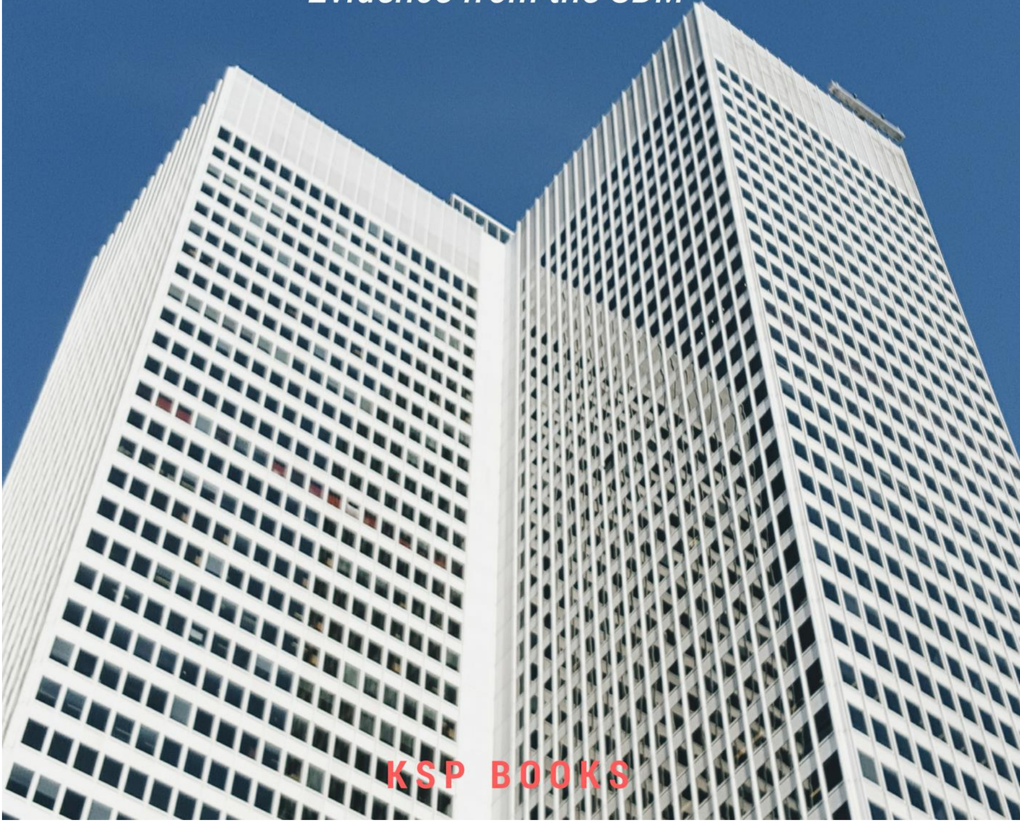
Bachar Fakhry

IMPACT OF THE CRISES ON THE EFFICIENCY OF THE FINANCIAL MARKET

Evidence from the SDM



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Preface - Summary

The efficient market hypothesis has been around since 1962, the theory based on a simple rule that states the price of any asset must fully reflect all available information. Yet there is empirical evidence suggesting that markets are too volatile to be efficient. In essence, this evidence seems to suggest that the reaction of the market participants to the information or events that is the crucial factor, rather than the actual information. This highlights the need to include the behavioural finance theory in the pricing of assets. Essentially, the research aims to analyse the efficiency of six key sovereign debt markets during a period of changing volatility including the recent global financial and sovereign debt crises. We analyse the markets in the pre-crisis period and during the financial and sovereign debt crises to determine the impact of the crises on the efficiency of these financial markets.

We use two GARCH-based variance bound tests to test the null hypothesis of the market being too volatile to be efficient. Proposing a GJR-GARCH variant of the variance bound test to account for variation in the asymmetrical effect. This leads to an analysis of the changing behaviour of price volatility to identify what makes the market efficient or inefficient. In general, our EMH tests resulted in mixed results, hinting at the acceptance of the null hypothesis of the market being too volatile to be efficient. However, interestingly a number of 2017 observations under both models seem to be hinting at the rejection of the null hypothesis. Furthermore, our proposed GJR-GARCH variant of the variance bound test seems to be more likely to accept the EMH than the GARCH variant of the test.

Key words: Efficient Market Hypothesis, Behavioural Finance Theory, Volatility Tests, GJR, GARCH, EGARCH-M, SWARCH, Sovereign Debt Market, Crises.

Contents

1. Introduction

The efficient market hypothesis has been the cornerstone of asset pricing since the mid-1960s. Essentially, as Malkiel (1962) and Fama (1965) hint the efficient market hypothesis simply dictate that the price of any asset should incorporate all available information immediately. This means that in the short term markets should follow a random walk as noted by Malkiel (2003). Yet the efficient market hypothesis relies on some untesTable assumptions like markets have to be perfectly competitive and market participants are rational risk averse profit maximisers. While these assumptions are made regularly in neoclassical economic, yet they do not always reflect the real world. Hence as hinted by Ball (2009), there have been many criticisms from policy makers and academics, especially in the aftermath of the financial crisis.

In essence, there is no way of testing the efficient market hypothesis directly. However, since the efficient market hypothesis dictates that prices should immediately reflect the information, thus meaning that markets should follow a random walk pattern in the short term. Hence, by testing the random walk hypothesis, we could test for weak form efficient market hypothesis using the variance ratio test as proposed by Lo & MacKinlay (1988). However, at the heart of the efficient market hypothesis, lays the key assumption that the price must immediate reflect the available information. Therefore, suggesting that the price must not deviate from the fundamental value by too much for too long, since, volatility is a measure of the movement in the price from the expected long-term price. Hence, a key test would be to test if the market is too volatile to be efficient using the variance bound test proposed by Shiller (1979) and Leroy & Porter (1981). Bollerslev & Hodrick (1992) argue that given the seasonality and clustering issues, a possible approach to the tests of market efficiency is the use of ARCH/GARCH models in the tests.

In essence, a market that is too volatile to be efficient hints at the requirement to study the psychology of the market participants. Since as De Bondt *et al.* (2008) hints market participants are homo sapiens and not homo economics. Therefore, pointing to the behavioural finance theory if we are going to understand such influencing anomalies as asset price bubbles and over- or under-reaction in the financial market. Both of which were present during the pre-crisis period and potentially both crises hint at the market participants' reactions to news and events leading to the price to deviate. Therein lays the key to understanding the behavioural finance theory; as Lee *et al.,* (2002) hints it is not the information that is important, it is the reaction of the market participants to the information. As highlighted by Blanchard & Watson (1982) and Branch & Evans (2011) the factors influencing the behavioural finance theory and in particular the asset price bubbles hint at the use of the ARCH/GARCH models in order to understand them. Hinted by Blanchard & Watson (1982) and more recently Branch & Evans (2013), another factor is that on some occasions an asset price bubble could periodically collapse suggesting the use of a regime-switching model.

With an estimated total global outstanding balance of $50.3 trillion as of end of 2013[1], the sovereign debt market is a large and key part of the global financial market. As stated by many (Giovannini, 2013; Fisher, 2013; Nakaso, 2013; Hannoun, 2013), it is often regarded as the low risk or risk free asset and thus large financial institutions are oblige to hold these assets as part of their portfolio by the Basel III regulations and national regulators. However, the sovereign debt crisis in both the Eurozone and US has highlighted a number of issues. Perhaps the biggest issue is how these securities are regarded as low risk, let alone risk free, as argued by Giovannini (2013), Fisher (2013), Nakaso (2013) and Hannoun (2013) among others. For these reasons, it would be interesting to test the impact of the crises on the efficiency of the sovereign debt market.

In essence, it is hard to argue against the fact that each of the recent financial and sovereign debt crises did change the global

[1] The Economist Intelligence Unit on 4th April 2014

financial market environment in general and more specifically the sovereign debt market. Importantly, this research does not go into any depth with regard to the impact of both crises on the financial market. However, the articles of Brunnermeier (2009), Caballero & Krishnamurthy (2009) and Masood (2010) amongst others highlight the multitude of articles written about the impact of the financial crisis. Equally, the sovereign debt crisis has attracted many research publications as illustrated by Schwarcz (2011), Metiu (2011) and Mohl & Sondermann (2013). The interesting factor is the impact of this changing global financial market environment on the efficiency of the sovereign debt market.

Although the efficientmarket hypothesis dictate that prices should reflect all available information. Yet whichever way you look at it, the key here is the information transmitted by the fundamentals and the news to the market participants. The evidence certainly does seem to be suggesting that there is a link between the pricing of information and the sovereign debt market as illustrated by Brandt & Kavajecz (2004) and Caballero & Krishnamurthy (2008), the later highlights the impact of information from news on the market participants in the financial market. However, the former highlights the impact of macroeconomic information on the sovereign debt market, which is key to understanding the impact of the fundamentals on the market participants.

This last statement is significant in understanding the sovereign debt crisis since the information underpinning the market is the macroeconomic policies of the central banks and governments, in other words monetary and fiscal respectively. These two policies are at the heart of the response to the financial crisis, as highlighted by Feldstein (2009) and Taylor (2008), and essential to understanding the ensuing sovereign debt crisis on both sides of the North Atlantic Ocean. The problem as hinted by Tobin (1971), there are issues in both policy responses to the financial crisis and at the heart of the sovereign debt crisis is the huge increase in the debt.

Although in general, the research targets the economics and finance academic environment. Yet the results and conclusions could be of interest to market participants and central bankers alike. Certainly, the emphasis on what influences the behaviour of price volatility in the sovereign debt market over an observed timescale including periods of financial and economical upturns and downturns would appear to market participants. Since highly volatile markets leads to added uncertainty, hence, as was obvious during the financial and sovereign debt crises market participants could suffer big losses. We hope this research shed lights on what makes markets highly volatile and therefore what moves the price in the financial market. On the other hand, this could also appeal to central bankers in their attempt at keeping market stability. Since the research sheds lights on the behaviour of market participants in a fast changing and highly volatile global market environment. In questioning the fundamental paradigms and theories underpinning asset pricing of the past 40-odd years, we hope to contribute to the academic discussions raging between proponents of the efficient market hypothesis and the behavioural finance theory

This last statement is the main motivation of the thesis to add to the discussion already taking place. On a more personal level, the motivation of undertaking such a hotly debated research is that it would provide a stepping-stone for my career as a research fellow in the academic environment where I can continue my research into the behaviour of volatility in the global financial market. Therefore, ultimately, contributing to the "next" theory of asset pricing. Another factor is that I wanted to extend my knowledge of the theories influencing asset pricing. In deciding to extend the research to cover the behavioural finance theory I hope I have added an important piece to the unfinished jigsaw. I have always subscribed to the age-old adjective "*You never stop learning*".

The introductory section of the thesis is in four main sections as is traditional with a research of this type. The first section is an in-depth description of the research idea and objectives. The second section is a review of the main contributions to the literature and thus knowledge made by the thesis. The third section is a brief review of the main conclusions in this research. The final section is a description of the structure of the thesis.

1.1. Objectives

The basic idea underpinning the research is the changing environment in the sovereign debt market in the aftermath of the financial and sovereign debt crises. An influencing factor in the pre-crisis period is that in many countries there was a prolonged economic upturn, which led to an asset price bubble in the mid-2000s. The research is based on the question did the financial and sovereign debt crises effect the efficiency of the sovereign debt market? In doing this, we hypothesise that the market is efficient and the alterative hypothesis is that the market too volatile to be efficient. Since essentially the market is either too volatile or not to be efficient, we need to analyse the behaviour of price volatility to understand what made the market efficient or inefficient during the pre-crisis, financial crisis and sovereign debt crisis period. This leads to the question: did the market participants underreact or overreact to events and information including news during the three observed periods?

Thus, the key questions underpinning the objectives are as follow:

1. Is the sovereign debt market efficient?

The efficient market hypothesis dictates that the market should incorporate all available information immediately into the price, thus meaning that the market resembles the random walk model as hinted by Fama (1965) and Malkiel (2003). This leads to the utilization of the Lo & MacKinlay (1988) variance ratio test in testing the observed sovereign debt markets for any deviation from the random walk model. We also follow Shiller (1979) and LeRoy & Porter (1981) in utilising the excess volatility in the sovereign debt market to determine whether the market is efficient. Since as hinted by Bollerslev & Hodrick (1992), the seasonality and clustering issues in the financial market, dictate the use of ARCH/GARCH models in testing and modelling the markets. We implement a version of the variance bound test (Shiller, 1979; 1981) using the GARCH model to test for excess volatility therefore testing the efficient market hypothesis. We also propose testing the efficiency of the market using a GJR-GARCH variation of the variance bound test to account for the different reaction of market participants to negative and positives shocks to the market.

2. Did the efficiency change in the aftermath of the financial and sovereign debt crisis?

We use a timeline analysis to identify whether the crises affected the efficiency of the market. The observations subdivide into three sample periods: pre-crisis, financial crisis and sovereign debt crisis. Using Table A1.1 in the appendix, we date the two crises periods. This allows us to analyse the change in the market efficiency and behaviour of price volatility in order to understand the effect of the both crises.

3. What does the volatility tell us about the behaviour?

The evidence seems to be suggesting that there are other factors influencing the sovereign debt market. We base our analysis of the behaviour of volatility in the sovereign debt market on the GARCH group of models introduced by Engle (1982) and Bollerslev (1986). As indicated by Branch & Evans (2011; 2013) the existence of bubbles leads to the use of two different GARCH models in order to understand the effect of bubbles on the sovereign debt market. Branch & Evans (2011) hints at feedback effects influencing the bubbles hinting at the use of the GARCH-m (Engle *et al.,* 1987) in understanding these feedback effects. As highlighted earlier in this review information affects the view of agents on the asset price and hence influence the bubble, this is crucial to understand the method of bubbles. In effect this point to the use of an asymmetrical model such as the EGARCH (Nelson, 1991) to understand this effect. Hence, we use the EGARCH-m (Nelson, 1991) to identify the feedback and leverage effects in the behaviour of volatility. And as Branch & Evans (2013) states there is certainly a hint of GARCH (Bollerslev, 1986) effect influencing the asset price bubble pointing towards volatility clustering effects. We use both the GARCH and EGARCH-m models to explain the behaviour of volatility in the sovereign debt market.

4. Does volatility follow a regime-switching trend in the sovereign debt market?

As alluded by Blanchard & Watson (1982), Evans (1991) and more recently Branch & Evans (2011), a periodic collapsing bubble can be analysed using a Markov switching process. There are many implementations of the SWARCH model, however the two most relevant are the Cai (1994) and Hamilton & Susmel (1994). The key to the Cai (1994) model is that the ARCH intercept is regime dependant, thus retaining volatility clustering and allowing the model to overcome spurious persistence. We opt to use the SWARCH model proposed by Cai (1994) to establish whether the trend in the price volatility does follow a regime-switching model and hence analyse the trend.

There are two additional objectives, which are contained within the efficient market hypothesis. One connected directly to the concept of the fundamental value whereas the other is at the heart of the assumptions underpinning the efficient market hypothesis. The key to understanding these two objectives lays in the two paradigms of economic: macroeconomics and microeconomics. In relation to this research, the different is that microeconomics is about the behaviour of rational market participants in the global financial market. Macroeconomic, on the other hand, deals with the fundamental economic indicators (i.e. inflation, growth and unemployment) and policy (i.e. fiscal and monetary) of the country.

The key assumptions underpinning the neoclassical economics theories of market participant behaviour dictate the efficient market hypothesis. These assumptions are at the heart of the on-going debate about the recent financial crisis and the banking sector. The debate mainly based around the microeconomics behavioural concepts of profit maximisation, rational market participants and risk aversion. In order to understand the effect of these concepts on the efficient market hypothesis, we need to study the theories influencing them.

Since as dictated by Fama (1965), the price must not deviate from the fundamental value in the longrun. This means that the price must reflect the fundamentals and news and therein lays the key to the second additional objective. This basis of the research is the sovereign debt market; hence, in order to study the impact of the fundamentals there is a need to research the macroeconomic theories. This highlights the fiscal and monetary policies implemented in the aftermath of the financial crisis. The objective is to analyse the theoretical foundation of these two policies and what are the benefits and costs of implementing such huge countercyclical policies.

1.2. Contributions to the Literature

The research contributes to the literature on financial economics in several ways. The main contribution is in the extension of the variance bound test; originally proposed by Shiller (1979; 1981) and LeRoy & Porter (1981). The variance bound test is essentially a test of whether the fundamental value as given by the present value equation does determine the behaviour of the price. Hence, as Shiller (1992) puts it the argument is that any excess volatility in the price is evidence of inefficient markets. Conversely, Shiller (1992) does not give any ideas as to which econometric model to build the variance bound test upon, and although Bollerslev & Hodrick (1992) point to the existence of seasonality and volatility clustering issues regarding the fundamental value leads tothe GARCH family of volatility models as a better way to test for excess volatility. Yet the majority of GARCH based variance bound tests use a plain vanilla symmetrical GARCH (p, q) model as derived by Bollerslev (1986). Since as documented by many including (Dungey *et al.,* 2009; Metui, 2011; Tamakoshi, 2011 and Mohl & Sondermann, 2013) market participants differentiate between negative news and positive news meaning they usually react with greater intensity to negative news. Hence, we proposed extending the variance bound test to include more complex, asymmetrical GARCH models by deriving a GJR-GARCH based variance bound test.

Another key contribution is that we research the effect of the crises on the efficient market hypothesis and the behaviour of price volatility. Since as hinted earlier the impact on the sovereign debt market did change in the aftermath of each crisis as illustrated by many[2]. This means that we subdivide the observation into three main observational periods: pre-crisis, financial crisis and sovereign debt crisis. By using this methodology, we could analyse the effect of each period and the impact of the crises on the efficiency of the sovereign debt market.

An influential contribution s wee undertake a study into what made the sovereign debt market efficient or inefficient in the aftermath of the crises by analysing the behaviour of volatility. Since as hinted by Blanchard & Watson (1982), Bollerslev & Hodrick (1992) and Evans & Branch (2011; 2013) amongst others the information contained in the GARCH family of volatility models could be the key to understanding many price anomalies in the sovereign debt market which cannot be explained by the efficient market hypothesis or neoclassical economics. Essentially, we use the GARCH, EGARCH-m and SWARCH models in the attempt to understand the behaviour of market participants in a fast changing environment, although there are many more that could be useful in providing an explanation.

In addition, we contribute to the literature via the observed dataset we use which has a double contribution. The first is that unlike all the empirical evidence concerning the sovereign debt market, we use the actual prices on the issues obtained from Bloomberg in our research. The past empirical evidence used the yields (Dotz & Fisher, 2011; Metui, 2011; Tamakoshi, 2011; Laopodis, 2010) and spreads (Mohl & Sondermann, 2013; Groba *et al.,* 2013; Favero & Missale, 2011; Missio & Watzka, 2011). The second contribution is the use of two issues for each of the sovereign debt market[3] to highlight the changing environment in the sovereign debt market following the crisis.

Perhaps the more important contribution is in the results. Firstly, the results seem to be indicating that the market environment does have an impact on the efficiency of the market. Although in general the market was too volatile to be efficient, however a key factor is that the markets are more efficient than was otherwise expected. Surprisingly during the periods of the crises, a number of the markets accepted the efficient market hypothesis most due to the GJR-GARCH. Hence, it would seem that the addition of an asymmetrical effect; may make the market more efficient. An influencing and key contribution factor in the possible explanation of the efficiency of the market is the

[2] For the impact of the financial crisis see Brunnermeier (2009), Caballero & Krishnamurthy (2009) and Masood (2010) and sovereign debt crisis see Schwarcz (2011), Metiu (2011) and Mohl & Sondermann (2013).

