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The correlation between bond market and stock market returns in Europe using a DCC GARCH

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Abstract

This master thesis aims to understand the time varying relationship between bond market and stock market returns. By using the Stoxx Euro 600 as a benchmark for the European stock situation and the Bloomberg Barclays EuroAgg Total Return Index Value Unhedged as a benchmark for European obligations, we will analyse how the correlation varies over time using a DCC GARCH. In a second step, we will examine what macroeconomic factors have impacted the relationship and what economic variables have a significant effect on the predictive model. The analysis is conducted over a period of 17 years, namely from 1998 to 2015, and we have used weekly log-returns for both indices. Understanding what drives correlation is crucial for different domains in finance, such as risk management, portfolio management and corporate finance.

Our choice for this subject is based on a personal interest. Given our academic career, starting with a bachelor in economics and management and pursuing a strongly in finance emphasized master's degree in financial management in coordination between LSM and ICHEC, we are aware of the importance of correlation in different financial domains. Our choice for Europe as the market of reference is straightforward simply because we want to become members of the financial industry within Europe.

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Chapter 1: Introduction

General problem

The problems analyzed during our research are linked to the dynamic correlation between bond and stock market returns in Europe. The objective is to give a detailed analysis of the evolution of correlation between bond market and stock market returns in Europe and to highlight factors that have an impact on the co-movements.

In order to achieve our main objective, we will use a Dynamic Conditional Correlation Generalized Autoregressive Conditional Heteroscedasticity (DCC GARCH) model, initially implemented by Engle (1999), in order to capture correlation between two series that would not be captured by a simple ARCH or its generalized (GARCH) version, which are only interested in a univariate volatility and not the interaction between two variables. More details regarding the different advantages and characteristics related to the DCC GARCH will be discussed later in the methodology section.

We can reformulate our main research objective as follows:

How the correlation between bond market returns and stock market returns has evolved in Europe since the implementation of the Euro zone?

As it is, this formulation needs a limitation. We will limit our analysis to a timeline consisting of 15 to 20 years of data until the end of 2015. The correlation estimations will be based on two representative indices, namely the Stoxx Europe 600 for equity and the Bloomberg Barclay's Euro Aggregate Total return bond index for bond data. Our motivation for this choice will be discussed later.

Furthermore, we will analyse the impact of structural changes and crises on the correlation. More precisely, we will take a closer look at the correlation during the creation of the European Monetary Union (EMU), during the DotCom bubble burst, and during the 2008 crisis and the sovereign debt crisis. An analysis of these sub questions will mainly be done using a graphical analysis, as in our opinion, this gives a good global view of the evolution and suits our less econometrical background.

We hope to find out that big changes in correlation will be linked to global and/or European shocks, be it political or economical. This sub question allows us to follow a consistent path during the research. This sub section can be stated as follows:

The impact of crises and structural changes on the correlation between bonds and stocks in Europe.

During the last process, we will regress our estimated correlations on a set of (hopefully) significant factors in order to, firstly, understand what factors really have an impact, be it positive or negative, on the correlation between bond market and stock market returns, and secondly, compute a model that will allow us to predict as precise as possible the future correlation. To obtain significant factors, we will regress a certain number of variables, motivated by the choice included in the papers analyzed during our literature review. We then seek to obtain a precise forecasting model including the most appropriate regressors.

This regression can be summed up in the following two sub-sections:

(i) Factors that impact the correlation between European bonds and stocks
(ii) Forecasting model to predict correlation between bond market returns and stock market returns in Europe.

Following this procedure, we will get a deeper understanding of how correlation evolved in Europe and what factors are necessary to keep in mind when considering comovements between bonds and stocks.

Eventually, we will sum up our results and conclude how correlation between bonds and stocks has evolved over the last 17 years in Europe and which crises and structural changes had an impact on the above-mentioned correlation. In addition to that, we will take a critical step and explain the different problems we have encountered during our research. As another part of the conclusion, we will go various paths for future researches that could be interesting on an academical level.

Context

Correlation, a standardized measure of co-movements between two variables, is not static (Andersson, Krylova, & Vähämaa, 2008): It would be misleading to consider a constant degree of co-movements between bonds and stocks over the last 15 to 20 years. The interest in this measure is thus due to its dynamic nature. The correlation between two variables depends on i) their covariance and ii) their volatility. This dynamic character of the measure is also the reason why it has been subject to many studies over the last decades. Researchers tried to develop the most appropriate model to capture most of the volatility characteristics, such as long-memory and heteroscedasticity. As a deep analysis of co-movements cannot be done by a simple econometric model, there is, in a first attempt, a need to qualify the different existing models and to rank their usefulness in order to estimate correlation.

Volatility, and thus correlation, of stocks and bonds plays a crucial role in the world of economics and management in different domains, such as in the asset allocation process of securities (Markowitz, 1952; Sharpe, 1964). The importance of volatility and correlation also finds its usefulness in risk management (Connolly, Stivers, & Sun, 2005) and the emphasis of such measures became even more central due to the implementation of the Basle Accord in 1996 (Poon & Granger, 2003).

In the US market, a constant low correlation could have been observed over the long run, with only a few sustained periods of negative correlation (Connolly et al., 2005). In addition, there is proof of a positive correlation in the US and in Australia since 1990 given the higher frequency of shocks (Rankin & Idil, 2014). This is an aspect which we are going to analyze in more detail in later sections in order to know if such a phenomenon is also observable in Europe. It is most often observable that there is a low positive correlation and that the measure is increasing during bear markets (Campbell, Koedijk, & Kofman, 2002; Chiang, Li, & Yang, 2015), but more about relating literature and its outcomes will be discussed in chapter 2, which is dedicated to the literature review.

After having seen that, as mentioned above, the correlation can often be slightly positive and even more in times of crisis or structural changes, there is also an explanation for the opposite co-movements, represented by a negative correlation, namely a phenomenon called “flight-to-quality” or “flight-to-safety” (Baele, et al., 2013; Chen, 2009)

“*When investors are scared, they look for safety. They adjust their portfolios to include more safe assets and fewer risky assets.... This kind of movement is usually referred to as a "flight to quality." Government bond prices go up, stock prices fall*.” Chicago Federal Reserve Bank News Letter, # 4, December 1987 (as cited in Barsky, 1989, p. 1132).

The flight-to-safety characteristic shows us that it is important, when analyzing correlation between the two chosen asset classes, to not forget the consumer confidence that plays an important role in the dynamic of correlation. This is linked to the fact that, in the end, it is the consumer who buys or sells securities, such as stocks or bonds in accordance with his personal beliefs of risk-return projections.

As our research is limited to the European market, we need to know which context we find ourselves in. Given the fact that most of the literature focuses on the United States, or the correlation between different countries and the possible contagion, the European case is poorly documented.

Motivation

First, correlation plays a crucial role in the managerial domain and at different levels of hierarchy (Nasar, 1992). Having a grounded understanding of the correlation between bonds and stocks in Europe allows the portfolio manager to implement an effective asset selection and allocation more easily, be it for the firm's own account or for the interest of its clients. In terms of risk management, the senior risk manager or chief risk officer is often concerned with different risk measures that also consider correlation to implement effective hedging strategies. As chief financial officer (CFO), you are concerned about correlation and co-movements among assets classes, such as stocks and bonds because it has an impact on the overall financial strategy of the firm.

Moreover, from a scientific point of view, our research will close the current gap of literature regarding correlation. There is much evidence of different correlation observations and characteristics outside Europe. Given the young age of the European Union and its related structural change, there is little contribution to the literature regarding correlation between bond market and stock market returns within Europe. In addition to that, a lack of data has always been a problem regarding a long-term analysis for Europe, but nowadays we find ourselves in an environment (nearly 20 years after the creation of the EMU) that offers a considerable amount of data. One last thing to consider is the dynamic environment that we capture in our analysis, namely the monetary changes in European countries, as well as important crises that change the situation of Europe.

Finally, our research is motivated by a social aspect of the bond-stock intra-European correlation given the fact that we analyze the correlation over several years in order to explain the factors that impact the co-movements and to generate a forecasting model. This will allow people to effectively allocate their assets and to hedge their positions which will lower any risks and potential losses.

Outline

As to the outline of our master thesis, we will start with a literature review collecting the, in our opinion, most important lecture over the last decades to fix the theoretical framework of our master thesis and to be aware of the gap in existing research papers. We recognized though, and as already mentioned above, that there is a clear research gap and this not related to correlation, but related to correlation inside Europe after the EMU creation. This collection of articles will be discussed in chapter 2.

Chapter 3 will serve as an explanatory basis in order to understand the model used during our research better. The focus of the chapter will lie on theoretical explanations adapted to the knowledge of a manager and not a sophisticated statistician or econometrician, as this is not the focus of our paper. The methodology will be based on the explanations of Orskaug (2009) as this paper helped us to better understand the mechanism behind a DCC GARCH and its practical usefulness.

Chapter 4 will focus on the results of our research. The results are obtained by estimating the correlation over the last 17 years between the EuroStoxx600, including 600 small-, mid- and big cap stocks inside Europe, and the Bloomberg Barclay's Euro Aggregate Total return bond index, using a DCC GARCH as explained by Engle (1999). Both indices have been selected thanks to their long historical data available and thanks to its panoply of bonds and stock from different regions and economic backgrounds.

Following the estimation of the correlation, we observe the output in order to recognize significant changes in the measure that we will link to real-world particularities to explain the changes. So be it, for example, that we can observe an increase in correlation during the creation of the EMU and during the 2008 and the sovereign debt crisis.

After having analyzed the correlation structure, we will compute a model that will serve two objectives. In the first place, this model will allow us to evaluate the significance of the different macroeconomic factors. Factors that will be tested include, for example, the implemented monetary policy in form of interest rates, the inflation across Europe, but also the fact that the EMU has already been in place (via a dummy variable). Secondly, the OLS regression will allow us to create a forecasting model including the most appropriate variables.

After having presented our results, we will conduct a discussion about possible interpretations of our results and possible recommendations that could lead to different outcomes in chapter 5. This chapter, compared to the previous chapter, will be based on a more subjective interpretation and also on our own perceptions.

Finally, the last part of our paper consists of our conclusions in which we will sum up our analysis and the different implications of our results. In order to maintain critical thinking, we will consider possible limitations of our paper and suggest possible future paths to go further in our analysis.

Chapter 2: Literature review

In this chapter, we will do a review of existing literature in accordance with our subject. Starting with a more general approach regarding related articles on a broader basis, we will get into more detailed subjects that will be useful for our research.

Firstly, we will start with volatility and co-movements of different asset classes in order to pursue the path in a second place with correlation in general. Afterwards, we will discuss literature regarding different ARCH and GARCH models, and the DCC GARCH in particular, as these econometric models, as well as its added value, in comparison to the other models, plays a crucial role in our master thesis. This section is also very important given the fact that we need to be aware of the different advantages and disadvantages of the several existing models.

As already mentioned, we will continue, after the more general review, with the discussion of more specific subjects such as flight-to-quality, herd behavior, EMU creation and sovereign debt crisis. Eventually, we have collected and analyzed articles regarding macroeconomic determinants of correlation which will be useful for our regression and forecasting.

Last but not least, we would like to highlight our motivation and the added value of our research again. One of the reasons why we analyze the European markets is that the scientific papers on this subject are generally more focused on the US markets. Even tough, there are several papers on the European markets in our literature review, the majority of the scientific researches cover the US markets. We think that our approach and our methods used to approach this to the subject can add value to the scientific researches that already exist on this subject.

Volatility and (G)ARCH models

As forecasting volatility is not always as straightforward as the understanding of the expression of volatility, namely the standard deviation of an asset, we started our literature review with an article explaining possible issues in forecasting volatility. As the name of their article suggests, Poon and Granger (2005) provide an overview of potential issues that can be encountered in their article.

By comparing 93 different studies in their paper, they get to the conclusion that it is difficult to rank among the different methodologies, but that there are different characteristics that need to be covered, which is achieved by using a GARCH based model. Even if GARCH only ends up on a second place in the ranking, the authors mention nonetheless that studies are based on different asset classes and that there is always a trade-off between the cost and the benefits of implementing a more accurate model.

Besides, Poon and Granger (2005) draw the lecturer´s attention to different characteristics of volatility, such as that the returns in financial markets show high autocorrelation, which is commonly known as “long memory”, a volatility asymmetry and shifts in volatility over time. In a final remark, the article suggests using high frequency data such as daily computation.

As has already been suggested (Poon & Granger, 2005), both authors have already found similar results in an early study (Poon & Granger, 2003) which concludes that GARCH based models seem to be the most appropriate to forecast volatility in times series. Both papers use a similar approach as the second article is an updated version of their research published in 2003. This gives us a consistent analysis providing similar findings.

Poon and Granger (2003) also explain that there is proof of statistical characteristics, such as the commonly called “fat tails”, kurtosis and volatility clustering in time series. A fact that has also been found by Mandelbrot (1963) and Fama (1965) regarding temporal dependencies between returns. As concluded by Andersen and Bollerslev (1998), ARCH models as originally explained by Engle (1982) and its generalized version the GARCH models (Bollerslev, 1986) do provide appropriate volatility forecasts. Poon and Granger also introduce findings from more recent research, namely that volatility tends to increase during bear markets and crises.

Correlation and DCC GARCH

Given the importance of correlation in our master thesis, this section is dedicated to this statistical concept and how to measure it accordingly. It will include articles about correlation among different asset classes and different (stress) periods and about models (mainly DCC GARCH) how the correlation can be estimated.

Nowadays, there is no doubt that correlation is dynamic over time. As evidenced by Rankin and Idil (2014), there is positive correlation since the 1990s in the US and this is mainly due to crises. Mighri and Mansouri (2013), Hartmann, Straetmans and De Vries (2004) and Campbell (2002) also found proof that a higher correlation can be observed during periods of crisis. Regarding this, our interest will be to observe whether there is a similar behavior in the European market or not.

It is argued that factors such as implemented policies, interest rates and uncertainty can be at the root of this phenomenon. Yang, Zhou and Wang (2009) provide in their research evidence from one and a half centuries regarding correlation and its possible factors in the US and UK. The authors included factors, such as business-cycles, inflation and monetary policy in their analysis, which we will (partly) include in our own research in order to observe if we have the same common factors in Europe that have an impact on correlation. These findings, as already mentioned above, are supported by Rankin and Idil in 2014. Regarding the diversification motivation of co-movements, the paper concludes that the US may be more efficiently diversified, given the fact that there is evidence for a lower correlation in times of recession compared to the correlation during expansions.

Chen (2009) supports Yang, Zhou and Wang's (2009) previous findings about different states of correlation and reformulates that the correlation of stocks and bonds, is that if the volatility in the stock markets increases (low volatility state to high volatility state) results in a reduction of the correlation (high correlation state to low correlation state) whereas an increase in bond volatility (low volatility state to high volatility state) will result in an increase of the stock bond correlations (low correlation state to high correlation state). This is mainly due to shocks in the bond price which are mainly related to shocks to the discount factor but this moves both, stock and bond prices, in the same direction whereas a shock in stock prices are mainly related to uncertainties regarding the cash flows, which has an enormous effect on bond prices but in the opposite direction.

To conclude, the stock prices are dominated by the “cash flow effect”, which can be mainly observed during recessions, whereas bond prices are mainly affected by a change in the discount rate, which can be observed during expansions. Thus, they normally observe a positive stock bond correlation during expansion and a negative correlation during recessions.

By using a DCC GARCH, Yang, Zhou and Leung (2012) try to explain the “asymmetric correlation and volatility dynamics among stock, bond and securitized real estate markets” as the title of their paper suggests. Their analysis focuses on the US market and includes the so-called REITs (Real Estate Investment Trust), but stops before the financial crisis of 2008.

Using a similar approach, by using a DCC GARCH, Mighri and Mansouri (2013) take over the relay and analyze correlation linked to data from the financial crisis between 2007 and 2010. Mighri and Mansouri used data about daily indices from the different countries in question. The outcome of various statistics supports earlier mentioned studies. There is evidence of skewness for all the indices used as well as a non-normality characteristic obtained through a Bera-Jarque test. The main points of their research can be summed up in two questions, which are applicable to our own research, namely:

i) *“Does the correlation between financial asset returns vary over time?”*

ii) *“Does this correlation increase during financial crises periods?”*

(Mighri & Mansouri, 2013)

Even if their analysis includes a cross-border point of view, between different countries in the world, their approach is similar to the one we are going to use during our own research and highlights the advantages of the DCC Garch Model. By using daily returns of the major stock indices of countries across the globe, the authors conclude that there is, in fact as already evidenced (Rankin & Idil, 2014), higher correlation during crises between US and European stock markets. Our focus will be more on correlation inside Europe between the bond market and stock market return, but the approach used by Mighri and Mansouri (2013) clearly illustrates an applicable path to follow.

This conclusion has already been supported in an earlier period (Solnik, Boucrelle, & Le Fur, 1996). There is proof of a volatility contagion across asset classes in the world and international correlation increases in periods of high market volatility. This paper examines correlations of different country securities with the US market and that correlation is anything but static.

The trend of the correlation for the US and European countries, such as Germany, France, Switzerland and the UK, finishes well above a correlation of 0.3, which is positive and thus supports later results.

