from each other, the Fed focused more on bond purchases and the ECB focused more on direct lending to banks. The US has a market based system whereby bonds play a relatively more important role than banks and Europe has a bank based system whereby banks play a relatively more important role. Eventually, each central bank chose the most appropriate method for stimulating their economy (Fawley and Neely, 2013). This thesis will mainly focus on the unconventional measures of the Fed and the ECB. The content, differences and similarities between the measures of the Fed and the ECB will be explained in chapter 2, literature overview.

It is generally argued that implementing conventional and unconventional monetary policies have an influence on exchange rates. Through lowering interest rates and QE, it is likely to expect a depreciation of a currency. This is supported by the (un)conventional monetary policies of the ECB and the value of the euro with respect to the US dollar. From approximately July 2014 the euro depreciated sharply against the US dollar. Yau & Nieh (2009) and Ma & Koa (1990) argue that the relationship between exchange rates and stock prices has important implications. The traditional approach states that a depreciation of a currency makes domestic corporations more competitive, which leads to an increase in export and eventually to higher stock prices.

The main goal of this thesis is to examine whether there exist comovement between US indices and Eurozone indices after the ECB announced/implemented their QE program. In addition, an analysis will be run to examine whether there is comovement within the selected countries in the Eurozone. Comovement among indices means that stock indices are not independent of each other and this has consequences for portfolio diversification. Thus, for investors it is important to know whether there is comovement between US and Eurozone indices. When there is no comovement between US and Eurozone indices, investors can diversify their portfolios by investing in US stock indices and Eurozone indices. If there exist comovement, investors should add stocks from other countries to optimize the risk and return of their portfolios. Furthermore, by running the analysis, a distinction is made between the announcement and the implementation of the QE program of the ECB because financial markets immediately incorporate news into stock prices. Another related goal is to examine the relation between the EUR/USD and stock market indices in the US and Eurozone. This thesis is built on the following research question:

''Does there exist comovement among Eurozone and US indices and is there a difference between the announcement and the implementation of the QE program of the ECB and what is the relation between the EUR/USD and the Eurozone and the US indices?''

This is an interesting research question because there are not many studies who examines the existence of comovement between US and Eurozone indices during the QE program of the ECB. In addition, this thesis also examines whether there is comovement among the selected countries within the Eurozone. By executing these analysis, it is interesting to make a distinction between the announcement and the implementation of the QE program in order to see what the influence of an announcement is on stock markets. Therefore this thesis will contribute to the existing literature about comovement. Thereby, it is also interesting to test the relation between EUR/USD and stock market indices in a period that the euro sharply depreciated.

Thus, there are two time periods for analyzing the existence of comovement: the period starting as of the announcement date: January 22nd 2015 – June 1st 2016 and the period starting as of the implementation: March 9th 2015 – June 1st 2016 . With these two different starting dates, it is possible to test whether the announcement of a QE program influences the existence of comovement. The time period for analyzing the relation between the EUR/USD and the stock markets is July 1st 2014 – June 1st 2016.

In chapter 2 will be the literature review, where the content and the consequences of the (un)conventional monetary policies of the Fed and ECB will be discussed in more detail and the definition of comovement will be discussed. In chapter 3, the selection of data will be discussed. The methodology that is used to run the analyses will be discussed in chapter 4. Thus, the augmented Dickey-Fuller test, the Johansen test and the Granger causality test will be explained in this chapter. Furthermore, the results of the empirical analysis will be discussed in chapter 5. Finally, in chapter 6 will be the conclusion of this master thesis followed by recommendations for further research on this topic. Other relevant findings and tests can be found in the appendix.

2. Literature review

This chapter contains a literature review about QE and comovement among stock markets. First, the definition of QE will be discussed. Secondly, the content and consequences of the monetary policies of the Fed and ECB will be explained. Then the transmission channels of QE will be explained. After that, the effect of unconventional monetary policies on stocks will be discussed and the relation between exchange rates and stock markets. Finally, comovement will be discussed followed by the empirical findings in the literature about comovement.

2.1 Quantitative easing

In the existing literature are several definitions of QE, which means there is no uniform definition for QE. Mario Draghi, president of the ECB, defines QE as outright purchases of assets. Ben Bernanke (former president of the Fed) and Reinhart (2004, p.87) describe QE as: ''changing the size of the balance sheet, by buying or selling securities to affect the overall supply of reserves and the money stock''. Fawley and Neely (2013, p.52) have a more comprehensive definition of QE: ''QE policies are those that unusually increase the monetary base, including asset purchases and lending programs''. It is important not to confuse quantitative easing with credit easing because they significantly differ from each other. Fawley and Neely (2013) differentiates credit easing and quantitative easing. They state that credit easing policies are intended to reduce the interest rate and restore market functioning. On the other hand, quantitative easing is an policy that unusually increases the magnitude of liabilities of a central bank. Credit easing aims at improving liquidity in credit markets and quantitative easing aims at increasing the monetary base and the balance sheet of central banks.

The following definition of QE will be used within this thesis: *Outright purchases of assets that are unusually increase the monetary base and will not be characterized as credit easing*. The Fed started in 2008 with implementing their QE policy as a response to the aftermath of the financial crisis. Initially, Ben Bernanke, called the unconventional monetary policies credit easing, but this label did not stick (Blinder, 2010). During the aftermath of the financial crisis, both the Fed and the ECB implemented unconventional monetary policies. Some of these unconventional monetary policies of the Fed will meet the definition of QE of this thesis. However, most of the unconventional monetary policies of the ECB will not meet the definition of QE of this thesis. Until January 22nd 2015, the ECB announced their QE program (more than 6 years after the announcement of the QE program of the Fed). Several unconventional measures of the ECB does not meet the definition of QE since these measures were sterilized or were characterized as credit easing. A comprehensive overview of the (un)conventional monetary policy of the Fed and ECB can be found in paragraph 2.2 and 2.3.

Central banks can use conventional and unconventional monetary policy in order to stimulate the economy. QE is seen as an unconventional monetary policy. In general, central banks will use unconventional monetary policies if conventional policies are useless. With conventional monetary policies, central banks are able to change interest rates, and set minimum reserve requirements for banks to influence the money supply. Central banks can influence the short-term interest rates by purchasing or selling securities within the banking system, to influence the level of reserves that banks hold. This policy is known as open market operations (Joyce et al., 2012). The use of this monetary policy is limited to an interest rate of zero, since households are not willing to pay interest on their savings. In this situation, central banks might decide to implement unconventional monetary policies like QE to stimulate the economy. Figure 1 shows that the federal fund rate was almost zero at the moment that the Fed started QE1.

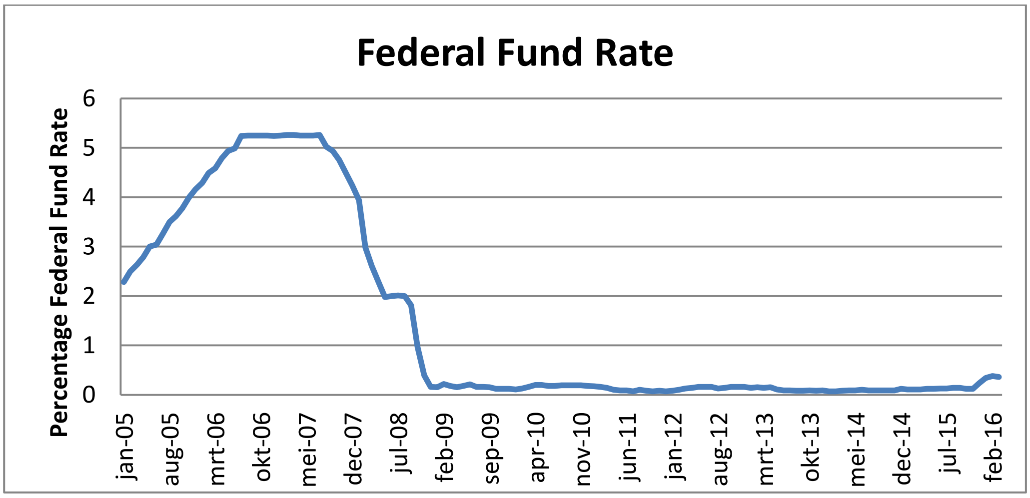

Figure 1: Federal Fund Rate from 2005 – 2016
Source: Board of Governors of the Federal Reserve System, 2016

2.2 (Un)conventional monetary policy Fed

The main objectives of the Fed are maximum employment, stable prices and moderate long-term interest rates (Haan, Oosterloo & Schoenmaker, 2012). The Fed was the first central bank who implemented a QE policy as response to the global financial crisis. The global financial system was under extraordinary stress and this stress was spilled over to the global economy. Initially, the Fed responded by executing conventional monetary policies. The Federal Open Market Committee lowered the target federal funds rate towards rates close to zero (see figure 1). From that moment onwards, the Fed was out of ammunition with regard to conventional monetary policies (Blinder, 2010). As already discussed, QE can stimulate the economy when the interest rates are close to zero. Therefore, the Fed started to use unconventional monetary policy. Ben Bernanke (2009) initially described the unconventional policy as credit easing because it resembles QE in one respect: ''it involves an expansion of the central bank's balance sheet. However, in a pure QE regime, the focus of policy is the quantity of bank reserves, which are liabilities of the central bank; the composition of loans and securities on the asset side of the central bank's balance sheet is incidental''. Nevertheless, economist described the monetary policy as QE. Figure 2 shows the increase of the total assets on the balance sheet of the Fed. The Fed focused its policies on reducing spreads and improving the functioning of private credit markets in order to stimulate the aggregate demand.

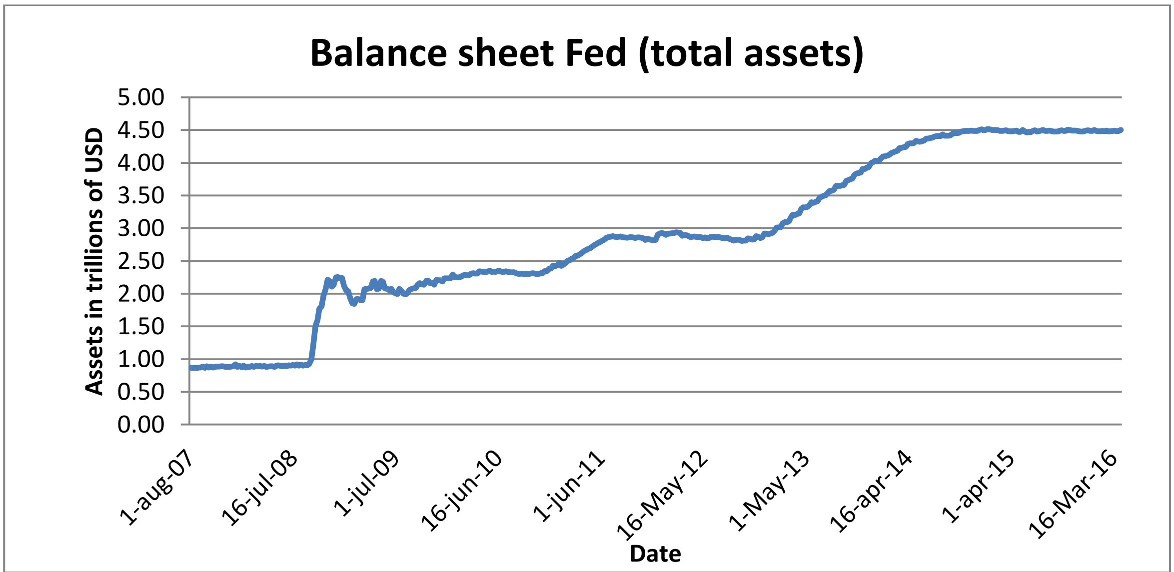

Figure 2: Total assets on balance sheet Fed (August 2007 – April 2016)
Source: Board of Governors of the Federal Reserve System, 2016

In November 2008, the Fed started with outright asset purchases. Initially, the Fed announced to purchase $100 billion in government-sponsored enterprise (GSE) debt and $500 billion in mortgage backed securities (MBS) which were issued by GSEs. A few months later, in March 2009, the Fed announced to expand the additional purchases with $100 billion in GSE debt, $750 billion in MBS and $300 billion in long-term treasury securities. The asset purchase programs which were launched in November 2008 and in March 2009 were commonly called QE1. These programs were initiated to support the economy and prioritize housing credit markets, which suffered due to the severe circumstances with respect to the US real estate, sales and construction (Fawley and Neely, 2013 and Buchik, 2014). The total combined purchases of QE1 were: $200 billion in GSEs, $1,25 trillion in MBS and $300 billion in long-term treasury securities. Consequently, these purchases have led to an expansion of the balance sheet of the Fed (see figure 2).

In 2010, the US faced high unemployment and low/declining inflation rates (Buchik, 2014). Therefore the Fed announced to maintain the size of its balance sheet by reinvesting the payments on the large-scale asset purchase (LSAP) into Treasuries. In August 2010, Ben Bernanke suggested that the Fed would purchase assets if conditions were going worse. Later, on November 3rd 2010, the Fed announced QE2. QE2 started in November 2010 and ended in June 2011. The Fed purchased an additional $600 billion in US treasures in order to lower the long-term interest rate and to increase inflation. By purchasing long-term bonds, the long-term interest rate will decrease, and this lower interest rate should stimulate investments and household spending. Consequently, an increase in investments and household spending will increase the inflation rate.