[3] The Greek was limited to just the 2002.

overreaction/underreaction stead state, which leads to the markets being efficient. This works by the over- and under-reaction within the observed period cancelling each other out, resulting in an overreaction/underreaction steady state meaning the markets accept the efficient market hypothesis for the observed period.

1.3. A Brief Review of the Main Conclusions

An influential part of the contribution to the literature on financial economic is our empirical evidence. Perhaps the most influential contribution in our research is the proposal to extend the variance bound test to include the GJR-GARCH model. In including the GJR-GARCH model, we accounted for the different reaction on the volatility from positive or negative shocks to the market. Interestingly our evidence seems to be suggesting that the use of different models of volatility would produce varying results of efficiency. Indeed the inclusion of the asymmetrical effect in the GJR-GARCH model seem to be hinting at the observed markets being increasingly efficient than using a plain vanilla symmetrical GARCH model. However, our test of the model specification given our observed datasets would point to the use of the GARCH model being more likely able to explain the information contained in the dependent variable. Nevertheless, notably the choice of the model depends on the observed datasets and periods.

As hinted in the previous paragraph, the observed dataset and periods explain part of the results. This is crucial in the conclusion for several reasons, firstly it highlight one of the main contributions, which is the impact of the crises on the efficiency of the sovereign debt market. The results from our empirical evidence seem to be going against expectation that during the financial and sovereign debt crises the observed markets were inefficient. Both our tests of the observed 2017 bonds seem to suggest that during both crises the majority of the observed markets were hinting at the rejection of the null hypothesis of the market being too volatile to be efficient. Coincidentally, during the pre-crisis period, the majority of the observed markets were hinting at inefficient markets in the 2012 bonds. However, what is more interesting is that for the same crises periods under the 2012 bonds the majority of the observed markets were inefficient. This could be due to the "on-the run" effect of the newly issued bonds and "maturity" effect of bonds approaching the end of lives.

The evidence from the GARCH models seem to be indicating that the behavioural finance theory is more likely to provide an explanation of asset pricing as indicated by various literature on the behavioural finance theory, especially Blanchard & Watson (1982), Bollerslev & Hodrick (1992) and Evans & Branch (2011; 2013). The evidence seems to be suggesting the existence of bubbles during the financial crisis, which hints at flights to quality or liquidity in action. The evidence certainly hints at the existence of a flight to quality or safety in the aftermath of the sovereign debt crisis.

In essence, this evidence is not surprising since market participants are homo-sapiens and not homo economics. The neoclassical economics assumptions underpinning the efficient market hypothesis, such as the existence of perfectly competitive markets and rational market participants, do not reflect the real world. Although there could be arguments made for both profit maximization and risk aversion, yet there is a conflict between the two illustrated by the financial crisis and to a lesser extent the sovereign debt crisis. As Abreu & Brunnermeier (2003) illustrates, the evidence certainly shows that even rational well-informed market participants seem to take by price bubbles and rides them too long. An interesting finding in our empirical evidence is that our results from the behaviour of volatility indicate that the efficient market hypothesis could be accounted for using the overreaction/underreaction hypothesis. Essentially, the counter-balances of these two reaction resulting in an overreaction/ underreaction steady stateindicating the efficiency of the market.

1.4. Structure of the Book

The structure of this thesis follows the standard format for a research of this type; divided into three main sections: Literature Review, Methodology and Empirical Evidence. However, each of these three sections subdivided into a number of sections reflecting the main subjects or objectivesmaking the thesis easy to publish as articles according to each objective. The literature review contains several key subjects linked to the behaviour of volatility in the sovereign debt market. The section reviews the theory and past empirical evidence where applicable. The next main section is the methodology, which lays the specification of the econometrics models used in the empirical evidence. The fourth section reviews the economic factors influencing the sovereign debt market including the main financial market indicators, monetary policies and fiscal policies over the observed period. These two sections build up to the empirical section, which present our evidence. As with all research, the final section presents the conclusions.

The literature review is the key section in any research of this type. Hence, there is a need to give a brief overview of the main sub-sections composing our literature review. The first section critically reviews the theories and neoclassical economics models influencing the assumptions of the efficient market hypothesis. It also reviews the literature on the theories and models underpinning the tests of the efficient market hypothesis. The second section briefly reviews the behavioural finance theory. Moving on to review the main factors and evidence influencing two key issues in the behavioural finance: underreaction/overreaction and the asset price bubbles. The third section critically evaluates the two fundamental macroeconomic policies influencing the sovereign debt market: monetary and fiscal policies. A special emphasis placed on countercyclical policies adopted by many central banks and governments in the aftermath of the financial crisis.

The fourth section is mainly a review of the theories and empirical evidence influencing the GARCH models of volatility in the sovereign debt market. It opens with a brief review of the alternative to the GARCH family of volatility models: ARCH, stochastic volatility and realized volatility. It continues to give an in depth review of the literature on the theoretical and empirical evidence of the GARCH models and also gives a brief overview of each model interpretations of the behaviour of volatility. The final part of this section is the switching ARCH/GARCH models, firstly reviewing the Markov switching model influencing these models. Then we review the theory and limited evidence of the SWARCH models.

2. Literature Review

In essence, this research is a study of the driving forces influencingthe price volatility in the sovereign debt market. In order to understand these forces we must therefore understand the influencing factors underpinning the two fundamental theories of asset pricing: the efficient market hypothesis and behavioural finance theory. As proposed by Malkiel (1962) and Fama (1965), the efficient market hypothesis argues that the price of any asset must immediately reflect fundamental information about the asset. Whereas the behavioural finance theory, as argued by Statman (2008) and Subrahmanyam (2007), states that in order to truly understand the movement of asset prices there is a requirement to include the psychology of the market participants.

Essentially, there are two factors underlying the efficient market hypothesis, the neoclassical economics theory and information (i.e. fundamentals and news). The assumptions underpinning the efficient market hypothesis are dictated by the neoclassical economics model of perfect competition which imply that market participants exhibit rational, risk averse (see Pratt & Zeckhauser 1987 and Kimball, 1993), profit maximising (see Friedman, 1953 and Alchian, 1950) behaviour. Since, the macroeconomic factorsmainly influence the sovereign debt market, thus dictating the fundamentals originate from the monetary and fiscal policies.

Testing the efficiency of the market utilises two basic assumptions of the efficient market hypothesis: the random walk model and the fundamental value. The efficient market hypothesis dictates that prices would resemble a random walk and prices should not deviate from the fundamental value in the long run as stated by Malkiel (1920 and Fama, 1965). Therefore, we review the variance ratio test and variance bound test proposed by Lo & MacKinlay (1989) and Shiller (1981a) respectively.

An opposing view is that various phenomena often influence asset prices, such as overreaction/underreaction as hinted by De Bondt (2000) and bubbles as defined by Barlevy (2007), which explained only by the inclusion of the behavioural finance theory. Put in simple terms, the behavioural finance theory dictates that the reaction of market participants to news or information that determines the price of the asset and since each market participant interprets the information individually the price deviate from the fundamental value.

Of cause the underlying themes of the research is the behaviour of volatility in the sovereign debt market. Hence, we review the literature and past empirical evidence on a number of volatility models such as the GARCH family first proposed by Engle (1982) and Bollerslev (1986). As highlighted by Blanchard & Watson (1982) and Branch & Evans (2011), the factors influencing the behavioural finance theory and in particular, the asset price bubbles hint at the use of the ARCH/GARCH models in order to understand them. Part of the research is to detect any changes in the behaviour of price volatility due to the impact of the financial and sovereign debt crises; in this case, the switching ARCH/GRCH models could provide an explanation of the behaviour of volatility before and after the crises. We mainly review the SWARCH models of Hamilton & Susmel (1994) and Cai (1994).

The structure of the literature review, split into two formats: the first three sections derive from the theoretical factors influencing the issues and a brief empirical subsection, which highlights the usage of the theory supplemented by a concluding review. The next three sections consist of two main sub-sections: theoretical and empirical evidence. The structure of the literature review is organised as following:

1. A review of the efficient market hypothesis and neoclassical economics influencing the assumptions of the efficient market hypothesis, followed by a review of the tests of the efficient market hypothesis
2. A review of the behavioural finance theory, overreaction hypothesis and rational bubbles
3. A review of the monetary and fiscal policies and their impact on the financial and sovereign debt crises

4. A review of the GARCH and switching ARCH/GARCH models

2.1. The Efficient Market Hypothesis

The dominant theory since the early to mid-1960s have been the efficient market hypothesis, developed through the contributions of prominence articles such as Malkiel (1962) and Fama (1965; 1970). However, to a certain degree the efficient market hypothesis relies on some untesTable assumptions and models. Yet it is possible to test the key assumptions of random walk and efficiency individually thru the use of prominent tests like the variance ratio and bound tests proposed by Lo & MacKinlay (1989) and Shiller (1981a) respectively.

At the basic level, the efficient market hypothesis is the perfect competition, which is widely used in neoclassical economics. Perfect competition implies the assumption that market participants are rational, risk averse and profit maximising. This assumption of market participants' behaviour extends to the efficient market hypothesis, as proposed by Fama (1965) and Malkiel (1962). This highlights the needs to evaluate the assumptions influencing the behaviour of market participants under uncertainty before we can research the efficient market hypothesis.

In this section, we will firstly evaluate the microeconomic behavioural theories influencing market participants under neoclassical economics. Next, we review the fundamental theory underpinning the efficient market hypothesis and analyse the empirical evidence on the pricing of information. Finally, we review the tests of the efficient market hypothesis and the empirical evidence of these tests.

2.1.1. The Microeconomics Behavioural Theories

Historically, neoclassical economics have been the dominant view in explaining the behaviour of financial markets under uncertainty. In essence, this view dictates that rational market participants should follow the key assumptions of profit maximization, Friedman (1953) and Alchian (1950), and risk aversion, Pratt & Zeckhauser (1987) and Kimball (1993), in their choice of investment. The key in understanding this argument is the negative correlation effect that the assumptions of profit maximization and risk aversion have on financial asset prices. This view have been criticised by many including proponents of the theory of behavioural finance such as Freeman *et al.,* (2004) and Kourtidis *et al.,* (2011). The key problem is the assumptions underpinning the view, are unrealistic, for example rational agents as explained by De Bondt *et al.,* (2008) and stockholder theory as argued by Philips (1997). In this section, we critically review the neoclassical view concentrating on the arguments influencing the assumptions of profit maximization and risk aversion.

However, since financial institutions with stockholders, dominate the sovereign debt market; it is necessary to discuss the stockholder theory. The stockholder theory dictates that businesses only exist to maximizethe stockholders wealth within the rule of the law; and as Alchian (1950) and Friedman (1953) hints this means the realization of profits; put simply as Alchian (1950, p.213) states:

> "This is the criterion by which the economic system selects survivors: those who realize positive profits are the survivors; those who suffer losses disappear."

This is also argued by Friedman (1953, p. 22)

> "Whenever the determinant happens to lead to behavior consistent with rational and informed maximization of returns, the business will prosper and acquire resources with which to expand; whenever it does not, the business will tend to lose resources and can be kept in existence only by the addition of resources from outside."

However, as many proponents of the stakeholder theory (such as Freeman *et al.,* (2004), Philips *et al.,* (2003), Philips (1997) and Hosseini & Brenner (1992)) would point out there is more to business ethics than just profits. The idea as defined by Jensen (2002) is that businesses have to take into account the interests of all stakeholders in the firm. By definition stakeholders includes all individuals and groups who can affect the welfare of the business and not just shareholders. However, Friedman (1970) argues that the only social responsibility for a business is to increase its profit.

This seems to be suggesting that as dictated by the market selection hypothesis in order for the financial institutions to survive, there is a need to attract investment funds and thus generate huge profits as hinted by Dutta & Radner (1999). The problem is that the behaviour of many of these financial institutions during the assert price boom of the mid 2000s points towards pure profit maximization. As defined by De Scitovszky (1943), pure profit maximization is the constant shifting of profit targets to maximize the utility function of the shareholders. In contrast, the key argument of Alchian (1950) and Tintner (1941) is that businesses just have to make a positive profit to survive. The key point is, if they make losses they struggle to survive as hinted by many including Alchian (1950) and Friedman (1953). A point in case is the bankruptcy of Lehman Brothers and hence the government bailout of many financial institutions during the financial crisis.

In a way this led to the accusations by many including government inquiries[4] into the crises of financial institutions being too risk loving and greedy. However, the point defined by Kimball (1993), standard risk aversion follows a marginal increasing function, which means that bearing one risk makes the market participant less willing to bear another risk. Another argument highlighting this is that increasing risk leads to an upward shift in risk aversion as noted by Diamond & Stiglitz (1974). This seems to be the overwhelming behaviour during the recent financial and sovereign debt crises. A counter argument is that market participants' behaviour seems to be following proper risk aversion. As defined by Pratt & Zeckhauser (1987), proper risk aversion dictates that with respect to two independent risks, the rejection of one risk does not automatically deflect the market participants from taking the other independent risk. This is mainly due to market participants hedging their risks by the use of derivatives instruments such as options and futures. An example is the use of credit default swaps as hedges against the risk of a government defaulting on its debts. However, a key point made in Alchian (1950) definition above is that companies that make losses do not survive and this highlights an alternative argument that many market participants display loss aversion rather than risk aversion. As defined by Kahneman *et al.,* (1991) and Thaler *et al.,* (1997), loss aversion dictates that market participants tend to be increasingly sensitive to a loss than to a gain or put simply the feedback effect. This is obvious from the reaction of the financial institutions during the sovereign debt crises where a loss made the institutions averse to any further losses. This meant that the crises quickly spread from Greece to other sovereign debt markets.

This leads us to the utility functions of the agents, since these agents caused the problems as often cited by government inquiries into the crises (see footnote 4). Given an option between a number of similarly risky investments, utility maximization theories dictate that the agent choses the one with the highest income. However, in a situation where the agents of financial institutions face investments of different risks, the key question is how can they choose the investment, whichmaximizes their utility? This problem occurs if interest rates are low and banks therefore take on larger risks for a higher return. This has resulted in the development of a sub-prime mortgage market, for example, where prices no longer reflect the risks, which ultimately led to the collapse of the market. The collapse occurred despite the existence of derivatives

[4] Such as the House of Commons Treasury Committee Report Number 416 in the UK and Financial Crisis Inquiry Commission Report of January 2011 in the US.

instruments such as CDS to insure against that risk. Surely, this would conflict with the utility maximization behaviour of buying risky securities such as subprime mortgage securities. Still, this behaviour can be justified as rational, when one takes into account an S-shaped utility curve. Friedman & Savage (1948) and Hartley & Farrell (2002) argue the possibility of non-concave or non-diminishing marginal utility function leads to different behaviour towards risk. This could explain the rational behaviour of the huge gamble taken by the agents during the recent housing and mortgage backed securities prices bubble. So in essence, the argument is that even efficient markets can lead to market instabilities. As the crisis has shown, however, many market participants did not actually know what they were buying as illustrated by (Beltran & Thomas, 2010; Brunnermeier, 2009; Gorton, 2008). Therefore, the validity of this argument is questionable in the least.

However, as argued by Pennings & Smidts (2003) the evidence points towards an S-shaped utility function curve governed by the agent's attitude towards profit and loss, in other words, the shape of the utility function depends on the initial situation, which is not compatible with rational behaviour. As this makes the utility function unsTableresulting in higher volatility of observed bond prices, as buying and selling of bonds depended on the changing utility function. So in essence, the argument is that even efficient markets can lead to market instabilities.

The utility function of the agents in the financial sector dictates the supply and demand model is the reverse of the standard model as suggested by Cifuentes *et al.,* (2005) and Shin (2005). And as hinted by Shin (2005), this means under profit maximization behaviour demand in high return assets increase putting upward pressures on the equilibrium price, while risk aversion behaviour not only reverses the demand for high return assets, due to the high risk associated with these assets, but also increases supply leading to a decrease in the equilibrium price. The sovereign debt crises elegantly illustrated this, in the high demand environment of the flight to liquidity or quality during the financial crises; governments were able to control the increase of demand by issuing more debt. During the sovereign debt crises demand for several sovereign debts decreased hugely but the point here is, the supply also increased putting huge downward pressures on the prices. The reasons are simple unlike the standard model of supply and demand which dictates when prices go down the issuer could reduce the supply to ease the pressures on the equilibrium price. The existence of a secondary market meant that as market participants became increasingly risk averse due to a high possibility of defaults, they sold the debts meaning the secondary market became overstocked and the prices plummeted. So no matter what the governments of the GIPS nations or the Eurozone tried to do, they could not reduce the supply and hence the yield.

As already hinted above, an argument often used against the neoclassical economics is that market participants are not all rational as suggested by Hong & Stein (1999) and Kourtidis *et al.,* (2011). In addition, unlike the assumption dictating that the impact on the prices from irrational market participants is short-lived, the evidence from Barberis & Thaler (2003) is that the impact is long-lived. The other issue concerning neoclassical economics is that the basis for many of the simplifying assumption of the models is that all market participants exhibit rational risk averse profit maximisation behaviour. As with the previous argument, the existence of heterogeneous market participants each with a different attitude to risks and earnings means that this assumption of homogeneous behaviour regarding risks and earnings does not hold. In this case, we need to use behavioural finance theories to identify the impact of heterogeneous market participants in different circumstances as illustrated by Hong & Stein (1999).

2.1.2. Review of the Efficient Market Hypothesis

Before we can start reviewing the efficient market hypothesis, there is a need to defineinformation in thecontext of this research. Although as hinted by Fama (1970) and Malkiel (2003), the efficientmarket hypothesisdictates that prices should reflect all available information (which is why we use prices rather than spreads to check for market efficiency in this thesis). It is common practice to distinguish information in terms of fundamental and non-fundamental information (Bollerslev & Hodrick, 1992). In other words, information is the summation:

- the fundamentals, such as yieldsor macroeconomic factorsin thesovereign debtmarket,as hinted by Cochrane (1991) and Malkiel (2003),
- non-fundamentals, such as informationfrom news (i.e. they do not have any direct relationship to the asset but still have the power to influence the price such as the 9/11 terrorist attacks, Lehman Brothers bankruptcy in 2008 and Japanese Earthquake in 2011), as hinted by Caballero & Krishnamurthy (2008).

Fama (1970) notes simply put the efficient market is a market where market participants are assumed to exhibit rational profitmaximization behaviour and prices always fully reflect available information. In essence, as Malkiel (2003) states the view influencing the efficient market hypothesis is information spreads quickly and priced into asset valuation immediately. Hence, as

Malkiel (2005) states this means that no arbitrage opportunities exists that allows for excess returns without excess risks. As Malkiel (2003) hints in an efficient market, competition will mean that opportunities for excessive risk adjusted returns will not persist. However, this does not mean that the efficient market hypothesis imply market prices will always be accurate and all market participants will always exhibit rational profit maximization behaviour.