In addition, the authors recognize a clear relationship between volatility and correlation. Similar results have already been evidenced, including commodity indices using a copula based approach (Lopez & Delatte, 2013).

Still in the context of the impact of market crises on the correlation, Hartmann, Straetmans and De Vries (2004) examined the links between government bonds and stock market returns during crises for the G5 countries. They conclude that the effect of spillovers from one G5 country to another are very high.

Even if the authors do not use dynamic models or multivariate models, such as the DCC GARCH, their results are in line with previous findings. A similar study (d'Addona & Kind, 2006) regarding the post-war G7 countries, starting in the 1980s until early 2000s, also states that in these countries, correlation has been often positive over time.

By explaining the increased correlation in declining markets, Campbell (2002) supports the general evidence that there is an increased correlation, which, against common assumption, is often positive. Campbell also concludes that models need to be implemented in a way that they can capture the dynamics of correlation. Furthermore, the author emphasizes the impact of correlation on the efficient frontier (Markowitz, 1952) when considering unconditional correlation or the more appropriate conditional correlation, which leads to a different risk-return outcome. The author uses data regarding bond and stock prices over nine years and by capturing 2500 observations. The data provides a first insight into distribution characteristics and is supported by more recent papers (Poon & Granger, 2005). It suggests that the indices analyzed (except for the FTSE100) show negative skewness and what has been called by Poon and Granger "fat tails", namely an excess kurtosis.

There is support for previous findings (Scruggs & Glabadanidis, 2003). Firstly, there is evidence that correlation is dynamic and time-varying, and that this variation can range from negative to positive correlation over the last 50 years. Similar conclusions were drawn by Rankin (2014) in a similar study 15 years later.

Regarding two further conclusions which have been backed by Chen (2009) in a later attempt is the fact that bond market variances increase with bond market return shocks, but are independent from stock market return shocks. On the contrary, stock market returns are not unaffected by bond market returns and its variance moves in relation with both, the bond- and the stock market return shocks.

Risk plays an important role in the stock-bond correlation environment, as will be discussed further. Phenomena such as flight-to-safety and risk-aversion will have a big impact on the co-movements of assets classes in times of market uncertainty.

As evidenced by Baele, Bekaert and Inghelbrecht (2010) and supported by Chiang et al. (2015), that the co-movements between the bond market returns and the stock market returns are mainly due to common macroeconomic factors. Baele further adds that risk aversion and market liquidity are important variables that need to be considered when analyzing correlation. The authors concluded that models which include an uncertainty or risk aversion variable outperform models that do not include them. Furthermore, ignoring a liquidity factors would lead, according to the authors, to a “failure” of the model.

Chiang (2015), in his recent research paper using an ADCC GARCH to capture correlation, comes to the result that positive correlation is linked to common macro-economic factors and negative correlation is linked to, as it is commonly known, flight-to-safety. The research uses both, daily and weekly data from six major advanced economy indices from 1992 to 2011 to compute the stock – bond correlation for the different countries. The author also likes to emphasize the usefulness of the DCC GARCH as employed by R. Engle (1999). Nonetheless, Chiang chooses to deploy an ADCC GARCH to capture asymmetry of shocks. In contradiction with previous findings, Chiang’s ADCC approach seems to find an opposite outcome compared to Rankin and Idil (2014), Hartmann et al. (2004) and R. Campbell et al. (2002), namely that in times of a good turning economy, correlation is positive while during bear markets the correlation is negative.

One paper written by Andersson et al. (2008) that tries to explain the impact of inflation, economic growth expectations and perceived stock market uncertainty on the dynamics of stock-bond correlations also comes to the conclusion that stock-bond return correlations are mostly positive over time. The authors use daily data based on the FTSE100 for the UK, the S&P500 for the US and the DAX for Germany.

The authors emphasize the importance of the understanding of the dynamics behind the above-mentioned correlation. As already stated in our introduction, Anderson, Krylova and Vähämaa support our opinion that correlation is crucial for asset allocation and risk management, but also for monetary policy as has also been confirmed by Nasar (1992).

Andersson comes to the conclusion that correlation is responding to expected inflation and market uncertainty, but there has been no proof of a significant impact economic growth expectations on the correlation between bonds and stocks. The paper concludes that bonds often have a stronger co-movement relationship with, what the authors call, “bond-like” stocks such as the so-called blue-chips. As already stated by Poon and Granger (2005; 2003), Baker and Wurgler (2012) also found out 10 years later in their study that correlation of bond and stock returns is unstable over time.

These findings are applicable to our own research thesis as we can be sure to encounter a dynamic correlation over time.

In a more general way, Baker and Wurgler (2012) also thought to have found an explanation for the co-movements, namely the fact that both asset classes are linked to the same common factors, a finding which has also been concluded earlier by Bekaert and Grenadier (1999). Nevertheless, we still need to find out if these common factors impact bond and stock returns in a same way.

An answer seems to be suggested by Shiller and Beltratti (1992). It has often been argued that there should be a simple negative relation between bond yields and stock prices, meaning that when expected long term bond yields rise, investing in bonds becomes more attractive and thus stock prices will fall, and vice-versa. This statement is to be used with caution. Firstly, there is, according to the authors, a difference between the presentations of the cash flows for both asset classes. While dividend cash flows are stable in real terms, the cash flow linked to coupon payments is stable in nominal terms, which already shows us that a common factor for bond and stock co-movements is inflation.

Furthermore, there is a difference between expected and actual yields. Thus, information about future cash flows can lead to a flight-to-safety even if there is no movement of yields as stated by the information. One needs to be cautious about statements suggesting that correlation is simply negative. (Baele et al., 2010; Rankin & Idil, 2014)

As Rankin and Idil explain in their article, and keeping in mind previous articles, we see that there are common factors regarding volatility of bond market and stock market returns, but that, contrary to common assumptions, the implying co-movements are not necessarily negative. Possible factors impacting correlation are cited in their paper including inflation, uncertainty, interest rates and monetary policy.

After having seen what you mean by correlation between stocks and bonds in general as well as the GARCH model, which can be used to determine this correlation, it is important to see which phenomena, that literature has identified, can influence this correlation. Generally, and all around the globe we identified the “flight-to-safety” or “contagion” phenomenon that influence the bond-stock correlation. Furthermore, the “herd behavior” has an impact on the correlation of stocks and bond. Last but not least, the academic literature identified general macroeconomic factors that can impact the stock-bond correlation. In addition to that, and since our academic research focuses on the European markets, more precisely stocks and bonds that are traded, respectively issued in Euro, we identified the European Monetary Union (EMU) as well as the Sovereign Debt Crisis as possible phenomena that might have a big impact on the stock-bond correlation, especially on European stocks and bonds. At this point, it is important to note that the macroeconomic factors that influence the stock-bond correlation and the “flight-to-safety”-like phenomenon are not mutually exclusive. In fact, “flight-to-safety”-like phenomenon can be triggered by macroeconomic factors or shocks as we will see on the following pages.

First of all, we will start with an analysis of the literature in regard to the “Flight-to-safety” and “Contagion” phenomena, followed by an analysis of the “herd behavior” literature. Then we will further investigate the academic literature of the macroeconomic factors in general. Finally, we will study the financial literature of the two more regional specific factors that can influence the stock-bond correlation: the EMU as well as the sovereign debt crisis.

The general importance of correlation has already been analyzed by Baker and Wurgler (2012). The authors recognized that the relationship between the stock and the bond markets are of fundamental importance for economists, investors in general and policy makers, which has also been explained by Nasar (1992).

While the importance for economics is more research based, policy makers want to understand this relationship because it has an impact on the implemented policies and outcomes. In addition to the two previous interest parties, investors want to understand the co-movements and its predictability in order to better diversify their portfolios.

Flight-to-safety and contagion

First of all, it is important to define "flight-to-safety" and its possible impact on the stock-bond correlation and thus on the financial markets and the economy in general. According to Baur and Lucey (2009) "contagion between stock markets or between bond markets [can be defined] as a significant increase of the correlation in a crisis period compared to a benchmark period (. . .). There is only contagion if markets co-move with a higher degree than in normal times". The authors Forbes and Rigobon (2002) define contagion as "a significant increase in the co-movements in the markets after a shock in a single country or a group of countries". Moreover, Brocato and Smith (2012) define the "flight-to-safety" phenomenon as a re-allocation from risky stocks to risk-free US bonds in times of high probability of capital losses in the stock market. While this paper generally analyzed the US markets we can give our own, more general, definition of "flight-to-safety": re-allocation of the capital from the risky stock market to risk free government bonds as a result of fears of capital losses in the stock market caused by general uncertainty or volatility in the stock market. As an example, in time of a crisis, investors move their capital away from equity and tend to invest in assets that are considered to be more secure than government bonds (T-bill or Deutsche Bund).

After having defined both "flight-to-safety" and contagion, it is important to see the impact these two phenomena can have on the market and to analyze whether the academic literature confirms this impact or not. Generally speaking, and as an observation from the definitions that we identified, we can already assume that those two effects have a significant impact on the stock-bond correlation. If investors tend to switch from stocks to bonds in times of a crisis, and more generally in times of high uncertainty and high volatility, this significantly reduces the correlation, but only in times of uncertainty.

So, these phenomena and their impact on the stock-bond correlation are highly linked to the general state of the economy and the financial markets. This observation is confirmed by Brocato and Smith (2012) as well as Gulko (2002), who observed in the US markets, a generally positive correlation over the long term between stocks and bonds but also observed a significant negative correlation in times of crashes or crises. Gulko (2002) used the term "decoupling" to describe this temporary disconnection of the stock-bond correlation from its normal positive relationship. While these two papers analyzed the US markets, we hope to observe a similar situation in Europe and generally all around the world. Regarding the existence of the "flight-to-quality" and the contagion effect the financial literature is split:

On the one hand, the authors Forbes and Rigobon (2002) argue that there is no contagion effect. In fact, this paper concluded that there was no contagion effect caused by some major crises located all over the world. They concluded that there was no contagion effect, or the effect wasn't significant enough to be considered as contagion, but rather a strong interdependence effect in the overall markets, meaning that all the markets are generally closely linked to each other. On the other hand, Baur and Lucey (2009) argue in favor of the existence of the contagion effect. More precisely, their paper concludes that both flight-to-safety and contagion exist and that they are frequent phenomena during crisis periods.

In addition, the authors of this paper came to the conclusion that they also occur at the same time in different countries, and if this is the case, then stock markets fall simultaneously and bond markets increase simultaneously distorting the correlation of the socks and the bonds. Since, and according to this paper, these assets classes de-correlate in times of a financial crisis, this is of course good news for investors. In fact, in times of a financial crash or crisis, there are asset classes with different price directions and thus giving the possibility of diversification in times when it is needed the most.

These results are confirmed by the views of Hartmann et al. (2004). As already mentioned before, this paper analyses G5 countries and estimates the probabilities that different financial markets (stock markets, bond markets, etc.) crash as this is a fundamental question for the general stability of the financial markets all around the globe.

Their analysis focuses on the stock markets alone and they found that a "co-crash" happens around 20 % of the times. Furthermore, and regarding the bond markets alone, this number is much lower and it is even lower regarding a "co-crash" in both stock and bond markets. In addition to their stock and bond market analysis, they also focused in one part of their study on the linkage between stocks and government bonds directly and, more precisely, the flight to quality and contagion part of this link. They highlight the importance of this co-movement in regard to international financial stability. This academic research concluded that flight to quality is as frequent as a simultaneous crash of bond and stock markets. They also found that, while single bond or stock market crashes are very rare, the conditional probability, meaning that a boom or a crash in one market is more likely if a boom or crash already happened in another market. This gives further proof of the existence of the flight-to-quality phenomenon.

The author Johansson (2010) also gives evidence of the existence of the flight-to-quality phenomenon in the Chinese markets. The authors of this paper studied the co-movement of stocks and bonds in nine Asian countries. They concluded that there are so-called volatility spillovers between the stock and bond markets in those countries, meaning that high volatility in one market spills over to the other markets. As a result of this, they could conclude that the volatility process of stocks and bonds are closely linked to each other. In addition, they found that the stock-bond correlation varies considerably over the course of time. In fact, while the correlation in general is positive, it even reaches negative levels in some of the countries. So, there are both times when the correlation is low and times when the correlation is high.

Moreover, they also found that the co-movement of stocks and bonds generally increases if there is financial turmoil which leads the authors of this academic paper to the conclusion that there are significant contagion effects. Furthermore, they analyzed the flight-to-quality effect among the nine countries and realized that in times of financial turmoil the capital moved away from the country rather than safe asset within the country. Finally, they conclude by highlighting, again, the importance of the stock-bond correlation in both portfolio management and policy making as it has a significant impact on both fields of activity.

The review of literature regarding the "flight-to-quality" and the contagion effect highlights yet again the importance of the stock-bond correlation in the financial world. More precisely, the correlation plays an important role in effective asset allocation and diversification, especially in times where it is most useful, namely in times of a crisis or general financial turbulence. However, the literature on this subject also showed that the academics are still split on the existence of these two effects. Some research papers argue in favor of the existence of "flight-to-quality" and contagion, and others argue in favor of the non-existence of these effects, respectively that their effect is not statistically significant. What is important for us regarding this subject is that we have to be careful in regard to the flight-to-quality effect as it can have a significant impact on the effectiveness of asset allocation, and thus portfolio management as well as the effectiveness policy making. Both aspects are crucial factors for the stability of the financial markets all around the world.

Herd Behavior

Firstly, it is important to review how the financial literature defines what can be understood under “herd behavior”. Secondly, we will analyze the effect of such “herd behavior” and its impact on the financial markets as well as the correlation between stocks and bonds.

Generally speaking, “herd behavior” belongs to the domain of behavioral finance which often distorts with the assumption that investors always act perfectly rational in order to maximize their wealth. In reality, investors often act based on cognitive biases and as a result act irrationally and make decisions based on their emotions and feelings rather than objective facts. This can lead to market anomalies that are inconsistent with the well-known efficient market hypothesis. Herd behavior is one of the many cognitive biases that can lead investors to act solely on their feelings and thus make irrational decisions (Phung).

More precisely, herd behavior leads investors to follow the general trends of the market without doing any research or thinking about the decisions. To put it in simple words: they just do what others do without thinking about it. In addition, the investors very often wouldn’t make the same choices if they were isolated from the others. There are a lot of reasons why herd behavior takes place: need for social acceptance, social pressure or people believe that a large group of investors cannot be wrong and thus decide to join the trend rather than opposing it (Cont & Bouchaud, 2000).

As a result, herd behavior can have an important impact on the stability of the financial markets in general and thus also have an important impact on the stock-bond correlation with all its consequences. We can confirm this assumption by reviewing the financial literature:

According to Bikhchandani and Sharma (2000), such “herding” behavior will have impacts on volatility in the financial markets, and thus is a part of our analysis of the stock-bond correlation. In fact, psychological economics are important when talking about both flight-to-safety and herd behavior. Herd behavior is not rational, to give an example the momentum strategy which consist of buying “winners” and selling “losers” based on past data which is in conflict with the efficient-market hypothesis. This paper concludes that the observed correlation in times of crises can be due to such herd behavior. This paper clearly links the psychological behavior with the correlation of the different asset types and, as a result, also the correlation between bonds and stocks.

We can confirm the conclusion of this first paper with the results of Cont and Bouchaud (2000). While this paper starts with the discussion that the distribution of stock returns and in general the price changes of financial assets have fat tails which often results in excess kurtosis. Even after correcting for heteroscedasticity in the data, which results in an excess of kurtosis, fat tails continue to exist.

Finally, this text concludes that the high volatility in the prices might not be a result of new information or linked to variations in fundamental economic data but is rather a result of crowd effects or herd behavior. Yet again, this confirms our assumptions that herd behavior or similar behavior has an impact on asset correlation in general and thus has an impact on the stock bond correlation. This herd behavior can be extremely dangerous since it can destroy the diversification effect if “the herd” takes a wrong direction at the wrong point of time.

Macroeconomic Factors

In this section of the literature review we are going to analyze both the effect of macroeconomic factors themselves on the stock-bond correlation as well as the general effect of macroeconomic announcements that can have an impact on this correlation. Macroeconomic factors like GDP growth rate, expected inflation, expected interest rates, or even unexpected macroeconomic changes, etc. can have an important impact on the stock-bond correlation. Furthermore, this impact on the correlation plays an important role for both investors as well as policy makers in general because it can deteriorate the diversification effect, respectively the policy changes that policy makers are trying to implement. However, depending on the direction of the change in correlation, both the effectiveness of the policies as well as the diversification effect can be enhanced by macroeconomic changes or announcements of macroeconomic changes.

Lingfeng (2002) analyzed the correlation between stocks and bonds among the G7 countries. He found out that uncertainty about long-term expectations of inflation is an important factor for the covariance of stocks and bonds. If the long term expected inflation is very uncertain there will be a stronger co-movement, so a higher covariance between stocks and bonds returns. Real interest rate and unexpected (not long-term) inflation also affect the covariance, in fact the real interest rate is likely to increase the co-movements and the effect of unexpected inflations is ambiguous depending on how dividends and real interest rates react to unexpected inflation shocks, of stock-bond returns but to a lesser degree. The general idea is that the co-movement of stocks and bonds is influenced by a "common exposure to macroeconomic factors: expected inflation, the real interest rate and unexpected inflation" (Lingfeng, 2002).