A few months after QE2 ended, the Fed implemented the Maturity Extension Program (MEP, also called Operation Twist). The goal of the MEP was to ease the financial market conditions and to stimulate the recovery of the economy. The Fed sold $400 billion of short-term Treasuries and they purchased $400 billion of long-term Treasuries. The goal of Operation Twist was to decrease the long-term interest rate relative to the short-term interest rate, and thus 'twisting' the yield curve. The monetary base did not expanded due to Operation Twist because the purchases of long-term Treasuries were funded by selling short-term Treasuries. Only the composition of the balance sheet changed and the total assets remained unchanged. Therefore this program was marked as credit easing and not QE. Conclusively, Operation Twist resulted in an increase of long-term Treasuries and it lowered the long-term interest rate (Joyce et al. 2012). Initially, Operation Twist would end by the end of June 2012, but the Fed announced to extend Operation Twist through the end of 2012, since Operation Twist was successful in lowering the long-term interest rate. The additional purchases were extended by $267 billion. In total, the Fed purchased for $667 billion long-term Treasuries and sold $667 billion short-term Treasuries (Federal Reserve System, 2013).

The third QE program of the Fed (also known as QE3) was introduced on September 13th 2012. The goal of QE3 was to foster maximum employment and price stability (Federal Reserve Bank, 2012) The only difference between QE3 and the previous QE programs is that the Fed decided to a pace of purchases instead of a total quantity. The Fed decided to start QE3 because the labor markets remained sluggish. Initially, QE3 encompasses a monthly purchase of $40 billion in MBS. In December 2012, the Fed announced to expend their purchases with long-term Treasuries under the MEP at the pace of $45 billion per month. These additional purchases were, in contrast with Operation Twist, not sterilized through the sale of short-term Treasuries (Fawley and Neely, 2013). Consequently, the monetary base increased due to QE3. By expanding the balance sheet of the Fed, the Fed is effectively printing money, which will ultimately lead to inflation (Bernanke, 2009). Ben Bernanke indicated in May 2013 to start with tapering in the future. Financial markets reacted immediately, the volatility increased and long-term yields on Treasuries rose around 100 basis points. At the end of 2013 the Fed decided to gradually start tapering over the next 10 months. Tapering started with $10 billion per month which was later increased to $15 billion per month. Eventually, the Fed ended QE3 in October 2014 (Kawai, 2015).

Now QE3 has ended, the Fed has a balance sheet with around $4.5 trillion assets (see figure 2). Janet Yellen, current Chair of the Fed, is heading towards monetary policy normalization. By reversing the QE program, the monetary normalization policy can be achieved. This means selling the purchased assets or by raising the interest rate, or a combination of both. There are two ways to decrease the amount of assets which are on the balance sheet of the Fed: (1) by not replacing the assets as they mature, and (2) by actively selling the assets back into the market (Kawai, 2015). The Fed announced in December 2015 to increase the federal funds rate target range to 25 to 50 basis points. This was the first increase in the interest rate since June 2006 (Federal Reserve System, 2016). Thus, the Fed already started with their monetary normalization policy and the Fed also announced to further increase the interest rate.

Now the QE programs of the Fed all ended, it is interesting to know whether the QE programs were a success. Engen, Laubach and Reifschneider (2014, p.26) conclude that the QE program of the Fed helped stabilizing the economy by providing liquidity to the financial markets that were seizing up. They estimated that the unconventional monetary policy did not provide an additional stimulus in the first 2 years due to the modest changes in the Feds policy and because the Fed anticipated on a more rapid rebound of the US economy. Thornton (2014) conclude that the unconventional policy of the Fed did not significantly lowered the 10-year Treasury yield. The conclusion regarding the effectiveness of the unconventional policy of the Fed is that the policy of the Fed have led to a more rapid recovery of the US economy to a certain extent. But, it is still difficult to draw a clear conclusion. Further research will help to draw a clear conclusion about the effectiveness of the policy of the Fed.

2.3 (Un)conventional monetary policy ECB

The primary objective of the ECB is price stability. The ECB specifies price stability as an inflation rate below but close to 2 per cent within the Eurozone in the medium term. Figure 3 shows that the ECB did not managed to obtain a steady level of inflation. Besides price stability, a high level of employment and sustainable and non-inflationary growth are important objectives for the ECB (Haan et al., 2012). The conventional monetary policy instruments of the ECB are refinancing operations, direct lending to banks against eligible collateral at two maturities (Fawley and Neely, 2013). Just after the eruption of the financial crisis, the ECB lowered the refinancing rate from 4.25 per cent to 1 per cent, from October 2008 to May 2009. The decrease of the refinancing rate shows some similarities with the policy of the Fed, who also started with lowering the interest rate in order to stimulate the economy. Just as in the US, lowering the interest rate did not sufficiently supported the economy and unconventional policies were required. These unconventional measures are subsequently referred as Enhanced Credit Support, which mainly focuses on banks. Due to the eruption of the financial crisis, the uncertainty regarding the creditworthiness of banks increased. Consequently, the interbank market did not work as it should be and became worse after the bankruptcy of Lehman Brothers. Resulting in an increasing demand for liquidity while interbank lending declined. The most important measures within the Enhanced Credit Support are: unlimited provision of liquidity, extension of maturity of long-term refinancing operations up to 3 year in 2012, liquidity provision in foreign currencies and outright purchases of covered bonds and sovereign bonds (Haan et al., 2012 and Szcerbowicz, 2012). These unconventional measures were aimed at supporting credit flows within the Eurozone, and therefore experienced as credit easing. There are differences between the unconventional monetary policies of the Fed and the ECB due to different systems. The US has a market-based system and the Eurozone has a bank-based system. Therefore, the Fed mainly focused on bond purchases since bond markets play relatively important role within the US economy. And the ECB mainly focused on improving liquidity for banks within the Eurozone in order to stimulate the economy because banks are mainly used to finance firms and households.

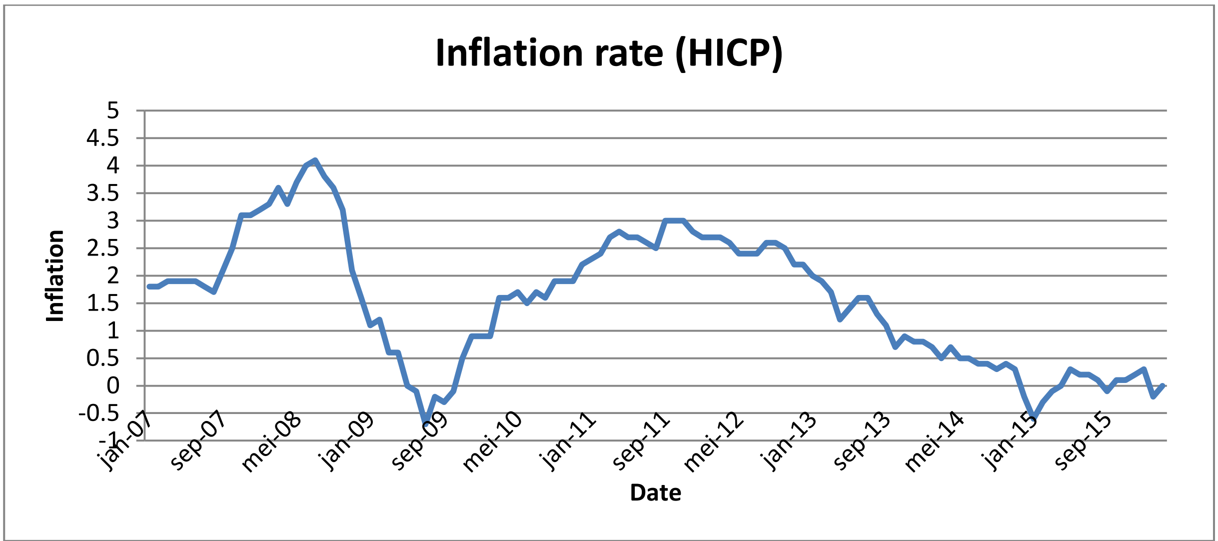

Figure 3: Inflation rate Eurozone (January 2007 – March 2016)
Source: Data retrieved from ECB Statistical Data Warehouse

On May 7th 2009, the ECB announced their first asset purchase program, Covered Bond Purchase Program (CBPP). First some background information of this asset purchase program will be given. The covered bond market is the most important issued bond segment in the capital market in Europe. Due to the financial crisis, the covered bond market became a key source of funding for banks within the Eurozone. A covered bond is a bond whereby the credit risk of the issuer is backed by a pool of (usually) high quality collateral (Beirne et al., 2011). After Lehman Brothers went bankrupt, spreads on covered bonds started widening and the liquidity in the secondary markets worsened. A well-functioning covered bond market is important with regard to financial stability within the Eurozone, since these bonds are used for funding of mortgage lending. While the crisis proceeded, spreads on covered bonds continued widening and the liquidity got worse. In addition, the lack of confidence in banks dried up the interbank lending market (Fawley and Neely, 2013). Therefore the ECB announced to start purchasing covered bonds. Under the CBPP, the ECB announced to purchase covered bonds (issued in the Eurozone) for a total amount of €60 billion. This decision surprised the financial markets because they expected a cut in the interest rate and not an outright purchase of private debt (Szcerbowicz, 2012). The objectives of the CBPP were to contribute to promoting the ongoing decline in money market term rates, easing funding for credit institutions, encouraging credit institutions to maintain and expand their lending business and improving market liquidity in important segments of the private debt securities market (Beirne et al., 2011). CBPP started in July 2009 and was fully implemented by the end of June 2010. Former president of the ECB, Jean-Claude Trichet, said that this purchase program was not QE because it would not expand the size of the balance sheet of the ECB. Trichet expected automatic sterilization and therefore justified the CBPP as credit easing (Fawley and Neely, 2013). Empirical evidence shows that during the period of the CBPP, the liquidity in the covered bond market improved and were moving closer to pre-crisis levels. Due to the CBPP banks were able to lower their overall funding costs. Beirne et al. (2011 p.6) conclude that CBPP had a positive impact on covered bond spreads and market liquidity and that the CBPP has been effective in achieving its objectives.

Despite the success of the CBPP, the situation with regard to the sovereign debt markets got worse. Initially, the sovereign debt markets remained relatively calm during the first two years of the financial crisis. In late 2009 countries were struggling with the consequences of the financial crisis as they needed to save banks from bankruptcy. The unemployment increased in many countries within the Eurozone and therefore their expenses to unemployed people increased. Greece was the first country to be shut out of the bond market in May 2010. In Ireland and Spain, tax revenues decreased due to declines in construction activities. The aftermath of the financial crises caused an increase in GDP ratios (Lane, 2012). The combination of the mentioned consequences of the financial crisis have led to an increased government debt for many countries within the Eurozone. At that moment, financial markets started questioning the solvency of countries with large deficits and high debt and a feedback loop between banking and sovereign credit risk started (Fratzscher, Loluca and Straub, 2014 p.4). A distinction can be made between the core countries and the peripheral countries in the Eurozone. The core countries which are used in this thesis are: Germany, France and the Netherlands. The peripheral countries within the Eurozone which are used in this thesis are: Italy and Spain. The core countries managed to deal better with the deteriorated circumstances in the Eurozone. In contrast, the peripheral countries faced difficulties during the aftermath of the financial crisis. Consequently, at the end of 2009 interest rates on government bonds of peripheral countries rose and made it more difficult for these countries to borrow money through capital markets. Figure 4 shows the development of long-term interest rates within the Eurozone. This figure also shows that long-term interest rates were close to each other by the end of 2009. Through the eruption of the sovereign debt crisis the interest rates in the peripheral countries, Spain and Italy, rose sharply. In contrast, interest rates of the core countries decreased. Especially in Germany, since Germany was seen as a safe heaven.

Eventually, Greece was the first country who received a loan from the European Union (EU) and the International Monetary Fund (IMF) in May 2010. Later, Ireland (November 2010) and Portugal (April 2011) also sought official funding. Spain also requested financial assistance in order to recapitalize its banking sector (Gomez-Puig et al., 2015). So, the assistance that Spain requested was from a different reason compared with Greece, Ireland and Portugal. With the beginning of the sovereign debt crisis in Europe, in the late 2009 and the beginning of 2010, the epicenter of the global financial crisis crossed the Atlantic toward Europe (Trichet, 2013).