According to Fama (1970), the efficient market hypothesis dictates that any model of expected price should follow the notation of $E(\tilde{p}_{j,t+1}|\phi_t) = [1 + E(\tilde{r}_{j,t+1}|\phi_t)]p_{jt}$. The importance of this equation in the concept of this research is ϕ_t. According to Fama (1970), this suggests that the expected price based on all available information at present is the price at present plus the expected return based on all available information at present. As Fama (1970), states this notation of the expected price, means regardless of whichmodel (e.g. APT or CAPM) used to derive the equilibrium price, expected return should fully reflect all information available at present, transaction costs and taxations being equal. Remember, as noted by Fama (1970), where expected excess value or return on the asset is equal to zero then by definition the excess value or return is a fair game with respect to the information available. In essence as quoted by Malkiel (1962), the expectation of the future price of the asset strongly influences the price of any long-lived asset. However, as put by Malkiel (1962), it is plausible that the recent past dictates the market participants' expectations.

As suggested by both Fama (1965) and Malkiel (2003), the efficient market hypothesis is associated with the idea influencing the random walk model. A big issue with regard to the pricing of information, as seen in numerous events during the recent financial and sovereign debt crises, is nobody can predict the impact of information especially under uncertainty. Hence, as Fama (1965) states during periods of uncertainty the equilibrium price can never be determined exactly. Moreover, as hinted by Fama (1965) the instantaneous adjustment property of the efficient market hypothesis may cause successive independent price changes, which imply prices follow the random walk model. As defined by Malkiel (2003, p.59)

> "The logic of the random walk idea is that if the flow of information is unimpeded and information is immediately reflected in stock prices, then tomorrow's price change will reflect only tomorrow's news and will be independent of the price changes today."

Although, as stated by Fama (1970), the random walk model does not state that past information has no value in assessing distribution of future returns. However, the random walk model does state that the sequencing of past returns has no value in assessing distribution of future returns. This last statement could infer the random walk model simply put is the direction in the short run of expected returns and hence prices is unpredicTable given all available information; however in the long run the trend in the market prices is partially predicTable as stated by Malkiel (2005). Furthermore, as stated by Timmermann & Granger (2004), this makes the efficient market hypothesis notoriously difficult to forecast prices and returns. The key logic behind this is if prices and returnswere forecasTable, it would mean the existence of unlimited profit, which would make the economy unsTable as noted by Timmermann & Granger (2004).

As hinted by Ball (2009), many in the regulatory, financial markets and academic environments were critical of the efficient market hypothesis in the aftermath of the financial crisis. The reasoning behind their argument boils down to the key notation underpinning the efficient market hypothesis that market prices should reflect all available information. This led to the false sense of security by regulators and market participants that market prices were correct based on all information leading to an asset price bubble. Ball (2009) argues that while like all good theories the efficient market hypothesis does have major limitations; however, appear to exaggerate the criticisms in the aftermath of the global financial crises. Since the theory of the efficient market hypothesis was only published by Fama (1965), this argument is invalid since there have been many crises based on the asset price bubble before the advent of the efficient market hypothesis. Ball (2009) points to the fact that the efficient market hypothesis states current asset prices are correct based on all available information; this means that market participants should accept asset prices as correct. However, in the pre-crises asset price bubble many market participants thought that asset prices were "incorrect" and hence they could beat the market. This does seem to suggest that for some market efficiency based on all information the price is right/ correct. However, this is misleading, since the efficient market hypothesis, as defined by Fama (1970), does not state that the price is right/correct; it only states the price should reflect all available information.

A key argument often put against the efficient market hypothesis is that sometimes asset prices deviate from the fundamental value as hinted by many including Barberis & Thaler

(2003) and De Bondt *et al.,* (2008). In addition, as illustrated by Barberis & Thaler (2003) these deviations can be long-lived and substantial. Another issue raised by Hong & Stein (1999) is that market participants may not have access to all the information. And even if they do, as suggested by De Bondt (2000) and Daniel *et al.,* (1998) they may have different sentiment about the information.

A key assumption used in the efficient market hypothesis is the existence of well-informed wealthy rational arbitrageurs who push the asset price back to its fundamental value (Fama, 1965). As Hong & Stein (1999) illustrate the existence of these arbitrageurs does not counter the effect of other market participants and Abreu & Brunnermeier (2003) argue that these arbitrageurs sometime like to take advantage of the circumstances therefore pushing the price further from the fundamental value.

Another key argument is that markets often go thru phrases where the efficient market hypothesis is not enough to explain the anomalies, e.g. bubbles (see Blanchard & Watson, 1982; Hong & Stein, 1999; De Bondt, 2000; Abreu & Brunnermeier, 2003). Hence, there is a need to research the psychology of market participants as suggested by De Bondt *et al.,* (2008) and Kourtidis *et al.,* (2011). This leads towards the use of the behavioural finance theory.

The evidence seems to suggest there is a link between the pricing of information and sovereign debt markets and as Brandt & Kavajecz (2004) hints there are two main mechanisms for the daily changes in yields on sovereign debts: flow of public information and price discovery. However, as illustrated by the numerous empirical studies, the majority of the evidence is on the effect of macroeconomic information and the heterogeneous interpretation, known as price discovery, or public information. Christiansen (2000) argues that contrary to equity and corporate bond, in general there is no private information in sovereign debts returns. Thus, generally any movement in the returns on sovereign debts must come from public information, i.e. macroeconomic announcementsand since the time varying return volatility of financial assets are autocorrelated and highly persistent, hence macroeconomic announcements could explain the high persistent observed in the volatility of sovereign debt markets. However, according to Greenwood & Vayanos (2010), macroeconomic variables sometimes cannot fully explain the variation in the yield curve and hence shifts in demand and/or supply of sovereign debts are other important drivers in understanding the movements in the yield curve.

According to Fleming & Remolona (1999), the key implications stemming from how public information influences the US Treasury market is the extent to which it drives the price movement and market makers are not confronted by imperfect information when trading. As implied by the article unlike many other financial markets, the treasury market being dominated by non-market based trading hence it is restricted by maximum or minimum limits on bid-ask spreads or price changes, therefore spreads and prices can adjust endogenously on public information. They identify two stages in the market's adjustment for price formation and liquidity provision in the immediate aftermath of the announcement of public information: during the brief first stage, there is a sharp and instantaneous change in prices and a reduction in the trading volume. During the next stage persistence trading surges leads to high price volatility and moderately wide bid-ask spreads.

Bollerslev *et al.,* (2000) analysed the 5 min intraday US Treasury bond futures data over the period January 1994 to December 1997; researching long-memory volatility in macroeconomic announcements in the observed data. They foundthat US Treasuries futures exhibit long memory volatility in certain macroeconomic announcements. According to their research, the open and close of markets have higher volatilities than mid-day. The results indicate macroeconomic announcement is a key source of US Treasuries market volatility compared with prior results for FX and equity markets.

In an empirical study by Balduzzi *et al.,* (2001) on the effect of regular macroeconomics news on a number of US Treasuries, the study found the greater the unexpected macroeconomic news announcement is, the more significant the impact on the price of at least one of the US Treasuries. They found that generally the price is usually the first affected by the announcement hinting that public information mainly drives the initial price adjustment. The next stage is the widening of the bid-ask spread suggesting informed trading drives both volatility and volume. The final stage is the continuation of the volatility and volume beyond the normality of the bid-ask spread hinting at liquidity trading. According to the article, different macroeconomic factors have different effects on the various securities. However, several announcements have significant impact on a number of securities and the impact varies depending on the maturity. They conclude that surprises in the announcement have a substantial impact on the price volatility but the bid-ask spreads seem to recover quickly hinting at public information being rapidly absorbed into the price.

In another empirical study by Brandt & Kavajecz (2004); show that price discovery is not necessarily concentrated around the time of the public information announcement. They imply at the existence of many factors influencing changes in the daily yield and therefore the structure of the yield curve but highlight two main complimentary factors: public information flow, such as periodically macroeconomic information releases, and heterogeneous interpretation of public information, i.e. price discovery, via trading in the Treasury market.

Interestingly, the Andersson *et al.,* (2006) study of the effect of macroeconomic news from various countries on price discovery in the German long-term government bonds market finds that in general macroeconomic news have a stronger longer-lasting impact on volatility. In addition, they found that macroeconomic news from the US have more influence than the Eurozone announcements or various countries within the Eurozone.

An important aspect of market participants' behaviour as hinted by Caballero & Krishnamurthy (2008) is market participants face immeasurable systemic risks under certain market conditions, which lead to market participants exhibiting flight to quality or liquidity behaviour. Acknowledged as Knightian Uncertainty, it is believed to explain the behaviour of market participants in the aftermath of a wide range of events such as the Lehman Brothers Collapse in September 2008, Greek sovereign debt crisis and 9/11 terrorist attacks. The common factor is the lack of previous similar events to base information on. However, these events are based on news and hence as hinted by Malkiel (2003) news is by definition unpredicTable resulting in price changes tending towards unpredictability and hence randomness.

2.1.3. A Review of the Tests of the Efficient Market Hypothesis

In testing the efficient market hypothesis, we need to test whether markets follow the random walk model and prices incorporate information immediately. The variance ratio tests of Lo & MacKinlay (1988) allow the testing of the random walk model, the influencing assumptionin the weak form efficient market hypothesis. However, a key factor is as stated by Fama (1970; 1991), any test of the efficient market hypothesis involves a joint hypothesis of the equilibrium expected rates of returns and market rationality. Thus, there is a need to review the variance bound test of Shiller (1979) and LeRoy & Porter (1981) which states any excess volatility in the price of any asset is the result of inefficient markets as argued by Shiller (1992). This would mean that in a rational market, fundamental information is not the driving force of the price and inefficiency in the market drives the price away from the long-term equilibrium.

As stated by Bollerslev & Hodrick (1992) past empirical evidence suggests that there is a difference between short and long horizons with short horizons displaying only minor violations of the efficient market hypothesis while with long horizons, large proportions are more predicTable based on the price variance being largely explainable by past prices alone. Ofcourse, this doesnot mean that markets are inefficient. A possible explanation is that the price variations could be due to time varying risk premium. However, as Poterba & Summers (1988) argue the magnitude of the variability is too large, to be explained by the rational pricing theory. The evidence from the long horizon tests seem to point at an overlapping issue suggesting the statistics are better estimated with an alternative asymptotic distribution as derived by Richardson & Stock (1989), although, as Bollerslev & Hodrick (1992) state this problem could also be overcome by using the vector autoregression method.

Although as pointed by Lo & MacKinlay (1988) an empirically refuTable efficient market hypothesis must be model-specific, historically the tests of the market efficiency have focused on the forecastability of assets prices or returns. Since as hinted by Fama (1970; 1991), the random walk hypothesis is used to test the weak form efficient market and hence the unpredictability of the financial market. As Illustrated by Charles & Darne (2009), in any $\{y_t\}_{t=1}^{T}$ series, the random walk hypothesis corresponds to $\alpha = 1$ in the first order autoregression model $y_t = \mu + \alpha y_{t-1} + \varepsilon_t$. The variance ratio test works by exploiting the fact that the variance of random walk increments is linear in all sampling intervals.

Of course, as stated by Lo & MacKinlay (1988) the empirical evidence against the random walk model does not mean a rejection of efficient markets or prices are not rational assessment of fundamental values. In essence, rational expectation of equilibrium prices need not follow a martingale sequence. Hence, although the empirical evidence may reject one economic model of efficient market, there may exist another model of efficient market, which could be consistent with the results.

The basis of the variance ratio test proposed by Lo & MacKinlay (1988) is the linearity in the sampling interval of the variance in the incremental random walk. This means that a random walk model (possibly with drifts) of asset prices would be such that the variance of the monthly sample of log-prices would be four times the variance of the weekly sample of log prices. Hence, a comparison of the variance of the period samples (e.g.

monthly and weekly) could indicate the plausibility of the random walk model in efficient markets.

Although as stated by Lo & MacKinlay (1988) traditionally the random walk model has been based on normally distributed homoscedasticity residuals, put simply residuals are said to be independently and identically distributed. However, there is strong evidence that financial time series follow a heteroskedastic and non-normal distribution. Lo & MacKinlay (1988) derive two tests of variance ratio to test the random walk hypothesis under heteroskedastic non–normal and homoscedasticity normal distributions. They set three theorems for the model to follow; two based on both tests and the third based on the heteroskedastic model.

The empirical evidence from Lo & MacKinlay (1988) using their variance ratio test rejects the random walk hypothesis for the weekly stock markets. Although as suggested earlier this does not mean they reject nor confirm the efficient market hypothesis. The omission of an economic model, which viably explains this behaviour of the asset prices, is the key issue.

Although Lo & MacKinlay (1988) originally proposed the overlapping data method as an improvement of the power of the variance ratio test, however, as stated by Charles & Darne (2009), the use of overlapping data led to issues concerning the exact distribution of the variance ratio statistics in the long horizon. Another issue concerning the distribution is that in multiple tests the asymptotic distribution can lead to a severe bias and right skewness in finite sampling, thus leading to misleading inferences. However, as illustrated by Lo & MacKinlay (1988) and Richardson & Smith (1991) a key benefit of using the variance ratio test is when testing the random walk against several alternative hypotheses.

The concept of the volatility tests is a comparison of the variability of prices with the variability of the future cash flows. The basic argument is that in an ideal world, future cash flows should determine the behaviour of prices today; therefore, as Shiller (1992) argues, any excess volatility is evidence of inefficient markets. As emphasized by LeRoy (1989), the underlining factor of the volatility or variance bound tests is that market efficiency dictates that asset price volatility should be relatively low in comparison with returns volatility. Another key factor, highlighted by LeRoy (1989), is there exists a negative relationship between the variances of the asset price and returns given the amount of information market participants have. Empirical evidence from Shiller (1979; 1981b) and LeRoy &

Porter (1981) suggests asset prices are more volatile than is consistent with the efficient market hypothesis.

And while the evidence is mostly geared towards the stock market with both LeRoy & Porter (1981) and Shiller (1981b) suggesting that the price seems to be more volatile than the returns in the stock market, suggests that the efficient market hypothesis is rejected due to information not being uniformed across all market participants. The empirical evidence provided by Shiller (1979) illustrates that the tests reject the expectation model; in essence, these results seem to be suggesting a negative relationship. This hints at the long-term interest being too volatile and therefore rejecting the efficient market hypothesis.

As emphasized by Shiller (1981a), there are a number of different interpretations for the simple pricing model depending on the underlying market and market variables used. For example in LeRoy & Porter (1981), they used earnings instead of the dividends used in Shiller (1981b) on the stock market and in Shiller (1979), he uses the long-term yields with the expectation model to analyse the bond market.

As Shiller (1979) emphasizes, an argument often made against rational expectation models of the term structure is long term interest rates are too volatile. The expectation model of the term structure dictates long averages of expected short-term interest rates plus a liquidity premium could dictatelong-term interests. Additionally, in a conditional mean rational expectation model any shock to the trend should only occur on the arrival of important new information, which does not happen too often. Past empirical evidence on long-term interest rates suggests that they follow the efficient market or random walk. Hence, the evidence of long-term interest rates being too volatile contradicts the past empirical evidence.

As stated by Shiller (1981a) the simple pricing model dictates that the price of any asset (i.e. stock or bond) is fundamentally the present value of rationally expected or optimal forecasTable earnings (i.e. dividends or coupons) divided by a discount factor. The efficient market hypothesis states that information regarding fundamentals is priced immediately. This would suggest that the change in the price depends on information about the dividends or coupons. Thus, any deviation from the long run equilibrium is therefore the result of information about the dividends or coupon rate. In essence, the basis of the present value is the long weighted moving average, thus suggesting that the equilibrium long run expected prices are smooth. However, a major issue is that occasionally asset prices are too volatilefor the information to explain away. This means that the changes in asset prices seem to be too large in association with the sequence of events influencing the information.

The basis of the volatility test of LeRoy & Porter (1981) are the three theorems about the relationship between the variance of the dependent and independent variable processes. The theorems are the basis for tests of validity of the present value relation in asset pricing. The efficient market hypothesis implies the present value relationship between the asset price and earning. This means that the theorems are validity by the efficient market hypothesis andthusthe variance bound test can test the efficient market hypothesis.

As Shiller (1981a) states, the inequalities suggest that using the volatility or variance bound tests of the efficient market hypothesis have certain advantages over the conventional tests such as simplicity and understandability. However, the key benefit is greater power of robustness to data errors such as misalignment. The basis of the empirical evidence is a number of inequalities, which limits the price and returns in terms of the standard deviation of:

- The equilibrium price (LeRoy & Porter, 1981a and Shiller, 1981b)
- The dividends or earnings (Shiller, 1981b)
- Dividends or earnings differentials (Shiller, 1979)

As hinted by Bollerslev & Hodrick (1992), a key factor in the financial market is many financial asset returns are characterised by periods of asset booms followed by periods of asset busts. Since the basis of most pricing models is around the mean-variance trade-off, thus the time variations of the conditional second moments of returns and the underlying process are important in the testing of market efficiency.

As suggested by Shiller (1981a), a possible test of the model is to use a conventional regression technique and the F-test on the resulting coefficients. However, based on the assumptions made earlier, conventional regression techniques no longer suggest the likelihood test and the volatility test have more power under certain parameters. Nevertheless, as pointed by Bollerslev & Hodrick (1992) the use of ARCH/GARCH models in the estimation process can overcome seasonality in fundamentals and volatility clustering issues.

As hinted by Cochrane (1991), there is a misinterpretation in the hypothesis underlining the volatility test as purposed by Shiller (1979; 1981b) and LeRoy & Porter (1981). Many seem to be suggesting that the hypothesis points to a rejection of the efficient market hypothesis when the test shows that prices are too volatile. In essence, the tests are equivalent to the Euler-equation based tests of the discount rate models; hence, the hypothesis is that markets are forecasTable due to the current discount rate models leaving a residual. In fact as hinted by Bollerslev & Hodrick (1992), the volatility tests are a joint hypothesis of the return generating process and first order condition for economic agents similar to the Euler-equation based tests.

As suggested by Cochrane (1991), opponents of the efficient market hypothesis do not argue that changes in prices are predicTable; the basis of their argument is why prices move so much in the absence of any relevant news on the fundamental factors e.g. dividends. In addition, tests of the coefficients in a return-forecasting regression or the variance bounds do not show the true and enormous size of the error term or the unpredicTable part of the price changes.

The evidence from the first generation of volatility tests as originally derived by Shiller (1979; 1981b) and LeRoy & Porter (1981) pointed to a clear rejection of the efficient market hypothesis with actual prices displaying excessive volatility in comparison to implied prices. As suggested by Shiller (1981a) a possible explanation was the existence of speculative bubbles and/or fads in the actual prices. As stated by Shiller (1981a), there are a number of alternative hypotheses such as rational bubbles, fads and unsuspected "disaster" or Knightian Uncertainty events. However, as suggested by Cochrane (1991), since the alternatives such as fads and bubbles are not tesTable hypothesis in a time varying model of asset pricing, i.e. there are no rejecTable models; the empirical evidence is not convincing. Moreover, Hayek (1945) presents a possible explanation for the market prices behaviour, market participants need not know all the information about the fundamental elements; hence, they only need to know their own piece of information and market prices.