However, while these three factors explain the correlation to a certain extent they are, however, dominated by the effect of long-term expected inflation on the stock-bond correlation. In fact, this paper concludes that the main mechanism behind the stock-bond correlation is that both, stocks and bonds prices, are the discounted sums of their cash flows. The difference between the cash flows of a stock and a bond is that the stocks cash flow is an infinite uncertain number of dividends, whereas the bond has a fixed predetermined number of coupon payments.

Consequently, factors that affect the discount rate of both stocks and bonds will have a positive effect on the correlation (they will move together and so the correlation will increase). Factors that only influence the discount rate of a stock will make bonds and stocks move in different directions and thus de-correlate them.

Finally, this academic paper shows that “the fact that stock-bond correlation is positively related to inflation is a disturbing message for investors” (Lingfeng, 2002). In fact, normally if inflation risk is high, the volatility of assets returns is high as well, which makes it difficult for the investor to diversify the investment risk. This is called the “Murphy's law of diversification”. In fact, in order for diversification to be most useful, if inflation risk is high, resulting in high volatility of asset returns, the stock bond correlation shouldn’t be positive but this academic research proved that it’s inverse.

The assumption that the main mechanism behind the stock-bond correlation is their discounted sum of cash flows is confirmed by Campbell and Ammer (1993). However, they also note that stock movements are mainly due to changing expectations about future cash flows, while bond price movement are more concerned with the interest rates.

Another important aspect is the impact of policy changes on the stock-bond correlation. Li and Zou (2008) analyzed “the impact of policy and information shocks on the correlation of the Chinese T-bond and stock return”. In fact, by using a modified DCC model, the so-called “MADCC model”, they could find that the Chinese capital markets react to large policy shocks, e.g. the large austerity measures of the Chinese governments in 2004. In addition, they found that the response to bad news is asymmetrical, whereas the response to good news is symmetrical. To put this in simple words, the co-movements of stocks and bond are heavily influenced by large macroeconomic policy shocks. One strong argument in favor of this is the 2004 announcement of austerity measures by the Chinese government which resulted in a drastic break in the stock-bond correlation. This academic paper is interesting because it has a similar approach to ours, at least partially, but it analyzes the Chinese market. However, this also shows in what way our research contributed to the academic world: while there are academic papers that focus on policy shocks on the stock-bond correlation on the Chinese market, we couldn’t find any well-established academic researches on this subject, more precisely for European markets. This illustrates to a part our contribution to the academic literature.

Some other important macroeconomic factors that could influence the co-movement of stocks and bond are financial market integration as well as cross-country influences other than the “flight-to-quality” phenomenon that we already studied. In fact, the author Baur (2010) studied the stock-bond relationship for eight developed countries in regard to financial market integration and cross-country influences. In fact, they found out that the stock-bond correlation depends more on cross-country factors than actual market integration.

More precisely, they found that both stock market returns as well as bond market returns heavily depend on the US stock and bond markets. Moreover, they found that this preeminence of the US markets on the international markets continued to grow over their research period (1994 – 2006). So, the authors of this academic research argue that the stock-bond correlation also heavily relies on the correlation that is present in the United States. Furthermore, they state that the primary causes of low levels of correlation are cross-country linkages rather than flight-to-quality or flight-from-quality phenomena. More precisely, they conclude that the low level of stock-bond correlation is “due to lower diversification benefits of cross-country stock or bond market investments” and as a result, investors reallocate their funds between stocks and bonds a lot more frequently.

After having analyzed the academic literature concerning macroeconomic factors in general, we will now continue with an analysis of the financial literature in regard to the impact of macroeconomic announcements on the stock-bond correlation.

The authors Christiansen and Ranaldo (2005) investigate the effect of macroeconomic announcements on the bond-stock correlation. In order to do that, they analyzed the effect of news items on the stock-bond co-movement. This academic paper studies the impact of US macroeconomic announcements on both variance and correlation of stock and bond returns. In fact, they generally assumed that announcements represent new information about an asset and if there is new information about an asset then the process of revaluation of this asset is triggered. More precisely, the markets are looking for a new equilibrium value of this asset. In fact, they conclude with the realization that it is not the surprise factor of an announcement that influences the correlation but rather the fact that an announcement occurs that influences the stock-bond correlation.

In addition, the effect of the announcement on the correlation is not stable over the course of time, in fact, it is dependent on the business cycle. Generally speaking, the market reaction is strongly reliant on the general economic situation and market conditions.

Explicitly, this academic research concludes that the overall impact of scheduled announcements on realized bond-stock returns is significant but the direction of the impact is strongly reliant on the business cycle (in expansions, news releases typically strengthen the co-movements of stocks and bonds) and on the current sign of the stock-bond correlation.

Usually, bonds react stronger to announcements and in recessions these reactions are stronger as well. In expansions, the stock-bond correlation is generally strengthened, suggesting that the real interest rate is the determining factor whereas in recessions the impact on the co-movement depends on the type of news. In fact, the researchers found that different news items have a different impact on the bond-stock correlation. News regarding Personal Income generally strengthen the correlation and news regarding Consumer Confidence weaken the correlation. To conclude, this paper found that the surprise component of a macroeconomic announcement has a small impact while the release itself has a lot stronger impact.

So, while it is generally well-known that surprises, meaning that economic reality opposes the expectations of the markets, move the markets and thus move the stock-bond correlation, we now have to assume that even announcement themselves, without even having a big surprise factor, can have a big influence on the stock-bond correlation as well. As a result of this we have to assume that both macroeconomic announcements and the surprise factor in the announcement, while to a lesser degree, can have an impact on the stock-bond correlation.

To conclude, in this part of our literature review it is important to note that there is a multitude of factors that can have crucial impact on both “regional” markets as well as international markets. Over the course of the financial literature in regard to macroeconomic factors we have realized that those factors are similar or at least closely linked all over the world. This suggests that those factors, while not specifically proven by a research paper, will most likely have an impact on our research as well. We should therefore pay close attention to these factors.

European Monetary Union

This section analyses the effect of the European Monetary Union on the stock bond correlation. We will start off with a brief overview of the EMU creation followed by a review of the financial literature about the general economic and social cohesion which also has an impact on the stock-bond correlation up to a flight-to-quality phenomenon that could be observed after the EMU creation.

Before reviewing the academic literature regarding the EMU and its effect on the co-movement of stocks and bonds, we would like to give a short overview of the history of the EMU and the Euro. In fact, you can say that the history of the Euro already began with the Treaty of Rome in 1957. In 1958, the “European Monetary Agreement” was put in place in order to aim for a general convertibility of the European currencies. In 1969, on The Hague Summit, the decision to make an Economic and Monetary Union was taken and Pierre Werner was ordered to make a report, which was later on called the “Werner Report”, on the feasibility of such a Union. The Werner Report suggested taking a 3-stage approach to create this Economic and Monetary Union. Unfortunately, as a result of the collapse of the Bretton Woods agreement as well as a lot of financial turmoil caused by the oil crises and other shocks, the plan to create this Union was temporarily dropped. The project re-launched with the creation of the “European Monetary System” (EMS) that aimed to stabilize the exchange rates via the “Exchange Rate Mechanism” (ERM), reduce inflation via a currency basket and to prepare the monetary integration. Finally, in 1990, the 3-stage process began: first of all, the restrictions of movement of capital were abolished for countries that participated, the Treaty of Rome was adapted and the Treaty of Maastricht, which introduced the European Central Bank and other institutions, was ratified. Secondly the “European Monetary Institute” was created with the purpose of strengthening the central banks coordination and monetary policy cooperation. Finally, on 1st January 1999 the Euro was launched in 11 countries and later in 2001 in a 12th. Nowadays 19 countries have opted for the Euro.

After having seen the history of the Euro, we will now analyze the academic literature in regard to the EMU in more detail. First of all, Berben and Jansen (2005) highlight the importance of the stock-bond correlation again. Generally, the co-movement of assets is important for investors, respectively portfolio managers, policymakers and supervisors, like central banks: investors are concerned about portfolio optimization, which is dependent and reliant on this correlation.

Supervisors are concerned about the stock-bond correlation because it, not only, directly determines the stability and health of the national or regional financial system, but it also impacts the global financial markets and the global financial system. In addition, it concerns Central Banks (CB) across the globe because the correlation of bond yield can directly influence the CB's ability to influence the interest rates via changes in their interest rate policy. This can have a big impact on their tools to achieve price stability. Furthermore, this academic research acknowledges that the development of an EMU was a process of financial market integration in Europe.

In fact, the introduction of the Euro in 1999 resulted in a removal of the exchange rate risk for countries that opted for the implementation of the Euro and the start of the single monetary policy for the Euro area began. At this point, the money markets became fully integrated. In addition to this monetary cohesion in the year preceding the creation of the EMU, there was also a strong economic and social cohesion among the different EMU participants.

Kim, Moshirian, and Wu (2006) investigated whether the co-movements between government bond and stock returns have been influenced by the creation and implementation of the European Monetary Union or not. First of all, the researchers found out that, on the one hand, there was an important stock and bond market integration within the Euro area, but on the other hand, stock-bond market integration at the country levels trended towards zero and sometimes even down to a negative level. In addition, they found out that bond market shocks have a bigger influence than stock market shocks. Moreover, there was inter-financial market integration within the EMU as a result of the elimination of the currency risk and real economic integration but there was also an aspect of uncertainty and concerns that was injected into the markets as a result of a common monetary policy. Finally, they conclude that the EMU has increased the effectiveness of diversification for the stock and bond markets on a country level.

Sovereign Debt Crisis

The sovereign debt crisis, or Euro zone crisis, that took place in Europe is an important factor for our analysis. This crisis had a huge impact on sovereign bonds as well as the financial markets in general and is a primary European crisis. Since it was an important crisis that took place in Europe, it is important to analyze the impact of this crisis on the stock-bond correlation. As a result, we think that this crisis in particular must have had an important influence on the stock-bond correlation and it is important to analyze the literature in regard to the sovereign debt crisis.

Before starting to talk about a sovereign debt crisis, it is important to know what is meant by the expression of crisis. Reinhart and Rogoff (2011) suggest several possibilities to define a crisis. Firstly, the authors explain the concept of quantitative definitions, which are not applicable to the European sovereign debt crisis, namely an inflation crisis which measures a threshold of 20% inflation per year, a hyperinflation crisis defined as a limit of 200% inflation rate or an exchange rate crisis which takes place in case of a country's currency depreciation of 15% a year.

In the context of the European sovereign debt crisis, the two following definitions and types of crises are more appropriate.

In the first place, there is the simple definition of different categories of debt crises. Default can be largely interpreted, such as a simple non-payment of interest, repudiation, or a restructuring unfavorable for the lender. Such a definition would be applicable to several EU countries where a restructuring of debt has taken place because a non-payment of debt would have otherwise occurred.

Secondly, Reinhart and Rogoff (2011) introduce the concept of banking crisis, which is an important notation for the European Union and its debt crisis given the fact that everything started with a financial crisis, which was followed by a banking crisis and spread over to a sovereign debt crisis. This is expressed as "contingent liability story", which means that the government takes on huge amounts of debt from private banks in order to guarantee their solvency, by risking the country's financial position. A similar finding was observed by Lane (2012). The paper explains that a bank crisis can either be defined as an occurred bank run in a country, or, as it is the case in Europe, the occurrence of large-scale government support and bailout programs.

One last important aspect introduced by the authors is the notion of “hidden debt”. It is defined as a debt the public is not aware of. In the context of Greece, the public was in fact not aware of the huge public deficit, even if it originated from book keeping irregularities, we think that the expression of “hidden debt” is nonetheless applicable.

Christopher, Kim, and Wu (2012) analyze the effects of sovereign credit ratings on the stock-bond correlation. In recent years, the influence and importance of credit rating agencies, like Moody’s or Standard and Poor’s, didn’t cease to grow and nowadays they represent an important tool to evaluate securities regarding their probability of default (PD). In fact, credit rating agencies nowadays include a multitude of factors to determine the PD of companies and governments like political environment economic situation etc...

This paper measures the impact of these credit ratings as well as changes to the ratings on the stock-bond correlation. There are three major conclusions that the authors of this research could make:

Firstly, they found out that sovereign ratings in fact significantly influence the stock-bond correlation, especially in the long term, but they found little evidence that there are significantly destabilizing effects in the short term.

Secondly, they could conclude that there is a positive association among the ratings and the general regional outlook on the stock-bond correlation. This means that if there are good news for a single country, investors tend to spread this positive outlook to the whole region leading to a higher, positive correlation among the different countries. However, bad news is considered to be country specific and thus lead-to a shift of funds to the other countries, thus lowering the correlation.

Thirdly, and this is rating up- or downgrade specific, investors tend to withdraw funds from the whole region if there is a downgrade in one country whereas if there is an upgrade in one country, investors tend to see it as country specific and don’t invest further in the countries of the region.

Finally, they conclude that as a result of their findings, credit rating agencies have a big impact on the co-movement of bonds and stocks and as a result of this a big impact on the stability of the financial markets as a whole. The credit rating agencies should be careful with this power in order not to reinforce their pro-cyclical effects.

Last but not least, they conclude with an important observation that took place in Europe: countries´ stock markets will, as a result of a downgrade, result in highly correlated sovereign debt markets.

Different factors played a crucial role in the European sovereign debt crisis, as observed by De Santis (2012). The author adds two other factors to the above-mentioned credit rating, that impacted the sovereign yield spread and thus made the bond market too expensive for EU countries in financial difficulties (Lane, 2012):

1. Aggregate regional risk factor
2. Country specific credit risk
3. Spillover from Greece

The third factor, namely the spillover from Greece, is very important given the fact that the budgetary problem encountered even had as a consequence an increase in spread to other EU members, even to the solid ones.

After having introduced the most important definitions and concepts, it is important to define the transition from a US financial crisis to a European sovereign debt crisis. A clear an structured explanation is offered by Lane (2012).

As mentioned earlier, private banks were hit by subprime ABS' and were thus in a position of large potential losses and needed governmental support, which can be seen as characteristics of a banking crisis (Reinhart & Rogoff, 2011). Member states' governments offered bailout packages and support in order to find themselves in a position of solvency problems. It follows that public debt increased in Spain, Greece, Italy and Ireland sharply after 2008.

The trigger for the outbreak can be seen as the more than twice as expected budgetary deficit announced by Greece. As explained above, the announcement had increasing sovereign yields as a consequence and member states, such as Greece, Ireland, Portugal, Spain and Cyprus, were no longer able to refinance themselves in the public bond market given the high interest rates.

Chapter 3: Methodology

Chapter 3 focuses on the methodology of our model used during the paper, namely the DCC GARCH, initially put in place by R. Engle (1999) in his paper and the so-called linear ordinary least squares regression. In a second attempt, we will quickly cover the methodology of the OLS regression used.

Our chapter will paraphrase the main ideas of Orskaug (2009) in relation to the DCC GARCH given the comprehensiveness of its paper. In addition to the formulations and explanations of Engle and Orskaug (1999; 2009), we will give additional comments that we find complementary to the existing papers in order to give the lecturer a more managerial perspective and understanding. We will try to simplify the complexity of this model as much as possible, because our paper is not focused on the econometrics behind the analysis, but on the outcome of the model.

DCC GARCH

As already mentioned, the explanation of the model will be entirely based on Orskaug (2009) given the complexity of the DCC GARCH model. Some further details are being provided by the original text of R. Engle (1999). Given the fact that our research is based on the provided results and not on the computation and accuracy (which has already been proved by different papers in the literature review chapter), this section is for those interested in the econometrical mechanics behind that. In other words, the model section is for informational and completion purposes.

According to R. Engle (2001), in presence of heteroscedasticity, the OLS estimators provide too narrow standard errors and confidence intervals. Given the GARCH model, in which variance is a parameter that needs to be estimated, they give thus a model that can be used as a forecast for such volatility (and correlation).

Orskaug starts by defining the DCC GARCH model as follows:

$$r_t = \mu_t + a_t$$

$$a_t = H_t^{1/2} z_t$$

$$H_t = D_t R_t D_t$$

Notation:

r_t = n x 1 vector of log returns of n assets at time t

a_t = n x 1 vector of mean-corrected returns of n assets at time t, with an expected value of 0 and a covariance of H_t

μ_t = n x 1 vector of the expected value of the conditional return at time t

H_t = n x n matrix of conditional variances of a_t

$H_t^{\frac{1}{2}}$ = Any matrix with n x n dimensions at time t such that H_t is the conditional variance matrix of a_t.