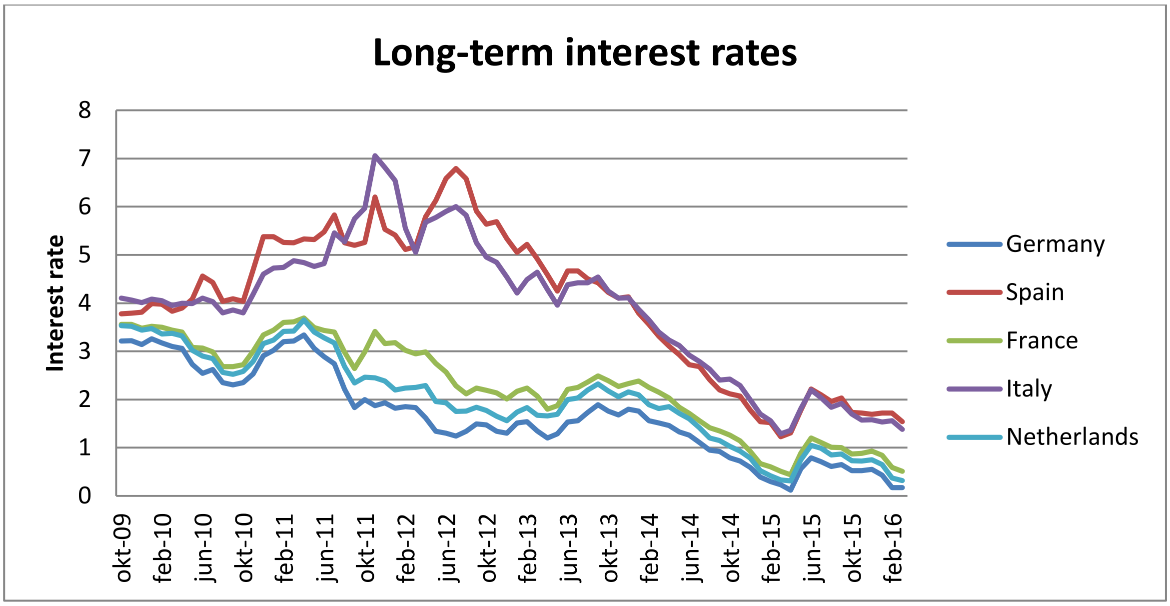

Figure 4: Long term interest rates in the Eurozone
Source: Data retrieved from ECB Statistical Data Warehouse

Consequently, the ECB announced in May 2010 its Securities Markets Program (SMP) in order to counteract the escalating sovereign debt crisis by purchasing government bonds of peripheral countries in the secondary market. The ECB explained its motives for the SMP as follows: ''to ensure depth and liquidity in those market segments which are dysfunctional''. The SMP differed from other asset purchase programs, since the size and the scope of the purchases were determined on an as needed-basis (Fawley and Neely, 2013, p.71-72). The ECB (2010) announced that its asset purchases were sterilized by specific operations that will be conducted to re-absorb the liquidity injection through the SMP. Since this was a sterilized program, the monetary base did not increased and therefore this program cannot be seen as QE. Fawley and Neely (2013), state that the SMP purchases appear to have contributed to hold down the yields on euro debt, especially on yields of Spanish and Italian debt. Fratzscher et al. (2014) found that SMP had a positive effect on stock prices in the ''core'' and ''periphery'' countries of the Eurozone and that SMP helped decreasing bond yields in peripheral countries. Eser and Schwaab (2015 p.164) also state that SMP lowered yields, which can be explained due to reduced liquidity risk premia and reduced default risk. In addition, they also found that bond yield volatility is lower on intervention days for most countries due to less extreme movements occurring when the ECB is operating in the market. Finally, Ghysels et al. (2014 p.14) found that SMP purchases have been successful in (temporary) lowering yields of countries under the program and above all in capping the volatility. The SMP ended in September 2012. To conclude, the SMP was successful in reducing bond yields and did not increased the size of the ECBs balance sheet since the purchases were sterilized. This shows similarities with Operation Twist, which was executed by the Fed and the Fed also sterilized their purchases and they were successful in lowering bond yields.

Despite the success of the SMP, the sovereign debt crisis continued. This resulted in a decrease of sovereign bond prices, which weakened bank balance sheets. Therefore, financial markets questioned the viability of a number of banks within the Eurozone. Consequently, the interbank market became dysfunctional and bank funding dried up in large parts of the Eurozone and the issuance of covered bonds was severely constrained (Cour-Thimann and Winkler, 2013 p.15). In response to the sovereign debt crisis, the ECB announced their second Covered Bond Purchase Program (CBPP2) in October 2011. The CBPP2 was an twelve-month program whereby the ECB purchased €40 billion of euro-denominated covered bonds in primary and secondary markets (Szczerbowicz, 2012 p.120). With CBPP2, the ECB aimed at easing funding conditions and stimulate and expand lending to customers. CBPP2 was also a sterilized program just as the first covered bond purchase program. Gibson, Hall and Tavlas (2015 p.17-18) state that the CBPPs had a positive, although modest, effect on bond prices and that CBPP had their greatest impact at bonds with longer maturity. In addition, Gibson et al. (2015 p.18) found that ''the Draghi effect'' appears to have led to a sharp increase in covered bond prices. Mario Draghi said on July 12th 2012 that the ECB would do whatever it takes to preserve the euro, Gibson et al. (2015) called this statement ''the Draghi effect''. They concluded that ''the Draghi effect'' have had a significantly larger effect than SMP because of the open-ended nature of this statement. The statement of Draghi is an example of the signaling or expectations channel, see paragraph 2.4 for more information about this channel.

The ECB announced their third covered bond purchase program (CBPP3) in September 2014 together with the purchase of a broad portfolio of transparent asset-backed securities (ABS). These programs were implemented in October 2014. The goal of these purchasing programs was to further enhance the functioning of the monetary policy transmission mechanism and to support the provision of credit to the economy (ECB, 2014).

These purchase programs also contributes to the main goal of the ECB, an inflation rate below, but close to 2%. Draghi mentioned these programs as credit easing. By purchasing ABS, the ECB facilitates new credit flows to the economy.

A few months later, on January 22nd 2015, the ECB announced to expand their purchasing programs by including bonds issued by euro area central governments, agencies and European institutions. The combined monthly asset purchases are €60 billion. This is the first time that the ECB purchased covered bonds, ABS and government bonds which were not sterilized. Initially, the purchases were intended to be executed until at least September 2016. The ECB expanded their purchasing program in order to avoid a situation in which the inflation in the Eurozone will drift towards historical lows. Thus, this program is designed to fulfil price stability within the Eurozone (ECB, 2015). The expansion of the purchasing program was not mentioned as credit easing. The balance sheet of the ECB increased through these monthly asset purchases. Therefore, the expansion of the purchasing program will be considered as the start of quantitative easing by the ECB. This QE program was implemented on March 9th 2015. In contrast to Trichet, Mario Draghi implemented the first QE program of the ECB.

Roughly a year after the implementation of the QE program of the ECB, the ECB again announced an expansion of their purchasing program. Investment-grade-euro-denominated bonds which are issued by non-bank corporations will be included in the list of assets. The new program is called: corporate sector purchase program (CSPP). Through this expansion, the total monthly purchase of assets will amount to €80 billion. With this expansion, the ECB wants to provide further monetary policy accommodation to obtain inflation rates below, but close to 2%. As of April 1st 2016, the purchase program will be increased from €60 billion to €80 billion per month and is intended to run until the end of March 2017, or beyond, if necessary (ECB, 2016). Figure 5 shows the monetary base of the ECB from January 2008 until April 2016. It shows an increase of the monetary base as of the start of the QE program of the ECB.

Thus, the Fed and the ECB both implemented QE policies in order to meet their main objectives and to stimulate the economy. The Fed started very soon with implementing their

QE program in comparison with the ECB. The Fed started by the end of 2008 and the ECB started in March 2015. The different starting moments of the QE programs of the ECB can be explained by different reasons, different economic systems and by political issues. As already discussed, the US has a market based system whereby bonds play an important role with regard to funding. In contrast, the Eurozone has a bank based system, whereby banks play an important role in funding. It is likely to expect that the different financial system within the Eurozone is the reason that the ECB initially implemented credit easing programs and did not implement QE. There have been political contradictions within the Eurozone about the unconventional monetary policy of the ECB. For example, Klaas Knot and Jens Weidmann, president of the Dutch central bank and the president of the Bundesbank, voted against the QE program which is announced in January 2015 (NRC, 2016). Thus, QE was not unanimous chosen.

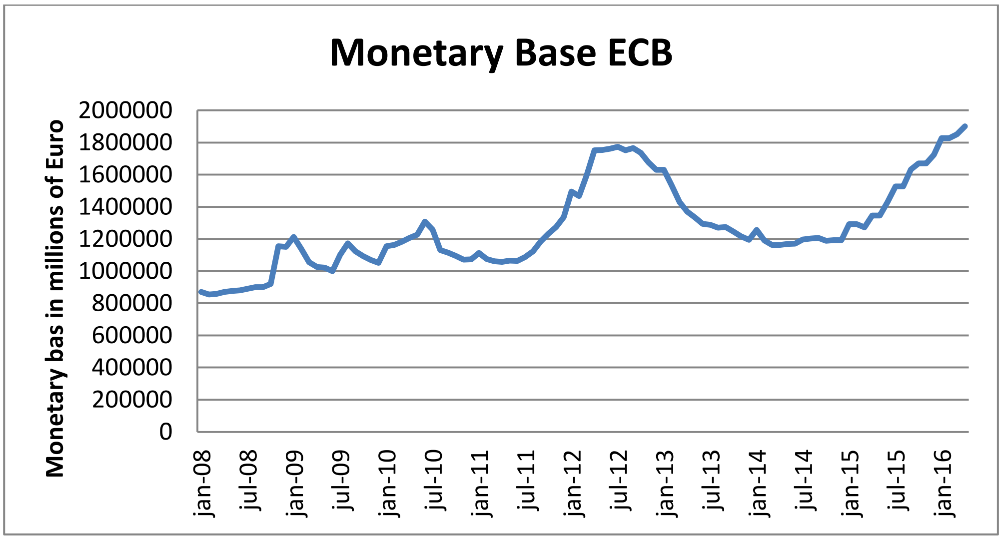

Figure 5: Monetary base ECB
Source: Data retrieved from ECB Statistical Data Warehouse

2.4 Transmission channels

In the two previous paragraphs, the conventional and unconventional monetary policies of the Fed and the ECB are explained. By executing these monetary policies, central banks wants to stimulate the economy. Often has the monetary policy not a direct influence on the economy, but the (un)conventional monetary policies can positively affect the economy through transmission channels. If central banks decide to implement conventional monetary policies, it can stimulate the economy through two types of channels: asset price channels (including interest rates) and credit channels (Fawley and Neely, 2013 p.53). However, lowering interest rates is limited when short-term interest rates are at zero (liquidity trap). As response to the financial crisis, central banks started to use unconventional monetary policies to lower the long-term interest rate and to stimulate the economy. There are several transmission channels through which unconventional monetary policies can stimulate the economy. The most important channels will be discussed in this paragraph.

If central banks are successful in lowering the long-term interest rates through unconventional policies, can this positively affect stock prices. Investors can calculate the value of a stock by calculating the present value of future cash flows (dividend). The interest rate will be used to discount future cash flows. Consequently, a lower interest rate means a lower discount rate, which will eventually means a higher present value. A higher present value indicates that future profits are more valuable, which will benefit stock prices. Higher stock prices can lead to an increase in consumption which can stimulate the economy and inflation rates.

A lower long-term interest rate (through unconventional policy) affects investment portfolios because bond prices will rise and yields will decrease. Fratzscher, Duca and Straub (2013 p.9) state that the intention of the purchases of long-term assets is to reduce bond yields and to push investors to other assets, which is also known as portfolio rebalancing. Through the decrease of bond yields, the demand for risky assets increased. Fratzscher et al. (2013) and Chen et al. (2011) argue that the portfolio rebalancing channel has an international spillover effect. For example, Fratzscher et al. (2013 p.6) found that the Fed's Treasury purchases triggered a large portfolio rebalancing out of bond markets, primarily into emerging markets stocks. Consequently, higher bond prices and higher stock prices increase the value of portfolios, which can lead to an increase in consumption. However, during a financial crisis, consumers might be cautious with their spending.

Another transmission channel is the signaling or expectations channel. A central bank can shows its commitment to a certain policy path. An example is Mario Draghi's statement that the ECB would do whatever it takes to preserve the euro. Gibson et al. (2015) found that this statement appears to have led to a sharp rise in covered bond prices. ''A credible commitment would as well inspire confidence and drive down risk premia while supporting asset prices'' (Chen et al. 2011 p.7). The confidence channel is similar to the signaling channel. Through unconventional monetary policies, central banks can give investors a better outlook of the economy. If investors have more confidence, they might decide to invest more in financial assets.

An unconventional monetary policy as QE can increase inflation expectations because the money supply increases, and this can be expected to have an effect on interest rates (Krishnamurthy and Vissing-Jorgensen, 2011). An increase in inflation expectations give consumers the incentive to consume today instead of later because prices will be higher in the future. Increased consumer expenditures, can stimulate the economy and corporate results, which can stimulate stock prices.

To summarize, implementing unconventional monetary policies helps in general to lower interest rates which can be good for stock prices. There are several channels which contributes to higher stock prices due to unconventional monetary policies such as QE. Higher stock prices can lead to higher consumer expenditures which will stimulate the economy. Finally, QE can also stimulate the economy through an increase in expected inflation. However, there are also economists who do not believe in these positive effects, but this will be discussed in the next paragraph (2.5).

2.5 Effects of unconventional policies on stock prices

In the previous paragraph, the transmission channels are discussed. And it turned out that in theory unconventional monetary policies have a positive effect on stock prices. Consequently, higher stock prices lead to an increase in consumption (through the wealth effect) which will support the economy. This paragraph will take a closer look at the effect of unconventional monetary policies on stock prices. Because of the of the financial crisis, stock indices declined sharply. Central banks started to implement (un)conventional monetary policies in order to stimulate the economy. Since they started with their unconventional monetary policies, stock indices increased. Most of the stock indices which are used in this thesis are higher at the moment in contrast to the stock prices before central banks started with their unconventional policies. Figure 6 shows that the S&P 500, AEX, IBEX, CAC40 and

DAX are higher at the moment than before central banks implemented unconventional monetary policies (especially because of the QE programs of the Fed). However, the IBEX, is slightly higher than before central banks implemented unconventional monetary policies. Figure 6 also shows that the FTSE MIB is lower at the moment. The reason that the FTSE MIB and the IBEX performed worse than the other stock markets indices might be because of the sovereign debt crisis. This crisis had a severe impact on Italy and Spain.