Efficient market hypothesis tests are always conditioned on the model of equilibrium expected returns. Simply put the basis of the tests isthe assumptions of normal price behaviour under the efficient market. However, as mentioned in Schwert (1991), there are a number of issues regarding the assumptions in the volatility tests. As hinted by Schwert (1991) the empirical evidence provided by Shiller (1992) is the existence of sampling errors and bias. This seems to be pointing at excess volatility not causing the bound violation present in the empirical evidence. However, as Shiller (1979) argues conventional tests of the efficient market hypothesis may be weak.

As stated by Schwert (1991), in fact past empirical evidence points towards expected earnings being time varying rather than constant. Hence, the excess volatility shown by some of the volatility tests could be due to time varying expected returns. As highlighted by Bollerslev & Hodrick (1992) relaxing the assumption of a constant discounts rate results in a mixed picture of excess volatility and market inefficiency. Another problem with the earlier models as stated by Bollerslev & Hodrick (1992) is that they did not take account of non-stationary prices and fundamentals in calculating and interpreting the test statistics results.

Of course, there are many alternative tests of market efficiency. One possible alternative test of the efficient market hypothesis as used by Fama & French (1988) and Lo & MacKinlay (1988) is to test for statistically significant negative or positive serial correlation, which would hint at predicTable prices. Fama & French (1988) found significant negative serial correlation in long horizon returns. Furthermore, Lo & MacKinlay (1988) found significant positive serial correlation in weekly and monthly holding returns.

Another alternative test for market efficiency suggested by Lai & Lai (1991) is the cointegration test whereby if the series are cointegration of i(0) suggesting both series are stationary at level order differentiation then it can be shown that the market is efficient. In theory, this means that if there is a cointegration relationship between two series then one series is an unbiased predictor of the other series, which is consistent with the efficient market hypothesis.

The Engle & Granger (1987) test for cointegration was originally used to test the market efficiency. The basic idea of the test was that the hypothesis of an equilibrium relationship existing between the two series, if the hypothesis was accepted then we could suggest that series one is an unbiased predictor of series two. The influencing factor is that the least square residuals are tested for stationarity; if the residuals are not stationary then the null hypothesis is rejected. However, Lai & Lai (1991) argue there are a number of issues regarding the Engle & Granger (1987) test; the first is that no inference can be made with respect to the coefficients and the second is the estimated standard errors can be misleading for hypothesis testing.

One possible solution is using the Johansen cointegration test proposed by Johansen (1988; 1991) to test the market efficiency. Using the maximum likelihood method, which allows the likelihood ratio to test the coefficients of the equilibrium relationship between the non-stationary series, can derive the test statistics. An advantage of the Johansen cointegration test is it utilises the vector autoregression model whereas Engle & Granger (1987) test uses a single equation model.

2.1.4. Concluding Review

In concluding, it is hard to understate the roles of the neoclassical economics view and efficient market hypothesis in modern finance. Yet both have attracted some big criticisms highlighted by the financial crisis and exacerbated by the global economic downturn and ensuing sovereign debt crisis. At the heart of the criticisms lay two key factors efficient markets and profit maximization highlighting the misinformation and under-pricing of risk in the pre-crisis period. Therein is the problem as argued in this section and the next section on behavioural finance, many neoclassical economics models are based on simplifying assumptions that do not hold in reality, for example the assumptions of rational market participants and perfectly competitive markets.

Another issue as highlighted by Ball (2009), many were critical of the efficient market hypothesis in the aftermath of the financial crisis. The issue seem to be based around the price is correct argument, however this is dangerously misleading; since the efficient market hypothesis only states the price should reflect allavailable information at the time. There are twoarguments regarding this issue; firstly, as highlighted by Ball (2009) in the pre-crisis period many market participants thought prices were incorrect and using sophisticated forecasting models, they could beat the market. Secondly, the efficient market hypothesis does not work when there is unequalled access to information resulting in incomplete or asymmetrical information. This goes back to the neoclassical economics assumption of perfect competition; in a perfectly competitiveenvironment, information should be complete and accessible to all market participants.

Of course, a key neoclassical economics assumption is that market participants are risk averse. However, as hinted by Buiter (2007) and Feldstein (2007), as early as 2005 many thought there was massive under-pricing of risks. Hence, market participants were not following this fundamental assumption of neoclassical economics and thus the efficient market hypothesis. This goes to the heart of the problem during any asset price bubble, as illustrated in the next section, it is often the case that market participants usually think they could beat the market and therefore consistently under-price risk in the attempt of making increasingly large profits. Therefore, distorting the market from the fundamental price leading to increased asymmetrical information.

The key is determining whether the financial market accept the efficient market hypothesis, we presented strong historical empirical evidence suggesting financial markets are not efficient. The tests and methods used to test the efficiency of the markets in the empirical evidences are wide ranging, e.g. variance bound tests (Shiller, 1979; LeRoy & Porter, 1981a), variance ratio tests (Lo & MacKinlay, 1988) and cointegration tests (Engle & Granger; 1987; Johansen, 1988). Moreover, although the majority of the evidence seems to be based around the stock market, yet it does suggest that the global financial market is not random and asset prices are too volatile to be explained by the information. This is the key to our research, if markets are too volatile to be efficient then what is explaining the behaviour of volatility in the markets. Another key factor to our research as pointed out by Bollerslev & Hodrick (1992), the use of GARCH models can overcome clustering issues with the variance bound tests. A possible issue in the variance bound tests is that market participants seem to react differently to negative or positive information. In order to analyse whether markets are more efficient during phases of negative or positive shocks, there is a requirement to include the asymmetrical/leverage effect in the variance bound test. However, a key issue is the selection of the lagged system influencing the variance bound test; there are a number of lagged systems within the daily frequency. Perhaps two of the most relevant lagged systems for such tests are:

- The weekly, which depending on the definition of the week in the observation could be a 5 or 7 day, lagged system
- The monthly, which depending on the definition of the month in the observation could be a 20, 22/23, 30/31 and 28/29 daylagged system

In concluding, it is easy to criticise the neoclassical economics view and efficient market hypothesis in the aftermath of the financial crisis and ensuing sovereign debt crisis. Many, including governments and central bankers, would argue that the pursuit of profit maximization and the assumption of efficient markets led to the financial and ensuing sovereign debt crises. However, both the neoclassical economics view and efficient market hypothesis are essentially just models of the financial market and are therefore best used as benchmarks and not observations of the real world. Used in that sense they might be powerful tools to regulate the markets and for market participants to really appreciate the risks and returns.

As mentioned in the last paragraph, the problem is while both neoclassical economics and the efficient market hypothesis are powerful benchmark tools; they do not reflect the real world. As stated by many including De Bondt *et al.,* (2008) and Kourtidis *et al.,* (2011) market participants are homo-sapiens and not homo economics, hence there is a requirement to include the behavioural finance theory.

2.2. The Theory of Behavioural Finance: An Alternative Theory

Essentially, as stated by De Bondt (2000), there are three perspective on asset prices: "the price is right" view proposed by Fama (1970), the price is driven by animal spirit view of Keynes (1936) and any uptrend in an asset price must eventually come down resembling Newton's law of universal gravitation. Interestingly the third perspective is the key to understanding the empirical studies of behavioural finance. As illustrated by section 2.1, some of the issues regarding the pricing of assets cannot be addressed without a reference to the behavioural finance theory. A criticism (for example De Bondt *et al.,* 2008 and Kourtidis *et al.,* 2011) often put against theneoclassical economics model and in particular, the efficient market hypothesis is that market participants are homo-sapiens and not homo economics. Hence, in order to address these issues there is a requirement to understand the psychology of the market participants. This led to the alternative theory of behavioural finance being put forward by Statman (2008) and Subrahmanyam (2007) amongst others. A key notion in behavioural finance theory as put by Bernard Baruch is:

> "What is important in market fluctuations are not the events themselves, but the human reactions to those events." (Lee *et al.,* 2002, p. 2277).

As illustrated in section 2.1, one of these issues is the price deviation from the fundamental value. As the comment from Bernard Baruch above hints, the key to understanding this deviation is the reaction of the market participants. This lends itself to the overreaction hypothesis as suggested by Barberis *et al.,* (1998), Daniel *et al.,* (1998), Hong & Stein (1999) and De Bondt (2000). This leads to another issue, the existence of bubbles, which causes the asset price to temporary deviate from the fundamental value in the short to medium term as illustrated by Kindleberger & Aliber (2005).

This section will give a brief overview of the behavioural finance theory. It will then evaluate the overreaction hypothesis.

The concluding part of this section is a review of the effect of rational bubbles.

2.2.1. A Brief Overview of Behavioural Finance Theory

In essence, De Bondt *et al.,* (2008) and Kourtidis *et al.,* (2011) argue that there is a necessity to understand the psychology of market participants in order to provide an explanation of market abnormalities, such as asset price bubbles and crashes, and comprehend the efficiency of the financial markets. This would seem to suggest it is difficult to fully understand and research the global financial market without reference to the behavioural finance theory. In addition, as hinted by Kourtidis *et al.,* (2011), the obvious existence of irrational market participants making random transactions in the market can only be adequately explained by taking account of behavioural factors. As stated by Barberis & Thaler (2003), the impact on the price from these irrational market participants can be long-lived and substantial. According to Barberis & Thaler (2003), these two issues (i.e. the psychology and the long-lived impact of irrational market participants) form the building blocks of behavioural finance.

As stated by Kourtidis *et al.,* (2011), whereas traditionally financial theories examines how people behave with respect to wealth maximization, behavioural finance is interested in how people "*actually*" behave in a financial environment. Essentially, as defined by De Bondt *et al.,* (2008) and Statman (2008) behavioural finance is thepsychological study of the market participants and their interaction with the financial markets where the market participants may be individual households or organizations. As stated by De Bondt *et al.,* (2008) the behavioural finance theory is not necessarily based on the assumption of rational market participants and efficient markets. An important factor in the behavioural finance theory, indicated by Statman (2008), is that market participants are assumed to behave normal in the sense that they act rational but with a limited information set. As a result, markets are not efficient but hard to beat. The main idea influencing the behavioural finance theory is a number of behavioural factors influences market participants, to fully understand this reaction of market participants there is a need to research these behavioural factors. Kourtidis *et al.,* (2011) state there are many behavioural factors highlighted in the literature on behavioural finance that explain the behaviour of market participants in the financial market. However, they limit their study to four major behavioural factors in analysing the market participants' behaviour in the financial market: over-confidence, risk tolerance, social influence and self-monitoring.

According to Subrahmanyam (2007) there seems to be evidence to suggest that the assumptions and models underpinning the behavioural finance theory are plausible. He state there is evidence to suggest that non-risk based factors influence the predictions of returns more than risk-based factors. There also seem to be evidence to suggest that psychological hypothesises about market participants' biases can be tested in an ex-ante manner. And although the evidence seem to be suggesting that markets are inefficient and predicTable patterns do exist, this doesnot mean that individual market participants can make large excess returns. However, there is evidence that institutional market participants are able to take advantage of these predicTable patterns in the financial markets. He argues that although there is evidence suggesting that irrational agents do influence the market in the short run, however there is also strong evidence that irrational agents do influence the market in the long run.

As hinted by Subrahmanyam (2007), there is evidence to suggest that asset prices are influenced by a reference price and the disposition effect. This evidence seems to be pointing towards the existence of a pattern in the trading activity of individual market participants. Moreover, as he hintsalthough there is evidence to suggest that market participants seem to be constructing their portfolios from a limited number of simple strategies like locality, knowledge and word of mouth. However, there seem to be a lack of emphasis in the literature on portfolio choice of market participants. Another key factor as stated by Statman (2008) is that the hypothesises underpinning the behavioural finance theory, such as the disposition hypothesis which predict market participants will realize rapid gains but defer losses, are tesTable. Thus meaning they can be rejected or accepted depending on the analysis of the data and have been shown by many empirical studies to be capable of accurately predicting market participant's behaviour.

2.2.2. The Overreaction Hypothesis

A key assumption of the efficient market hypothesis is that current prices should fully reflect all information on the asset as hinted by Fama (1965) and Malkiel (1962). There is an issue with this statement in that the current price does not reflect the information but the sentiment of the market participants with respect to the information as suggested by De Bondt (2000) and Daniel *et al.,* (1998) among others. Therein lays the key to understanding the overreaction hypothesis (as hinted by Barberis *et al.,* 1998; Daniel *et al.,* 1998; Hong & Stein, 1999) and De Bondt, 2000); since market participants have different perspectives on how to interpret the new information, therefore the price could deviate from the fundamental value. Essentially, as hinted by De Bondt (2000), the overreaction hypothesis states that sometimes market participants tend to disproportionately react to information (fundamentals and news) causing a temporarily and dramatic deviation from the fundamental value. Usually the price does revert to the fundamental value within a short period of time as market participants digest the information.

In essence, according to De Bondt (2000), most overreactions are due to errors in market participants' forecasts. A common issue is that market participants are often upbeat during bull markets and gloomy during bear markets, this is reflected in their perspectives of the asset price. Another issue is the problem of overestimation of the information on the asset during the issuance or initial public offering stage by the agents. According to Barberis *et al.,* (1998), a key factor in the overreaction hypothesis is that a sequence of good or bad news can lead to an overreaction by market participants assuming the continuation of the trend. Daniel *et al.,* (1998) suggest there is a differentiation based on whether the information is public or private. Thus meaning market participant are overconfident in their private information leading to an overreaction in the market. Whilst in general they tend to underreact to public information. Moreover, as discussed in Barberis *et al.,* (1998) the evidence seems to be pointing at some market participants' conservative attitude to updating the model incurring the underreaction hypothesis.

However, as Hong & Stein (1999) highlight it is essential to analyse the interaction between heterogeneous market participants. They analyse two types of bounded rational market participants: momentum traders and news watchers and to illustrate the effects on one another both types have simplifying assumptions. The results seem to be suggesting that when news watchers pick up new information, in general they underreact. This is mainly due to the gradual diffusing of information and the assumption that they do not observe prices. When short run momentum traders enter the market, seeing a chance to profit, instead of pushing the price towards the fundamental value, they cause an overreaction to any news. While in the short run market participants could make a profit, in the long run they make losses due to the price exceeding the long run equilibrium price. According to Hong & Stein (1999), the inclusion of well-informed fully rational arbitrageurs does not eliminate the effects of other less informed and rational market participants. Thus meaning overreaction continues to have an impact on the price.

Recent empirical evidence have painted a mixed picture for the overreaction hypothesis, in Spyrou *et al.,* (2007) they find a split between large and small capitalization stocks in the London Stock Exchange. Large capitalization stocks were consistent with the efficient market hypothesis, while medium to small stocks seem to underreact to news shocks for many days. This underreaction is unexplained by risk factors or any other known effect.

Kirchler (2009) finds evidence of underreaction leading to overvaluation during bullish markets and undervaluation during bearish markets by market participants. This leads to an asymmetrical effect between the bull markets and bear markets with the bull markets illustrating a higher degree of consistency to the efficient market hypothesis. The reasoning for the observed underreaction in the market is the relatively high volatility influencing the fundamental value.

However, contrary to the two previous articles, Lobe & Rieks (2011) find significant evidence of short-term overreaction in the Frankfurt stock exchange is not limited to small capitalization stocks. The explanation seems to be in the anomalies and stock characteristics. However, transaction costs and unpredicTable markets mean that market participants may not be able to exploit these effects. This means that due to the unforeseeable direction of the reaction and the existence of transaction costs prohibiting the implementation of consistent profit making strategies, they conclude the evidence seem to be suggesting no violation of the efficient market hypothesis.

2.2.3. A Review of the Effects of Rational Bubbles

Essentially, as hinted by Barlevy (2007) the popular notion is bubbles are initiated by rapid upwards pressures on the price of a particular type of asset or index in a short interval of time, eventually causing downward pressures to correct the price or more dangerously a collapse in the price. In simple terms, as hinted by Blanchard & Watson (1982), a popular notion defines a bubble as a price deviation from the fundamental value that is apparently unjustified by the information available at the time. This was evidence in the technology boom of the late 1990s to early 2000s and housing market boom of the early to mid-2000s. As illustrated by Kindleberger & Aliber (2005), history is filled with such episodes, the first recorded bubble often referred to as the Dutch tulip bubble of the 1630s, the South Sea Company bubble of 1719-1720 and the US stock market bubble of the 1920s, which ended with the Wall Street crash of 29th October 1929.

However, as Barlevy (2007) argues this popular definition is ambiguous about the scale and length of time of a bubble. At the heart of this argument is the fact large price swings could occur under normal market conditions due to shifts in supply and demand. An example is an asset with cyclical changes in demand, therefore causing dramatic price changes. These price changes are sometimes known as fads. In essence, as Barlevy (2007) states many economists define a bubble as a rapid upwards deviation from the fundamental value.

As noted by Blanchard & Watson (1982), therein lays the difference between economists and market participants. Economists believe that any deviation from the fundamental value is evidence of irrational behaviour whereas market participants believe extraneous events could influence the price of any asset or index. In other words, "crowd psychology" is an important element in the behaviour of asset pricing as pointed by Blanchard & Watson (1982). And as Brunnermeier (2001) highlights, there is empirical evidence provided by LeRoy & Porter (1981) and Shiller (1979) among others of excess volatility in asset prices meaning prices deviate from their fundamental value more than predicted by the efficient market hypothesis. This evidence would suggest there could be rational deviation from the fundamental value i.e. rational bubbles. Rational bubbles appear in asset prices

> "If market participants are willing to pay more for the stock than they know is justified by the value of the discounted dividend stream because they expect to be able to sell it at an even higher price in the future, making the current high price an equilibrium price" as defined by Gurkaynak (2008, p.166).

Furthermore, as Blanchard & Watson (1982) point rational behaviour and expectation does not imply that prices must follow fundamental values. Of course, there is some evidence of irrational behaviour in the market that could cause irrational bubbles for a survey of this type of asset price bubbles see Vissing-Jorgensen (2004).

As stated by Abreu & Brunnermeier (2003), the efficient market hypothesis implies that bubbles do not exist by virtue of the existence of rational well informed and financed arbitrageurs guaranteeing that any potential mispricing will be corrected (Fama, 1965). However, as Abreu & Brunnermeier (2003) argue some rational arbitrageurs also like to take advantage of the bubble to further their earnings while the bubble last, hence ideally leaving the market just before the crash. Nevertheless, since each rational arbitrageur have their own model and assumption of when to leave this leads to asymmetrical information and different viewpoints. The key argument against the assumption of the existence of rational and financed arbitrageurs is this incoordination between the very agents that will supposedly correct any mispricing in the assets. Moreover, as Abreu & Brunnermeier (2003) illustrate many supposedly rational agents have lost out on huge profits or made huge losses by mistiming their exit. As exemplified by the different cases of Julian Robert, Tiger Hedge Fund, and Stanley Druckenmiller, Quantum Fund, during the tech bubble of the late 1990s early 2000s see Abreu & Brunnermeier (2003, p. 175).

As Blanchard & Watson (1982) illustrate there are a number of theoretical paths for the development of a bubble. The first is as they term the deterministic bubble where the upward price deviation is justified by higher capital gain but the price deviation grows exponentially. This means in rationality the price inflation has to go on forever meaning it is implausible. The second path introduces the concept of probabilities into bubble where chance of a bubble continuation is π and the chance of the bubble bursting is $1-\pi$. Thus means that the probability of the bubble ending may be a function of either the duration of the bubble or the distance of the price from the fundamental value.