D_t = diagonal square matrix of conditional standard deviations of a_t at time t

R_t = n x n conditional correlation matrix of a_t at time t

z_t = n x 1 vector of iid errors such that the expected value is 0 and $E[z_t z_t^T] = I$

Regarding some further specifications of above mentioned variables, Orskaug also specifies that the elements of the diagonal square matrix D_t are the standard deviations $\sqrt{h_{it}}$ defined as $h_{it} = \alpha_{i0} + \sum_{q=1}^{Q_i} \alpha_{iq} \alpha_{i,t-q}^2 + \sum_{p=1}^{P_i} \beta_{ip} h_{i,t-p}$.

$$D_t = \begin{bmatrix} \sqrt{h_{1t}} & 0 & 0 & 0 \\ 0 & \sqrt{h_{1t}} & 0 & 0 \\ 0 & 0 & \sqrt{h_{1t}} & 0 \\ 0 & 0 & 0 & \sqrt{h_{1t}} \end{bmatrix}$$

Specifying the conditional correlation matrix R_t of the standardized residuals $\varepsilon_t = D_t^{-1} \alpha_t \sim N(0, R_t)$ where the disturbances are following a normal distribution with mean 0 and variance R_t.

$$R_t = \begin{bmatrix} 1 & \rho_{12.t} & \cdots & \rho_{1n.t} \\ \rho_{12.t} & 1 & \cdots & \cdots \\ \cdots & \cdots & 1 & \rho_{n-1,n.t} \\ \rho_{1n.t} & \cdots & \rho_{n-1,n.t} & 1 \end{bmatrix}$$

We can write the square matrix of conditional variance as $H_t = D_t R_t D_t$

Orskaug also explains that one needs to consider two requirements when specifying a form of the conditional correlation matrix R_t:

1. The square matrix of the conditional variances of a_t, H_t needs to be positive definite given the fact that it is a covariance matrix. This can be ensured by ensuring that R_t is positive definite.
2. All the elements included in the correlation matrix R_t need to be, per definition, less than one.

To guarantee that both requirements are met, Orskaug decomposes R_t into $R_t = Q_t^{*-1} * Q_t * Q_t^{*-1}$ where $Q_t = (1 - a - b) * \underline{Q} + a * \epsilon_{t-1} * \epsilon_{t-1}^T + b * Q_{t-1}$. Q_t^* is a diagonal matrix consisting of the square root of the diagonal elements of Q_t in order to rescale given matrix which leads to an ensured second requirement and $Q_t^{*-1} = diag\{Q_t\}^{-1}$ (Séverine, 2015).

Even if Orskaug analyzes three different distributions for the standard errors z_t, we assume, as already done by R. Engle (2001), that the standardized errors are following a Gaussian distribution.

The scalars a and b are going to be estimated using a two-step approach.

<u>Two-step approach</u>

Given the normality assumption, Orskaug states that, per definition, the one can estimate the parameters by using a Max Log-Likelihood method. The log-likelihood function of the correlation estimator is given by (Orskaug, 2009):

$$Ln\big(L(\theta)\big) = -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + \ln(|H_t|) + a_t^T H_t^{-1} a_t)$$

Then by substituting $H_t = D_t R_t D_t$, we get:

$$Ln\big(L(\theta)\big) = -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + \ln(D_t R_t D_t) + a_t^T D_t^{-1} R_t^{-1} D_t^{-1} a_t)$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + 2\ln(|D_t|) + \ln(|R_t|) + a_t^T D_t^{-1} R_t^{-1} D_t^{-1} a_t)$$

Step 1

During the first step, we replace the correlation matrix R_t in the previous equation by the identity matrix in order to obtain the quasi-likelihood function, given by:

$$\ln\big(L_1(\emptyset)\big) = -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + 2\ln(|D_t|) + \ln(|I_n|) + a_t^T D_t^{-1} I_n D_t^{-1} a_t)$$

$$= -\frac{1}{2}\sum_{t=1}^{T}(nln(2\pi) + 2\ln(|D_t|) + a_t^T D_t^{-1} I_n D_t^{-1} a_t)$$

$$= -\frac{1}{2}\sum_{t=1}^{T}\left(nln(2\pi) + \sum_{i=1}^{n}\left[ln(h_{it}) + \frac{a_{it}^2}{h_{it}}\right]\right)$$

$$= \sum_{i=1}^{n}(-\frac{1}{2}\sum_{t=1}^{T}\left[\ln(h_{it}) + \frac{a_{it}^2}{h_{it}}\right] + constant$$

In accordance with Orskaug (2009), we can see that the log-likelihood of the previous expression equals the sum of the log-likelihoods of the univariate GARCH equations of n assets. In this first step, we thus have an estimation of the parameter $\emptyset = \emptyset_1, \dots, \emptyset_n$ which also allows us to make an estimation of the conditional variance h_{it} and the residual error $\in_t$ for each asset n.

It follows that the parameters a and b are the only parameters that are still unknown and that are going to be estimated during a second step.

Step two

Using the previous obtained estimated parameters from step one in the correctly specified log-likelihood equation, we obtain the second step quasi-likelihood function:

$$\ln\left(L_2(\psi)\right) = -\frac{1}{2}\sum\nolimits_{t=1}^{T}(nln(2\pi) + 2ln(|D_t|) + ln(|R_t|) + a_t^T D_t^{-1} I_n D_t^{-1} a_t$$

$$= -\frac{1}{2}\sum\nolimits_{t=1}^{T}(nln(2\pi) + 2ln(|D_t|) + ln(|R_t|) + \in_t^T\ R_t^{-1} \in_t$$

As a result of the conditioning on the parameters in the first step of the estimation D_t is constant and we can exclude the constant terms and maximize:

$$\ln\left(L_2^*(\psi)\right) = -\frac{1}{2}\sum\nolimits_{t=1}^{T}(ln(|R_t|) + \epsilon_t^T R_t^{-1}\epsilon_t)$$

This is the final expression that is going to be maximized in order to estimate the correlation parameters.

(Orskaug, 2009)

OLS regression

In this section, we will quickly cover the methodology of the OLS regression analysis. Our explanations will be based on a compressible work provided by Wooldridge (2014).

The OLS regression consists in the fact of drawing a straight line in the middle of a dataset, such as it minimizes the sum of squared residuals. The residuals are the difference between the straight line and the actual observed value, as represented in the illustration below.

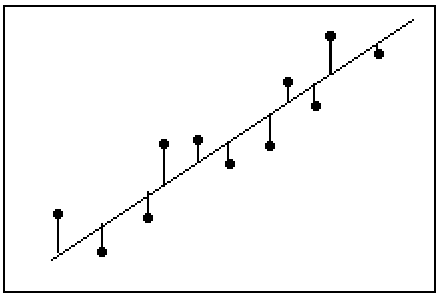

Figure 1 – Illustration of residuals

By minimizing this difference, we obtained the best suitable linear model for our given dataset.

More precisely, the model of a multiple regression can be noted as followed:

$$y_t = \beta_1 + \beta_2 x_{2t} + \beta_3 x_{3t} + \ldots + \beta_k x_{kt} + u_t \quad ; \; t = 1; 2; \ldots; T$$

With:

$y_t = Thedependent\ variable$

$x_{kt} = \ The\ independant\ variables$

$\beta_{kt} = The\ coefficients\ of\ the\ independant\ variables$

$u_t = The\ disturbance\ or\ error\ \ term$

The equation of the line, which represents the predictive model, is given by:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1 x_1 + \cdots + \hat{\beta}_n x_n$$

Further details regarding the ordinary least squares (OLS) regression can be found in appendix 3. In our case, the explained variable (Y) is the estimated correlation between stock and bond returns over time and the explanatory variables (X).

Chapter 4: Data collection

Continuing our path with the specification of data used during our research. The chapter is split into two parts, namely data collection for DCC GARCH and for a forecast model using an Ordinary Least Squares (OLS) regression where we regress our obtained correlation on various factors.

Given our motivation to include the potential impact the effective creation of EMU would have had on correlation in Europe, we start our data collection on 31st July 1998 and we include information about our indices up to 25th December 2015. We would have preferred to start our analysis on 1st January 1995, but due to a lack of data during prior periods in Europe, we must be satisfied with this time horizon because there is no other index that reaches as far back. As 1998 is still prior the effective creation of the EMU, namely 1st January 1999, we consider that it is still useful for our analysis.

DCC GARCH

For the correlation estimation, we used weekly log-returns of the Euro Stoxx600 and the Bloomberg Barclays EuroAgg Total Return Index Value Unhedged. As already introduced by Perego and Vermeulen (2016), the choice of frequency is a bit problematic given different opening and closing times of financial markets, but the authors proposed to use weekly data in order to solve synchronization issue. We have chosen to compute the weekly returns in order to firstly eliminate daily fluctuations that are not necessary to analyze whether there has been a structural change in correlation, and secondly because we are taking into account a long-time horizon which would result in a big amount of data.

The Stoxx Europe 600 has been chosen because of its several useful characteristics. A detailed factsheet of the Stoxx Europe 600 is available in appendix 1. Firstly, this index englobes equity from different market capitalization ranges, namely small cap, mid cap and high cap, across Europe. In addition to this, the Stoxx Europe 600 has a sufficient big size, with 600 stocks included, to be used in our correlation analysis. One last important feature of this index is the fact that it includes the most important stocks from across 17 different countries in Europe. (Baur, 2010, retrieved from https://www.stoxx.com/index-details?symbol=SXXP)

Eventually, we considered that this index is perfectly suitable for our analysis given the fact that it provides a sufficient dataset and time horizon for 600 of the most important stocks in different asset classes and market capitalization ranges.

Regarding the Bloomberg Barclays EuroAgg Return Index, we agreed on this index after an in-depth analysis of several bond indices. A detailed factsheet of our reference index can be found in appendix 2.

This bonds index allows us to cover the major bond classes in Europe. The Bloomberg Barclays EuroAgg Total Return Index Value Unhedged is "a benchmark that measures the investment grade, euro-denominated, fixed- rate bond market, including treasuries, government-related, corporate and securitized issues." ("Bloomberg Barclays EuroAgg Total Return Index Value Unhedged EUR," 04/07/2017, retrieved from https://www.bloomberg.com/quote/LBEATREU:IND)

Our choice for this index is motivated by its diversified structure, but inside Europe and including euro-denominated securities. It is important to say that this Bloomberg Barclay's index includes corporate and governmental obligations, as well as securitized issues. Furthermore, our choice for this index is also based on the fact that it only includes fixed-rate bonds, which is, in our opinion more useful for our analysis and there are no underlying features that could mislead our analysis.

Given the fact that we used these two indices to analyze the prevailing correlation in Europe, it is important that the core of both benchmarks is not too heterogeneous. In fact, we conclude that both indices are of a similar nature that can be used as a benchmark an analysis of correlation inside Europe as they both include assets from several classes. When considering both, the Stoxx Europe 600 and the Bloomberg Barclays EuroAgg Total Return Index Value Unhedged, we can say that standard stocks and bonds inside Europe across different countries and industries are covered, which allows us to obtain a general correlation in Europe that is not falsified by data focused on different segments.

Stoxx Europe 600					
Average	Standard deviation	Kurtosis	Skewness	Minimum	Maximum
0,0594%	2,7144%	6,395615454	-0,593747079	-21,5354%	13,2433%
Bloomberg Barclays EuroAgg Total Return Index Value Unhedged					
Average	Standard deviation	Kurtosis	Skewness	Minimum	Maximum
0,0954%	0,4695%	1,871230039	-0,425049722	-2,4481%	2,0100%

Figure 2 – Descriptive statistics of reference indices

OLS regression

In this section, we will describe out data selection process for our regression analysis. More precisely, in order to compute our regression analysis, we need data that can potentially influence the stock-bond correlation over the course of time. As already mentioned in the previous section, the stock-bond correlation represents the explained variables while the different datasets that we will present in this section represent the explanatory variables. We try to explain the movements in the stock-bond correlation with the variables that we will represent in this section.

In order to collect as many valuable factors as possible that can possibly influence the stock bond correlation, we created four categories in which we regrouped the factors to spot a potential trend in the data that we collect. In other words, we made four thematically different groups, each one of them emphasizing a different aspect that could potentially influence the stock-bond correlation. If one topic provides more statistically significant factors and as a result of that dominates other topics, it could be interesting to analyze these factors and similar factors more in detail in future research papers. Moreover, by categorizing the factors into different groups, we hope to cover almost every aspect that can influence the stock-bond correlation.

The four groups that we created are: “Base Factors”, “Macroeconomic Factors”, “Financial Factors” and “Policy Factors”. The “Base Factors” category consists of basic factors that globally impact the economy and as a result of that could influence the correlation of stocks and bonds. The “Macroeconomic Factors” category includes general macroeconomic factors and events that influence the global economy and as such can have an impact on the stock-bond correlation. In the third category, we have financial factors. In this category, we regrouped factors that are more specific to financial markets and therefore could have an impact on the correlation of stocks and bonds. Finally, we have the “Policy Factors” topic which includes economic or monetary policy aspects that might affect the stock-bond correlation because of their impact on the financial markets.

CATEGORY	NAME	VARIABLE	EXPLANATION	SOURCE	FREQ.
Base	European Union Gross Domestic Product	EU_GDP	Gross Domestic Product (GDP) measures the final market value of all goods and services produced within a country. It is the most frequently used indicator of economic activity. This procedure is adjusted for inflation. Calculated for the countries that are part of the EU.	Eurostat (Retrieved via Bloomberg)	Q
	Eurozone Gross Domestic Product	EURO_GDP	Gross Domestic Product (GDP) measures the final market value of all goods and services produced within a country. It is the most frequently used indicator of economic activity. This procedure is adjusted for inflation. Calculated for the countries that are part of the Eurozone.	Eurostat (Retrieved via Bloomberg)	Q
	United States Gross Domestic Product	US_GDP	Gross Domestic Product (GDP) measures the final market value of all goods and services produced within a country. It is the most frequently used indicator of economic activity. This procedure is adjusted for inflation. Calculated for the US.	Bureau of Economic Analysis (Retrieved via Bloomberg)	Q
	Inauguration of the euro	EuroInauguration	The official inauguration date of the Euro.	European Commission	/
Macroeconomic	European Union Consumer Price Index	EU_CPI	The harmonized index of consumer prices (HCIP) is a measure of prices paid by consumers for a market basket of goods and services. It is calculated using the same methodology across countries to allow for comparable measures of inflation.	Eurostat (Retrieved via Bloomberg)	M
	Eurozone Consumer Price Index	EURO_CPI	The harmonized index of consumer prices (HCIP) is a measure of prices paid by consumers for a market basket of goods and services. It is calculated using the same methodology across countries to allow for comparable measures of inflation.	Eurostat (Retrieved via Bloomberg)	M
	United States Consumer Price Index	US_CPI	Consumer prices (CPI) are a measure of prices paid by consumers for a market basket of goods and services.	FED (Retrieved via Bloomberg)	M
	Subprime Crisis	SubprimeCrisis	Start date of the subprime crisis.	Investopedia	/
	Sovereign Debt Crisis	DebtCrisis	Start date of the sovereign debt crisis in Europe.	Investopedia	/
Financial	CBOE Volatility Index	VIX	The Chicago Board Options Exchange Volatility Index reflects a market estimate of future volatility based on the weighted average of the implied volatilities for a wide range of strikes.	Bloomberg	W
	Bank of America Merrill Lynch GFSI Liquidity Risk	Liquidity_Risk	The Liquidity Risk index is a measure of funding stress in the global financial system as measured by spread-based relationships in rates, credit and currencies. Levels greater/less than 0 indicate more/less stress than is normal.	Bloomberg	W
	Germany Generic Govt 10Y Yield	GG10Y	The rates are comprised of Generic German government bonds. These yields are based on the bid side of the market. Yields are yield to maturity and pre-tax.	Bloomberg	W
	US Generic Govt 10 Year Yield	USG10Y	The rates are comprised of Generic United States on-the-run government bill/note/bond indices. These yields are based on the ask side of the market. Yields are yield to maturity and pre-tax.	Bloomberg	W
Policy	ECB Main Refinancing Rate	ECBRate	The main refinancing rate decided by the ECB.	ECB	/
	Quantitative Easing	QE	Start date of the 60 bn Quantitative Easing program of the ECB.	ECB	/

With: W = Weekly
M = Monthly
Q = Quarterly
/ = Does not apply

In this table, we provide a summary of our variables in regard to their denomination over the course of this paper, a short definition, the source and the frequency of the data. The official source is given in this table; however, it is of course important to note that the data was often retrieved via a Bloomberg Terminal because of practical reasons. Nevertheless, we also have some data sets where the official source is the Bloomberg Terminal. We noted the different cases in the table in order to avoid any confusion in regard to the sources of our data.

In the following sections, we will explain the different categories as well as the factors that we chose for each category in more detail.

a) Base Factors

The “Base Factors” category covers a wider array of base factors that might have an influence on the stock-bond correlation.

One first factor that we included in this category is the official introduction of the Euro. As already mentioned beforehand, the Euro was officially launched on 1st January 1999. On this same date, the European Central Bank as well as its monetary policy got operational (European Commission). Overall this is the date of birth of the Euro and it represents an important baseline factor in our research. In our research paper, we will represent the official inauguration date of the Euro as a so-called dummy variable. More precisely, this date represents qualitative information meaning that it represents a characteristic which cannot be expressed as a numerical value and thus cannot be easily compared with other data. In comparison to qualitative data, you can also have quantitative data which can be expressed as a numerical value and as a result of that easily be compared with other quantitative data. A dummy variable can be used to quantify the qualitative aspect of data by giving it a value of either 0 or 1. The dummy variable takes the value of 0 or 1 if a characteristic is true or not or if an event got triggered or not. In our case, we called the dummy variable “EuroInauguration” and it takes the value of 0 while the Euro was not officially established (before 1st January 1999) and it takes the value of 1 after the official introduction of the Euro (after 1st January 1999).