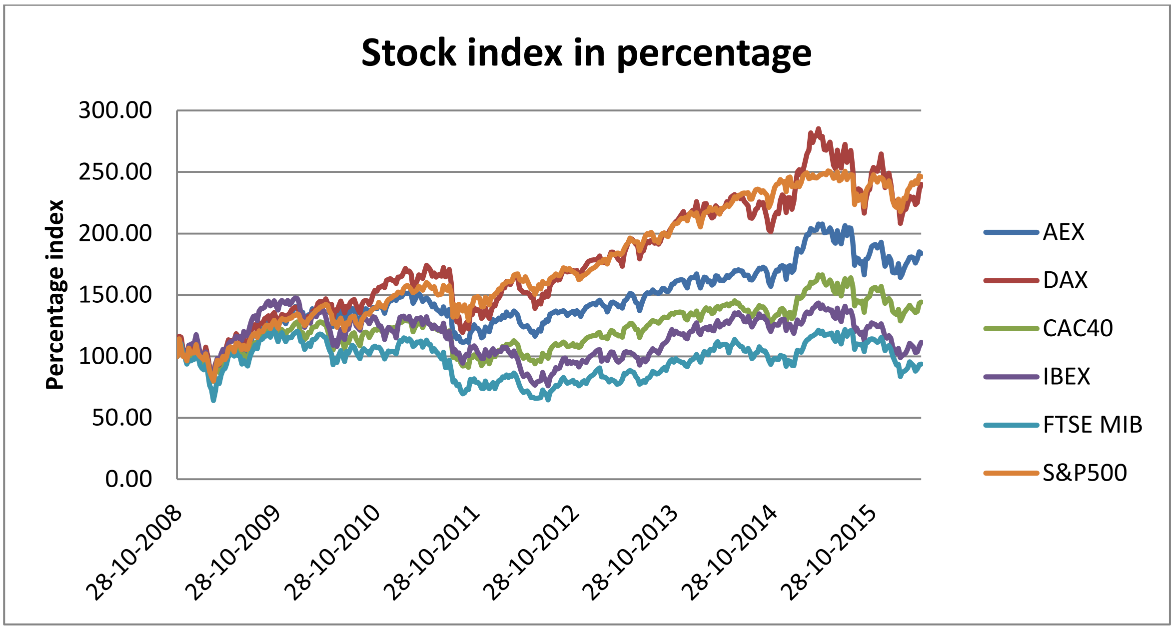

Figure 6: Stock indices in percentage
Source: Data retrieved from Datastream

Figure 7 shows the development of the stock market indices which are used in this thesis as of the announcement date of the QE program of the ECB. Immediately after the announcement of the QE program of the ECB, stock market indices increased. This suggest that the announcement of a QE program influences stock prices. Therefore, the announcement effect will be tested in chapter 5. Figure 7 also shows that stock markets did not continued to perform well. Thus it seems that the QE program of the ECB did not boost Eurozone stock markets. We have to be cautious with a conclusion, as the QE program is still going on.

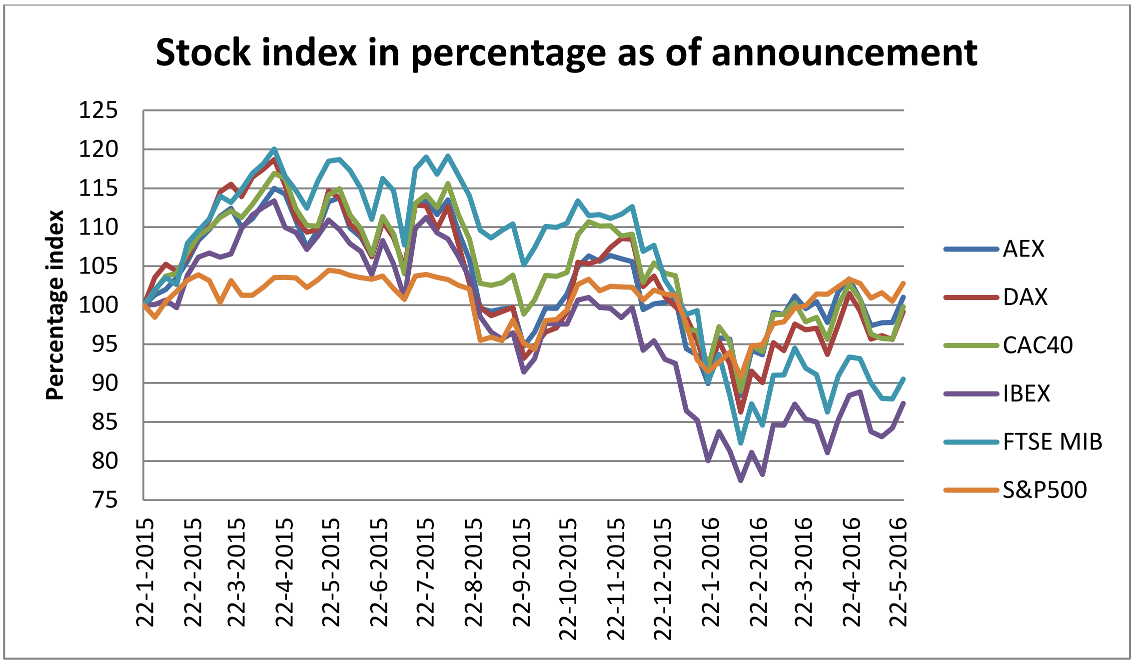

Figure 7: Stock indices in percentage as of announcement date
Source: Data retrieved from Datastream

Dobbs et al. (2014p.15&18) state that in theory and all else being equal, ultra-low interest rates can boost stock prices in the long-term. However, they believe that not else will be equal and therefore might the effect on stock prices not be significant. They conclude that the ultra-low interest rates by themselves does not point to an increase in stock prices over time. Fawley and Neely (2013 p.81) state that research on the effects of QE indicates that it had the desired effect on asset prices, thus also on stocks. Joyce et al. (2010 p.3) found that stock prices fell immediately after the QE announcements but strengthened thereafter. They state that if investors rebalance their portfolios from bonds to more risky assets, the compensation for the risk of holding stocks (equity risk premium) will fall. Consequently, this boost stock prices even more. Joyce et al. (2010 p.26) state the announcement of a QE program might give investors an outlook for the economy as a whole. If the outlook is worse than investors expected, stock prices might fall in the short-term. Finally, they conclude that it is not clear what the immediate effect of the QE announcement on stock prices will be, but they do expect higher stock prices in the long-term due to QE policies. Fratzscher et al. (2013 p.2) found that QE1 of the Fed boosted stock prices, especially in the US and that QE2 boosted stock prices worldwide. Buchik (2014) found that the impact of the QE program of the Fed has been the strongest in stock markets.

Based on theory, the development of stock indices (see figure 6) and the empirical findings, it is likely to expect that unconventional monetary policies in general have a positive effect on stock prices.

2.6 Relation between exchange rates and stock markets

This paragraph will first focus on the theoretical relation between exchange rates and stock markets. Secondly, the empirical findings regarding the relation between the exchange rates and stock markets will be discussed. Exchange rates are important for multinational corporations. If a currency rises in value against another currency, goods of the exporting corporation will become more expensive. The demand for these products might decrease and so will the export. In contrast, a depreciation of the currency will make the currency cheaper and makes imports more expensive and exports cheaper (Madara and Fox, 2014). Thus, the exchange rate can influence imports and exports. A weaker currency probable leads to an increase of exports. An increase in exports might boost the financial results, which might boost the stock prices of that specific corporation. However, a depreciation makes the import of commodities more expensive which will harm the financial results, but it is likely to expect that corporations export more than import. And therefore, it is likely to expect that a depreciation of a currency will increase the financial results. To conclude, a depreciation of a currency might boost stock prices. As already discussed in the previous paragraphs, higher stock prices might boost the economy. Therefore central banks might have the incentive to intervene in the foreign exchange markets in order to control its currency value. Central banks are in control of interest rates and they attempt to control the money supply (Madara and Fox, 2014 p.208). If central banks are intervening in the foreign exchange markets in order to devaluate a currency, stock prices might increase due to an increase of exports. However, we should be cautious since imports becomes more expensive. A weak currency can also contributes to reducing unemployment and higher inflation, which will support the economy.

Neely (2015 p.110) found that the unconventional monetary policy of the Fed reduced the value of the US dollar. This showed that centrals banks are not toothless when short-term interest rates are near to zero. He concludes that devaluation of the US dollar probably stimulated the US economy through export channels. The depreciation of the US dollar during the unconventional monetary policy of the Fed can be explained by the increased money supply. Unconventional monetary policy can devaluate a currency, and a weaker currency might boost stock prices, through an increase of export. This might give stock markets of countries with unconventional monetary policies an advantage compared to stock markets in countries without unconventional monetary policy. At the end of 2013, the Fed started with gradually tapering their monthly purchases and QE3 ended in October 2014. In September 2014, the ECB announced to start with their purchase programs of covered bonds and asset backed securities. These two decisions might be the reason for the sharp decline with respect to the value of the euro (see figure 8). After the ECB announced to expand their purchase program, and thus QE, the euro depreciated even more.

Bahmani-Oskooee and Sohrabian (1992 p.463) investigated the relation between stock prices and exchange rates. They tested for the existence of a two-way relationship between stock prices and exchange rates. They conclude, based on the Granger causality test, that there exist a bidirectional causal relationship between stock prices of the S&P 500 and the EUR/USD exchange rate, at least in the short run. However, they were unable to establish cointegration among the EUR/USD and the S&P 500. Ajayi, Friedman and Mehdian (1998 p.248) state that there exist unidirectional causality, in the Granger sense, between the stock and currency markets in all advanced economies (Canada, Germany, France, Italy, Japan, UK and US). They concluded that exchange rates are responding to stock markets. Grange, Huang and Yang (2000) state that exchange rates lead stock prices, which is commonly defined as the traditional approach with regard to stock markets and exchange rates. Ramasamy and Yeung (2005 p.169) found that during the four years of the Asian crisis (1997 – 2000) most of the East Asian countries showed that stock prices Granger cause movements in exchange rates.

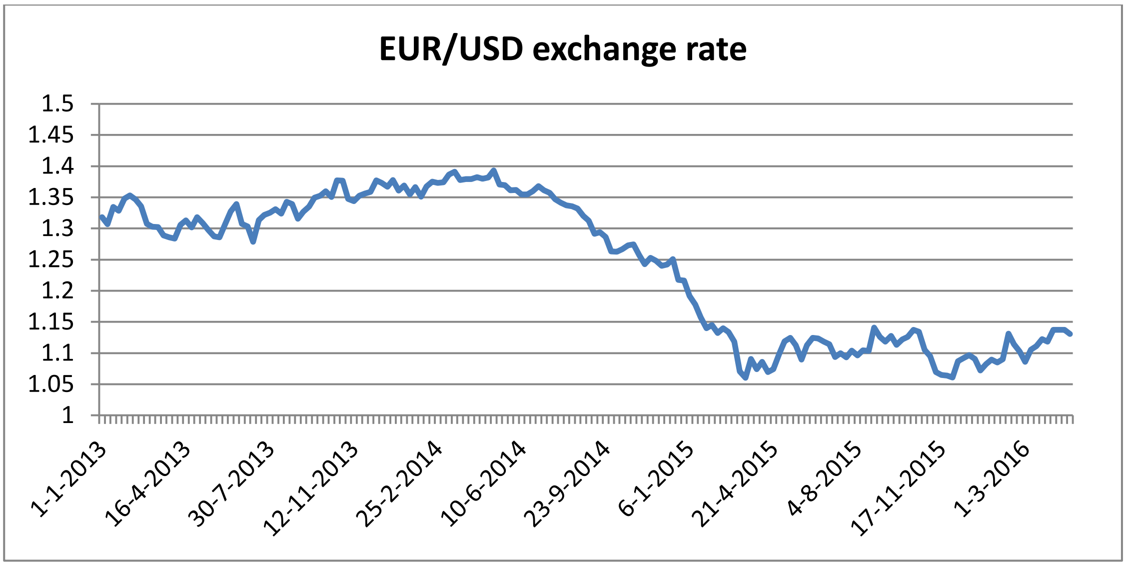

Figure 8: EUR/USD exchange rate
Source: Data retrieved from Datastream

So, according to the literature, it is likely to expect an increase in stock prices if the home currency depreciates. However, we should be cautious since import becomes more expensive. In addition, based on the existing literature, a relationship between stock markets and exchange rates is expected.

2.7 Comovement

There is not one uniform definition of comovement. Therefore the definition that Baur (2004) uses will be used to describe the definition of comovement. Baur (2004 p.4) describes the definition of comovement as follows: ''the definition is based on the notion that co-movement is equal to con-movement (in the same direction). Thus, comovement is common movement which is in line with definitions of terms like co-integrating , co-breaking or co-trending''. Since comovement is in line with the term cointegration, the definition of cointegration will also be explained. Cointegration implies that two time series share similar stochastic trends. The time series are cointegrated if the residuals are stationary. Therefore they never diverge to far from each other (Hill, Griffiths and Lim, 2012 p.488). It often appears that a crash of a stock market index has a strong impact on other stock market indices. This phenomenon is defined as contagion. Forbes and Rigobon (2002 p.2223) describe contagion as follows: ''a significant increase in cross-market linkages after a shock to one country (or a group of countries).'' An example of contagion is the stock market crash of October 1987 in the US. Consequently, major stock market indices around the world were affected by this crash (Forbes and Rigobon, 2002). Another, and more recent example, is the global financial crisis.

It is interesting to investigate whether there exist comovement among stock markets from a portfolio diversification point of view. Equity risk can be reduced through portfolio diversification because portfolio diversification helps investors reduce the non-systematic risk (Goetzmann and Kumar, 2008). This can be achieved by combining assets which are not perfectly correlated. Therefore it is important for investors to know whether there exist comovement among stock markets, since this decreases diversification benefits.

Kasa (1992) found that there was comovement among the US stock market and the German stock market from 1974 until 1990. Horvath and Poldauf (2011) found that the US stock market is strongly correlated with the stock market in Germany from 2000 until 2010. Besser and Yang (2003) found that there exist a long-term relation between the US stock market, German stock market and French stock market. Yang, Min and Li (2003 p.1253) state that many studies show a long-term cointegration relation among major international stock markets. Corhay, Rad and Urbain (1993 p.389) found the evidence of cointegration between stock markets of several European countries over the period 1975 – 1991. In addition, this reveals the existence of some common long-run stochastic trends. Evans and McMillan (2006) found a high correlation between Germany, Belgium, Finland, France, Greece, Italy, Netherlands, Spain, Sweden, Turkey and the UK during the period January 1994 – April 2005.