In essence, these two paths move independently of the fundamental value. However, this is 0 not necessarily the path bubbles take. As hinted by Blanchard & Watson (1982), there is a third path that bubbles could take which is linked to the fundamental value. This path is governed by the existenceof a ratio between the fundamental value and the price in a bubble, which continues as long as the bubble still exists. An example is that the ratio is at 0.25 if the bubble continues and 0 if the bubble bursts. Thus meaning that as long as the bubble continues the price will go up by a further 25% of the fundamental value, however if the bubble burst then the price will collapse with the fundamental value.

An illustration of the long held assumptions underpinning most models and theories in the financial market shows with or without them bubbles can still occur. As shown by Blanchard & Watson (1982) and illustrated earlier, prices can still deviate from the fundamental value even if we take into account the arbitrage assumption thus creating or maintaining a bubble.

Blanchard & Watson (1982) show that there can be bubble even after accounting for the assumption of all agents having access to the same information on the asset. However, it is known that bubbles are increasingly likely to occur if there is an information differential among the agents butthe key questionwould these bubbles have greater intensity and duration? The answer probably lays in the expectation of the agents and their models. As explained earlier agents can take different viewpoints based on their information.

A key assumption influencing many theories and models of financial asset pricing is that market participants or agents are risk averse. Moreover, as illustrated by Blanchard & Watson (1982), since bubbles are likely to increase the risk associated with the assets at the centre of the bubbles. Hence, risk averse agents require higher returns to encourage them to hold the assets. This means that the price will not only have to increase due to the increased probability of a crash but also due to the increase in risk aversion to compensate agents.

Branch & Evans (2011) raise another intruding assumption based on agents' ability to use econometric models to learn about the price deviation from the fundamental value. Rather interestingly, the results seem to indicate that adaptive learning techniques can reinforce bubbles and the ineviTable crashes. This can be exemplified by the agents' attitude to risks in the market; the econometrics models are used to readjust estimates of risk and hence expected returns. Conversely, when combined these two forces can cause the price to deviate from the fundamental value. In a market where the risk factors are perceived to be low and the returns are relatively high, this can lead to an upward deviation from the fundamental value. As agents continually readjust their models due to the perceived low risk factor and hence raising prices, thus reinforcing the positive feedback effect which inevitably leads to a bubble. Eventually, the changing estimates of risk are deemed to be too high for the expected returns leading to downwards pressures on the price. This leads to a hiked in the risk factors, which forms the negative feedback effect and hence the price crashes below the fundamental value.

This raises the interesting topic of using econometrics to model the effect of bubbles and their ineviTable crashes on the prices of assets. As Blanchard & Watson (1982) illustrate the positive/non correlation between the innovations in the bubbles and asset returns could lead to the bubble increasing the conditional variance in the price. This leads to the possible modelling of bubbles by different econometrics models to understand the factors influencing the bubbles. Branch & Evans (2011) hints at feedback effects influencing the bubbles hinting at the use of the GARCH-m (Engle *et al.,* 1987) in understanding these feedback effects. As highlighted earlier in this review, information affects the view of agents on the asset price and hence influences the bubble; this is crucial to understanding the method of bubbles. In effect this point to the use of an asymmetrical model such as the GJR-GARCH

(Glosten *et al.,* 1993) or EGARCH (Nelson, 1991) to understand this effect. In addition, as Branch & Evans (2013) states there is certainly a hint of ARCH and hence GARCH effect influencing the asset price bubble pointing towards volatility clustering effects.

However, on some occasions there can be the appearance of multiple bubbles occurring over a short duration. This periodic collapse in a bubble can be analysed thru the use of a Markov process as alluded by Blanchard & Watson (1982), Evans (1991) and more recently Branch & Evans (2011); this process can be modelled by the use of Markov Switching models (Hamilton, 1988). Moreover, since as illustrated previously the correlation between the innovations and asset returns points to the use of the ARCH/GARCH models, so hinting at the use of the SWARCH (Hamilton & Susmel, 1994; Cai, 1994) to model the impact of the bubble on the behaviour of price volatility.

In a survey of the econometric tests for rational asset price bubbles, Gurkaynak (2008) critically reviews the econometrics methods proposed for the detection of rational asset price bubbles. Surveying the literature on:

- Variance Bound Tests see Shiller (1979; 1981b) and LeRoy & Porter (1981)
- West's Two Step Tests see West (1987)
- Integration/Cointegration Based Tests see Diba & Grossman (1988)
- Intrinsic Bubbles see Froot & Obstfeld (1991)
- Bubbles as an Unobserved Variable see Wu (1997)

Gurkaynak (2008) concludes there are issues underlining the econometrics tests for rational bubbles, both theoretically and empirically. Whether the researcher conclusion hints at the existence of a bubble or fundamental factors in the data is really a matter of what side of the argument the researcher is on. In essence, the bubble remains a term that encompasses the asset pricing movement unexplained by the fundamental model.

As highlighted by Evans (1991), there have been many tests, see Blanchard & Watson (1982), which have found evidence that asset prices deviate from their fundamental values. This evidence could be interpreted in two different ways depending on which side of the argument you are on; it is either evidence of the existence of bubbles and fads or unobservable market fundamentals. An alternative test for the bubble hypothesis, as explained by Evans (1991, p. 922, footnote 2), is to analyse the stationarity properties. As stated by Evans (1991), a suggested behaviour of some bubbles is that they generate an explosive component that is detecTable over the dividend at stationary using k-differentials. This has shown that bubbles do not exist. However, as Evans (1991) illustrates theexistence of a type of bubble, which cannot be detected using stationarity analysis leads to standard unit root and cointegration tests being unable to distinguish between stationary processes and periodically collapsing bubbles.

As West (1987) states previous empirical studieswere unable to detect bubbles, due to the tests being too few and not powerful enough. In overcoming the issues of previous tests, he develops and applies a test specifically for the alternative of bubbles. He uses a two present value estimates method: one using an arbitrage equation while the other is an ARIMA model. The basis of the test is if the markets are in accordance with the efficient market hypothesis than the two sets of estimates should be the same, apart from the sampling errors. However, the alternative hypothesis of the two estimates being different would suggest the existence of a bubble. Using the Standard and Poor's 500 index (1871- 1980) and Dow Jones index (1928-1978), the data rejects the null hypothesis of no bubbles. As West (1987) states the rejection seem to be due to the coefficients in the regression of the price on the dividends being upward bias.

As Philips *et al.,* (2011) hints standard econometrics tests seem to have difficulties in detecting rational bubbles. Hence, they use a forward recursive regression method based on the ADF unit root test which when added to new techniques permitting valid asymptotic confidence intervals for explosive autoregressive processes and tests of explosive behaviour in the time series; would allow for the identification and dating of explosive behaviour in the asset pricing. Basically the idea consists of a repeated right tailed ADF test. This technique would overcome the criticism of Evans (1991), as highlighted previously, on some tests inability to detect periodically collapsing bubbles. Using the new technique on the NASDAQ index from 1973 to 2005, they identify and date the dotcom bubble of the 1990s as starting in 1995 and ending between September 2000 and March 2001.

In essence as Philips *et al.,* (2012) state just like the existence of multiple financial crises in a long time series, so is the likelihood of multiple asset pricing bubbles in a long time series. Therein lays the problem if as we have already illustrated it is difficult to detect a single bubble then as Philips *et al.,* (2012) points detecting multiple bubbles with periodically collapsing behaviour is substantially more complicated. However, this is important not only for market participants but also to central bank, economists and regulators who want to control asset price bubbles. Hence, Philips *et al.* (2012) extend the econometrics test of Philips *et al.,*

(2012) to the possible existence of multiple bubbles by generalising the repeated right tailed ADF test to a more broader and flexible range of sample sequence. Using the extended generalised method on the S&P 500 index from January 1871 to December 2010, they detected key historical bubbles including the stock market bubble of the 1920s and dotcom bubble of the 1990s. In comparison, the alternative tests including the Philips *et al.,* (2011) test detected fewer explosive rational bubbles.

2.2.4. Concluding Review

In concluding, it is hard to explain the recent financial and to a certain extent sovereign debt crises without referring to the behavioural finance theory. In essence, the psychology of humans dictates that under normal conditions each market participant would interpret the given information about a financial asset differently. The nature of financial crises is such that information becomes increasingly asymmetrical and news has a greater impact than fundamentals. Hence, as illustrated throughout this section, there is ample evidence suggesting that financial markets are governed by the reaction of market participants to events such as De Bondt *et al.,* (2008), Kourtidis *et al.,* (2011) and Lee *et al.,* (2002). Another factor highlighted by Bernanke (2010) and Barberis (2011) is the possibility of increases in asset prices beyond the fundamental value dictated by the information over a period. These two factors point to the existence of asset price bubbles and overreaction hypothesis influencing the behaviour of prices and hence volatility.

As illustrated earlier, evidence in the financial markets suggest a mixed picture for the overreaction hypothesis see Spyrou *et al.,* (2007), Kirchler (2009) and Lobe & Rieks (2011). On the other hand, the evidence seem to suggest that market participants do react to certain extreme events such as the 11 September 2001 terrorist attacks, Lehman Brothers Bankruptcy and the Japanese tsunami of 2011. This seem to be explained by Knightian Uncertainty which dictates under certain market conditions market participants are faced with immeasurable systemic risks which lead to market participants overreacting as hinted by Caballero & Krishnamurthy (2008). In essence, this evidence seems to be suggesting that it is news and not fundamentals influencing the financial markets during any financial crisis. In addition, the overreaction/underreaction hypothesis may provide a part of the explanation for the asset price bubbles.

There is ample evidence throughout history of asset price bubbles, yet a fundamental weakness of the efficient market hypothesis is its assumption that bubbles cannot exist due to the existence of rational well-informed and financed arbitrageurs see (Fama, 1965). However, as illustrated earlier in this section, there is a hint of catch 22 for these arbitrageurs that lead to huge losses or miss-opportunities see (Abreu & Brunnermeier, 2003). This highlights the difficulties of planning strategies during episodes of asset price bubbles, since it is very difficult to know when an asset price bubble will burst. The problem is further complicated by the existence of mixed evidence in the detecting of asset price bubbles see (Evans, 1991; Gurkaynak *et al.,* 2008). An interesting and influencing factor in the context of our research, as illustrated previously, is that it could be possible to model the effect of bubbles and their ineviTable bursts using econometric models.

Indeed, there are many features of asset price behaviour picked up by the GARCH family of volatility, which can explain the behaviour of market participants. Key among those is the fact that in some cases price changes of similar magnitude irrespective of signs tend to follow each other as highlighted by Mandelbrot (1963) and Branch & Evans (2013), this is sometimes referred to as clustering. As illustrated by Blanchard & Watson (1982) and Branch & Evans (2011), another key behaviour is demonstrated by many market participants is the risk/return trade-off, which dictates that the higher the risk the higher the required returns acknowledged as the feedback effect. It is a well-established fact that market participants react to market shock differently as hinted by Black (1976) and Glosten *et al.,* (1993). This suggests that a negative shock has a greater impact on market participants than a positive otherwise known as the asymmetrical/leverage effect. Ofcourse in some cases the behaviour of the market participants seem to be changing in a manor suggesting a temporary shift in their behaviour towards an asset as alluded by Hamilton & Susmel (1994) and Cai (1994). In addition as hinted by Blanchard & Watson (1982) amongst others, a bubble can periodically collapse. These two behaviours can beanalysed by a regime-switching model.

In conclusion, behavioural finance is an essential theory in the explanation of the behaviour of asset price volatility. This is highlighted by the existence of homo-sapiens in the global financial market as the decision makers. In essence, neoclassical economics and the efficient market hypothesis do not explain certain types of behaviours in the financial market such as asset price bubbles andmarket participants' reactions to news or information. However, the mixed empirical evidence, especially in the case of testing for asset price bubbles and to a lesser extent the overreaction hypothesis, seem to be pointing towards a lack of econometrical tests and understanding of how market participants react to certain events and information.

2.3. The Review of Economic Policies

The financial crisis and ensuing economic downturn and sovereign debt crisis have bought a heated debate about which policy to implement during a long and deep economic downturn. Both countercyclical monetary and fiscal policies have their benefits and costs. The debate is between inflationary pressures see (Rudebusch, 2010) or high taxes see (Tobin, 1971). The other issue is that lags in the implementation of any fiscal stimulus policy may have a delayed and hence adverse effect on the economy see (Friedman, 1948). However, as hinted by Feldstein (2009) and Taylor (2008) it seems that there is a need for both policies in the current climax. In this section of the literature review, we critically review the theory and evidence for both stimulus policies.

2.3.1. The Macroeconomic Arguments Influencing the Monetary Policy

In a way, as Bernanke & Reinhart (2004) state the function of monetary policy is to influence the prices and yields of financial assets, thereby affecting the economic decisions and hence the direction of the economy. Moreover, as Clarida *et al.,* (1999), Romer & Romer (1989) and Bernanke & Mihov (1996) state that monetary policy influences the economy in the short term.

According to Friedman (1982), a monetary policy targeting full employment or economic growth is not feasible. Furthermore, as Barro & Gordon (1983) argue there is no changing relationship between monetary policy and employment. Additionally, as Friedman (1968) states many would suggest that the role of monetary policy is to keep interest rates low in order to offset the interest payment on sovereign debt in an alternative fiscal policy solution. However, as illustrated by many episodes of high inflationary pressures holding interest rates low, i.e. cheap money, could be counterproductive.

Friedman (1968) advocated the used of an aggregate money supply target to control the economy and asset prices. This means in times of an economic upturn there would be a decrease in money supply and in times of an economic downturn, there would be an increase. There is the option of alternating between policies of inflation rate targeting thru the use of interest rate and aggregate money supply targeting by altering money supply as suggested by Bernanke & Reinhart (2004). Moreover as argued by Bernanke & Reinhart (2004), a key question is what happens when the short-term interest rate is approximating or at zero. According to

Bernanke & Reinhart (2004), there are a number of options open to the central bank:

- Since the prices of many financial assets depend on the expected short-term interest rate in the long run, a possible option is to influence the market participants short to medium term expectation on the short-term interest rate. This could be either unconditional or conditional on a set of economic factors.
- Another option is to change the composition of its balance sheet. In essence, this involves either selling and buying short//long or selling and buying different assets e.g. selling sovereign debt in favour of stocks or other bonds. This would have the same effect of changing the supply/demand curve and hence the equilibrium price.
- Another alternative is to embark on a policy of quantitative easing or increasing money supply by expanding the balance sheet. In essence, this would mean the central bank buying financial assets from commercial banks, thereby reducing the risk factors and increasing the money in the economy. A key condition of this policy is that the overnight rate is zero.

However, as argued by both Leeper & Roush (2003) and Woodford (2007), there is limited evidence to suggest a relationship between inflation and money supply. In fact, the evidence seems to be suggesting an increase in money supply leads to an increase in the rate of inflation in the long run. Additionally, as Clarida *et al.,* (1999) states the optimal monetary policy is to target an optimal inflation rate by adjusting the nominal rate, thus altering the real rate.

As stated by Leeper & Roush (2003), many central banks (i.e. Bank of England and more importantly in the context of this research the European Central Bank and Federal Reserves[5]) have opted to a long run policy of inflation rate targeting thru the use of interest rates. The problem with this policy is which price index to use and at what level should the target be set. As Bernanke & Mishkin (1997), hints the index needs to allow for shocks or a one-time shift in the short run without affecting the long run trend. A major issue as pointed by Bernanke & Mishkin (1997) is that setting, inflation rate targets too low, i.e. close to zero, could cause unanticipated deflation, which can creates major problems to the financial system and inevitably economic contraction. A case in point is Japan.

[5] The Maastricht Treaty mandates price stability as the primary objective of the European Central Bank. The Economic Growth and Price Stability Act of 1995 require that the Federal Reserve maintain price stability.

Bernanke & Gertler (1999) suggest that since monetary policy has been relatively successful in the fight against inflation, it is likely that the next issue facing monetary policy will be a different target. They argue that evident from a number of industrialised nations seem to be pointing at increased volatility in asset prices that is instrumental in stock and real estate bubbles. Therefore, by tuning monetary policies to respond to asset price volatility, central bankers could reduce the threat of a bubble. The key word here, being 'reduce' because, while monetary policy is a key element, it is not the only required element in the elimination of the asset price bubble. They discuss several methods open for policymakers to use in controlling asset price bubbles. In concluding, they hint at a lack of desirability in responding to asset prices instead suggesting a flexible inflation-targeting policy.

Tobin (1983) states that the monetary policy of one nation could influence financial markets and instruments, i.e. interest and foreign exchange rates, of the other nations. In short as Tobin (1983) states the interdependent of the global economies and financial markets means a coordination of monetary policies. In other words as Tobin (1983, p.16) referring to the European Community, Japan and the US says:

> "None of the three locomotives can claim it is too small to influence the world economy"

Benigno & Benigno (2006) also argue this point and Devereux & Sutherland (2007) who agree an integrated globalise economy makes it hard for any country to be mutual exclusive in monetary policy. Devereux & Sutherland (2007) also argue that due to the integration of financial markets and the diverse nation of market participants' portfolios, there is a need for monetary policy to control for inflation and foreign exchange rates, continuing that the optimal policy should be asset price stability using inflation targeting. This argument was the basis for Taylor (2009a) suggestingto introduction of global inflation reference target to eliminate the adverse effect of onecountry's policyon others

Many articles have documented the recent financial and sovereign debt crises[6] leading to the global economic recession. In the aftermath of these crises, monetary policy had to adapt to a fast changing and challenging environment. Here we will review the literature on monetary policy during the crises and economic downturn.

[6] Financial crisis (Brunnermeier, 2009; Chari *et al.,* 2008; Gorton, 2008; Grosse, 2010) Sovereign debt crisis (Blundell-Wignall & Slovik, 2011; Caceres *et al.,* 2010).

As highlighted by Blanchard *et al.,* (2010), in the advent of the crises two key factors challenged the long held views. The first factor is that sTable inflation is necessary but not by itself sufficient. Some have argued that the theory is too limiting and does not incorporate the increases in house prices. However, the problem is that no single inflation index could account for the movement in prices. Another issue is that both the combined stability of inflation and output could lead to misrepresentation of the undesirable behaviour of asset prices and credit aggregates. The second factor is that settinginflation too low leads to deflationary pressures or deteriorating fiscal positions.

As Bernanke (2009) hints aggressive reduction of interest rates is the first course of action available during a financial crisis for any central bank. However, as Bernanke (2009) states another key role of the central bank is to act as the lender of last resort to financial institution. This means the provision of liquidity in the shape of short-term loans for financial institutions i.e. commercial banks and primary brokers such as investment banks.

In many ways the provision of liquidity had mixed results, as Bernanke (2009) states on the one hand it does reduced the stress of short-term liquidity and increase the ability for these financial institutions to lend and operate in the market. However, as hinted by Bernanke (2009), as was obvious during the financial crisis and to a certain extent the sovereign debt crisis, this does not solve the problems in certain markets such as the commercial paper and asset backed loans. The problem with the asset backed loan market was the loss of confidence in the quality of the assets held by these financial institutions. So many central banks gave short-term loans against commercial papers and triple A rated asset backed securities in an attempt to provide liquidity to these markets according to Bernanke (2009).