Moreover, we included the Gross Domestic Product (GDP) growth in the “Base Factors” group. Generally, you can say that the GDP growth displays the general state of the economy or the economic performance. The general state of the economy (Crisis, Recession, Boom, etc.) influences the bond and stock markets and vice versa. In this context, it makes sense to include the GDP as a variable that should be compared to the stock-bond correlation that we computed.

Since we analyze the stock-bond correlation of the European markets, we decided to include, on the one hand, the GDP of the European Union and, on the other hand, the GDP of the Euro area. The GDP of the European Union represent the GDP growth of all the member states of the European Union. It is important to note that the member states of the EU varied over the course of our analysis period. These changes are of course included in the calculation of the EU GDP.

The GDP of the Euro zone represents the GDP growth of all the member states that implemented the Euro. The same procedure holds true for the computation of the Euro zone GDP.

Last but not least, we decided to also include the GDP of the United States in this category. In fact, since the US represents the "biggest player" on the financial markets and since the global economy is often influenced by the general state of the US economy (Arora & Vamvakidis, 2004) it might be interesting to include the US GDP in our regression analysis to see if it can influence the European stock-bond correlation as well or not.

We downloaded these data sets directly from Bloomberg in order to analyze them in our regression analysis.

b) Macroeconomic Factors

The "Macroeconomic Factors" category includes a variety of factors and events that have a macroeconomic importance and as a consequence also have an impact on the financial markets which can of course influence the correlation between stocks and bonds.

We included the inflation in this category. For our regression analysis, we included the inflation of the European Union as well as the inflation for the Euro zone. The inflation, by definition, is the general price increases of goods and services in an economy. It is measured with the help of a so-called Consumer Price Index (CPI). Generally, a CPI of a country should be composed of all the different goods and services that the population consumes frequently, like food, water, sanitary products, fuels, education, etc. The CPI should be a representative "consumer basket" of the population. This CPI is then used to measure the overall price changes over the course of time. For our regression, we used the inflation levels that were calculated based on the data of the "Harmonized index of consumer prices (HCIP)". More precisely, Eurostat combines different sets of CPIs of different countries and assembles into the HCIP. The current and official level of inflation is calculated based on this Harmonized index of consumer prices. Moreover, the monetary policy of the Euro area is based on the level of inflation calculated via the HCIP (European Central Bank).

Yet again, we downloaded these data sets directly from Bloomberg in order to analyze them in our regression analysis.

Furthermore, we wanted to include and analyze the impact of two major macroeconomic events that heavily influenced the financial markets and a result of that might have an impact on the stock-bond correlation:

Firstly, we decided to include the subprime crisis of 2007 in this section. Even though the origin of this crisis is mainly in the US, it still led to a global financial crisis which had a huge impact on the financial markets. As a consequence, we assume that this crisis can have a significant impact on the correlation of bonds and stocks. Since this event represents a qualitative characteristic rather than a quantitative characteristic, we used a dummy variable to quantify this event. The dummy variable takes the value of 1 if the event is triggered and 0 if the event isn't triggered. In our case, we called the dummy variable “SubprimeCrisis” and it takes the value of 0 before and after the subprime mortgage crisis and it takes the value of 1 during the crisis. More precisely, we defined the subprime crisis as the period from 2007 to 2010. During this period, the dummy variable takes 1 as value meaning that the event is currently taking place.

Secondly, we included the sovereign debt crisis or Euro zone crisis that took place in Europe in this group. This crisis had a huge impact on sovereign bonds as well as the financial markets in general and is a primary European crisis. As a result, we think that this crisis in particular can have an important influence on the stock-bond correlation. Yet again we used a dummy variable to quantify this event. The dummy variable is called “DebtCrisis” and it takes the value of 0 before and after the sovereign debt crisis and it takes the value of 1 during the crisis. We defined the starting date of the sovereign debt crisis as January 2010, so the moment the EU discovered irregularities in the balance sheet of the Greek government and revised its deficit from 3 percent up to over 12 percent which triggered the start of the sovereign debt crisis which spread across Europe (European Commission, 2010). We consider the sovereign debt crisis to be active until the end of our observation period.

c) Financial Factors

The “Financial Factors” category consists of factors that are more specific to the financial markets in general and because of that can have an impact on the correlation of stocks and bonds.

First of all, we included the 10-year yield of a Germany Generic Government bond (Germany Bund) in this category. These yields are computed based on the following criteria: “*The rates are comprised of Generic German government bonds. These yields are based on the bid side of the market. Pricing source for the bond is the Bloomberg Generic Composite (BGN) rate. The generic will not update if we do not have rates for the underlying benchmark bonds, or if we do not have the underlying terms on the curve.*” (Bloomberg, 2017b).

We suspect that the stock-bond correlation is influenced by the yield of the German Bund because the German Bund represents an important factor in the European bond markets.
Secondly, we also included the 10-year yield of a US Generic Government bond. Even though the US T-bill it is more important in the US, it still represents an important indicator for the financial markets. As a result, we decided to include it in our regression analysis because we think that the US T-bill still might have an impact on the correlation.

Furthermore, we also included the so called VIX index in this category. The VIX index or more precisely the “Chicago Board Options Exchange SPX Volatility Index (CBOE Volatility Index)” represents a measure of economic uncertainty as well as volatility in the financial markets. In fact, if there is uncertainty or higher volatility in the markets we suspect that investors tend to switch to safer assets and as a result of that it can have a significant impact on the stock-bond correlation. Because of that it will be interesting for our research paper to observe the impact of higher fears in the financial markets on the correlation of stocks and bonds.

Finally, we decided to also include the liquidity risk in the “Financial Factors” category. We used the “BofA Merrill Lynch GFSI Liquidity Risk Index” as a measure of liquidity risk in the global financial markets. More precisely the “*BofA Merrill Lynch GFSI Liquidity Risk Index is a measure of funding stress in the global financial system as measured by spread-based relationships in rates, credit and currencies. Levels greater/less than 0 indicate more/less stress than is normal*” (Bloomberg, 2017a). This index represents another factor of stress in the financial markets and we suspect that in case of lower levels of liquidity the uncertainty will increase and as a result of that investors might flee to other assets that are considered as safer. In a nutshell, we think it is important to consider this factor in our regression analysis as it might have an influence on the correlation of stocks and bonds.

Again, we downloaded all these data sets directly from Bloomberg in order to analyze them in our regression analysis.

d) Policy Factors

The “Policy Factors” category embodies factors that are linked to the monetary policy decisions by the European Central Bank.

We included the ECB main refinancing rate, so one of the major monetary policy tools of the ECB as a factor that could potentially influence the stock bond correlation. As already seen in the literature review, the inflation can play an important role in determining the stock-bond correlation.

Moreover, we wanted to include one major policy shock in this section namely the enormous Quantitative Easing (QE) program that the ECB launched in 2015. The QE program was announced in January 2015 and launched already in March 2015 (European Central Bank, 2015). The ECB decided to buy assets for 60 billion Euro per month. This amount of the asset purchase program was a huge surprise for the financial markets. The ECB bought bonds from the banks and as a result of that wants to increase the prices of bonds, give liquidity to the financial markets and reduce the interest rates.

As a result, they hoped to boost the economic growth and job creation by stimulating investments as well as general the consumption because of the cheaper borrowing costs. We used a dummy variable to quantify this event. The dummy variable is called “QE” and it takes the value of 0 before they put in place the asset purchase program (period before March 2015) and it takes the value of 1 after the launch of the asset purchase program. The QE program is still active that’s why it will be active until the end of our observation period.

Chapter 5: Results

During this chapter, we are going to present our results obtained in a first attempt of the DCC GARCH used to estimate the stock-bond correlation in Europe over time, and in a second attempt of the OLS model used to create a forecast model and in order to assess the significance of the different factors.

This approach gives us two different points of view:

Firstly, thanks to the graphical analysis of the stock-bond correlation over time, we can easily see when there was an important change in correlation, but also when there was not. In other words, there are economic events that would be expected to have an impact on the degree of stock-bond co-movements, but we can see in the graph that this has not always been the case. Using such a graphical approach is, in our opinion, best suited given our background and our time constraint to get a first overall view on correlation evolution over time. As already mentioned, this first point of view is important to find ourselves in a general context of correlation and to see when there has been a change in trend.

Secondly, a more mathematical approach used during our OLS regression will give us the possibility to assess the importance of different factors on correlation. Contrary to the first, graphical, analysis, this approach allows to narrow down from a global view on correlation into a detailed model construction where the timing of changes is not so important, but more the mechanics behind these changes. To reformulate the motivation of this second analysis, we can say that the important question is “why”, while the motivation in the graphical analysis is “when” and “how”.

Eventually, thanks to the DCC GARCH we will see which events had an impact on general correlation and its trend over time, while an OLS regression gives a view of the importance of economic variables, such as economic growth and the volatility index on correlation. In addition, there are factors that will lead to a cross-sectional analysis and a combined result of findings in both approaches, the graphical and the mathematical.

After this analysis, we will end up with a forecast model that will (hopefully) be able to predict future correlation in Europe.

Correlation over time using a DCC GARCH

Regarding the correlation over time, a graphical analysis is used. This choice is motivated by the fact that the numbers are based on estimations, but that a visual chart is enough to get a first intuition of whether there has been a change in correlation and when it took place. We also give possible reasons for the changes in correlation, based on economic incidences that took place at given periods.

DCC GARCH correlation estimators			
Average	Standard Deviation	Minimum	Maximum
-0,1096965173	0,092065917	-0,3062501858	0,2354140356

Figure 3 – Descriptive statistics

In general, we have a correlation of -0.11 over our given time frame. General theory about stock-bond correlation assumes that the relationship between bonds and stock returns is, in fact, opposite. Nonetheless we found evidence of periods where given co-movements are positively linked, as can be seen in figure 3 on the next page, which is also in line with the literature that suggests that in time of crises and uncertainty, correlation is positive.

With a standard deviation of 0.092, we can suggest that the range of correlation should be most of the time negative. A maximum correlation of 0.235 can be observed during the week of 14/05/2010 and a minimum correlation of -0.306 during the week of 21/03/2003. Interesting findings have been concluded regarding this minimum and maximum correlation that will be discussed later in this section.

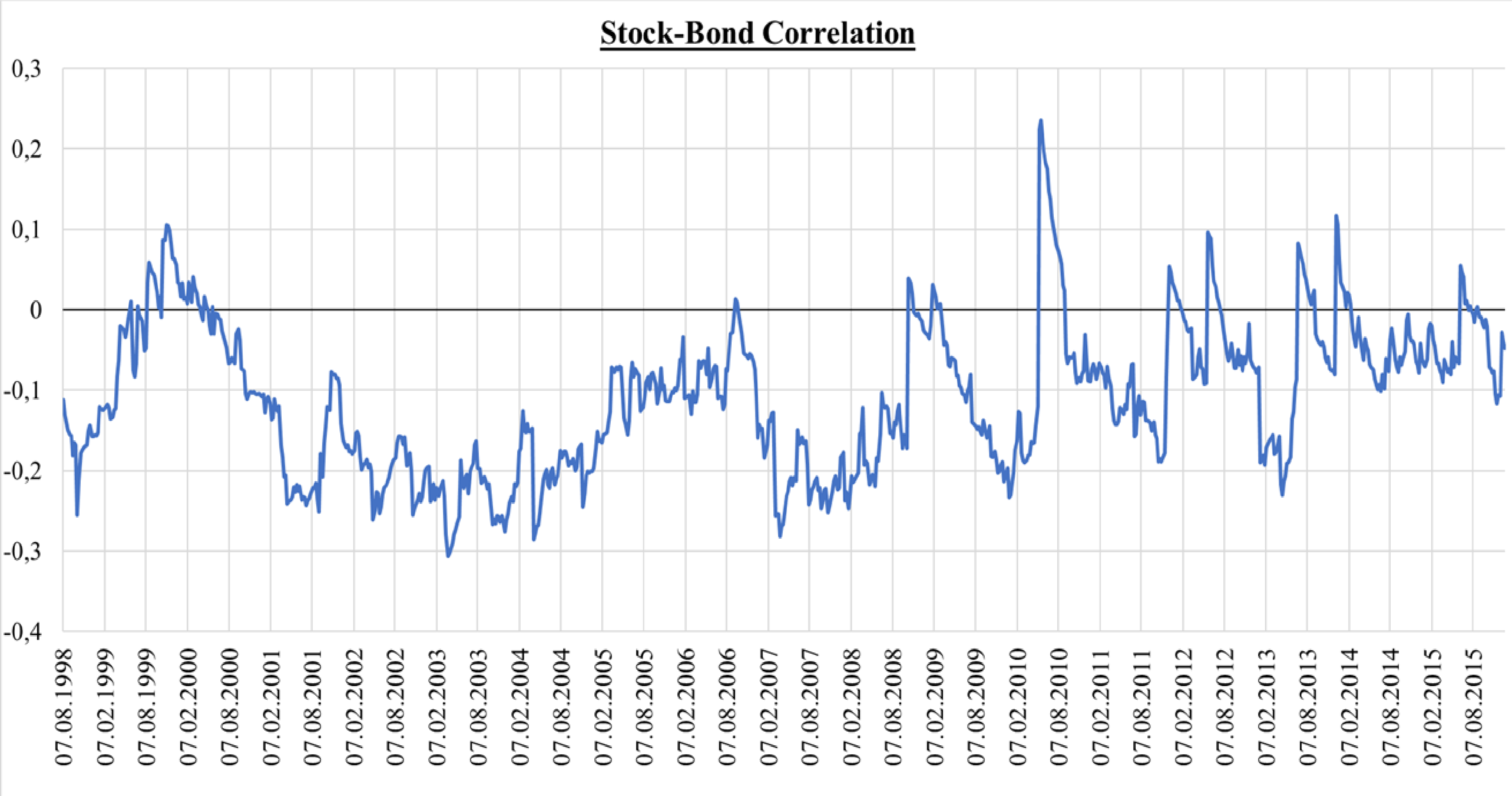

Figure 4 – Stock-Bond correlation from 1998 to 2015 using a DCC GARC

From **1st January 1999** on, correlation started to increase until mid-2000, when it eventually spiked at an estimated correlation of 0.1.

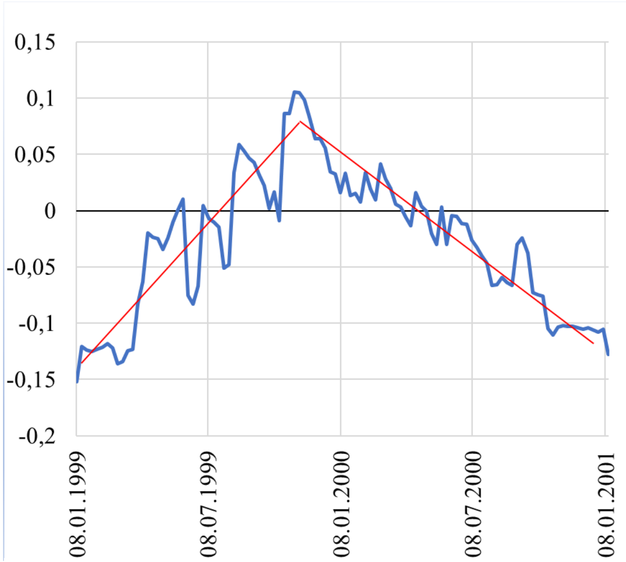

Figure 5 – Correlation between 1999 and 2001

In fact, this date marks an important date in the history of the Euro. The finalization of the European System of Central Banks (ESCB) and the implementation of a European Central Bank (ECB) was taking place until the end of December 1998 and became effective on 1st January 1999 (Arora & Vamvakidis, 2004). During stage 3 of the implementation of a currency union, the exchange rates between the Euro and the EMU members got irrevocably fixed on 1st January 1999, and the Euro become official tender form this date on (even when only under "cashless" form until 2001) (Johansson, 2010). This timeframe exactly matches the time of our analysis for which the correlation spiked and became positive, and found its way back to its prior 1999 level.

As an explanation for this increasing, and even positive correlation, we can cite the observed phenomenon of Mighri and Mansouri (2013), Hartmann et al. (2004) and R. Campbell et al. (2002), namely that an increased correlation is often due to crises or general uncertainty in the markets. In our opinion, this is a reasonable explanation for the change in 1999 because an implementation of a monetary union englobing different countries with different views and cultures is everything but straightforward and easy to achieve.

The correlation found its initial level back in the beginning of 2001. This can be due to the fact that uncertainty had vanished as the EMU project advanced until the effective putting in circulation of euro banknotes in the member countries, which was 1st January 2001. Once this date was reached, correlation was back at its initial level from the prior crisis.

As we can see in figure 5, in **September 2001** there was an abrupt rise in correlation from -0.25 up to -0.075 during the next few weeks following this date. The terror attacks on 11th September 2011 can presumably be seen as the reason for this jump (Nikkinen, Omran, Sahlström, & Äijö, 2008).

This atrocity gives rise in the western world to the uncertainty regarding terrorist threats and that no country, not even the United States of America are in security. We can say that even if this event was not in the heart of Europe itself, it had a spillover effect on European markets. This small jump in correlation cannot be seen as a structural change in correlation, because on an overall outlook, the period in which this terror attacks happened, can be best described as a benchmark period with no structural changes and a "normal" correlation.