There is also literature that examined cointegration and causal linkages among the US and European stock markets, and other stock markets e.g. Asian stock markets. Ranpura, Patel & Patel (2011) tested whether the Indian stock market was affected by developed countries. They found that the Indian stock index was affected by the Hang Seng, STI (Singapore), DJIA (Dow Jones), FTSE (London) and DAX. Yang, Kolari and Min (2003) found that the long-run cointegration relationship among the US, Japan and ten Asian stock markets strengthened during the Asian crisis of 1997 – 1998. The US had during this crisis a substantial influence on Asian stock markets. There are many studies that showed cointegration among the US and Eurozone, and the Asian countries. Thus, other literature showed that cointegration and causal linkages does not only exist among the developed countries but also among the US, European, and Asian countries. The core countries of the Eurozone and the US are very influential countries with regard to the economy as a whole and therefore they might influence stock markets among Asia.

Gilmore and McManus (2002) found that US stock markets are not cointegrated with the stock markets in Czech Republic, Hungary and Poland during the period from 1995 until 2001. Kanas (1998) tested whether the US and the six largest European stock markets were cointegrated from January 1986 until November 1996. The result was that the US stock market is not cointegrated with any of the European stock market indices. He concluded that these findings were in contrast to previous evidence on linkages between the US and European stock indices. These findings imply that risk can be reduced through diversification, by investing in the US stock market and the European stock indices (Kanas, 1998 p.607).

To conclude, based on the literature, long-term comovement and/or correlation is expected between stock markets in the US and the core countries of the Eurozone. It is questionable whether there is comovement between US stock markets and the peripheral Eurozone countries, as the peripheral countries were hit severely by the sovereign debt crisis. However, based on the existing literature, comovement is expected between countries within the Eurozone.

3. Data

In this chapter the data of the empirical analysis will be discussed. First, the data of the comovement tests will be discussed, followed by data of the test about the relation between the EUR/USD and stock markets in the US and Eurozone. Weekly data will be used for the empirical analysis of this research. Weekly data will be used to avoid synchronization problems due to the different trading hours between the US stock markets and the Eurozone stock markets. Daily data might contain more noise than weekly data and therefore weekly data is used. The data is retrieved from Thomson Reuters DataStream and will be analyzed with Stata. Data of the US stock market and Eurozone stock markets will be used to run the comovement tests. The data is denominated in local currency to avoid changes in exchange rates. The US stock market is the S&P 500, which is commonly used as the stock market of the US. The S&P 500 represent the 500 largest corporations of the US and contains stocks from many different industries. These 500 corporations will be representing the US stock market. The selected stock markets within the Eurozone are: DAX (Germany), CAC40 (France), AEX (Netherlands), IBEX (Spain) and FTSE MIB (Italy). More information about the chosen stock markets can be found in Appendix VI. These five counties are the major and biggest countries within the Eurozone (except the Netherlands). With the selection of the Eurozone stock indices, the distinction has been made between core countries (Germany, France and the Netherlands) and the peripheral countries (Spain and Italy). This distinctions has been made because the peripheral countries were hit severely by the sovereign debt crisis. The fact that the selected peripheral countries within this research were hit by the sovereign debt crisis is displayed in figure 6. As discussed in the introduction, there will be a distinction between the announcement and the implementation of the QE program of the ECB. Therefore two different time periods will be used, one period which starts as of the announcement and another period which starts as of the implementation. Thus, the two time periods for analyzing whether there exist comovement among stock markets will be: Period as of announcement: January 22nd 2015 – June 1st 2016 and period as of implementation March 9th 2015 – June 1st 2016. The end date, June 1st 2016 is chosen because as of this moment the empirical analysis started.

Data of the US stock market, the Eurozone stock markets and data of the EUR/USD will be used to test the relation between the EUR/USD and stock markets. This test will use the same stock indices which are used for the comovement tests. This analysis has a slightly different approach, as the time period starts at July 1st 2014. This date has been chosen because as of this date the euro depreciated sharply against the US dollar (see figure 8). Therefore it is interesting to test what the relation between the EUR/USD and stock markets is at the time that euro sharply depreciated. The time period of this analysis will be: July 1st 2014 – June 1st 2016. In addition, robustness checks are performed for the same time periods of the comovement tests. Thus, the two time periods of the robustness check are: period as of announcement: January 22nd 2015 – June 1st 2016 and period as of implementation date: March 9th 2015 – June 1st 2016. The results are presented in Appendix V.

4. Methodology

In this chapter the methodology of the empirical analysis will be discussed. Three different methodologies will be used within this thesis. The augmented Dicky-Fuller test and the Johansen cointegration test will be used to test whether the time series is cointegrated. The Granger causality test will be performed to test whether there is a causal relationship between time series.

For performing these empirical analysis, the Akaike Information Criterion (AIC) will be used to determine the maximum numbers of lags that can be used for the analysis. The AIC lag selection is useful when the sample size is small (Liew, 2004).

4.1 Dicky-Fuller test

The augmented Dickey-Fuller test will be used to test whether the time series is stationary or nonstationary. If the time series is nonstationary, the augmented Dickey-Fuller test will be used to test whether the residuals are stationary, and thus whether the time series are cointegrated. More information about the Dickey-Fuller test is explained in appendix I and is also explained in Carter Hill, Griffiths & Lum (2012). It is important to test for stationarity in order to avoid spurious regression. Spurious regression is obtaining apparently significant regression results from unrelated data when you use nonstationary series in a regression. The Dickey-Fuller test is commonly used to test whether the time series is stationary or nonstationary. The augmented Dickey-Fuller test is an extension of the regular Dickey-Fuller test and it allows the possibility of auto correlated error terms. By adding as many lagged first differences as needed, you ensure that the residuals are not auto correlated (Carter Hill, Griffiths, & Lim, 2012 p.485-486). The augmented Dickey-Fuller test which will be performed without a trend and with a constant term.

When the augmented Dickey-Fuller test is performed it results in a τ (*tau*) statistic. Consequently, its value must be compared to specially generated critical values. If the (τ) statistic is larger than the critical value, the null hypothesis (H_0) cannot be rejected, thus the original time series is nonstationary. In contrast, if the (τ) statistic smaller is than the critical value, the null hypothesis is rejected. Consequently, the alternative hypothesis is accepted (H_1) and the original time series is stationary. **More important, in the case of testing the**

residuals, if the null hypothesis cannot be rejected, the residuals are nonstationary, meaning that the time series are not cointegrated. In contrast, if the null hypothesis can be rejected, thus the residuals are stationary, the time series are cointegrated.

Thus, the augmented Dickey-Fuller test will be performed to test whether the time series is cointegrated. "Cointegration implies that y_t and x_t share similar stochastic trends, and, since the difference et is stationary, they never diverge too far from each other" (Carter Hill, Griffiths, & Lim, 2012; p. 488-489).

To conclude, first, the augmented Dickey-Fuller test will be performed to test whether the time series is stationary or nonstationary. Secondly, the residuals will be tested to find out whether the stock indices are cointegrated.

Hypothesis to test stationarity of time series

H_0: (τ) statistic $\geq$ critical value: time series is non-stationary.

H_1: (τ) statistic $<$ critical value: time series is stationary.

Hypothesis to test stationarity of residuals:

H_0: (τ) statistic $\geq$ critical value: residuals are non-stationary. The time series is not cointegrated.

H_1: (τ) statistic $<$ critical value: the residuals are stationary. The time series is cointegrated.

4.2 Johansen test

Besides the Dickey-Fuller test, another cointegration test will be used, the Johansen test. The Johansen test was introduced by Johansen in (1988). The Johansen test is a popular method of testing for cointegration. The Johansen test allows to perform a multivariate analysis, so the Johansen test allows to test more than one cointegrating relationship at a time. Since this thesis will test whether there is comovement between US indices and the selected Eurozone indices and whether there exist comovement within the Eurozone, the Johansen test is an useful test. To use the time series for the Johansen test, it is important that the time series is integrated at order I [1]. This means that the time series is stationary at its first difference. It's expected that stock indices are stationary at I[1] because they do not display characteristics of nonstationary time series. Stationary time series are often described as having the property of mean reversion. Mean reversion assumes that stock prices will move to their average (Carter Hill, Griffiths and Lim, 2012 p.477).

Hjalmarsson & Österholm (2007) are explaining the Johansen test in their paper. Their explanation will be used within this master thesis and for executing the empirical analysis. The methodology of the Johansen test starts with the vector autoregressive (VAR). The VAR model is a general framework to describe the dynamic interrelationship between stationary variables (Carter Hill, Griffiths, & Lim 2012 p. 499).

$$y_t = \mu + A_1 y_{t-1} + \cdots + A_p y_{t-p} + \varepsilon_t \qquad (1)$$

Where y_t is an n×1 vector of variables that are integrated of order one – commonly denoted I(1), and ε_t is an n×1 vector of innovations.

This VAR can be rewritten as:

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \, \Delta y_{t-i} + \varepsilon_t \qquad (2)$$

Where

$$\Pi = \sum_{i=1}^{p} A_i - I \qquad (3)$$

And

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j \qquad (4)$$

If the coefficient matrix $\mathbf{\Pi}$ has reduced rank r < n, than there exist n×r matrices $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ each with rank r such that $\mathbf{\Pi} = \boldsymbol{\alpha}\boldsymbol{\beta}'$ and $\boldsymbol{\beta}'\mathbf{y}_t$ is stationary. r is the number of cointegrating relationships, the elements of $\boldsymbol{\alpha}$ are known as the adjustment parameters in the vector error correction model and each column of $\boldsymbol{\beta}$ is a cointegrating vector. It can be shown that for a given r, the maximum likelihood estimator of $\boldsymbol{\beta}$ defines the combination of y_{t-1} that yields the largest canonical correlation of Δy_t with y_{t-1} after correcting for lagged differences and deterministic variables when present. For the Johansen cointegration test two different likelihood ratios are proposed that test the significance of these canonical correlations and thereby the reduced rank of the $\boldsymbol{\Pi}$ matrix: The trace test and the max statistics test, shown in equation (5) and (6).

$$J_{trace} = -T \sum_{i=r+1}^{n} \ln\left(1\hat{\lambda}_i\right) \quad (5)$$

$$J_{max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (6)$$

T is the sample size and λ_i is *i*:th largest canonical correlation. Using the trace test, you test the null hypothesis of r cointegrating vectors against the alternative hypothesis of n cointegrating vectors. When the null hypothesis can be rejected, there is at least one cointegration relationship. When the trace statistic is higher than the critical value, we reject the null hypothesis, and when the trace statistic is lower we accept the null hypothesis. With the maximum eigenvalue test, the null hypothesis is the same, but the alternative hypothesis not. The alternative hypothesis is r + 1 cointegration vectors. An important limitation of the Johansen test is that it does not show which variables are cointegrated.

Hypothesis

H_0: time series are not cointegrated

H_1: at least one of the time series is cointegrated

4.3 Granger causality test

The Granger causality test is performed to determine whether one time series is useful in forecasting another time series. With regard to this thesis, the Granger causality test is used to determine whether a certain stock market is useful in forecasting another stock market. Or whether a stock market is useful in forecasting an exchange rate. The Granger causality test is developed by Granger (1969) in order to describe the causal relationships between variables in a model.

The Granger causality test is helpful in testing whether y can be explained by its past values and whether adding lagged values of other variables, x, can help in explaining y. Variable y is ´´Granger caused by x´´ if the coefficients of the lagged values are significant. The formula for the Granger causality test is:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + \alpha_2 y_{t-2} + \cdots \alpha_k y_{t-k} + \beta_1 x_{t-1} + \beta_2 x_{t-2} + \cdots \beta_k x_{t-k} + \varepsilon_t \qquad (7)$$

$$x_t = \alpha_0 + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \cdots \alpha_k x_{t-k} + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \cdots \beta_k y_{t-k} + \varepsilon_t \qquad (8)$$

With the Granger causality test, only past values of x can Granger cause y, since future values cannot forecast present or past values. However, if x occurs before y, it does not necessarily mean that x caused y. The Granger causality test only tests on variable y. To conclude, the Granger causality test determines whether variable x supports in forecasting variable y. The Granger causality test is two-sided performed. First, it tested whether the US stock market influence the Eurozone stock markets. Secondly, it is tested whether the Eurozone stock markets influence the US stock market. This is also be done between the DAX and the other Eurozone stock markets. The DAX has been chosen because Germany is the most influential country within the Eurozone. Finally, the Granger causality test is also performed to test whether the stock markets influence the EUR/USD and the other way around. This test is performed for three time periods, time period starting as of the announcement, the time period as of the implementation and the time period as of July 1st 2014.

Hypothesis for testing causality among stock markets in the US and Eurozone

H_0: Lagged S&P 500 does not influence a Eurozone stock market index

H_1: Lagged S&P 500 influences the a Eurozone stock market index

Hypothesis for testing causality among stock markets within the Eurozone

H_0: Lagged DAX does not influence a Eurozone stock market index

H_1: Lagged DAX influences the a Eurozone stock market index

Hypothesis for testing causality among EUR/USD and stock market indices

H_0: Lagged EUR/USD does not influence a selected stock market index

H_1: Lagged EUR/USD influences a selected stock market index

These hypotheses are also tested the other way around. For example, it is also tested whether the selected Eurozone stock markets influence the S&P 500.