However, as Mishkin (2009) says many have argued that monetary policy has been ineffective during the financial crisis and similarly to a certain extent the sovereign debt crisis. In addition, Mishkin (2009) hints that the majority of these arguments could be broken into two conclusions: credit easing has failed and hence monetary policy is ineffective, so there is no reason to continue with it. The second conclusion is easing monetary policy could lead to inflationary pressures. Contrary to this view, Mishkin (2009) argues that aggressively relaxing monetary policy by cutting interest rates have helped reduced credit and macroeconomic risks. The key thing is that it had kept interest rates on default-free bonds such as Treasuries lower. In providing liquidity to the financial markets, the central banks have reduced the inability of the markets to perform.

In essence, as stated by Mishkin (2009), controlling inflation is down to controlling the expectation of the markets and public about future inflation. The key here is clear communication about the monetary policy and the reputation of the central bank in controlling inflation.

Taylor (2009a) argues the key issues with the policies were firstly that a deviation from the standard and largely successful monetary policy meant that interest rates were too low for too long which caused the bubble. Secondly, a misdiagnosis of the problem early in the crisis meant for the policy makers, providing liquidity took priority over focusing on the root of the problem, which was a rise in risks. The third problem was the ununiformed action of providing assistance to one some and none to other financial institutions.

Friedman (1968) warned against fixing nominal interest rate when inflation was moving, as it would cause instability. Since as Blinder (2010) states effectively there was a fixed zero nominal interest rate, thus meaning a drop in inflation will lead to a rise in real interest rates causing deflationary pressures. This generally leads to a downwards-trending economy with weak aggregate demand. The problem is that once nominal interest rate hit the zero lower bound, "*conventional monetary policy is out of bullets*" as Blinder (2010, p.466) puts it. Therefore, as is the case with the ECB and Federal Reserve, the central banks started using unconventional monetary policy including quantitative easing.

According to Blinder (2010), quantitative easing works thru two channels, either by flattening the yield curve or reducing risks/increasing liquidity. And as Blinder (2010) states there two methods of operating a quantitative easing policy: the first method is thru changing the composition of the balance sheet from "riskless" or short to risky or long securities. The second is to increase money supply and buy securities therefore enlarging the balance sheet.

As stated by Krishnamurthy *et al.,* (2011), the idea behind flattening the yield curve is to sell short term in favour of long-term securities. Thus flattening the yield curve and reducing the long-term interest rates, in the hope of stimulating economic activity. As highlighted by Krishnamurthy *et al.,* (2011), the evidence does point to a reduction in the medium to long-term interest rates. In contrast to the evidence of small impact on risky assets of the purchasing of only Treasuries and agency bonds as hinted by Krishnamurthy *et al.,* (2011). However, there is strong evidence that the purchase of risky or illiquid assets does have a positive impact on the rates of these assets.

As Rudebusch (2010) states an issue for any central bank, regarding these unconventional monetary tools is the exit strategy. One key factor in the decision is that these tools could lead to high inflationary pressures, however a counter argument is that exiting too quickly could lead to big issues concerning the economy and financial market. A case in point is quantitative easing where exiting the policy too quickly could lead to an increase in supply and hence to a high downwards pressures on the assets prices. As highlighted by Rudebusch (2010) there is little historical empirical evidence on the effect of the timing and magnitude of selling the securities. In fact, as will become clear in the next paragraph, there is recent evidence from the Japanese economy and financial market on the effect of unconventional stimulus monetary policies. The case of Japan seems to suggest deflationary pressures are just as likely.

In order to assess the likely impact of the current use of unconventional monetary policies on the economy and financial markets, it is essential to understand the experience of Japan's monetary policy of the late 1990s-early 2000s. As Shiratsuka (2010) argues, there are similarities between the actions of the Bank of Japan in the late 1990s-early 2000s and the major central banks responses throughout the recent crises and economic downturns. In order to ease the pressures of liquidity and credit, the Bank of Japan changed its main monetary policy to targeting a level of outstanding balance of the current account balances, which was originally set to 5 trillion yen, and eventually rising to 30-35trillion yens. Due to the deflationary pressures, until the inflation rate stabilised and above zero, the Bank of Japan was committed to this policy. Initially the Bank of Japan concentrated on the long term Japanese government bonds, in the later stages of the policy they diversified to asset-backed securities.

Since, as stated by Shiratsuka (2010), the evidence suggests monetary expansion had little effect on output and inflation in the case of Japan and given that our research is essentially on the behaviour of financial markets. This means that we will concentrate on the impact of the Bank of Japan policy on the Japanese financial markets. The policy and commitment led to the restoration of liquidity in the markets, therefore stabilizing the financial sector. However, the positive impact from the quantitative easing policy did not transfer to the wider non-financial commercial sector suggesting that the policy did not have a strong impact on the deflation expectation of the financial markets.

Another big issue is due to the Bank of Japan lending schemes, which were at very low interest rates, the financial institutions became reliance on these schemes and hence the money markets were unable to recover. In the end, the key to the success of the policy was the clear communication and commitment by the Bank of Japan as hinted by Shiratsuka (2010).

2.3.2. The Macroeconomics Argument Influencing the Fiscal Policy

At the heart of the argument on whether or not to use a fiscal stimulus policy are two related basic issues. The issues are the costs and impact of any such fiscal stimulus policy on the economy. A key factor is, as highlighted by the recent use of fiscal stimulus policies, they can be very expensive and hence adding to the already high debt levels of most countries. As Tobin (1971, p.91) states

> "How is it possible that society can merely by the device of incurring debt to itself can deceive itself into believing that it is wealthier? Do not the additional taxes which are necessary to carry the interest charges reduce the value of other components of private wealth?"

Hence, in the medium to long term the burden of the debt on the economy is likely to be high either, leading to a reduction in the fiscal expenditure or an increase in the tax levels in the longrun and in some cases both. A point illustrated by Auerbach (2003) who argues past experiences hints at increases in tax and/or decreases in expenditure whenever there is a large increase in expenditure leading to a budget deficit. However, as Keynes (1923) argues

> "The long run is a misleading guide to current affairs. In the long run we are all dead. Economists set themselves too easy, too useless a task if in tempestuous seasons they can only tell us that when the storm is past the ocean is flat again."

However, as Auerbach (2003) hints that any fiscal stimulus would have to take into account the huge debt and cost of servicing that debt. The problem is as Mydral (1939) states during a depression all types of fiscal revenue decrease even without a reduction in the tax rates while the fiscal expenditure increases holding welfare expenditure sTable. Hence, as Mydral (1939, p.183) highlights

> "with few exceptions, a budget is never, and never has been balanced in a depression"

Mydral (1939) states that the optimal fiscal policy depends on the state of the economy, whether it is in a temporal setback or a prolonged stagnation. In essence, a stagnating economy, as in the case of the US in the 1930s, hints at specific adjustment issues in the structure of the economy. The problem is most fiscal stimulus policies do not attack the fundamental root causes of the large adjustment problems. Hence, in such situations the optimal fiscal policy is the one that patiently reforms the deep causes of the adjustment problems. As Magud (2008) argues, the initial economic condition at the time of the shock based on the fiscal status of the government should determine the fiscal policy response to the economic downturn.

As Magud (2008) explains the classical fiscal policy, approach to an economic downturn implies the reduction of government fiscal deficit by a decrease in expenditure. Therefore, reducing demand for credit and hence the interest rates, this should have the effect of rising demand for investments and consequently the economy pulls out of a recession via the private sector. In contrast, Keynesian fiscal policy dictates that the government should response by raising expenditure to boost aggregate demand and hence output improving employment. As put by Keynes (1936) since the level of output and employment are determined by aggregate demand, hence in an economic downturn the government need to stimulate demand to improve the economy.

However, Friedman (1948) proposed that a fiscal policy should be fixed and based on a sTable and progressive personal taxation system whereby government expenditure on goods and services would not change unless the perspective of the "community" changes. Moreover, Friedman states that changes in the tax system should reflect the changing "community" perspective on the levels of expenditure on goods and services.

Friedman (1948) argued against fluctuating the fiscal policy with the business cycle, stating that lags would make the stimulus too late to have any real impact. A point also argued by Blanchard *et al.,* (2010) who state that lags in the fiscal policy meant that in general the impact of a stimulus policy on the economy was too late due to most recessions being too short. Remember, many recessions since the late 1980s have lasted only two or three quarters in many advanced countries, the obvious exception was Japan. As Blanchard *et al.,* (2010) hint the prevailing view in many advanced economies was the reduction of sovereign debt to more sustainable and sTable levels. And as Blanchard *et al.,* (2010) state many were sceptical about the effect of fiscal policy and the general view was that monetary policy provided sTable output gap, hence there was little reason to use another policy. Therefore, as Blanchard *et al.,* (2010) indicate the main fiscal policy response to a shock to output was the automatic stabilisers, which kicked in whenever the economy showed signs of a downturn, as these policies did not affect the sustainability and stability of the debts.

Auerbach (2002) hints at uncertainty regarding the size of the impact from a fiscal stimulus policy on the output. He states that there is little evidence to suggest a fiscal stimulus policy would have a stabilizing impact on the economy. Also suggests contractionary fiscal policy may have a bigger positive impact on output.

In order to understand the general factors influencing the current arguments, there is a need to review the current literature. As was highlighted by Blanchard *et al.,* (2010) and Auerbach (2002) not so long ago the consensus was that fiscal stimulus policies did not work mainly due to the large impact on the debt and the lagged effect and hence countercyclical monetary policy was the way forward during economic downturns. However, as highlighted by Blanchard *et al.,* (2010) the basis of this view the factors that are redundant in the 2008/2009 environment. Previously stated by Magud (2008) the fiscal policy response should be determined by the economic condition at the time and the fiscal statistics.

As Taylor (2000) hints in the 1980s and 1990s, the emphasis was on using the automatic stabilizers as the tool of choice for fiscal stimulus policy. Mainly, because the economic environment did not need a full stimulus policy, but also because of advances in monetary policy rendering such policies and their huge expenditure redundant. However, as Taylor (2009) states this view has changed amongst academics and policy makers alike in the aftermath of the financial crisis, which led to the deepest recession since the 1930s. He highlights the success of the rebate policy of 2001 and 2008 in overcoming the fiscal stimulus policy lag problems. Nevertheless, he concludes that there is no rationality for the revival of fiscal stimulus policies.

Although Feldstein (2002a) agrees that there is little evidence of fiscal stimulus policies having a positive impact on the economy, yet he argues there is one strong area where the use of fiscal stimulus policies could have a positive impact on the economy. A long and sustained economic downturn where interest rates, inflation and aggregate demand are low or falling; examples are the Japanese economy of the 1990s to early 2000s and the US economy during the great depression of the 1930s. A key argument against the use of fiscal stimulus policies is that they increase the budget deficit and thus lead to a higher total debt; however, as Feldstein (2002a) notes a fiscal stimulus policy need not raise budget expenditure. If the policy aimsat, providing increased incentives to spend then it could increase economic activity, therefore reducing the fiscal deficit.

Feldstein (2009) argues contrary to popular beliefs the evidence suggests that the massive stimulus programs of the 1930s did not do as well as some believe. Unemployment remained high until the outbreak of World War 2, so it was war that finally brought unemployment under control. Yet the pursuit of active fiscal policy in the form of Keynesian economics remained even after the war, leading to increasingly volatile cyclical economics. This led to high inflation and unemployment throughout the 1960s and 1970s.

Hence as stated by Feldstein (2009), in the 1980s counter cyclical policy shifted to the use of monetary policy instead, this resulted in a sTable economy where both inflation and unemployment were relatively low and sTable. Generally, during this period economic downturns were the results of monetary policy attempting to reduce inflation by raising interest rates for the short run. The reversal of this monetary policy tightening took place when inflation was under control, which meant that consumers were able to take advantage of the interest rates and more importantly expenditure increased.

As Feldstein (2009) highlights the difference is that the current economic downturn was caused by the massive under-pricing of risks and excessive leverage by the banks because of the low interest rates. Consequently, the financial crisis forced the banks into a re-pricing of risk and deleveraging which caused the credit markets to freeze. The problem is that most householders/ consumers are reliant on the credit markets to offset their expenditure when this froze consumer expenditure collapsed. Feldstein (2009) estimated the loss on the economy of the reduction in consumer expenditure to be $400 billion per year resulting in an economic downwards spiral. This led to a sharp decrease in house and share prices, which eroded the householder wealth to the tune of $10trillion as estimated by Feldstein (2009).

Both Taylor (2008) and Feldstein (2009) states given the economic environment, it is hard not to see why many are considering a second fiscal stimulus. Since the economic downturns lasted 18 months, from December 2007 to June 2009 and interest were and still predicted to remain low, previous issues with fiscal stimulus such as the policy lags and high interest rates did not impede. However, Taylor (2008) argues given the increase in debt it is natural for householders to think there will be tax increases in the medium to long run.

However, as Taylor (2008) argues there is a requirement to analyse the first stimulus in order to learn about the options for the second stimulus. As both Feldstein (2009) and Taylor (2008) argue, the evident shows the temporary rebate plan of the Economic Stimulus Act of 2008 did not have the desired impact on personal expenditure. Taylor (2008) states this was not surprising since the permanent income theory of Friedman dictates that temporary increases in income will lead to only small temporary changes in consumption. In short, limited period income will not lead to an economic recovery and will lead to a long-term increase in the debt. Another lesson highlighted by Taylor (2008) is do not aim the stimulus at a particular group and increase taxation on business and investments. In an economic downturn where two factors threaten householders, a reduction in their lifelong savings and unemployment, the last thing they need is increase taxes, which might put their jobs on the lines or further reduce their investments. Taylor (2008) argues the key weakness underpinning most stimulus policies and indeed most policymakers' statements is the lack of predictability and agreement to a sTable plans ensuring that the financial markets remain unsTable and householders and firms cannot properly plan. In essence, both Feldstein (2009) and Taylor (2008) argue against short-run stimulus policies, which do not stabilize the economy and leads to massive debt with little impact on the economy.

Both Feldstein (2009) and Taylor (2008) argue a permanent tax cut and indefinite postponement of tax rises on wealth, dividends and capital gains is likely to help. Feldstein (2009) also argues that under the current climax of high youth unemployment and low demand, the defence budget should not be decreased, the defence sector is key in maintain output and providing young unemployed with the skills to use when the economy recovers. As Feldstein (2009) states evidence suggests that research and development by business and academia will likely lead to new opportunities for the economy, hence he argues against cut in research funds and for investments tax credits. Essentially, both Feldstein (2009) and Taylor (2008) argue since there is an obvious agreement for a fiscal stimulus policy, it is of paramount important that the policy is aimed at permanent long run solutions that will stabilize both the financial markets and economy.

Aizenman & Pasricha (2010) found that although the federal stimulus expenditure was high but the evidence seems to suggest the collapse in the local and state budgets neglected the impact of the stimulus. This was mainly due to the big reductions in tax revenue and limited borrowing capabilities of the states. The problem is there are many issues regarding any new stimulus policy concerning both public and economists alike. The main issues as highlighted by Aizenman & Pasricha (2010) are:

- the lagged effect which could lead to inflationary pressures in the long run,
- the high debt/GDP ratio which could be a signal for higher taxation or/and a reduction in the federal expenditure in the long run,
- the moral hazard issue of rewarding states that are less prudent, especially in the case of the US,

However, as in the recent case of Valencia in Spain, this is not limited to the US.

Although there is an obvious, lack of literature on the impact of the recent US Fiscal Cliff and Debt Celling crisis episodes on the financial markets. Yet it is vital to understand the impact of the fiscal cliff on the global financial market. To put things in to perspective, the US sovereign debt market is by far the largest single financial market with an estimated $16.7trillion as of end 2013 according to the Federal Reserve Bank of St Louis. The world's biggest financial institutions and sovereign wealth funds regard the US sovereign debt market as the risk free liquid benchmark financial asset in many of their portfolios. Bearing this in mind, a default by the US Federal government would probably lead to a financial crisis on a scale many times larger than the recent financial and Eurozone sovereign debt crises. However, the key question is would any of the two main parties, the Republican or Democrats, haverisked the dangerous consequences of a global financial system meltdown and deeper global recession just when the global economy was struggling to recover from the deepest recession since the 1930s? The answer lays in the deadline agreement on each occasion with both sides making concessions. Another key question is how did both crises affect the global economy and financial markets in both the short term and long term?

One could look at the previous default by the US for clues; in 1979, the US defaulted on interest payments, which resulted in a hike on interests for US Federal debts and inevitably US households' debts and firms' debts. However, the impact on the global economy and financial markets were limited. The problem is, as explained earlier, the integrated global financial sector of today is different from 1979 and many global financial institutions regard the US Treasuries market as the risk fee liquid market. The answer may lay in the reaction of the market to the Greek sovereign debt crisis. However, if the US does default it will be a technical default on a single interest payment. This however will be enough to signal a single downgrade in the credit rating of the US Treasuries as hinted by the credit rating agencies.

In order, to understand the effect of the economic downturn and sovereign debt crisis on the Eurozone, there is a need to understand the effect of monetary union on the monetary and more importantly fiscal policies. As highlighted by Gali & Perotti (2003), the main criticism of the Maastricht Treaty and the Stability and Growth Pact is the constraints they put on the fiscal policy of member states of the Eurozone with ratios of 3% deficit and 60% debt to GDP. The argument is during an economic downturn, the member states cannot use a fiscal stimulus policy to ease the pressure because of the limits on the deficits put by the Stability and Growth Pact. As a result, the Stability and Growth Pact could work against the countries, in an economic downturn, due to the procyclical effect on the economy. This means that instead of increasing expenditure to assist in a fiscal stimulus policy, the countries may have to tighten fiscal policy making the downturn worse because they have lost control of monetary policy. The criticism that the Stability and Growth Pact in some countries has impaired the ability to provide an adequate level of services and infrastructure extends this argument.

At the time, Gali & Perotti (2003) did not find much evidence in support of these arguments. In contrast, they find evidence of increasing counter-cyclical policy, although not at the level of some other industrialized nations. While public investments in services and infrastructure have steadily decreased over the years but that is not limited to the Eurozone countries, they find evidence of reductions in public investments in other industrialized countries. They conclude one reason for their findings is that since the initiation of the EMU, real recessions have been rare amongst the member countries. Hence, the empirical evidence may not have tested the constraints implied by the Stability and Growth Pact.

However, the current environment changed that perspective. The already large debts in some countries, while in some countries an economy that has been on a downward trend for a long time before the financial crisis. The fiscal stimulus policies only served to worsen the fragile economy in those countries and led to a complete imbalance between the revenue and expenditure with unemployment rising. This led to the sovereign debt crisis as markets lost trust in the fiscal policy of most of these countries in the aftermath of the Greece upwards revival of their fiscal deficit. This along with the inability of the Eurozone leadership to come to a unified agreement on how to solve the economic crisis underpinning the sovereign debt crisis led to the deepening of the crisis. The other problem is as highlighted earlier by Taylor (2009b) is miscommunication, as hinted by Carmassi & Micossi (2010). The problems were amplified by the display of confusion among the European Community and often conflicting statements by politicians.

A key issue in any financial market is as Keynes (1932) states since the markets require a diverse range of government debts of various maturities and types, it would be possible for the government to minimize the cost of debt by supplying heterogeneous debts. This is especially so during a financial crisis where flights to quality, liquidity or safety are in action. However, Mydral (1939) hints some governments attempt to conceal budgets deficits and thus present a "balanced" budget, this leads to asymmetrical information during economic upturns as well as downturns. This could lead to a lack of trust by the financial markets in the governmental statistics as in the case of Greece recently.