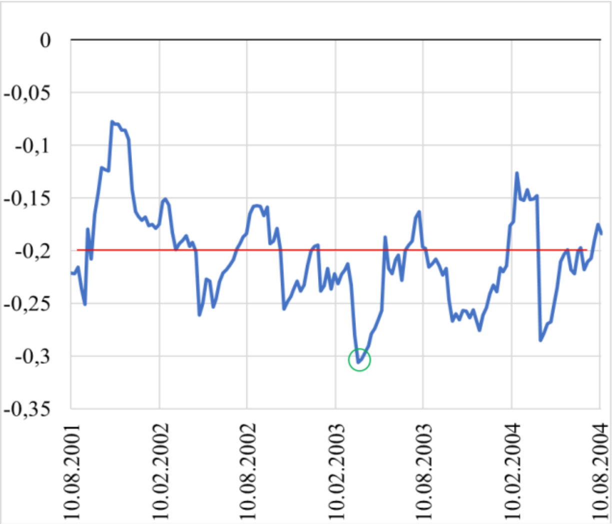

Figure 6 – Correlation between 2001 and 2004

From 2001 until 2005, there was no significant change in the stock-bond correlation. In our DCC GARCH estimations, there is only proof of normal fluctuations around the mean of -0.2, which is not unusual. This period is in fact in line with the theory in finance, namely that stocks and bonds move in opposite ways, due to the "flight-to-safety" phenomenon. Besides, we can find the lowest correlation of -0.306 (represented in figure 6 by the green circle) during the week of 21/03/2003.

Starting from the figures, we will analyze if there were in fact no major economic problems during this period. Given the relatively "normal" correlation with an average of -0.2 and no high volatility, it would be logical to assume that the European markets were not hit by crises between 2001 and 2005.

In fact, the only crisis that occurred, and this was only at the beginning of the 2000s, was the Dotcom bubble burst (Beattie). One could argue that, as it is the case for the terrorist attacks on 9/11, that this incident has a bigger impact on the US markets, even if a little spillover effect could be observed. We conclude that during the above-mentioned period, there was no major crisis or period of uncertainty, which is in line with the results we obtained for our correlation estimates. This conclusion is backed by different findings according to the literature, as stated during our literature review chapter, that periods of higher correlation are most often market by uncertainty, while periods of lower correlation are represented as normal given economic theory about correlation and opposite co-movements.

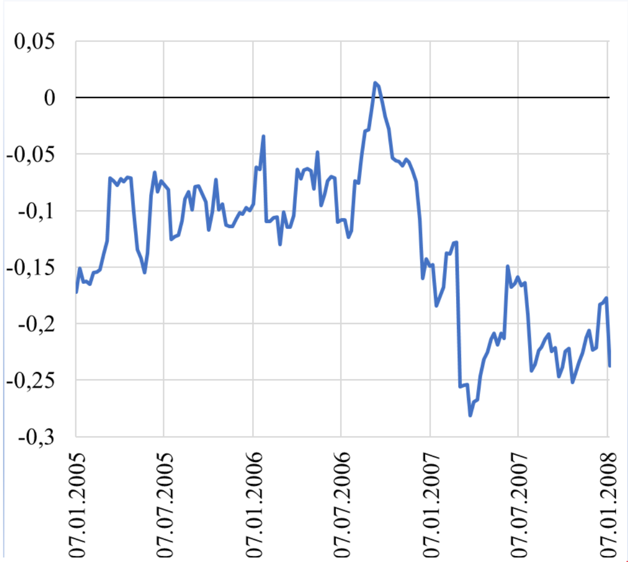

Figure 7 – Correlation between 2004 and 2008

While the average correlation between 2001 and 2005 was -0.2, there was an upward shift (as can be seen on the right in figure 6) starting in 2005. **Between 2005 and 2007**, the average correlation shifted up to -0.9, which is even below the overall average for our time frame. During the period represented in figure 7, correlation has constantly been higher and peaked during the end of 2006 and even became slightly positive for two weeks and reached 0.013.

This period was marked by a major uncertainty inside the European Union in the context of a European constitution. On 29th October 2004, the heads of state or government of member states signed the “Treaty establishing a Constitution for Europe” (Dumont, 2016). This treaty could have been ratified by congress of the different member states, nonetheless, some countries decided to ask their citizens via a referendum, and this was the moment the uncertainty regarding a European constitution started. Former president Jacques Chirac fixed the referendum date in France on 29th May 2005 while in the Netherlands the referendum date was fixed on 1st June 2005.

Both people voted against the implementation of the proposed EU constitution which let the European Union in a state of uncertainty about how to continue further integration ("EU constitution: Where member states stand," 2007; Sciolino, 2005).

The two weeks following the outcome of the referendum were marked by an increase in stock-bond correlation in Europe, namely from -0.16 up to -0.06. This proves again that uncertainty plays a major role in the determination of correlation. The results obtained cannot be a coincidence, because up to 2007, the obtained correlation estimates, and in linkage with the literature, provide sound results regarding the link between uncertainty and a higher correlation.

The uncertainty come from a doubt in Europe as a whole, as has been stated by Jean Quatremer on diploweb.com:

"Since May 29 2005, date on which the French rejected the draught constitutional treaty, followed three days later by the "no" vote in the Netherlands, the EU has been in a coma. […] In Brussels, the nerve centre of European institutions, the French and Dutch referenda were interpreted as a rejection, not only of the text under scrutiny, deemed, rightly or wrongly unsatisfactory, but of the "masters of Europe as a whole" : governments, Commission, European Parliament. All were stunned and have still not found the way to bounce back, assuming, that is, that such a way exists ; and that is quite a big assumption. […] What matters are not so much the reasons for the vote as what it means. When we try to explain to our European partners that the French referendum should be seen as a rejection of a certain Europe, a sanction by the pro-European left, their answer goes something like this : "Are you joking ? From the far right to the far left, a majority of French voters said 'no' and the pro-European section of the vote, assuming it exists, is very much a minority". Dumont (2016)

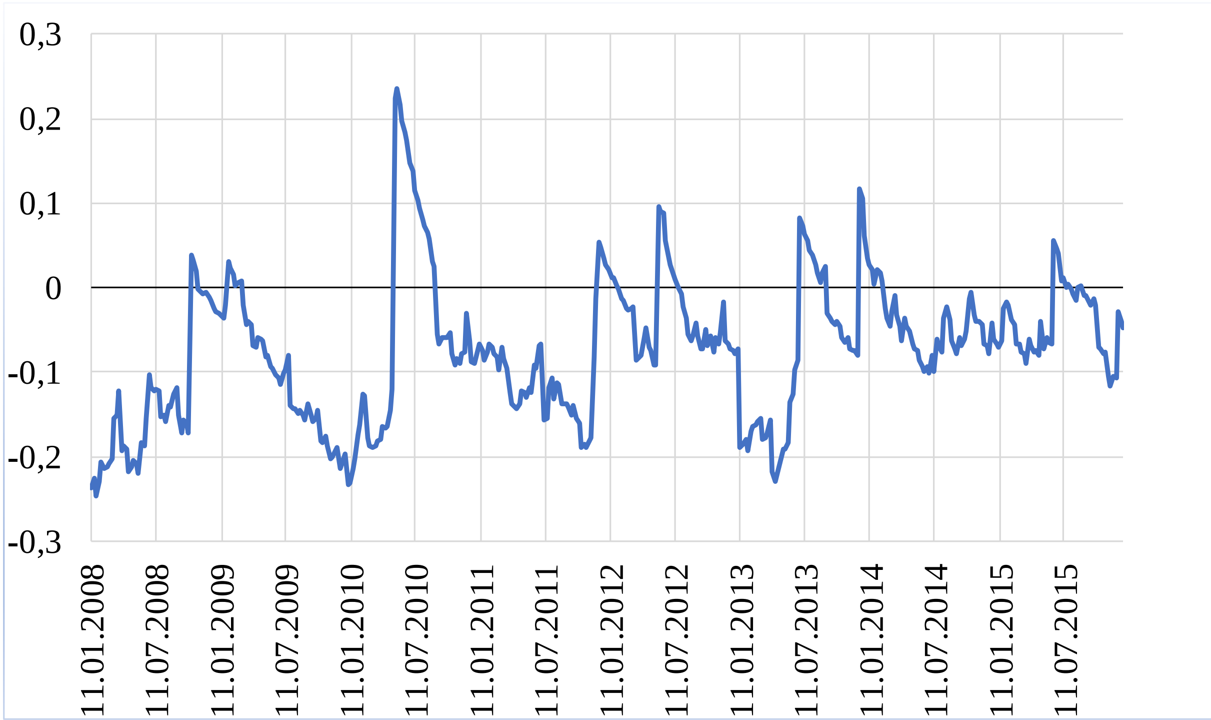

Figure 8 – Correlation from beginning 2008 until 2015

The next period will cover several more years compared to the previous smaller intervals, given the linkages and quick following of events starting during the world financial crisis and going over to the European sovereign debt crisis. The period is marked by many different events, and it will be less clear which event actually had an impact on the correlation in Europe.

Starting at the **end 2008**, the correlation was much more volatile, as can be seen in Figure 8. This is most certainly due to the start of the 2008 financial crisis, marked by the collapse of the investment bank Lehman Brothers on September 15th ("Case Study: The Collapse of Lehman Brothers," 2017). We can clearly see that following the official filing for bankruptcy of Lehman Brothers, the stock market and bond market return correlation in Europe started rising in order to reach a peak of 0.038 one month after the filing.

Contrary to the previous non-European crises, such as 9/11 and the Dotcom bubble, the fall of Lehman Brothers had an enormous spillover effect due to the banks interconnections with European banks. Following the contagion of the US crisis, banks started to get bailouts from government such as the Hypo Real Estate in Germany, Bradford & Bingley in Great-Britain and Fortis in the BeNeLux area ("Europe sees three bank bailouts in two days," 2008). With the problem of financial institutions filing for bankruptcy, different member states also start to struggle.

This contagion clearly shows, as a result, why correlation became higher, and even positive after the bankruptcy of Lehman Brothers on 15th September 2008. Considering the fear and uncertainty about the insolvency of a financial institution, it is not necessarily more attractive to invest in bonds than in stocks. Even if the bonds offer a higher security, as also explained by the "flight-to-safety" phenomenon, there are no real winners when the investee/lender goes bankrupt. We thus assume that the higher (and even positive) correlation is linked to the tremendous uncertainty not only investors, but also clients are facing. It became too risky to invest, be it as stocks or bonds, and this explains the shift from a normal opposite co-movements to a to certain extent co-movements in the same direction.

This being said, a purely European crisis follows, starting at the **end of 2009**. After the bailout of several institutions, it came to light that a few member states of the European Union are facing budgetary problems linked to a too severe public deficit. There are concerns about countries, such as Ireland, Portugal, Spain and Greece ("Timeline: The unfolding eurozone crisis," 2012).

At the **beginning 2010**, as already mentioned above, there were several concerns about the budget deficits of different member states, but it was, in our opinion, information about Greece that was at the roots of a soaring of the correlation. In January, the Greek budget deficit had been revised upwards from 3.7% to a new level of 12.7%, which already led to an increase in correlation. Afterwards, an additional revision of the Greek deficit followed in April, namely after correcting the accounting irregularities, the deficit would amount not less than 13.6%. The stock-bond correlation found its maximum of 0.24 during this period, namely in the weeks following the disclosure of these irregularities. This highly positive correlation can be explained due to the uncertainty of spillover effects. As Greece was subject to different bailout packages, uncertainty rose.

The next soaring, and crossing of the x-axis, of the correlation between bonds and stocks happened at the **end of 2011** and reached a level of 0.054. This can be explained by the fact that the EU agreed to further expand bailout packages ("Leaders agree eurozone debt deal after late-night talks," 2011). This agreement resulted in a more interconnected market with a higher risk of spillover and contagion. As this risk was rising, correlation among bonds and stocks also tended to increase as there was a major time period of uncertainty and crises.

In May 2012, correlation rose again to nearly 0.1. This time, we can observe that the main reason for this sharp increase is linked to an event in Spain, namely the bailout request of Bankia ("Spain's Bankia seeks 19bn-euro bailout from government," 2012). This happened after the part nationalization of the bank. Here again the anxiety is key to the higher as usual correlation. Given the situation where the Spanish banking system may need additional funds from the Euro zone to bail out its banks, investors and clients are concerned. Afterwards, the correlation found its way back to -0.2 at the beginning of 2013.

The stable period didn't hold very long, and the stock bond correlation rose again in the middle of 2013 to a value above 0 and on average of 0.04 for the two following months. Even if there is a sign of two consecutive increases of correlation in the middle and at the end of 2013, there is no proof of economic events that could be at the root of this movements. The only economic event that was a more positive one, namely the fact that Ireland is the first country to exit the EU bailout program at the end of 2013 ("Ireland becomes first country to exit eurozone bailout programme," 2013). This does not explain the positive correlation in our opinion.

We think that this only represents the general volatility in a period marked by uncertainty. As the general level of correlation is already high during the period, a high volatility can result in a crossing of the x axis for no obvious reason. **After June 2013**, the average correlation stayed relatively high at -0.035 until the end of our time frame.

Predictive model using an OLS regression

Now we will present the results of our regression analysis as well as an interpretation of the results. Firstly, before analyzing the results of our regression, we will present the descriptive statistics of our variables and briefly analyze them. Secondly, we graphically analyze and compare the different factors of each data section (topic) with the stock-bond correlation. We decided to only include the quantitative data and leave out the dummy variables in our graphics. Last but not least, after the analysis of our variables and the graphical comparison, we will analyze the results of the regression itself to verify the conclusions that we made in the previous sections.

We computed the descriptive statistics of each of our variables including the computed correlation itself. This table already gives a first impression of the different variables:

a) Descriptive Statistics

CATEGORY	VARIABLE	TYPE	AVERAGE	MEDIAN	MIN.	MAX.	STD. DEV.	OBS.
Correlation	Correlation	/	-0,1097	-0,1091	-0,3063	0,2354	0,0921	908
Base	EU_GDP	% Growth	1,5958	2,0000	-5,4000	4,6000	1,9339	69
	EURO_GDP	% Growth	1,3690	1,8000	-5,5000	4,5000	1,9951	69
	US_GDP	% Growth	2,2056	2,4000	-4,1000	5,3000	1,8728	69
	EuroInauguration	Dummy	/	/	/	/	/	/
Macroeconomic	EU_CPI	% Inflation	1,8905	2,0000	-0,5000	4,4000	0,9138	211
	EURO_CPI	% Inflation	1,7825	2,0000	-0,7000	4,1000	0,9363	211
	US_CPI	% Inflation	2,2152	2,1000	-2,1000	5,6000	1,3072	211
	SubprimeCrisis	Dummy	/	/	/	/	/	/
	DebtCrisis	Dummy	/	/	/	/	/	/
Financial	VIX	Level	17,5573	14,8811	7,5866	62,4004	8,1241	886
	Liquidity_Risk	Level	0,2157	0,0600	-0,6400	3,8400	0,5185	834
	GG10Y	% Yield	3,3475	3,7275	0,0780	5,6300	1,3749	908
	USG10Y	% Yield	3,84	4,00	1,45	6,77	1,26	908
Policy	ECBRate	Level	2,12%	2,00%	0,05%	4,75%	0,01	/
	QE	Dummy	/	/	/	/	/	/

Figure 9 – Descriptive statistics

We will move over to the graphical analysis of our different variables regarding the computed stock-bond correlation. We would like to highlight again that using a graphical approach is, in our opinion, a good alternative given our background and our time constraint to get a first overall view on the evolution of the different variables regarding the evolution of the correlation.