5. Empirical results

In this chapter the empirical analysis which are discussed in the previous chapter will be presented and discussed. Paragraph 5.1 will present the most important findings of the augmented Dickey-Fuller test. Paragraph 5.2 will discuss the most important findings of the Johansen test. Finally, in paragraph 5.3 the results of the Granger causality test will be presented and discussed.

5.1 Augmented Dickey-Fuller test

This paragraph will make the distinction between the two time periods of these analysis. First, the results of the time period as of the announcement date will be discussed (January 22nd 2015 – June 1st 2016). Secondly, the results of the time period as of the implementation date will be discussed (March 9th 2015 – June 1st 2016).

5.1.1 Augmented Dickey-Fuller test as of announcement date

The augmented Dickey-Fuller test is used to test whether stock markets are cointegrated. First, the original time series and the first differences are tested. Finally, and most important, the residuals are tested. The analyses of the time period as of the announcement are based on 71 weekly observations. AIC lag selection is used to determine the maximum numbers of lags for the augmented Dickey-Fuller test. The number of lags, which will be used to test whether the time series is stationary or nonstationary, is determined by leaving insignificant lags out. The following critical values which are generated by Stata are used for the augmented Dickey-Fuller test:

Augmented Dickey-Fuller test - Critical values		
1%	**5%**	**10%**
-3.552	-2.914	-2.592

Table 1: Critical values – Augmented Dickey-Fuller test – as of announcement

Original time series & first differences

Table 2, see appendix II, shows the maximum numbers of lags and the numbers of lags that are used for the analysis. After the number of lags is determined, the augmented Dickey-Fuller test is performed to test the original time series. Table 3, shows an overview of the original time series. It can be concluded that all of the original time series are nonstationary.

This was expected since time series are called random walks because they appear to wander slowly upward or downward with no real pattern (Carter Hill, Griffiths and Lim, 2012). Because the time series are nonstationary the mean, variance and covariance will change over time and that will make them unpredictable.

Augmented Dickey-Fuller – Original time series – Announcement date	
	Test-statistic
S&P 500	-2.231 (Nonstationary)
AEX	-2.040 (Nonstationary)
DAX	-1.706 (Nonstationary)
CAC40	-1.993 (Nonstationary)
IBEX	-1.009 (Nonstationary)
FTSE MIB	-0.976 (Nonstationary)

Table 3: Augmented Dickey-Fuller test – original time series

Table 4 and table 5, both in appendix II, show the numbers of lags that are used for testing the first differences and it shows whether the first differences are stationary. All of the first differences are stationary, which was also expected. This means that the time series are integrated at order I [1] and therefore, the time series can be used to perform the Johansen test.

Residuals

To determine whether the time series are cointegrated, the residuals need to be tested on whether they are stationary. If the residuals are stationary, the time series are cointegrated. This test is performed to find out whether there is cointegration between US stock markets and Eurozone stock markets and is also performed to test whether stock markets are cointegrated within the Eurozone. Thus, the following dependent and independent variables were used for testing the residuals:

- Testing for cointegration between US and Eurozone stocks indices: the S&P 500 is used as independent variable and the Eurozone stock indices are used as dependent variable.
- Testing cointegration among Eurozone stock indices: The DAX is used as independent variable and the other Eurozone stock indices are used as dependent variable.

The S&P 500 is chosen as independent variable because the US is one of the most influential economies in the world and the DAX is chosen as independent variable because Germany is seen as the core country within the Eurozone and is considered as the most stable economy within the Eurozone.

If you test the residuals on stationarity, other critical values should be used. The critical values are taken from Carter Hill, Griffiths and Lim (2012) and are presented in table 6.

Augmented Dickey-Fuller test - Critical values for cointegration test		
1%	**5%**	**10%**
-3.96	-3.37	-3.07

Table 6: Critical values for cointegration test – Augmented Dickey-Fuller

First, the cointegration test among the US and Eurozone stock indices will be discussed. Table 7, in appendix II, shows the numbers of lags that are used to test the residuals. Table 8 presents the results of the residuals analysis. All outcomes are nonstationary, which means that the US stock market is not cointegrated with Eurozone stock markets. To conclude, the US stock market and the Eurozone stock markets are not cointegrated in the time period starting as of the announcement of the QE program of the ECB.

Augmented Dickey-Fuller – Residuals – Between US and Eurozone	
	Test-statistic (S&P 500 independent variable)
AEX	-2.347 (Not cointegrated)
DAX	-2.126 (Not cointegrated)
CAC40	-1.897 (Not cointegrated)
IBEX	-0.934 (Not cointegrated)
FTSE MIB	-0.760 (Not cointegrated)

Table 8: Results augmented Dickey-Fuller test – residuals – US and Eurozone

Table 9, see appendix II, shows the numbers of lags that are used to test the residuals of stock markets within the Eurozone. Table 10 presents the results of the residual analysis. The results show that the residuals of the AEX are stationary. This means that the AEX is cointegrated with the DAX at 95% significance level. The residuals of the CAC40, IBEX and the FTSE MIB are nonstationary. Thus, the residuals of the CAC40, IBEX and the FTSE MIB are not cointegrated with the DAX. To conclude, as of the announcement of the QE program of the ECB, the AEX is cointegrated with the DAX at 95% significance level. The CAC40, IBEX and FTSE MIB are not cointegrated with the DAX during this time period.

Augmented Dickey-Fuller – Residuals – Within Eurozone	
	Test-statistic (DAX independent variable)
AEX	-3.451 ** (Cointegrated)
CAC40	-2.934 (Not cointegrated)
IBEX	-2.764 (Not Cointegrated)
FTSE MIB	-0.804 (Not cointegrated)

Table 10: Results augmented Dickey-Fuller test – residuals – Within Eurozone
* Significant at 90%   **Significant at 95%   *** Significant at 99%

5.1.2 Augmented Dickey-Fuller test as of the implementation date

This paragraph contains the same procedures as the previous paragraph (5.2.1). However the time period of the analysis is different. This time period start as of the implementation of the QE program of the ECB instead of the announcement date. The critical values for this Dickey-Fuller test will be different because the critical values depend also on the number of observations. The critical values for the augmented Dickey-Fuller test which are generated by Stata are based on 65 observations and are presented in table 11.

Augmented Dickey-Fuller test - Critical values		
1%	**5%**	**10%**
-3.560	-2.919	-2.594

Table 11: Critical values – Augmented Dickey-Fuller test – as of implementation

Original time series & first differences

Table 12, in appendix III, shows the number of lags of the original time series that are used for the analysis. Table 13 presents an overview of the original time series. Again it can be concluded that the time series are nonstationary. Thus this is in line with the expectation that time series are often nonstationary.

Augmented Dickey-Fuller – Original time series – Implementation date	
	Test-statistic
S&P 500	-2.162 (Nonstationary)
AEX	-1.988 (Nonstationary)
DAX	-1.811 (Nonstationary)
CAC40	-1.790 (Nonstationary)
IBEX	-1.111 (Nonstationary)
FTSE MIB	-0.837 (Nonstationary)

Table 13: Augmented Dickey-Fuller – Original time series

Table 14 and 15, both in appendix III, show the numbers of lags that are used for the first differences and it shows whether the first differences are stationary or nonstationary. Again all first difference are stationary. This means that the time series are integrated at order I [1] and therefore the time series can be used to perform the Johansen test.

Residuals

To determine whether the time series are cointegrated, the residuals are tested on whether they are stationary. If the residuals are stationary, the time series are cointegrated. Again the distinction will be made between the US stock market and the Eurozone stock markets and stock markets within the Eurozone. Thus, this is the same as in the previous paragraph but this paragraph contains data as of the implementation of the QE program of the ECB. The critical values of table 6 will be used for the residuals tests.

Table 16, see appendix III, shows the number of lags that are used for testing the residuals of the S&P 500 and the Eurozone indices. Table 17, shows the outcome of the residual analysis. All stock market residuals are nonstationary, which means that the S&P 500 is not cointegrated with the Eurozone stock markets. The conclusion remains the same compared to the results of the augmented Dickey-Fuller test for the time period as of the announcement, there is no cointegration among the US stock market and the Eurozone stock markets.

Augmented Dickey-Fuller – Residuals – Between US and Eurozone	
	Test statistic (S&P 500 independent variable)
AEX	-1.797 (Not cointegrated)
DAX	-1.142 (Not cointegrated)
CAC40	-0.622 (Not cointegrated)
IBEX	-0.117 (Not cointegrated)
FTSE MIB	0.912 (Not cointegrated)

Table 17: Augmented Dickey-Fuller test – Residuals – US and Eurozone

Table 18, see appendix III, shows the lags that are used for testing the residuals of the Eurozone stock markets. Table 19 presents the results of the of the residual analysis within the Eurozone. It shows that all residuals are nonstationary and thus not cointegrated. To conclude, the Eurozone stock markets are not cointegrated during the time period as of the implementation.

Augmented Dickey-Fuller – Residuals – Within Eurozone	
	Test-statistic (DAX independent variable)
AEX	-2.930 (Not cointegrated)
CAC40	-2.629 (Not cointegrated)
IBEX	-2.001 (Not cointegrated)
FTSE MIB	-0.645 (Not cointegrated)

Table 19: Results augmented Dickey-Fuller test – Residuals – Within Eurozone

5.2 Johansen cointegration test

The Johansen test is also performed for two different time periods. First, the results of the time period as of the announcement date will be discussed (January 22nd 2015 – June 1st 2016). Secondly, the results of the time period as of the implementation date will be discussed (March 9th 2015 – June 1st 2016).

5.2.1 Johansen cointegration test as of announcement date

The Johansen test is the second cointegration test that is performed. This test is a useful cointegration test, as it allows to test all time series together in one test. The Johansen test can only be used if the time series are integrated at order I [1]. In paragraph 5.1.1, the augmented Dickey-Fuller test is performed to test whether the first differences are stationary. Table 5, see appendix II, shows that the first differences are stationary and thus that the time series are integrated at order I [1]. This means that the time series can be used for the Johansen test.

Table 20 and table 21 present the results of the Johansen test regarding the US stock market and the Eurozone stock markets. The Johansen cointegration test is performed with one lag and with a constant term. Table 20 presents the trace statistics, and all trace statistics are smaller than the 5% critical values. Thus, the number of cointegrating equations is 0. Table 21 shows the max statistics, and all max statistics are smaller than the 5% critical values, which means that the number of cointegration equations is 0. This result is similar to the augmented Dickey-Fuller test because both tests showed that there is no cointegration between the US stock market and the Eurozone stock markets as of the announcement of the QE program of the ECB.

Johansen cointegration test - Trace – US and Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Trace statistic**	**5% critical value**
0	.	80.1068	94.15
1	0.31248	53.8799	68.52
2	0.29617	29.2941	47.21
3	0.14906	17.9951	29.68
4	0.11287	9.6116	15.41
5	0.09747	2.4329	3.76

Table 20: Results Johansen test – Trace statistic

Johansen cointegration test - Max – US and Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Max statistic**	**5% critical value**
0	.	26.2270	39.37
1	0.31248	24.5858	33.46
2	0.29617	11.2990	27.07
3	0.14906	8.3835	20.97
4	0.11287	7.1787	14.07
5	0.09747	2.4329	3.76

Table 21: Results Johansen test – Max statistic

Table 22 and 23 present the results of the Johansen cointegration test which is performed for stock markets within the Eurozone. The Johansen cointegration test is performed with one lag and with a constant term. The trace statistic and the max statistic are both smaller than the 5% critical values. Thus, there exist no comovement between stock markets in the Eurozone according to the Johansen test. This result is in contrast with the result of the augmented Dickey-Fuller test. The augmented Dickey-Fuller test showed that the DAX and AEX were cointegrated.

Johansen cointegration test - Trace – Within Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Trace statistic**	**5% critical value**
0	.	63.6794	68.52
1	0.28374	40.3193	47.21
2	0.24658	20.5004	29.68
3	0.14156	9.8154	15.41
4	0.09786	2.6064	3.76

Table 22: Results Johansen test – Trace statistic

Johansen cointegration test - Max – Within Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Max statistic**	**5% critical value**
0	.	23.3602	33.46
1	0.28374	19.8189	27.07
2	0.24658	10.6850	20.97
3	0.14156	7.2090	14.07
4	0.09786	2.6064	3.76

Table 23: Results Johansen test – Max statistic

5.2.2 Johansen cointegration test as of implementation date

The Johansen cointegration test is also performed for the time period as of the implementation of the QE program of the ECB. Table 15, see appendix III, shows that the first differences are stationary and thus integrated at order I [1], therefore the Johansen cointegration test can be performed for this time period. The Johansen test is performed with one lag and with a constant term.

Table 24 and 25 present the results of the Johansen cointegration test regarding the US stock market and Eurozone stock markets. Table 24 shows the trace statistic, and all trace statistics are smaller than the critical values. Table 25 shows the max statistic, and also all max statistics are smaller than the critical values. Thus, the exist no cointegration between US stock markets and the Eurozone stock market as of the implementation of the QE program of the ECB. This result is similar to the result of the augmented Dickey-Fuller test for the time period as of the implementation

Johansen cointegration test - Trace – US and Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Trace statistic**	**5% critical value**
0	.	71.4797	94.15
1	0.33893	44.9901	68.52
2	0.26286	25.4714	47.21
3	0.16408	14.0010	29.68
4	0.11213	6.3897	15.41
5	0.08575	0.6522	3.76

Table 24: Results Johansen test – Trace statistic

Johansen cointegration test - Max – US and Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Max statistic**	**5% critical value**
0	.	26.4896	39.37
1	0.33893	19.5186	33.46
2	0.26286	11.4704	27.07
3	0.16408	7.6113	20.97
4	0.11213	5.7376	14.07
5	0.08575	0.6522	3.76

Table 25: Results Johansen test – Max statistic

Table 26 and 27 present the results of the Johansen cointegration test which is performed for stock markets within the Eurozone. The Johansen cointegration test is performed with one lag and with a constant term. Table 26 shows the trace statistics, and all trace statistics are smaller than the critical values. Table 27 presents the max statistic, and also all max statistics are smaller than the critical values. Thus, there exist no cointegration between stock markets in the Eurozone. This result is similar to the result of the augmented Dickey-Fuller test for the time period as of the implementation date.