2.3.3. Concluding Review

In concluding, as will be illustrated in section 4.2 and by many such as Feldstein (2009) and Taylor (2008; 2009b), the financial crisis and ensuing economic downturn left the global economy in such a state that conventional countercyclical monetary policy on its own was never going to be enough. However, neither were any conventional fiscal automatic stabilizers enough to tackle the economic issues as illustrated by Feldstein (2009) and Taylor (2008; 2009b). This highlighted an argument between proponents of unconventional monetary and fiscal stimulus policies. In truth, the debate was about whether using any unconventional policy to stimulate the economy in the short run would outweigh the costs of implementing such policies in the long run. The other debate was whether to use unconventional fiscal policies or unconventional monetary policy.

It is essential to note, as highlighted earlier in this section, that long before the turn of the century monetary policy in both the Eurozone member states and the US have been successful in controlling inflation and keeping the economy growing as hinted by Bernanke & Gertler (1999) and Taylor (2009a). Therefore, many academics, economists and policy makers saw little need for stimulus policies, especially fiscal as highlighted by Auerbach (2002) and Blanchard *et al.,* (2010).

In essence, such was the state of the economy that both policies were used in the early stages in some countries such as the US and UK. And in the absent of monetary policy to stabilize their economy, contrary to the stated constraints of the Stability and

Growth Pact, many Eurozone member states implemented unconventional fiscal stimulus policies. As will be illustrated by section 4.2, these policies resulted in high debt/deficit to GDP ratios and highly inflated central banks' balance sheets with very low interest rates. However, though these statistics could contribute to a huge share of the problems in the sovereign debt markets, it is fair to say that asymmetrical information and the ensuing lack of trust was at the heart of the initiation of the sovereign debt crisis as in the case of the Greek crisis. On top of that, there was a generallack of agreement between the different parties on how to solve the crisis as in the Eurozone sovereign debt crisis and the US fiscal cliff crisis. The problem as indicated by the fall in prices to below the par values of the sovereign debts from the GIPS group of nations over the past few years and recently the US, is this crisis hits demand.

In many way, the issue today is that how to scale back the stimulus policies without hurting the economy. With respect to monetary policy, the problem is the longer the unconventional monetary policy is still in use the higher the chance of inflationary pressures in the long term. However, in contrast, the quicker the reduction in central bank's balance sheet, the more likely, that the market will become over supplied which will hit the asset prices leading to a liquidity trap. The concern for monetary policy makers is how to unwind the quantitative easing policy without leading to inflationary pressures and downwards pressures on the asset prices. The problems faced by the fiscal policy makers are similarly tough; the choice is between higher taxes or lower expenditure, get the balance wrong and the economy could be in a bad state for the long run.

In concluding, the issue at the heart of this hot debate remains unresolved that is how to stimulate an economy, which had just faced a big financial crisis leading to a huge economic downturn. There is a hint of catch 22 about this in that as Tobin (1971) hints in the long run there are issues with both policies one leads to inflationary pressures and the other leads to either tax increases or expenditure decreases. However, as Keynes (1923) argues the problem is there are big issues facing the economy in the short run.

2.4. Review of the Models of Volatility

Volatility is a key indicator of the risks in the financial markets and a measure of the price movement in accordance with the information. In a one period hypothetical world, there are two methods of calculating the volatility based on past price or returns data: variance and standard deviation. This assumes that market participants will not hold the asset for more than one period and more importantly, volatility is unconditional. However, as observed by Engle (1982) and Bollerslev (1986), a relevant factor in the research of financial/economical time series is that most, if not all, observed datasets seem to be following a time varying volatility or conditional variance pattern. Hence, as hinted by Engle (2001), the calculation of the volatility usually used an equally weighted average of the standard deviation or variance method with a fixed number of recent lags, e.g. 22 or 5 days for a working month or week respectively. A key weakness in this method was the assumption of equal weights, mainly because recent observations should carry a greater weight than older observations. Furthermore, this method renders useless any observation older than the chosen fixed period. Hence, disregarding any past information on the volatility contained in the older observations. As Engle (1982) alludes, the current conditional variance depends upon all past information. As noted by Engle (2001), thus far virtually no methods took into account all past information accounted for in the observations.

Engle (1982) introduced the ARCH model, a generalised model of the bi-linear model devised by Granger & Andersen (1978), which had the drawback of the unconditional variance being either zero or infinity. As Bollerslev *et al.,* (1992) states the ARCH model allowed for the changing variance and covariance as noted earlier by Mandelbrot (1963) and Fama (1965) amongst others. As described by Engle (1982), the ARCH allowed a discrete time stochastic process to estimate the conditional variance. As hinted by Bollerslev (2008), the q^{th}-order linear ARCH as described by Engle (1982) captured another financial time series phenomena first hinted by Mandelbrot (1963), volatility clustering, as defined later in this review. See Bollerslev *et al.,* (1992) for a more in depth review of the theory and empirical evident underpinning the use of the ARCH model of volatility in finance.

There are many other alternative models of time varying volatility such as stochastic volatility, realized volatility and EWMA as advocated by RiskMetrics™ (JP Morgan, 1996)[7]. Although they are not within the scope of this research, yet mainly due to their innovative and different method of modelling the volatility, there is a need to discuss two such models: stochastic volatility and realized volatility.

[7] J.P. Morgan (1996), 'RiskMetrics – Technical Document', [Retrieved from]. (accessed on 27 December 2013).

As Ghysels *et al.,* (1996) states, the origin of stochastic volatility came from researching a different issue. Clark (1973) suggested that asset returns follow a time deformational approach yielding a time-varying model of volatility. As Ghysels *et al.,* (1996) illustrate two further models of stochastic; volatility came thru different works by Tauchen & Pitts (1983) and Hull & White (1987). In a key research on financial returns using two stochastic processes, Taylor (1982) derived a discrete time stochastic volatility model as an alternative to the ARCH model. In general as Andersen & Benzoni (2010) hints, there are two distinct applications for stochastic volatility models in the literature. One application is to signify that the volatility in financial returns displays a time varying random fluctuation. The second imply that returns variation seems to follow unobserved random shock, therefore inferring that volatility is inherently latent. However, as hinted by Bollerslev & Zhou (2002), the estimations of stochastic volatility models were difficult due to two reasons: the assumed latentvolatility and the general unavailability of closed form expressions for the corresponding transitions density functions for continuous time models.

However, as illustrated by McAleer & Medeiros (2008), the previous two families of volatility models briefly discussed, ARCH and stochastic volatility, do not fully describe several phenomena's' observed in financial time series. Realized volatility as defined by Andersen & Benzoni (2008) is nonparametric ex-post estimate of the return variation. Essentially, the model is an aggregated number of high frequency, usually five minutes, returns as noted by Asai *et al.,* (2012). Therefore, they overcame the limitations of the other two models as illustrated by Corsi *et al.,* (2006), Andersen *et al.,* (2003) and McAleer & Medeiros (2008) among others.

As previously stated, according to Bollerslev & Hodrick (1992) there is evidence of seasonality and volatility clustering issues effecting the fundamentals and prices. Therefore, pointing to the use of ARCH/GARCH models to overcome these issues in the Shiller volatility test. Another important factor in the use of GARCH models is as illustrated by Blanchard & Watson (1982) and Branch & Evans (2011; 2013), there are several features within an asset price bubble that can be picked up by the use of the GARCHfamily of volatility models. Branch & Evans (2011; 2013) hints at feedback and asymmetrical features in an asset price bubble, therefore implying the use of GARCH-m and GJR-GARCH in order to understand the impact of bubbles on asset prices.

However, a much less reviewed model but of equal significant in the explanation of the behaviour of volatility is the SWARCH model. Although the evident on the regime switching in the sovereign debt market in the last few year have been strong (Georgoutsos & Migiakis, 2009; 2010 and 2012; Pozzi & Sadaba, 2013 and Schuster & Uhrig-Homburg, 2012). There seem to be a lack of emphasis on the effect of regime switching in the conditional volatility in the financial market in general and more specifically in the sovereign debt market. And in general, the evident in the literature isn't strongly oriented towards the issues of the sovereign debt market i.e. Christiansen (2008) research is geared toward the short rate models and Abdymomunov (2013) is more towards identifying financial stress in the financial sector (essentially the US banking sector) using a number of financial indicators or variables. As hinted by Blanchard & Watson (1982) and more recently Branch & Evans (2013), a relevant factor is that on some occasions an asset price bubble could periodically collapse thus alluding to the use of a Markov switching model to understand the impact of a bubble on the prices.

The rest of this review is concerned with the use of the GARCH family in the estimation of the conditional variance and the interpretation of the behaviour of volatility. The structure of this review follows the standard format of first critically reviewing the theoretical model underpinning the chosen GARCH models and then reviewing the recent empirical evident in the literature on the sovereign debt market volatility. We will review a number of behaviours modelled by the GARCH family: volatility clustering, feedback effect, leverage effect and leverage-feedback effect. We conclude by reviewing the SWARCH models of Cai (1994) and Hamilton & Susmel (1994).

2.4.1. The use of the GARCH Family in the Sovereign Debt Market

Perhaps the best and most widely used group of time varying volatility models are the GARCH family. There are many research papers based on the use of the univariate GARCH family to capture the time varying volatility. And as illustrated and summarised by Engle (2001) and Bollerslev (2008) there are many variants of the univariate GARCH model, each proposed to address a different issue in the time varying volatility. In this section, we intend to concentrate on a limited number of the GARCH family addressing the following volatility issues within the sovereign debt market: volatility clustering, leverage, feedback and leverage-feedback effects.

A key observation, frequently referred to as volatility clustering, often made in finance and economic is that

> "Large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes" as quoted by Mandelbrot (1963, p. 418).

As intendedoriginally, the introduction of the ARCH model proposed by Engle (1982) aimed at modelling the volatility clustering effect. The model was generalised by the introduction of the GARCH model by Bollerslev (1986), which benefited from the inclusion of a flexible lag structure and long memory.

The literature is full of research into the volatility clustering effect in the sovereign debt market, using variant of the GARCH model, two such papers are Jones *et al.,* (1998) and Bollerslev (2000). In researching the persistent of volatility in the US Treasury market through macroeconomic news announcement shocks, Jones *et al.,* (1996) using a GARCH model find that there is limited or no persistent in volatility on bond markets in the days following the announcement. However, Bollerslev (2000) using a FI-GARCH model find the presence of long memory volatility in the bond markets in the aftermath of announcements. There are many other researches, which have identified volatility clustering in the sovereign debt market such as Christiansen (2000).

However, as indicated by Engle *et al.,* (1987), theory dictate that market participants require increasingly high premium on returns for investing and/or holding increasingly risky assets which is often referred to as the feedback effect. Engle *et al.,* (1987) devised the ARCH-m model, which was generalised as a GARCH-m to model the feedback effect, thus extending the ARCH-m by inserting the conditional variance into the conditional mean equation.

There are many research papers on the feedback effect in the sovereign debt market. However, two of the most influential in the context of our research are Engle *et al.,* (1987) and Bollerslev *et al.,* (1988); both papers were interested in researching the time-varying risk/return trade off in the context of the sovereign debt market. And indeed Bollerslev *et al.,* (1988) use a multivariate GARCH model to estimate the CAPM Beta These are two distinct empirical evident for the feedback effect, while Engle *et al.,* (1987) originally introduced the ARCH-m to model the risk-return trade-offs in the term structure of US interest rates. They conclude that the risk premium sought by the market participants is not constant; it varies with respect to the perception of uncertainty over time. Bollerslev *et al.,* (1988) derived a model first purposed by Engle *et al.* (1987) in extending the ARCH-m to include the conditional covariance and thus implementing a multivariate GARCH-m model. They extended the CAPM to be time varying by using the conditional covariance to calculate the Beta and time varying CAPM to calculate the expected returns from the 6-month Treasury bill, 20-year Treasury bond and stocks. Among the conclusions they observe is that the results points at the CAPM Beta being time varying.

A key observation made primarily in stock markets, there is a negative correlation between returns and volatility as hinted by Black (1976). Thus meaning a negative movement has a greater impact than a positive movement of similar magnitude on the volatility. Glosten *et al.,* (1993) proposed a model, aka GJR-GARCH, extending the GARCH-m model to allow for asymmetries in the conditional variance, thus generalising the GARCH-m to model the leverage-feedback effect. It is essential to note that the GARCH-m is integrated into the GJR-GARCH model which mean that when there is no leverage effects the model collapses to a GARCH-m.

However, another model often used to estimate the leverage effect is the EGARCH proposed by Nelson (1991). The key different is that unlike many other GARCH models where the need arises to constraints the coefficients to ensure the positive conditional variance, the EGARCH model uses the log of the conditional variance. However, as Bollerslev (2008) notes the inclusion of the log of the conditional variance complicates the unbiased forecasts for the future variances. As stated by Nelson (1991), an extension to the EGARCH could be the capture of the leverage-feedback effect by combining the EGARCH and GARCH-m, thus deriving the EGARCH-m. Unlike the GJR-GARCH, the EGARCH-m model does not contain the GARCH-m model; the EGARCH-m is from two separate models. This is helpful in analysing the feedback and leverage effects due to the separation of the effects coefficients.

The leverage or asymmetrical effect is well documented in the stock markets but little empirical evident have been documented in the sovereign debt market e.g. Dungey *et al.,* (2009), especially with the `GJR-GARCH. In a sense Dungey *et al.,* (2009) is interesting not only due to the leverage effect research in the sovereign debt market but also to the flight to quality effect. Dungey *et al.,* (2009) analyse the leverage effect of flight to quality in respect to the US Treasuries market. Using the asymmetric GARCH model TGARCH (or TARCH) proposed by Zakoian (1994), they explain the positive sign asymmetries find in most flights to quality. During any period of uncertainty such as the recent banking crisis, increasingly risk averse market participants tend to sell high-risk assets and buy low risk assets. As noted by Dungey *et al.,* (2009), this leads to low risk asset markets, such as the US Treasuries, exhibiting positive sign asymmetries i.e. '*a positive price shock in the low risk asset may generate a disproportionately large volatility response*'. While the high risk asset will suffer from negative asymmetries.

Like the leverage effect there is limited empirical evident of the leverage-feedback effect in the sovereign debt market i.e. Brunner & Simon (1996). Brunner & Simon (1996) use the EGARCH-M model to research the robustness of the predictive powers of the yield curve in using the conditional variance as the risk premium. They use the excess returns of the US Treasury 10 year notes, 20 and 30-year bonds over a one-month bill; from the Federal Reserve over the period from January 1968 to March 1993 using a weekly frequency provided the data. They find highly significant evident of leverage effect and the results from the EGARCH-M seem to hint at a feedback effect, although the slope of the yield curve continues to forecasts excess returns. There is a positive correlation between the volatility on the excess returns and the level of short-term rates.

Recently much of the empirical evident have concentrated on the volatility during the financial or sovereign debt crisis and their effect on the Eurozone. It is important to note that the underlying issue in most of these researches is the effect of the crises on the integration of the financial markets within the Eurozone. Another key issue studied is the contagious effect of the crises especially among the GIIPS nations within the Eurozone due to monetary unification. Good examples of such studies on the effect of the recent crises on the volatility within the Eurozone are Dotz & Fisher (2011), Metui (2011), Tamakoshi (2011) and Mohl & Sondermann (2013).

In a research on the effect of the financial crisis on the Eurozone sovereign debt markets, Dotz & Fisher (2011) used a number of univariate GARCH-in-mean specifications to analyse the liquidity, risk premium and expected loss component in ten Eurozone sovereign debt markets. The empirical study use daily yield data from eleven Eurozone sovereign debt markets over the period between 4 February 2002 and 30 April 2009. The results seem to indicate in the aftermath of the rescue of Bear Stearns in March 2008 market perceptions to sovereign debt risks changed where many sovereign debt markets were previously seen as safe havens with a negligible implied probability of default, now were seen as having high default risks. The high-implied default probabilities reflect an increasing expected loss influenced by the soundness of the country's financial sector, among others. Although there is little evidencethe widening spreads of high yields spreads' countries impact both risk and liquidity premia; the evidence seems to suggest that these two premia had a major role in other countries widening spreads. However, the dominant roles of the expected loss seem to points to fundamental sovereign factors playing a key role in comparison with global factors such as market participants' risk aversion.

In a paper researching contagion among the Eurozone sovereign debt markets, Metui (2011) employ the GJR-GARCH model to analyse the effect of news on spread volatility relative to the US Treasury 10 year note yields. They use daily 10-year benchmark yields from 11 core, Eurozone and the US markets obtained from Datastream between 1April 1999 and 29 April 2011. In concluding, the results seem to be suggesting a strong leverage effect for all countries; hinting at a surprise increase in the yield premia having greater impact than a surprise decline. Using timeline analysis they illustrate that volatility in the one period ahead 95% VaR seem to correspond with the periods of high financial distress during the recent financial and following sovereign debt crises. They find statistical evident of contagion in the Eurozone during a credit crisis in one or more countries. This last statement is of importance due to the integrated markets meaning sovereign debt crises in small open economies such as Greece, Ireland and Portugal can become systematically important due to contagion links. Concluding, they argue for the implementation of an early warning mechanism for market participants in the sovereign debt market; implementing a periodic stress test on sovereign borrowers.

In an empirical research into the volatility spillover effect of 10-year sovereign debt yields during the Eurozone sovereign debt crisis, Tamakoshi (2011) use a number of AR(k)-EGARCH (p, q) model specifications to fit each of the seven datasets. Theyuse daily 10-year yield data from seven Eurozone members (i.e. GIIPS plus Germany and France) observed over the period between 1 January 2007 and 31 March 2011. He concludes that the analysis points to the existence of short-term spillover effects across the seven Eurozone countries with the biggest pre-crisis spillover coming from Portugal and France. However, the biggest post-crisis spillover comes from Portugal and Italy. Although Germany remains the strongest economy and has the best credit rating driven by strong sound fiscal policies, yet the evident seem to hint at volatility spillover effect from Germany on some Eurozone long-term bond yields. Concluding, this finding has important implications for portfolio diversification in the Eurozone sovereign debt markets.

In a study by Mohl & Sondermann (2013) on the impact of political communication on the spreads of the GIIPS nations relative to the German benchmark yields during the Eurozone sovereign debt crisis. They use an EGARCH model to measure the conditional mean and variance among three categories of political communications concerning restructuring, bailout and the European Financial Stability Facility. They use the daily spreads and news over the period between 1st May 2010 and 30th June 2011 from Haver and a number of news agencies (i.e. Bloomberg, Dow Jones Newswire, Market News International and Reuters). The results seem to be hinting at a limited impact on statements concerning bailouts. However, statements concerning restructuring increased volatility and the EFSF decreased volatility. Their results seem to be indicating statements from major contributing nations about the restructuring seem to have more impact than receiving nations. In contrast, statements on the EFSF from receiving countries have a larger negative impact on the conditional volatility. In concluding, they state that political communication played a key role in the Eurozone crisis. They extend their finding by supporting the calls for an improve communication discipline.