It is important to get a first point of view of the possible relationships that our variables might have. We will abstain ourselves from making definite conclusions based on this graphical analysis.

b) Base Factors

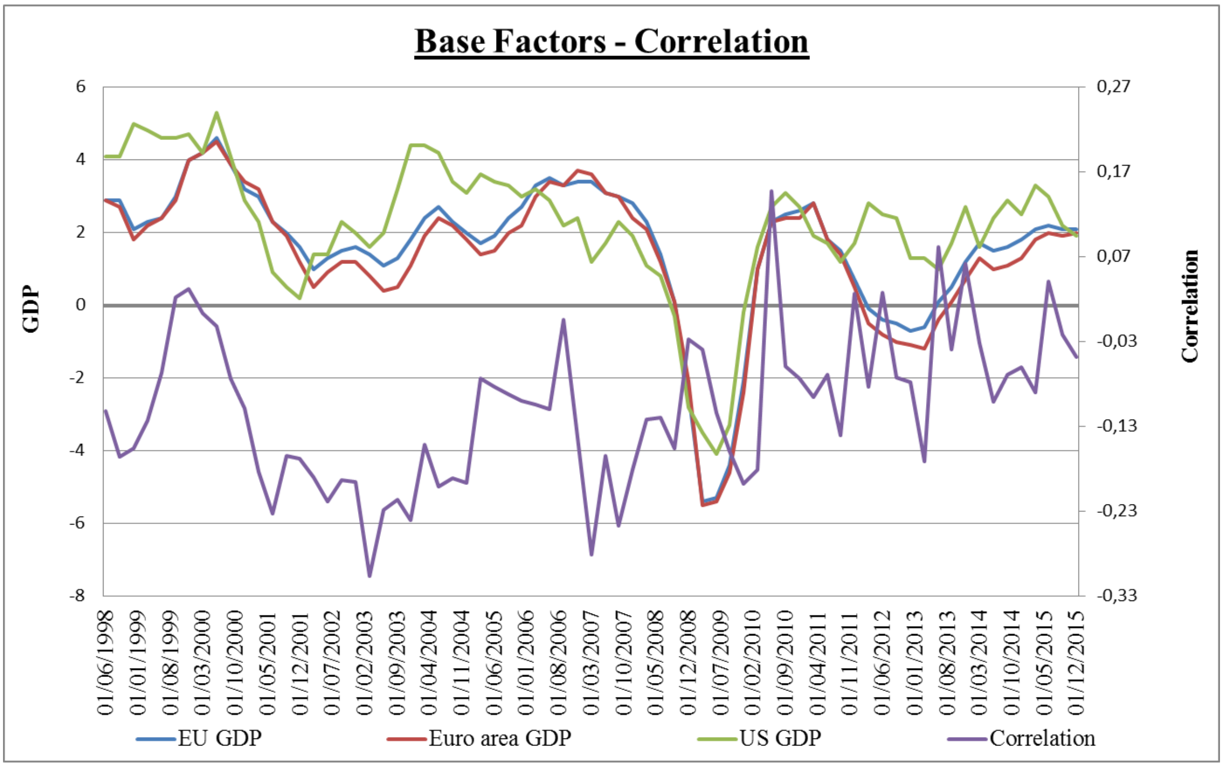

Figure 10 – Base factors in comparison to the stock-bond correlation

While we can't draw a definite conclusion on this graph, we can still observe a general trend: we can see on this graph that every time the GDP drops, the stock-bond correlation drops as well even tough with what seems to be a small delay. This observation also holds true for the opposite, if the GDP increases the stock-bond correlation increases as well. Yet again there might be a small delay of the correlation in regard to the evolution of the GDP. This observation holds true for EU, Euro zone as well as USD GDP. In fact, you can especially observe this phenomenon during the period of 2008/2009 as well as 2011/2012, when the GDP of the three regions drops sharply and the correlation drops as well. As a consequence of this first graphical analysis, we suspect that the GDP and the stock-bond correlation might have a positive β.

c) Macroeconomic Factors

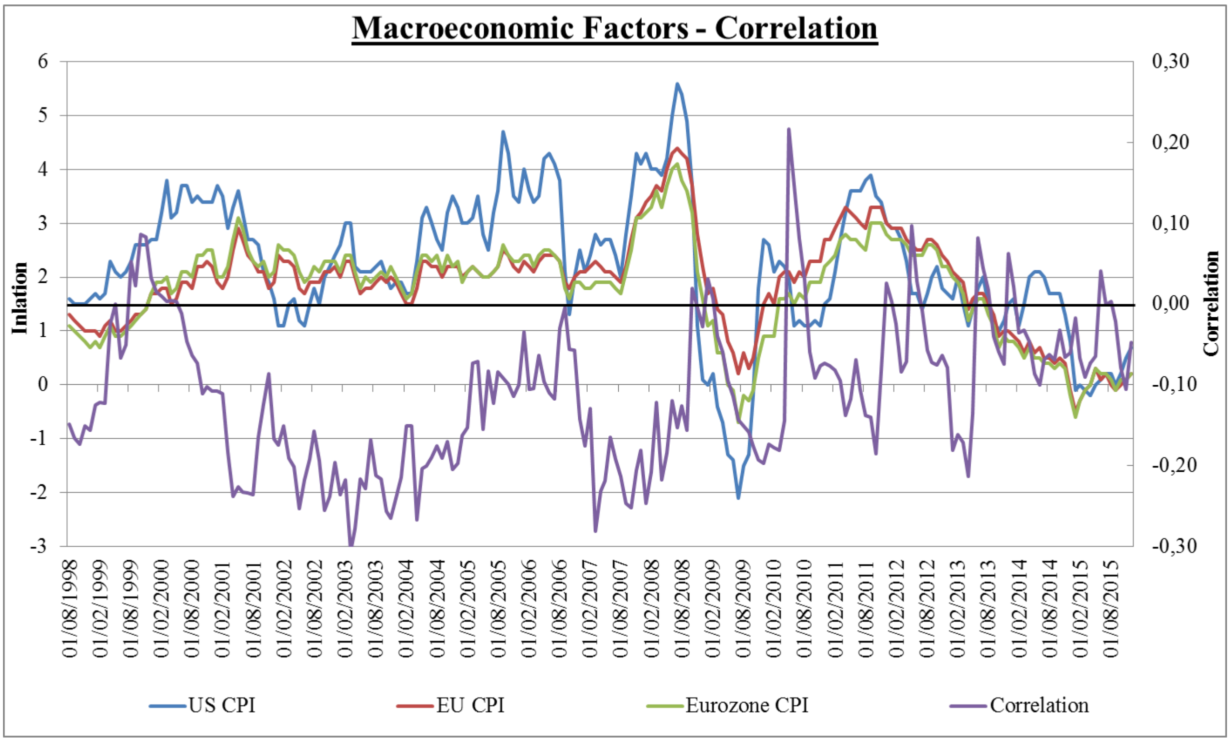

Figure 11 – Macroeconomic factors in comparison to the stock-bond correlation

This graphical representation suggests that the correlation and the inflation might have a positive relationship. In fact, you can observe on this graph that generally when the inflation increases, the correlation increases as well. If the inflation decreases, the correlation decreases as well. This hints to a positive relationship between these variables but it is important that we can’t make definite conclusions solely based on this graph. Moreover, we think that there is yet again a slight delay in the correlation’s reaction to a decrease or increase of the level of inflation. This observation can be made for US, EU and Euro zone inflation levels.

d) Financial Factors

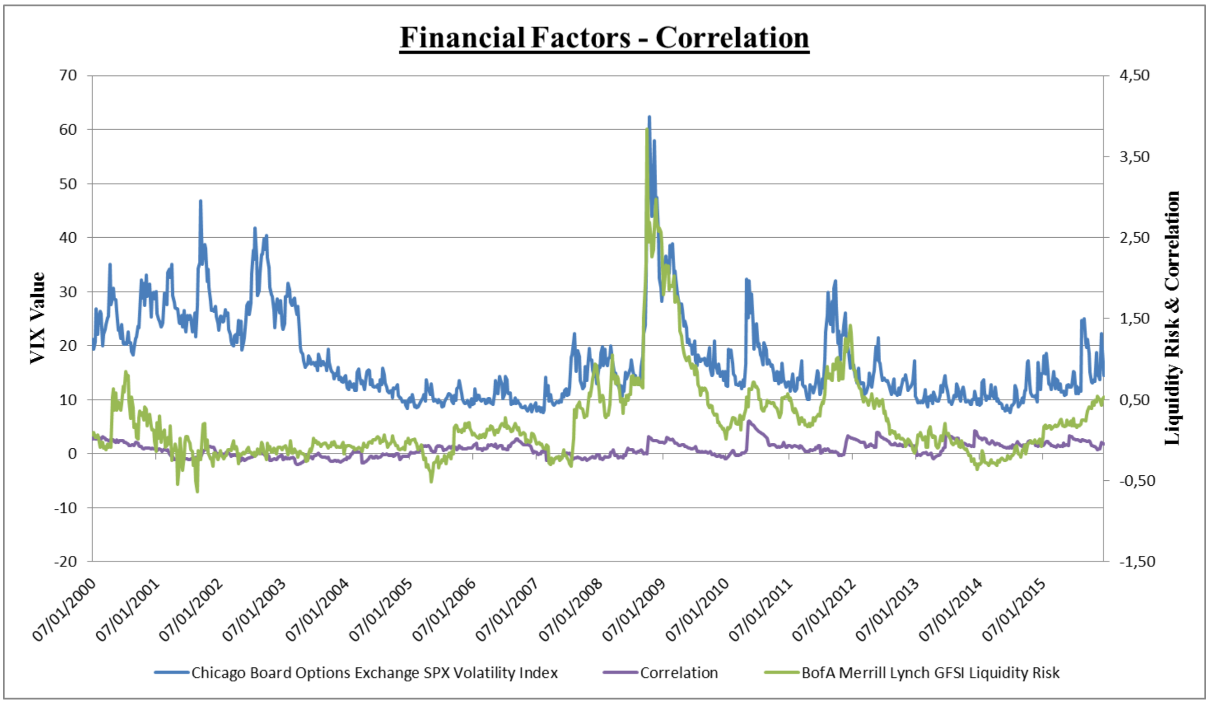

Figure 12 – VIX and Liquidity Risk in comparison to the stock-bond correlation

Here we can observe that every time both the VIX and the Liquidity Risk Index drastically increase, the correlation will increase as well. You can especially observe this during 2008/2009 when the VIX and the Liquidity Risk Index peak and the correlation increases as well even up to a positive state. You can observe similar situations during 2010/2011 and 2011/2012, when the VIX and the Liquidity Risk Index peak again and the stock-bond correlation will also make a jump and turn positive for a short period of time. These observations suggest that the volatility measures that we included in the financial factors category might have a positive relationship with the stock-bond correlation.

We did not include the German Bund and the US T-bill in this graph because it visually skewed the graph and we couldn't detect a reliable relationship with the stock-bond correlation. However, it is important to note that we cannot make conclusions solely based on our graphical representation. It is still possible that, despite the fact that we cannot observe a graphical relationship, the variables are statistically significant in our regression analysis and that these two variables might have a significant impact on the co-movements of the stocks and bonds.

e) Policy Factors

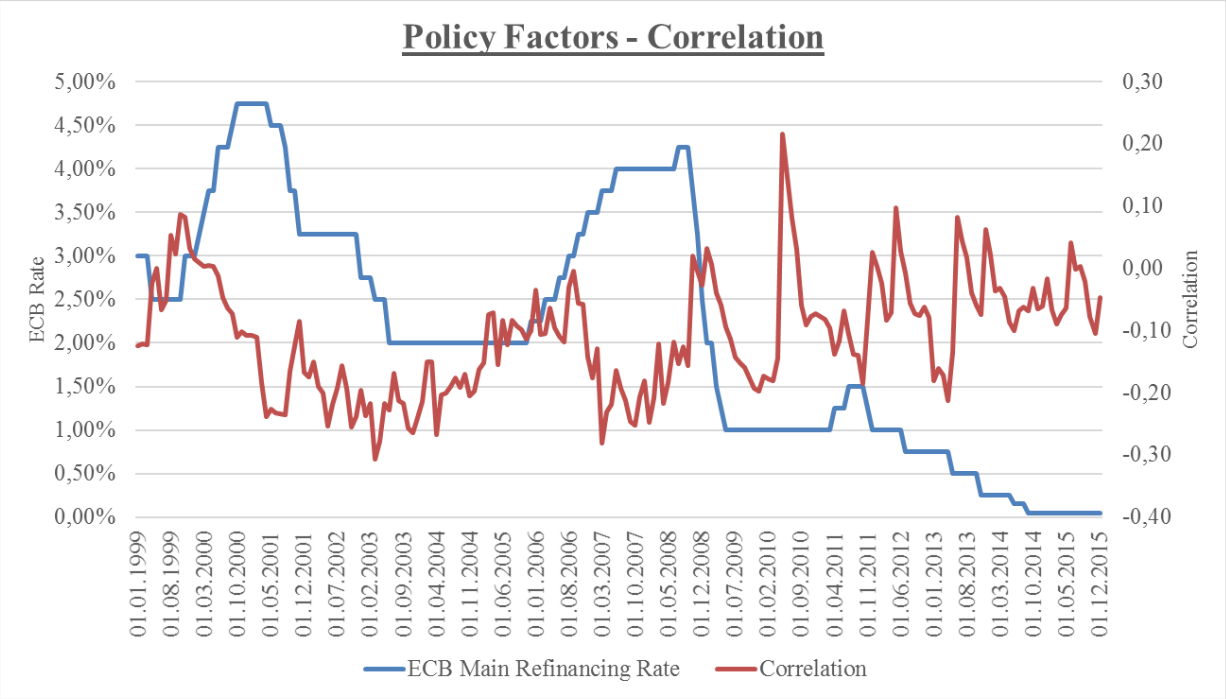

Figure 13 – Policy factors in comparison to the stock-bond correlation

If you graphically compare the ECB Main Refinancing Rate to the stock bond correlation you observe an inverse relationship: if the ECB rate increases, the stock-bond correlation decreases if the ECB rate decreases, the stock-bond correlation increases. You can see this during the early 2000s: when the rate increases, the correlation decreases. When the rate decreases in 2003/2004 or 2008/2009, the stock bond correlation increases and even turns positive. We think that those two variables have a negative relationship.

f) Regression analysis

In order to not to falsify our regression, we adjusted the frequency of the data that we used. Since the GDP is reported quarterly, we adjusted the rest of the datasets accordingly and based our regression analysis on quarterly data. Moreover, since the data collection of the Liquidity Risk Index started only in 2000, we made two separate regressions:

First of all, a regression starting in 2000 with all the datasets included except for the dummy variable “EuroInauguration” because in this point in time it would be redundant.

Secondly, we made a regression analysis starting in 1998, so before the Euro was officially in use in order to include the dummy variable “EuroInauguration”. As a consequence, we couldn’t include the Liquidity Risk Index in this regression analysis.

Last but not least, we computed one regression for each of our four categories of factors so that we can use them to compare the results of those regressions to the results of our overall regression (Appendix 5 to 8).

Over the course of the following pages we will analyze both of these regressions in more detail. We will analyze the regression statistics like the R^2 and Adjusted R^2 and compare them to the individual regressions of each category. Moreover, we will analyze the coefficient for each variable in detail and explain their impact on the stock-bond relationship. We will also verify if our variables are statistically significant or not and check their relevance over different levels of significance. Finally, we will compare those results with the conclusions of our graphical analysis as well as the findings of our literature review.

In the following table, you can see the results of our first regression:

Regression starting 2000			
Variable	Coefficients	t Stat	P-value
Intercept	-0,2061	-2,0067	0,0503
EU_GDP	-0,0652	-0,9469	0,3483
EURO_GDP	0,0596	0,9383	0,3527
US_GDP	0,0131	1,0839	0,2837
EU_CPI	-0,0520	-0,4908	0,6258
EURO_CPI	0,0818	0,7742	0,4425
US_CPI	-0,0250	-1,4565	0,1516
SubprimeCrisis	-0,0012	-0,0290	0,9770
DebtCrisis	0,0628	1,2173	0,2293
VIX	0,0014	0,6455	0,5216
Liquidity_Risk	0,0879	3,1597	0,0027
GG10Y	-0,0892	-2,0670	0,0440
USG10Y	0,0958	2,4074	0,0199
ECBRate	-1,3312	-0,6046	0,5483
QE	-0,1005	-1,7778	0,0816
with	R Square	Adjusted R Square	Observations
	0,5604	0,4348	64

Figure 14 – OLS regression starting 2000

In this table, you can see the results of our second regression:

Regression starting 1998			
Variable	Coefficients	t Stat	P-value
Intercept	-0,2671	-1,8367	0,0718
EU_GDP	-0,1198	-1,6529	0,1042
EURO_GDP	0,1093	1,6362	0,1076
US_GDP	0,0147	1,3164	0,1936
EuroInauguration	0,0581	0,6221	0,5365
EU_CPI	0,0103	0,1054	0,9164
EURO_CPI	0,0449	0,4463	0,6571
US_CPI	-0,0236	-1,2995	0,1993
SubprimeCrisis	0,0206	0,4816	0,6320
DebtCrisis	0,0276	0,5062	0,6148
VIX	0,0040	1,9140	0,0609
GG10Y	-0,1063	-2,4209	0,0189
USG10Y	0,1017	2,5400	0,0140
ECBRate	-2,2487	-0,9808	0,3311
QE	-0,0609	-1,0040	0,3199
with	R Square	Adjusted R Square	Observations
	0,4603	0,3204	69

Figure 15 – OLS regression starting 1998 (excluding liquidity risk factor)

The results of the individual regressions for each of our categories can be found in appendices 5 to 8. While these are not in the focus of our analysis, they will still be used to compare them to our two main regressions analyses.

First of all, we will analyze the goodness of fit statistic R^2. R^2 is the most common goodness of fit statistic and it measures how well our regression fits the data by measuring the variation in regard to the mean of the dependent variable. R^2 can take a value between 0, in this case the model doesn't explain any of the variation of the data, or 1 in this case the model explains 100% of the variation in the data. If the R^2 is too high this would hint to a problem of multicollinearity, which could lead to problems testing the statistical significance of our coefficients. Furthermore, it is important to note that we cannot make conclusions whether our regression model is adequate or not, solely based on R^2. However, it already gives a first impression on how well our model fits the data.