Johansen cointegration test - Trace – Within Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Trace statistic**	**5% critical value**
0	.	57.1997	68.52
1	0.30678	33.7493	47.21
2	0.23763	16.3848	29.68
3	0.11699	8.4220	15.41
4	0.09582	1.9757	3.76

Table 26: Results Johansen test – Trace statistic

Johansen cointegration test - Max – Within Eurozone			
Number of cointegrating equations	**Eigenvalue**	**Max statistic**	**5% critical value**
0	.	23.4503	33.46
1	0.30678	17.3645	27.07
2	0.23763	7.9628	20.97
3	0.11699	6.4463	14.07
4	0.09582	1.9757	3.76

Table 27: Results Johansen test – Max statistic

5.3 Granger causality test

The Granger causality test is performed for three different time periods. First, the results of the time period as of the announcement date will be presented (January 22nd 2015 – June 1st 2016). Secondly, the results of the time period as of the implementation date will be discussed (March 9th 2015 – June 1st 2016). Finally, the results of the time period as of July 1st 2014 will be discussed (July 1st 2014 – June 1st 2016).

5.3.1 Granger causality test as of announcement date

Table 28, see appendix IV, presents the lag selection for the Granger causality test for analyzing whether stock markets in the US and Eurozone influenced each other. Table 29 presents the results of the Granger causality test. It shows that the US stock market causes none of the Eurozone stock markets. In addition, the Eurozone stock markets causes none of the US stock market either. Thus, the first column states whether the lagged S&P 500 Granger causes the Eurozone stock markets and the second column states whether a lagged Eurozone stock market Granger causes the S&P 500. Thus, it seems that the US stock market and the Eurozone stock markets are not influenced by each other during the time period as of the announcement.

Granger causality test - US and Eurozone		
	S&P 500 causes …	… causes S&P 500
AEX	No	No
DAX	No	No
CAC40	No	No
IBEX	No	No
FTSE MIB	No	No

Table 29: Granger causality test – US and Eurozone – as of announcement

Table 30, in appendix IV, shows the lag selection for the Granger causality test for analyzing whether stock markets within the Eurozone are causing each other. Table 31 summarizes the results of the Granger causality test and shows two causal relationships. The DAX has influence on the CAC40 and the IBEX has influence on the DAX. It might be expected that the DAX influences the CAC40 since the Germany is seen as the most economically stable country within the Eurozone. It is interesting to see that the IBEX seems to cause the DAX. However, we should remain cautious with interpreting these results, since they are only significant at 90% confidence level.

Granger causality test - Within Eurozone		
	DAX causes …	**… causes DAX**
AEX	No	No
CAC40	Yes *	No
IBEX	No	Yes *
FTSE MIB	No	No

Table 31: Granger causality test – Within Eurozone – as of announcement
* Significant at 90% **Significant at 95% *** Significant at 99%

5.3.2 Granger causality test as of implementation date

Table 32, see appendix IV, shows the lag selection for the Granger causality test for analyzing whether stock markets in the US and Eurozone influenced each after the ECB implemented their QE program. Table 33 summarizes the outcomes of the Granger causality test. It shows that as of the implementation of the QE program of the ECB, the DAX and CAC40 cause the S&P 500. This seems somewhat remarkable because it seems that the implementation has more effect than the announcement. This is different compared with the results of the cointegration tests that are performed in the previous paragraphs. The S&P 500 does not cause any of the selected Eurozone stock markets, which is similar to the outcome of the Granger test as of the announcement date.

Granger causality test - US and Eurozone		
	S&P 500 causes …	… causes S&P 500
AEX	No	No
DAX	No	Yes **
CAC40	No	Yes **
IBEX	No	No
FTSE MIB	No	No

Table 33: Granger causality test – US and Eurozone – as of implementation
* Significant at 90% **Significant at 95% *** Significant at 99%

Table 34, see appendix IV, shows the lag selection for the Granger causality test for analyzing whether stock markets within the Eurozone influenced each other. Table 35 presents the outcomes of the Granger causality test and shows that Eurozone stock markets did not cause each other in the time period as of the implementation of the QE program of the ECB.

Granger causality test - Within Eurozone		
	DAX causes …	**… causes DAX**
AEX	No	No
CAC40	No	No
IBEX	No	No
FTSE MIB	No	No

Table 35: Granger causality test – Within Eurozone – as of announcement
* Significant at 90% **Significant at 95% *** Significant at 99%

It is likely to expect that the country/countries in which QE is implemented, influences other stock markets. Specifically, if there is QE in the US, it is likely to expect that the US stock markets Granger causes Eurozone stock markets. In addition, if there is QE in the Eurozone, it is likely to expect that the Eurozone stock markets Grangers causes the US stock markets.

5.3.3 Granger causality test as of July 1st 2014

Table 36, see appendix IV, presents the lag selection for the Granger causality test for analyzing the relation between the EUR/USD and the selected stock market indices. Table 37 presents the outcomes of the Granger causality test. It shows that all selected stock market indices influence the EUR/USD in the time period, July 1st 2014 – June 1st 2016. Interestingly, the EUR/USD influences the IBEX and FTSE MIB.

Granger causality test – EUR/USD and stock market indices		
	EUR/USD causes …	… causes EUR/USD
AEX	No	Yes ***
DAX	No	Yes ***
CAC40	No	Yes ***
IBEX	Yes ***	Yes **
FTSE MIB	Yes **	Yes ***
S&P 500	No	Yes **

Table 37: Granger causality test – EUR/USD – as of 1 July 2014
* Significant at 90% **Significant at 95% *** Significant at 99%

In appendix V, a robustness check has been performed. The Granger causality test is performed for the same time periods of the cointegration tests. The results of the time period which starts as of the announcement showed that the DAX caused the EUR/USD at 90% confidence level and that the IBEX causes the EUR/USD at 95% confidence level. The results of the time period as of the implementation shows that there does not exist a causal relation between the selected stock markets and the EUR/USD. Thus, the time period as of July 1st 2014 showed that all selected stock markets influenced the EUR/USD and the time period as of the announcement showed a small influence of the selected stock markets on the EUR/USD. Finally, as of the implementation, there is no causal relation between the selected stock markets and EUR/USD.

6. Conclusion

After the start of the global financial crisis, the global economy stagnated, unemployment rates increased heavily, banks needed to be saved and stock prices crashed. Initially, central banks conducted conventional monetary policy in order to counteract the global financial crisis. It turned out that these monetary policies were not sufficient in recovering the economy. Central banks lowered their interest rates near to zero, but were still not able stimulate the economy enough, they were caught in a liquidity trap (Krugman, 1998). Therefore central banks started to implement unconventional monetary policies. Some forms of unconventional monetary policies is called QE. There is no uniform definition of QE, and therefore the following definition of QE is used within this thesis: *Outright purchases of assets that are unusually increase the monetary base and will not be characterized as credit easing*. The Fed was the first central bank who started their unconventional monetary policy as response to the financial crisis and most of their monetary policies were defined as QE. The ECB also started with unconventional monetary policies after the eruption of the financial crisis. However, most of the policies of the ECB were defined as credit easing and thus not QE. This can be explained due to the different financial systems, the US has a market based system and the Eurozone countries have a bank based system. Nevertheless, the ECB announced their QE program in January 2015 to avoid a situation in which the inflation in the Eurozone will drift towards historical lows. The monetary policies of the centrals banks can stimulate the economy through several transmission channels. A low interest rate can lead to a higher present value of stocks because future profits are more valuable which makes stocks more interesting to invest in. A low interest rate can also push investors to other more risky assets like stocks which can lead to an increase in stock prices. If investors become more wealthy through the increase of stock prices, the economy can benefit through an increase of consumption.

Because of the financial crisis, stock prices crashed and centrals banks started to implemented (un)conventional monetary policies to support the economy. All stock markets within this thesis are higher at the moment than before the unconventional monetary policies were implemented, except the Italian stock index, see figure 6 for an overview. This can be explained because of the impact of the sovereign debt crisis. It is likely to state that

QE has a positive effect on stock prices. The EUR/USD exchange rate is important with regard to the import and export of multinational corporations and thus the results of these corporations. A depreciation of the EUR/USD can lead to an increase of exports of Eurozone corporations because the euro becomes cheaper, but import becomes more expensive because of the weaker currency. It is likely to expect that multinational corporations export more than import. Therefore, it can be expected that corporations benefit from a weak home currency. The euro depreciated sharply as of July 2014 and therefore it implies that Eurozone corporations benefited from a weaker euro. Consequently, this can lead to better results which can be translated into higher stock prices.

This research is performed in order to find out whether the US and Eurozone stock indices are cointegrated and also whether stock indices within the Eurozone are cointegrated. In addition, the relationship between the EUR/USD and stock market indices is also tested. The definition of cointegration is in line with comovement and can be defined as moving in the same direction. Specifically, this thesis investigates whether stock indices are moving in the same direction. The cointegration tests are performed for two different time periods. The first time period starts as of the announcement of the QE program of the ECB (January 22nd 2015 – June 1st 2016). The second time period starts as of the implementation of the QE program (March 9th 2015 – June 1st 2016). The end date, June 1st 2016, is the date that the empirical analysis started. These two time periods are chosen in order to investigate whether the announcement has an effect on cointegration between stock markets indices. The cointegration tests are performed with weekly data of the S&P 500, AEX, DAX, CAC40, IBEX and FTSE MIB. The relationship between the EUR/USD and stock market indices is performed for a different time period (July 1st 2014 – June 1st 2016). The starting date of this analysis has been chosen because as of this date the euro depreciated sharply against the US dollar. Therefore it is interesting to investigate what the relation is between stock market indices and the EUR/USD.

The results of the empirical analyses will be discussed for each time period separately. The first period which will be discussed is the period which starts as of the announcement of the QE program of the ECB. First, the augmented Dickey-Fuller test is performed, and showed that the US stock market is not cointegrated with the selected

Eurozone stock markets. However, the augmented Dickey-Fuller test showed that the AEX is cointegrated with the DAX. Secondly, the Johansen test is performed and also showed that the US stock market is not cointegrated with the selected Eurozone stock markets. It also showed that stock markets within the Eurozone are not cointegrated. Also the Granger causality test showed that there was not a causal relationship between the US stock market and the selected Eurozone stock markets. However, the Granger causality test showed that the DAX causes the CAC40 and that the IBEX causes the DAX, both on 90% confidence level. Thus, the empirical test showed that the US stock market is not cointegrated with the Eurozone stock markets and that there is no causal relation. This is not in line with most of the literature, as most of literature showed that the US stock market and Eurozone stock markets, especially the core countries, are cointegrated. However, the findings are in line with Kanas (1998) who found that the US stock market is not cointegrated with any of the European stock markets. The findings regarding cointegration and causality within the Eurozone are partially in line with the literature. There exist cointegration among the DAX and AEX (based on the augmented Dickey-Fuller test) and there is also causality among two stock markets at a 90% confidence level.

The second time period which is analyzed is the time period as of the implementation of the QE program of the ECB. The augmented Dickey-Fuller test showed that the US stock market is not cointegrated with the selected Eurozone stock markets. There also exist no cointegration among Eurozone stock markets. The results of the Johansen test are similar to the results of the augmented Dickey-Fuller test, there is no cointegration among the US stock market and Eurozone stock markets and not among Eurozone stock markets. The Granger causality test showed that the DAX and the CAC40 causes the S&P 500. This test also showed that there exist no causality among Eurozone stock markets. Thus, the stock markets are not cointegrated, which is not in line the most of the literature, as most of the literature showed that the US stock market is cointegrated with Eurozone stock markets. Again, these findings are in line with the findings of Kanas (1998). The DAX and the CAC40 causes the S&P 500, which is the only relation that is found between the US and the Eurozone stock markets. This causality, in the time period as of the implementation, is remarkable because it is likely to expect that the announcement has more effect than the implementation itself.

The third time period of this thesis which is analyzed is, July 1st 2014 – June 1st 2016. In this time period, the relation between the EUR/USD and stock markets is investigated. The results of the Granger causality test show that all stock markets within this thesis causes the EUR/USD. It also shows that the EUR/USD causes the IBEX and FTSE MIB. These findings are in line with the most of the theoretical findings who concluded that exchange rates and stock markets are related. A robustness check has been performed to test the causal relation between the EUR/USD and the selected stock market for the time period as of the announcement and as of the implementation. The period as of the announcement showed a small influence of the selected stock markets on the EUR/USD and the period as of the implementation showed no causal relation.

To conclude on the research question, with regard to comovement, in general, there are not many results who show comovement among the stock market indices within this thesis. There only exist comovement between the DAX and AEX in the time period as of the announcement (only based on the augmented Dickey-Fuller test). The results of the Granger causality test implies that the Eurozone has a small influence on the US. Thus, comovement among stock markets was found in the time period as of the announcement and not in the period as of the implementation. This implies that the announcement of the QE program matter with respect to comovement. Surprisingly, causality was found between the US and Eurozone stock markets as of the implementation of the QE program. To conclude, investors can diversify their portfolios by adding US and Eurozone stocks, as the US and Eurozone stock markets are not cointegrated. By diversifying their portfolio, they can reduce the non-systematic risk. This is in line with the conclusion of Kanas (1998) who implied that risk can be reduced with a diversified portfolio of US and Eurozone stocks. With regard to the EUR/USD and stock markets, all stock markets within this thesis causes the EUR/USD in the time period as of July 1st 2014 and the EUR/USD only causes the IBEX and FTSE MIB. The time period as of the announcement showed a small influence of the selected stock markets on the EUR/USD. Finally, as of the implementation, there is no causal relation between the selected stock markets and EUR/USD.

Recommendations for further research

It is recommended to further investigate the effects of QE on comovement. First, it is important to know the long-term effects of QE on comovement. Secondly, it is important for investors to know whether there exist comovement among stock markets with respect to portfolio diversification. When the QE program of the ECB has ended, the QE program of the ECB can be investigated as a whole on the existence of comovement. If the QE program of the ECB has ended, it can be compared with the QE program of the Fed or other central banks. In addition, it can also be compared with a time period without QE in order to see whether there is a difference between both time periods with respect to comovement. Comovement between Eurozone stock markets and other stock markets, for instance Asian stock markets, can be conducted. The ECB purchases covered bonds, asset backed securities, government bond and corporate bonds, and further research can investigate the influence of QE on these products. The euro depreciated sharply as of July 2014 and depreciated further after the announcement of QE of the ECB, but the euro did not depreciated further as of the implementation of the QE program. Further research can be conducted in order to find out why the euro did not depreciated any further. To conclude so far, there exist almost no comovement among stock markets and it seems that QE program of the ECB does not have a positive effect on stocks. Further research can be conducted to find out why there exist almost no comovement and why QE does not have a positive effect on stocks because many studies showed comovement among the US and Eurozone stock markets. In addition, many studies state that QE is good for stock prices.

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Appendix I

In this appendix the augmented Dicky-Fuller test and cointegration will be explained according to Carter Hill, Griffiths and Lim (2012, p.475-477). They state that ''a time series y_t is stationary if its mean and variance are constant over time and if the covariance between two values from the series depend only on the length of time separating the two values, and not the actual times at which the variables are observed''. If the time series y_t is stationary, it is true that:

$$E(y_t) = \mu \quad \text{(constant mean)}$$

$$\text{var}(y_t) = \sigma^2 \quad \text{(constant variance)}$$

$$\text{cov}(y_t, y_{t+s}) = \text{cov}(y_t, y_{t-s}) = \gamma_s \quad \text{(covariance depends on } s\text{, not } t\text{)}$$

There are three different versions of the Dickey-Fuller test (Carter Hill, Griffiths and Lim 2012, p.486-487):

- If the series appears to be wandering or fluctuating around a sample average of zero, use the Dickey-Fuller test with no constant and no trend.
- If the series appears to be wandering or fluctuating around a sample average which is non-zero, use the Dickey-Fuller test with constant and no trend.
- If the series appears to be wandering or fluctuating around a linear trend, use the Dickey-Fuller test with constant and with trend.

Cointegration

A general rule is not to use nonstationary time series in order to avoid spurious regression. However, there is an exception to this rule. It is expected that if the time series is nonstationary that their difference or any linear combination of them, such as e_t to be nonstationary as well. But, if the difference of e_t is stationary, than are y_t and x_t are said to be cointegrated (Carter Hill, Griffiths and Lim 2012, p.488)

Appendix II

Augmented Dickey-Fuller test as of the announcement date

Original time series

AIC lag selection - Original time series		
	Maximum numbers of lags	**Number of lags used**
S&P 500	max lags: 1	lags used: 0
AEX	max lags: 1	lags used: 0
DAX	max lags: 1	lags used: 0
CAC40	max lags: 1	lags used: 0
IBEX	max lags: 1	lags used: 0
FTSE MIB	max lags: 1	lags used: 0

Table 2: AIC lag selection – original time series – as of announcement

First differences

AIC lag selection - First differences		
	Maximum numbers of lags	**Number of lags used**
S&P 500	max lags: 0	lags used: 0
AEX	max lags: 0	lags used: 0
DAX	max lags: 0	lags used: 0
CAC40	max lags: 0	lags used: 0
IBEX	max lags: 0	lags used: 0
FTSE MIB	max lags: 1	lags used: 0

Table 4: AIC lag selection – first differences – as of announcement

Augmented Dickey-Fuller - First differences	
	Test statistic
S&P 500	-8.465 *** (Stationary)
AEX	-8.894 *** (Stationary)
DAX	-8.622 *** (Stationary)
CAC40	-9.202 *** (Stationary)
IBEX	-9.013 *** (Stationary)
FTSE MIB	-9.823 *** (Stationary)

Table 5: Augmented Dickey-Fuller test – first differences – as of announcement
* Significant at 90% **Significant at 95% *** Significant at 99%

Residuals

AIC lag selection - Residuals – Between US and Eurozone (S&P 500 as independent variable)		
	Maximum numbers of lags	**Number of lags used**
AEX	max lags: 1	lags used: 0
DAX	max lags: 1	lags used: 0
CAC40	max lags: 2	lags used: 0
IBEX	max lags: 2	lags used: 0
FTSE MIB	max lags: 2	lags used: 0

Table 7: AIC lag selection – residuals – Between US and Eurozone

AIC lag selection - Residuals - Within Eurozone (DAX as independent variable)		
	Maximum numbers of lags	**Number of lags used**
AEX	max lags: 1	lags used: 0
CAC40	max lags: 1	lags used: 0
IBEX	max lags: 1	lags used: 0
FTSE MIB	max lags: 1	lags used: 0

Table 9: AIC lag selection – residuals – Within Eurozone

Appendix III

Augmented Dickey-Fuller test as of the implementation date

Original time series

AIC lag selection - Original time series		
	Maximum numbers of lags	**Number of lags used**
S&P 500	max lags: 1	lags used: 0
AEX	max lags: 1	lags used: 0
DAX	max lags: 1	lags used: 0
CAC40	max lags: 1	lags used: 0
IBEX	max lags: 1	lags used: 0
FTSE MIB	max lags: 1	lags used: 0

Table 12: AIC lag selection – original time series – as of announcement

First differences

AIC lag selection - First differences		
	Maximum numbers of lags	**Number of lags used**
S&P 500	max lags: 0	lags used: 0
AEX	max lags: 2	lags used: 2 **
DAX	max lags: 0	lags used: 0
CAC40	max lags: 0	lags used: 0
IBEX	max lags: 0	lags used: 0
FTSE MIB	max lags: 0	lags used: 0

Table 14: AIC lag selection – first differences – as of implementation

* Significant at 90%   **Significant at 95%   *** Significant at 99%

Augmented Dickey-Fuller - First differences	
	Test statistic
S&P 500	-9.012 *** (Stationary)
AEX	-5.665 *** (Stationary)
DAX	-8.518 *** (Stationary)
CAC40	-7.902 *** (Stationary)
IBEX	-7.824 *** (Stationary)
FTSE MIB	-8.039 *** (Stationary)

Table 15: Augmented Dickey-Fuller test – first differences – as of implementation

* Significant at 90%   **Significant at 95%   *** Significant at 99%

Residuals

AIC lag selection - Residuals – Between US and Eurozone (S&P 500 as independent variable)		
	Maximum numbers of lags	Number of lags used
AEX	max lags: 2	lags used: 0
DAX	max lags: 2	lags used: 2 **
CAC40	max lags: 2	lags used: 1 **
IBEX	max lags: 2	lags used: 2 **
FTSE MIB	max lags: 2	lags used: 1 **

Table 16: AIC lag selection – residuals – Between US and Eurozone
* Significant at 90%   **Significant at 95%   *** Significant at 99%

AIC lag selection - Residuals - Within Eurozone (DAX as independent variable)		
	Maximum numbers of lags	Number of lags used
AEX	max lags: 1	lags used: 0
CAC40	max lags: 1	lags used: 0
IBEX	max lags: 1	lags used: 0
FTSE MIB	max lags: 1	lags used: 0

Table 18 : AIC lag selection – residuals – Within Eurozone

Appendix IV

Granger causality test as of announcement date

AIC lag selection - Granger causality test – US and Eurozone	
	Number of lags
AEX	Lags: 1
DAX	Lags: 1
CAC40	Lags: 1
IBEX	Lags: 1
FTSE MIB	Lags: 1

Table 28 : AIC lag selection – Granger causality test – US and Eurozone

AIC lag selection - Granger causality test – Within Eurozone	
	Number of lags
AEX	Lags: 1
CAC40	Lags: 1
IBEX	Lags: 1
FTSE MIB	Lags: 1

Table 30 : AIC lag selection – Granger causality test – Within Eurozone

Granger causality test as of implementation date

AIC lag selection - Granger causality test – US and Eurozone	
	Number of lags
AEX	Lags: 1
DAX	Lags: 2
CAC40	Lags: 2
IBEX	Lags: 1
FTSE MIB	Lags: 1

Table 32 : AIC lag selection – Granger causality test – US and Eurozone

AIC lag selection - Granger causality test – Within Eurozone	
	Number of lags
AEX	Lags: 1
CAC40	Lags: 1
IBEX	Lags: 1
FTSE MIB	Lags: 1

Table 34 : AIC lag selection – Granger causality test – Within Eurozone

Granger causality test as of 1 July 2014 (EUR/USD and stock market indices)

AIC lag selection - Granger causality test – EUR/USD stock market indices	
	Number of lags
AEX	Lags: 2
DAX	Lags: 4
CAC40	Lags: 2
IBEX	Lags: 4
FTSE MIB	Lags: 4
S&P 500	Lags: 1

Table 36 : AIC lag selection – Granger causality test – EUR/USD and stock market indices

Appendix V

The euro depreciated heavily as of approximately July 1st 2014 and therefore the relation between the EUR/USD and the selected stock markets is tested. It is also interesting to investigate the relation between the EUR/USD and the selected stock markets in the time period as of the announcement and as of the implementation. These results show whether the announcement of QE and the implementation of QE influences to relation between the EUR/USD and stock markets. Thus, to test the results of the same time periods which are used for the cointegration tests, a robustness check is performed for these two time periods.

Table 38 presents the lags that are used for the Granger causality test for the **time period as of the announcement**. Table 39 presents the results of the Granger causality test and shows that the EUR/USD does not cause one of the selected stock markets. In addition, only the DAX and IBEX cause the EUR/USD.

AIC lag selection - Granger causality test – EUR/USD stock market indices	
	Number of lags
AEX	Lags: 2
DAX	Lags: 1
CAC40	Lags: 2
IBEX	Lags: 1
FTSE MIB	Lags: 2
S&P 500	Lags: 1

Table 38: Granger causality test – EUR/USD – as of announcement date

Granger causality test – EUR/USD and stock market indices		
	EUR/USD causes …	… causes EUR/USD
AEX	No	No
DAX	No	Yes *
CAC40	No	No
IBEX	No	Yes **
FTSE MIB	No	No
S&P 500	No	No

Table 39: Granger causality test – EUR/USD – as of announcement date

* Significant at 90% **Significant at 95% *** Significant at 99%

Table 40 shows the lags that are used of the Granger causality test for the **time period as of the implementation**. Table 41 presents the results of the Granger causality test and shows that there does not exist a relation between the EUR/USD and the selected stock markets.

AIC lag selection - Granger causality test – EUR/USD stock market indices	
	Number of lags
AEX	Lags: 1
DAX	Lags: 1
CAC40	Lags: 1
IBEX	Lags: 1
FTSE MIB	Lags: 1
S&P 500	Lags: 1

Table 40: Granger causality test – EUR/USD – as of implementation date

Granger causality test – EUR/USD and stock market indices		
	EUR/USD causes …	… causes EUR/USD
AEX	No	No
DAX	No	No
CAC40	No	No
IBEX	No	No
FTSE MIB	No	No
S&P 500	No	No

Table 41: Granger causality test – EUR/USD – as of implementation date
* Significant at 90% **Significant at 95% *** Significant at 99%

Comparing these results with the results of the time period starting at July 1st 2014, there are less relations between the EUR/USD and stock markets. The time period as of July 1st 2014 showed that all stock markets cause the EUR/USD, the time period as of the announcement shows only two relations and the time period as of implementation shows no causality at all between the EUR/USD and stock markets. The time period as of July 1st 2014 showed that the EUR/USD causes two stock markets, but for the time period as of the announcement and the implementation, the EUR/USD does not cause any stock market. To conclude, the robustness check shows significant differences among the relation between the EUR/USD and the stock markets, compared with the initial results. It might be suggested that investors expected an intervention of the ECB and an increase of the interest rate of the Fed. This can be a reason for investors to sell euro's and to purchase US dollars because it is likely to expect that QE has a decreasing effect on the value of the euro and that the increase of the interest rate of the Fed has an increasing effect on the value of the US dollar.

Appendix VI

S&P 500 (United States): The S&P 500 is a capitalization-weighted index of 500 stocks. It measures the performance of the broad US economy through changes in the aggregate value of the 500 stock, which represent all major industries (Bloomberg, 2016).

AEX (Netherlands): The AEX is a free-float adjusted market capitalization weighted index of the 25 leading Dutch stocks (Bloomberg, 2016).

DAX (Germany): The DAX is the German total return index of 30 selected blue chip stocks. The stocks use free float shares in the index calculation (Bloomberg, 2016).

CAC40 (France): The CAC40 is the most widely-used indication of the Paris markets, which reflects the performance of the 40 largest stocks listed in France. They are measured by free-float market-capitalization and liquidity (Bloomberg, 2016).

IBEX (Spain): The IBEX is the official index of the Spanish Continuous Market. The index is comprised of the 35 most liquid stocks traded. The stocks use free float shares in the index calculations (Bloomberg, 2016).

FTSE MIB (Italy): The FTSE MIB consist of the 40 most liquid and capitalized stocks. In the FTSE MIB foreign stocks are eligible for inclusion (Bloomberg, 2016).