In the first regression, our R^2 is 0.56 and as a result of that our model explains approximately 56% of the variation. The R^2 of this first regression analysis is neither too high nor too low, so we can say that our model generally fits the data without taking about the extreme values. The R^2 of the second regression is 0.46. Again, we can say that the R^2 of this second regression model is neither too high nor too low. Since the R^2 for the first regression model is higher than the R^2 of the second regression model, one might say that the first model fits the data better. However, there is one key issue with the goodness of fit statistic R^2, namely, the statistic always changes if you change the variables or add more variables. In addition, R^2 never decreases if you add one or more variables. In order to solve this issue and to be able to really compare which one of the different regression models fits the data best we can use the adjusted R^2. The adjusted R^2 statistics takes into account the additional loss of degrees of freedom by adding more variables. More precisely, unless R^2 increases more than the offsetting caused by the addition of the variable, the adjusted R^2 will decrease if we add new variables. Thus, we can use this statistic to compare the different regression models.

The adjusted R^2 of the first regression is 0.43 while the adjusted R^2 of the second regression is 0.32. Solely by comparing the goodness of fit statistics we can say that the first regression model is more appropriate because it is able to better explain the variation in the selected data. In addition to that, we will compare these adjusted R^2 statistics to the adjusted R^2 of the individual regressions of each category (Appendices 5 – 8). The adjusted R^2 for the "Base Regression" is 0.087, for the "Macroeconomic Regression" its 0.22, concerning the "Financial Regression" it is 0.36 and for the "Policy Regression" it is 0.14.

As a consequence, we can say that our first regression model has the best fit to the data because it is able to explain 0.43 of the variation in the data which we consider to be sufficient to make predictions and conclusions if the coefficients are statistically significant.

Now we will analyze the different variables and their coefficients for the two main regressions.

First of all, we will analyze the first regression in more detail. Generally, our null hypothesis indicates that the estimated coefficient is equal to zero while the alternative hypothesis states that the estimated coefficient is not equal to 0:

$$H_0 = \beta_{kt} = 0\,;$$
$$H_1 = \beta_{kt} \neq 0$$

In order to determine the statistical significance of our variables, we will analyze the computed p-value at the 1%, 5% and 10% significance level. If the p-value of our coefficient is lower than 0.01, 0.05 or 0.1 respectively then they can be considered to be statistically significant in regard to our null hypothesis.

We can observe that the liquidity risk is statistically significant at the 1% significance level: our variable Liquidity_Risk has a p-value of 0.0027, which is lower than 0.01. This is coherent with Baele, Bekaert and Inghelbrecht (2010). According to these authors, market liquidity is an important variable that needs to be considered when analyzing the correlation of stocks and bond and ignoring liquidity factors would lead to a "failure" of the model. The coefficient of the liquidity risk is 0.0878. As a result, we can say that the stock-bond correlation and the liquidity risk have a positive relationship. If the selected liquidity risk index increases by 1, the correlation increases by 0.0878. This is of course an unsettling observation for investors. If the liquidity risk increases the stock-bond correlation increases as well this leads to a deterioration of the diversification effect which has a huge impact on the effectiveness of asset allocation in portfolio management.

At the 5% significance level, we can observe that both the Germany Generic Government 10Y Yield and the US Generic Government 10 Year Yield are statistically significant. The p-value of GG10Y is 0.044 and it has a coefficient of -0.0892. The variable USG10Y has a p-value of 0.0199 and a coefficient of 0.0958. All other things being equal, if the Germany Generic Government 10Y Yield increases by 1, the correlation between stocks and bonds will decrease by 0.044. The USG10Y and the correlation have a positive relation. Under ceteris paribus if the US Generic Government 10 Year Yield increases by 1 the stock-bond correlation will increase by 0.0958.

If we take a significance level of 10%, we observe that both the intercept and QE are statistically significant. The intercept represents the constant term of the linear regressions, the value where our computed best-fit line passes the y-axis. It is the mean value that the stock-bond correlation takes when all the other variables have the value of 0, even if in our case this can be considered as impossible. It is essential to include the intercept in order not to falsify the regression analysis by forcing the best-fit line to pass through y=0. However, we make no conclusions based on the statistical significance of the intercept because despite its general importance for a regression analysis, it doesn't play an important role from an economic point of view.

The enormous quantitative easing program of the European Central Bank is statistically significant at the 10% significance level. The dummy variable QE has a p-value of 0.0816 and a coefficient of -0.1005. Subsequently, the 2015 quantitative easing program of the ECB has a negative relationship with the co-movements of stocks and bonds. If all other factors stay the same and when the QE takes the value of 1, meaning that the QE program is active, the stock-bond correlation decreases by 0.1005. In other words, the activation of the QE decreases the stock-bond correlation. This seems to be very plausible since the QE program of the ECB focuses solely on fixed income and as a result of that can drastically change the stock-bond correlation. This holds especially true in regard to the amounts that the ECB invested during the QE program. This observation is of course good news for investors because it makes diversification and asset allocation more effective.

Concerning the GDP and the CPI, we came to the conclusions that these factors are not statistically significant at the 10% significance level because their p-value is higher than 0.1. These findings are coherent with the research of Lingfeng (2002), which couldn't retain GDP as a variable that influences the correlation between stocks and bonds among the G7 countries. However, this is in contrast to the findings of Lingfeng (2002) which concluded that there is "common exposure to macroeconomic factors: expected inflation, the real interest rate and unexpected inflation" (Lingfeng, 2002).

The same observation holds true for our dummy variables SubprimeCrisis and Debt Crisis. These variables have a p-value that is higher than 0.1. As a result, we can reject the H_0 hypothesis that these variables are statistically significant. This observation confirms the conclusions of Forbes and Rigobon (2002) who argue that there is no contagion or flight-to-quality effect caused by major crises but opposes the findings of Baur and Lucey (2009) who argued in favor of the existence of the flight-to-safety and contagion effect. During our regression analysis, we could not observe a contagion effect.

Now we will analyze the result of our second regression analysis in more detail. We make the same assumptions than for our first regression model: our null hypothesis states that the estimated coefficient is equal to zero while the alternative hypothesis states that the estimated coefficient is not equal to 0:

$$H_0 = \beta_{kt} = 0 \; ;$$
$$H_1 = \beta_{kt} \neq 0$$

We will test the statistical significance of our variables at the 1%, the 5% and the 10% significance level.

The outputs of our second regression suggest that at the 1% significance level, none of our estimated coefficients is statistically significant.

However, at the 5% significance level we can observe that both the GG10Y, so namely the Germany Generic Government 10Y Yield, and the USG10Y, so the US Generic Government 10 Year Yield, are statistically significant. The GG10Y has a p-value of 0.0189 and the USG10Y has a p-value of 0.014. The coefficient of the GG10Y has a value of -0.1063, which suggest that the 10Y German bund yield has a negative relationship with the correlation. More precisely, if all other conditions stay the same, or commonly called ceteris paribus, if the German bund yield (expressed in %) increases by 1 the correlation will decrease by 0.106. On the other hand, the estimated USG10Y coefficient has a value of 0.101 and as a result of that the US 10Y yield has a positive relationship with our correlation. All other things equal if the US 10Y yield increases by 1 (expressed in %) the correlation will also increase by 0.1017. We observed similar result in our first regression analysis.

The coefficients of these variables have a slightly higher magnitude in comparison to our first regression, but the direction and their statistical significance is the same.

At the 10% significance level both the intercept and the VIX are statistically significant. In our regression model, the intercept has a p-value of 0.0718 and a coefficient of -0.2671. While the intercept plays a crucial role in the computation of the regression analysis it is not of interest to further analyze the value of the constant term. The Volatility Index has a p-value of 0.0609 and the computed coefficient is 0.004. As a consequence, the VIX and the stock-bond correlation have a positive relationship. Ceteris Paribus, if the VIX increases by 1 point the correlation increases by 0.004. More precisely, if the volatility and uncertainty in the markets increase, as measured by the volatility index, the correlation between stocks and bonds increases as well. This is of course bad news for the financial markets because if the stock-bond correlation increases, diversification gets less effective. Furthermore, if volatility or uncertainties are high, investors diversify their risks by, among other things, investing in different asset types. If, as observed by our findings, diversification gets less effective this has a negative impact on all types of investors. This finding is confirmed by Baele, Bekaert and Inghelbrecht (2010) or Chiang et al. (2015). The authors concluded that models which include an uncertainty or risk aversion, variable outperform models that do not include them. So, in our case we can conclude that the VIX is both statistically significant and economically relevant for our analysis of the stock-bond correlation.

The EU, Euro zone and US GDP all have a higher p-value than 0.1 and thus cannot be considered to be statistically significant. This is coherent with the conclusions that we made based on our first regression model.

Moreover, the EU, Euro zone as well as the US CPI, also have a p-value that is higher than accepted under the 10% significance level. As a consequence, we have to reject the null hypothesis that the CPI is statistically significant in regard to the stock-bond co-movements. We made the same conclusions in our first regression analysis.

The ECBRate, has a p-value of 0.331 which is higher than the allowed 0.1. Because of that this variable is not statistically significant. The same holds true for EuroInauguration which has a p-value of 0.5365.

One major difference between our two regressions is that the VIX is not statistically significant in the first regression. In the first regression, the VIX has a p-value of 0.5 and a coefficient of 0.001 whereas in the second regression the VIX has a p-value of 0.0609 and is relevant at the 10% significance level. The first regression results oppose the conclusions of Baele, Bekaert and Inghelbrecht (2010) that the general volatility is a crucial variable in explaining the co-movements of bonds and stocks and stands in contradiction with our second regression. Moreover, the dummy variable QE is statistically significant in our first regression analysis which no longer holds true for our second regression for which we couldn't make conclusions based on this variable.

To conclude, we can say that for both of our regressions the Germany Generic Government 10Y Yield and the correlation US Generic Government 10 Year Yield are statistically significant at the 5% significance level and thus have a direct impact on the stock-bond correlation. In addition, we found that the VIX is statistically significant for our first regression and the liquidity risk for our second regression. Both of these variables represent uncertainty or general turmoil in the markets which has a significant impact on the correlation. These findings are coherent with our findings during the literature review. Last but not least, for our second regression we found the dummy variable QE to be statistically significant at a 10% significance level. This was not a huge surprise for us in regard to the big impact that the ECB's QE program had on the financial markets all around Europe.

Chapter 6: Conclusion

To sum up, we have estimated in a first attempt the correlation between stock market return, by using the Stoxx Europe 600, and the bond market return, for which we have used the Bloomberg Barclay's Euro Aggregate Total return bond index, since 1998 by using a DCC GARCH.

We have found that correlation in given periods is most of the time negative with an average correlation between the European stock and bond market returns of -0.11. This correlation is nothing but stable. This statistical characteristic motivated our choice to use a model that captures the dynamics and the conditionality of correlation. The DCC GARCH model does not need the underlying times series to be homoskedastic and without serial correlation. This is an important feature of the model given the conditional character of correlation, namely that periods of high correlation are followed by periods of high correlation and vice versa.

As already encountered during our literature review, we see that during our period, there are some weeks and months where the correlation spiked and became even positive. This is most often due, and confirmed by the literature, to market uncertainty and crises. Thus, for example, during the implementation of the Euro as a single currency in 1999 and consecutive peaks after the financial crisis in 2008, a period which has been marked by high uncertainty and which could be considered as a market crisis. It is not a surprise that correlation was highest during this period, namely in May 2010 with a value of 0.235. This peak was reached due to the beginning of the European sovereign debt crisis. Greece revised its budget deficit at the beginning of 2010, which led to an incredible market uncertainty and doubts about the European Union as a model. We have been able to assign most of the extreme correlation movements to economic problems in the real world.

Regarding the macroeconomic factors, we have made a bit of a surprising finding, namely that only three variables are significant at a significance level of 5%. For the other variables, we fail to reject the null hypothesis, namely that they are significantly different from 0.

The first factor that is significantly different from 0 is the liquidity risk factor, as defined by the BofA Merrill Lynch GFSI Liquidity Risk Index. Unfortunately, we could not test this factor for our whole sample due to a lack of data available. Nonetheless, we included this variable since 2000 which gives us a sufficiently long-time horizon to make a conclusion.

Secondly, we observed that the German 10 year "Bund" yield is significantly different from 0 (with a p-value of 0.044) and thus has an impact on overall correlation in Europe. With a coefficient weighting of -0.09, we observe a negative relationship between correlation and the 10y Bund yield. This means that increasing yields (and thus decreasing prices) result in a decrease in correlation. In other words, when investors sell their German Bunds, the price falls (and the yield increases), to buy stocks and so we have an increasingly negative correlation between European bonds and European stocks.

Lastly, the US 10-year bond yield is also significantly different from 0 with a p-value of 0.02. The relationship between the estimated correlation and the T-Bond is positive with a coefficient weight of 0.1. This means that an increasing yield on the 10-year US bond (and thus a decreasing price) has links to an increasing correlation inside Europe. The interpretation is not as straightforward as for the Bund. In our opinion, a decrease of T Bond prices is linked to a downsizing of US bonds (which happens in theory only in a market crises period) and as an alternative investment, investors start switching to European securities (bonds or stocks) which will lead to an increasing correlation.

All these things considered, we can say that estimated correlation in Europe is only impacted by factors that have direct links to the bond and stock market returns, such as the US and German 10-year yield, but also the liquidity factors. However, factors indirectly linked to the stock and bond market have no significant effect on correlation. Variables included in our regression, such as GDP, VIX, CPI, ECB interest rates do not have a significant impact on the evolution of the correlation according to our analysis.

All our findings have a potential impact on different domains. Such it is the case that, as already mentioned in the introduction, correlation has implications on risk management, portfolio management and different managerial domains. As already mentioned in the introduction, correlation data is often used as input for different models, such as portfolio allocation, analysis of the timing of new projects, pension fund management and different risk assessment models. A clear understanding of what moves correlation in Europe will help to improve the models, and thus the output.

A better model will have an impact on the realized gains, or also in more general terms on added value:

- Portfolio managers can be able to achieve a more coherent asset allocation as it is being stated by the father of modern portfolio theory, Harry Markowitz (1952), in which correlation is an important input;
- Risk managers can provide more economically realistic risk assessment reports. Correlation is also used by risk managers for hedging purposes and it is thus important to know if assets are positively or negatively correlated;
- Project managers will have the possibility to plan the timing of their projects better. Like this, managers will know whether it is better to keep investments in bonds, or to switch and to invest in projects when yields will become lower.

These different aspects considered, we can say that the understanding of correlation, as well as its forecast, is crucial in financial domains.

Even if we have tried to be as complete as possible, there are some limitations linked to our research. We will enumerate the most important ones, starting with the limitation that could impact our findings the most:

- The fact that our correlations obtained during the DCC GARCH regression are only estimations will have an impact on the OLS regression conducted in a second step. In other words, we use different x variables as explained during our analysis section in order to estimate an explanatory model for our y value, whereas the y value (namely the correlation between bond market and stock market returns) itself is already an estimation. We thus find ourselves in a situation where we are doing estimations starting from estimations which could potentially result in an incoherent result. Even if our analysis has been conducted properly, the results are always to be looked at with certain caution given the fact that it only is an estimation.
- The second limitation we have found is the fact that the output of an estimation, or even analysis, can only be as good as its raw data and its input. Given our relatively long-time horizon and the relatively young age of the European Monetary Union (EMU), it was difficult to find appropriate data that covers 17 years. Fortunately, we ended up finding two realistic and available benchmark indices, one for the European stock market and one for the European bond market respectively.

- In addition, analysis can always be more detailed or englobe more aspects and elements. This is notably the case in our analysis for the dynamic character of the EMU and the different notations. We notably had discussions if we only focused on Euro zone members, on EU countries or on Europe. It was also important to know if we considered a well-diversified benchmark, or a benchmark that includes companies given its economic importance. We analyzed only stable companies, be it only Euro denominated, investment grade bonds in our bond benchmark, or the 600 biggest companies in Europe and ignoring its geographical location. Furthermore, adding different other variables to include pan-European stocks, and also low rated bonds, but also defaulting companies would either create a dataset and a complexity impossible to handle and to analyze, or would lack of availability of sources that could be used.

In a later attempt, we would have several future research suggestions that could be of an interesting nature for the analysis of correlation:

- As we had to define our time frame before starting the analysis, there were events posterior to our last included day that could have had material effects on correlation in Europe. There has been the event which has been defined as the so-called “Brexit”, which consists of a referendum in the United Kingdom that aims the exit of the member out of the European Union. Such an announcement could already have had an impact on correlation, but the fact that the referendum passed and that the United Kingdom triggered article 50 of the Treaty of Lisbon on March 29th and is presumably leaving the EU in 2019 (Jason Beattie, 2017), will certainly have had an impact on the stock-bond correlation in Europe.
- In addition to the Brexit, there has been a major event in the United States which could surely have an impact on European correlation, namely the presidential elections. After the inauguration of Donald Trump as the new President of the United States of America, stock markets, represented by indices such as the S&P500, Nasdaq and Dow Jones, have seen a high volatile period (DeCambre, 2017). It has been seen that announcements and “tweets” made by the President have a big impact on the financial markets. In our view, it would thus be interesting to include the period of Donald Trump’s presidency in a future analysis.

- As correlation does not only exist between bond market and stock market returns, it would be interesting to analyze the relationship that exists between different countries inside Europe. Given our research, we have only focused on a European wide correlation between bonds and stocks, but in a further analysis there could be a similar approach but for different asset classes between different European countries which would also allow to conclude if there are what is called a contagion risk between the markets inside Europe.

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