Of course, there are other univariate GARCH/ARCH models of volatility, which could be useful in our research of the behaviour of volatility. Here we briefly analyse four such models:

- GARCH-X by Brenner *et.al.,* (1996)
- GARCH-Jump
- Spline-GARCH by Engle & Rangel (2008)

Interest rates are essential in theoretical and empirical economic and finance. Hence, modelling the volatility of interest rates However, as noted by Brenner *et al.,* (1996), models which parameterize volatility as a function of the level of interest rates tend to overemphasize the sensitivity of volatility to the level. In addition, GARCH models fail to capture the relationship between interest rate levels and volatility. Hence, Brenner *et al.,* (1996) proposed an extension to the GARCH model to allow the volatility of the interest rate to depend on the levels of the interest rate and the shocks to the information. However, the empirical evidence regardingthe variants of the GARCH-X model is mostly in the volatility of the short-term interest rate. Good examples of such studies are Meade & Maier (2003), Staikouras (2006) and Hou & Suardi (2011).

A key feature of the impact of news on financial assets is a temporarily hike in the return and volatility otherwise known as a jump. A number of studies have highlighted jumps in the volatility of the sovereign debt market in the aftermath of news or announcements regarding events or fundamentals, such as Jones *et al.*, (1998) and Bollerslev *et al.,* (2000). However, another channel of research on jumps in volatility is thru communication by policy makers such as central bankers or politicians. Good examples of such research are Collignon (2012), Collignon *et al.,* (2013) and Dewacther *et al.,* (2014). Essentially, under GARCH jumps can be modelled using two different methods: GARCH-Jump Mixture and non-normal distribution GARCH. The GARCH-Jump Mixturerelies on a combination of the GARCH and jump whereby the GARCH accounts for the smooth changes in the volatility and the jumps explain the large infrequent discrete movement in the returns e.g. the GARJI model proposed by Maheu & McCurdy (2004). According to Dael & Yu (2005), the problem with this method is that it requires substantial amount of processing power and may not provide a better-fit top the distribution of the data. The second method relies upon a non-normal distribution model of the underlying data (e.g. student t, skewed t-distribution, non-central t-distribution) and a GARCH model capable of picking up the non-normality. However, with this method, a problem is that the jump could occurs in the volatility and not in the data.

Since as stated earlier there is no private information in sovereign debt returns, therefore the movement in the returns must be coming from public information. In essence, public information in the sovereign debt market is from two sources: news and macroeconomic announcements. And since macroeconomic announcements is a regular source of price movement in the sovereign debt market, hence there has been many researches on the relationship between macroeconomics indicators and the sovereign debt market such as Balduzzi *et al.,* (2001), Brandt & Kavajecz (2004) and Andersson *et al.,* (2006). Engle & Rangel (2006) recognise that volatility is higher during macroeconomic announcements. However, there is a limitation in these studies, since as hinted by Engle & Rangel (2008) part of the problem is the difference in the data frequency level. In essence, price/return volatility has a much higher frequency than macroeconomics indicators/announcements. In order to overcome this issue Engle & Rangel (2008) introduced the Spline-GARCH model, which allows the linking of high frequency financial data with the low frequency macroeconomic data. The model is also based upon a key factor in that unlike most GARCH models the unconditional variance is time varying. There seem to be a lack of empirical evidence with respect to the Spline-GARCH model in the sovereign n debt market. However, Becker & Clements (2007) using a slightly modified version of the Spline-GARCH model found that number of macroeconomics indicators have significant explanatory powers on the unconditional volatility in the S&P 500 index. Azad *et al.,* (2011) using the Spline GARCH also found a strong relationship between the volatility in the Japanese interest rate swap markets and macroeconomics indicators.

2.4.2. The use of the MV-GARCH Family in the Sovereign Debt Market

While univariate GARCH are certainly of importance in studying the behaviour of volatility in the sovereign debt market, however as Silvennoinen & Terasvirta (2008) states it is equally essential to understand the co-movements of returns and volatility. The two key factors in the co-movements of financial assets are correlation and covariance. However, in the context of the behaviour of volatility in any financial market, the research of integration/diversification and contagion/spillover effects is highly relevant at any time. Mainly due to the recent financial and sovereign debt crises, the empirical evidence in these issues has increased. While to a certain extent these effects can be modelled using univariates GARCH models as Christiansen (2007) shows, yet the basis of the majority of empirical evidence are multivariate GARCH models such as the BEKK proposed by Engle & Kroner (1995) and DCC proposed by Engle (2002). There are other multivariate GARCH models; Bauwens *et al.,* (2006) and Silvennoinen & Terasvirta (2008) provide a good summary on the theories and models of the multivariate GARCH models.

As Abad *et al.,* (2010) concludes the evidence on integration within the Eurozone sovereign debt market was not strong even before the financial and sovereign debt crises. The problem is that the crises had increased the diversification among the Eurozone countries. However, while this could be a problem for policy makers, this is not a problem for market participants who hold partial or complete sovereign debt portfolios, mainly due to the opportunities for portfolio diversification within the Eurozone.

As illustrated by Pericoli & Sbracia (2003) and Louzis (2013) the evidence on contagion and spillover effects are strong. As noted by Pericoli & Sbracia (2003), this evidence is not limited to countries within a region but there is also evidence of cross-regions volatility transmissions. Louzis (2013) also notes the strong evidence of cross-markets spillover effects during the crises highlighting the volatility transmission between the stock and sovereign debt markets during the Eurozone sovereign debt crisis.

As noted previously, much of the recent empirical evidence has concentrated on the spillover effect and contagion during the financial or sovereign debt crisis and their effect on the Eurozone. Good examples are Missio & Watzka (2011), Favero & Missale (2011) and Groba *et al.,* (2013). Another popular route in the recent empirical evidence is the effect of market integration on portfolio diversification as hinted by Laopodis (2010).

In an empirical study, into dynamic linkage in the yields among the four major sovereign debt markets, Laopodis (2010) used two econometric models: a bivariate VAR model and the DCC model. They use monthly data on the 10-year yields from four major sovereign debt markets (i.e. the US, UK, Germany and Japan) over the period between 1990 and 2009. In concluding, they found significant short-run relationship among the yields in the pre-euro period. They also find that US yields have an increased significant impact on the British and Japanese yields in the post-euro period. The resulting correlations between the British, German and American markets seem to vary over both periods. However, the Japanese correlation with the other three markets has strong upside and downside variances. They suggest that the inclusion of the German and American bonds in a portfolio may not reduce overall risk. These findings seem to suggest that higher integrations and close substitution of sovereign bonds diminishes market participants' portfolio diversification. Moreover, greater interdependent of the sovereign bond yields reduces the central bank's ability to influence the long-term interest rates and hence objective.

In a research on the effect of financial contagion and sovereign credit rating announcements from the sovereign debt crisis on seven Eurozone yield spreads, Missio & Watzka (2011) use a DCC multivariate model. Using daily yields from eight Eurozone 10-year sovereign debt markets observed over the period from 31 December 2008 to 31 December 2010 obtained from Datastream. Fitch provided the ratings announcements during the period for each country, in addition to Moody's and S&P for the Greek negative rating announcements. In common with the analysis, there are two conclusions to the study. In term of the effect of financial contagion, they state that strong dynamic correlation results from the DCC model for a number of countries in relationship with Greece, especially during the summer of 2010, hint at financial contagion. This period of high dynamic correlation coincides with the first bailout of the Greek economy. In term of the effect from rating announcements, the results seem to hint at strong dynamic correlations for a number of countries in relation with Greece concerning bad rating announcements. However, in both cases other DCC results seem to imply that financial contagion only effect economically or politically unsTable countries.

In a paper researching the determinants of sovereign debt yield spreads on German bunds of 10 Eurozone members, Favero & Missale (2011) use the BEKK to analyse the effect of contagion for Italy and Spain. They use the weekly 10-year yields of 10 sovereign debt markets to calculate the spreads on German bunds over the period June 2006 to June 2011 while also using the US Baa and Aaa rated corporate bonds to calculate the risk aversion spread. They also use other key economic factors. The results seem to indicate the financial crisis and following sovereign debt crisis both affected the Italian and Spanish spreads. It would seem that the local economic fundamentals could explain part of the volatile effect on the spreads of these two markets. However, the overreaction to global risk factors among the financial markets, which can heighten the contagion effect, explains the other part. Given the other issues discussed in the paper and the contagion effect, they conclude that maybe Eurobond is not what is wanted right now but increase political integration and introduction of Eurozone fiscal governance will help. However, they argue that maybe the introduction of the Eurobond will help with these two policies.

In an article researching the impact of distressed economies in the EU sovereign debt market, Groba *et al.,* (2013) analyse the transmission of default risks among the EU countries during the recent financial and sovereign debt crises using the information contained in the CDS. The article used an EGARCH and a bivariate BEKK to capture the leverage and volatility spillover effects respectively in the observed CDS markets. They use the weekly CDS spreads with maturities 1, 3 and 5 years denominated in US$ for 14 EU sovereign debt markets[8] observed over the period 2008 – 2010. In common with Dotz & Fisher (2011), the results from the EGARCH model seem to be hinting at a regime switch in the CDS spread volatilities among the observed markets in March 2008. A key finding is the observation of a transmission of risk from the GIIPS nations to other nations during the observed period. This seems to be pointing at a fragmentation of the EU sovereign debt market into financially distressed economies and other EU nations.

[8] The 11 core Eurozone members plus Denmark, Sweden and the UK

2.4.3. A Review of the Markov Regime-Switching ARCH Models

As stated by Hamilton (1989) the basis of a number of previous researches studying the relationship between the business cycle and GNP is the assumption of the observed data following a linear stationary process. However, as a number of studies have proved the assumption of linearity and stationary in key macroeconomic datasets is weak. Hence, in an article on non-stationary time series and the business cycle, Hamilton (1989) introduced a regime-switching model based on an autoregression method using a discrete-state Markov process. See Hamilton (2008) and Piger (2011) for a more descriptive survey of the different Markov switching models.

Like the GARCH group of models, the multivariate Markov switching models has a number of scenarios to prove the case. There are a number of complex multivariate models such as the Markov switching vector autoregression as defined by Krolzig (1997) and vector error correction. As hinted by Krolzig (1999; 2000), the Markov switching vector autoregression model extends the Markov switching autoregression model to a multivariate model with vector autoregression as the basis. This model allows for the analysis of the relationship between endogenous variables in a Markov switching model over the observed period. Hence, a key factor in the use of this model is the co-integration of economic variables during different regimes. Since we will only be using a univariate Markov switching model, we will not be diving into an in depth analysis of the multivariate models. See Krolzig (1997) for a more descriptive analysis of the various multivariate Markov switching models.

The recent financial and sovereign debt crises have certainly resulted in an uplift in empirical studies of the Markov switching model in the sovereign debt market i.e. Georgoutsos & Migiakis (2009; 2010; 2012), Pozzi & Sadaba (2013) and Schuster & Uhrig-Homburg (2012). However, the basis of most of this evidence is a multivariate Markov switching model, i.e. Georgoutsos & Migiakis (2009) using MS-VECM. Most of the basis of the recent research is around the sovereign debt crisis and to a lesser extent the financial crisis effect on the Eurozone sovereign debt market.

It has long been acknowledge financial markets sometimes go thru alternate periods, characterized by high volatility and others by low volatility as noted by Hamilton & Susmel (1994) and Cai (1994) among others. In researching monthly short-term interest rates, Hamilton (1988) concludes the possible present of regime shifts in ARCH effects could explain the estimates of the ARCH-m of Engle *et al.,* (1987). In fact a common problem in the estimation of ARCH/GARCH is spuriously high persistent of volatility across subsamples as stated by Hamilton & Susmel (1994). Diebold (1986) and Lamoureux & Lastrapes (1990) argue that structural changes in the observed dataset could be the reason for a high estimate of the ARCH/GARCH parameter, which leads to high persistent.

Thus meaning that sometimes, simple ARCH/GARCH models do not entirely explained volatility, there is a need to combine the regime-switching capabilities of the MS model with conditional volatility models such as ARCH/GARCH. As noted by Cai (1994), a key factor in the use of SWARCH is the endogenisation of parameter shifts, thus allowing shifts to be determined by the observed dataset. Additionally, a key advantage is that it distinguishes between the effects enabling the analysis of their impact on the properties of the observed dataset. This led to a number of integrated models generally called SWARCH, i.e. Cai (1994), Hamilton & Susmel (1994) and Hamilton & Lin (1996). As the name suggests the SWARCH model was a combination of the MS and ARCH.

Gray (1996) introduced a GARCH version of the SWARCH in analysing the regime-switching behaviour of one-month US T-Bill yield's volatility; found a mean reverting high volatility with low volatility persistence. He also finds the opposite behaviour with a non-mean reverting low volatility state with high volatility persistence. However, the evident for conditional volatility as oppose to stochastic volatility in the sovereign debt market is not strong. Dahlquist & Gray (2000) used a similar model to Gray (1996) in analysing the short-term interest rates of EMS members. They conclude there is a different between "non-credible" and "credible" regimes whereas "non-credible" regimes displayed high and volatile interest rates with strong mean reversion. "Credible" regimes previously characterized by low volatility and weak mean-reversion, which seem to display a unit-root like behaviour.

Although the MS-GARCH models seem to produce stronger results than the SWARCH, however as Cai (1994) states the complexity of the estimation in integrating a GARCH with the Markov switching model makes it less feasible in large datasets. The problem is that the lagged structure of the GARCH model means that each state in a Markov switching model takes two values, thus implying a total of 2^t probabilities. Moreover, as stated by Guidolin (2012) the GARCH model has high volatility persistence, which can be a double-edged knife. On the one hand, it can be an advantage for research such as the one influenced by Cai (1994) and Hamilton & Susmel (1994) in highlighting that the high volatility persistence observed in some research is the result of regime switch. On the other hand, the use of a Markov Switching model could exaggerate the high volatility persistence displayed in a GARCH model. Another issue is as highlighted by Guidolin (2012); the MS-GARCH model is hugely complicated to estimate. Although Gray (1996) and Dueker (1997) overcame these issues, however their models are very complicated. There are several alternative MS GARCH models, which are summarised by Guidolin (2012) and Hamilton (2008).

Although the models of Cai (1994) and Hamilton & Susmel (1994) are based on SWARCH implementation, they adopt different methods of implementing the SWARCH. Cai (1994) models the shifts in the asymptotic long-run variance of the SWARCH process. Thus in this model the intercept of the conditional variance is allowed to change in response to the discrete shifts in the regimes. Whereas Hamilton & Susmel (1994) also model the shifts in the dynamic process of the conditional variance, this means that the basis of the regime shifts are the changes in the scales of the conditional variance.

The literature on the empirical evident of the SWARCH in the sovereign debt market is not a huge one in comparison with other models. Although the Markov switching and GARCH models separately have been the focus of attention since the financial and sovereign debt crises, yet there is a drought in the empirical evident of the SWARCH. As with the other models analysed in this research, we find a two way split in the evident with a group, such as Christiansen (2008), researching the yields and the second group of research such as Abdymomunov (2013) studying the returns. The significant of these two papers is that they also use different SWARCH implementations whereas Christiansen (2008) uses the Cai (1994) method; Abdymomunov (2013) uses the Hamilton & Susmel (1994) method.

In a research on the relationship between the volatility on the short rate of the US and UK and the US and Germany, Christiansen (2008) extended the Cai (1994) implementation of the SWARCH model to a bivariate model in order to estimate both volatilities, i.e. US and UK and US and Germany, simultaneously. The research used the weekly 1-month Eurodollar, Libor and Euromark[9] for the US, UK and Germany respectively; observed from January 1975 to December 2004 obtained from the Federal

[9] After the introduction of the Euro, the rate used was Eurocurrency

Reserve and Datastream. They found the inclusion of the level effect and regime switching in the model seems to be rendering the ARCH effect in the conditional volatility insignificant. In addition, the regime switchingoccurs in the level or constant in the ARCH model specification. Moreover, they find evident suggesting that neither a state dependant level nor volatility have an advantage over the other. The results seem to be indicating a mixed picture with each country short rate model conforming two different models with respect to the two states. However, there is a difference in the models each country conformswith respect to the states. There seem to be no evident of contagion between the US and Germany and US and UK. However, in general they did fund some evident of Granger causality. This seems to be suggesting that the ECB in particular can exert some influence on the Eurozone short rate volatility.

In a study on the impact of financial stress from abrupt and large changes in the volatility of key financial variables on the US financial, Abdymomunov (2013) extends the Hamilton & Susmel (1994) model to a multivariate SWARCH model. They use transformed weekly TED spreads, value-weighted stock NYSE returns and capital-weighted CDS from a number of bank a\s the financial variables. Various places such as Bloomberg and the FRED database of the Federal Reserve Bank of St Louis provided the data observed over the period 6 December 2000 to 29 September 2010. However, the CDS data observed between 10 November 2004 and 29 September 2010. They find strong evident of the high volatility state in the joint variables mimicking times of financial stress such as the subprime crises and credit crunch in August 2004 and the Lehman Brothers bankruptcy in September 2008. The results seem to suggest that a possible indicator of financial stress could be the joint variables regime-switching model.

2.4.4. Concluding review

In concluding, there was a large and growing literature on the use of the GARCH family to analyse the behaviour of volatility in the financial market and in particular the sovereign debt market e.g. Engle *et al.,* (1987), Bollerslev *et al.,* (1988), Brunner & Simon (1996), Jones *et al.,* (1998), Bollerslev (2000) and Christiansen (2000). This has grown over the last few years due to the recent financial and sovereign debt crises e.g. Dungey *et al.,* (2009), Dotz & Fisher (2011), Metui (2011), Tamakoshi (2011) and Mohl & Sondermann (2013). Essentially, the empirical evidence of the last few years has illustrated the changing behaviour of volatility during a period of crises. However, what is important to notice in these articles is the different impact from the financial and sovereign debt crises on the sovereign debt market.

In essence, this evidence certainly points to a change in the behaviour of volatility in the aftermath of each of the crises. During the financial crisis the evidence seem to be suggesting that most sovereign debt markets were seen as safe haven due to the crisis in the financial market e.g. equity, asset backed securities (such as MBS and CDO) and corporate bonds especially those issued by the financial sector. While the evidence during the sovereign debt crisis seem to hint at a flight to safety from the GIIPS nations to the German and US markets as contagion/ spillover effects impacted the market. This point to a change in the behaviour of market participants during both crises, which can be picked, using timeline analysis with fixed subsamples, linked to the financial and sovereign debt crises. Although, the financial and sovereign debt crises had their roots long before the summer of 2007 and autumn of 2009 respectively. Yet most analysts and academics would acknowledge the Bear Stearns' Funds problems on 7thJune 2007 as the start of the global financial crisis as hinted by Brunnermeier (2009) and the Greek annual deficit revision on 5th November 2009 as the start of the sovereign debt crisis as hinted by Lane (2012). Therefore, we can subdivide both the 2012 and 2017 observed datasets into samples corresponding to the global financial and sovereign debt crises.

In essence the period before the financial and sovereign debt crises was highlighted by the asset price bubble, introduction of the Euro and some extreme events i.e. 11 September 2001 terrorist attacks. It is interesting to see how the asset price bubble effected the behaviour of volatility in the sovereign debt market and hence the market participants. The problem is the evidence is not clear when the bubble started which is inductive of how difficult it is to spot a bubble in the first place as highlighted previously. Although there is ample evidence that the main market behind the mid-2000s asset price bubble, the housing market, had collapse by 2005 as hinted by Masood (2009). Yet the asset backed price bubble was still going strong until early to mid-2007 as noted by Masood (2009). The aftermath of the introduction of the euroblighted the pre-crisis period, which continued to affect the global financial market for a number of years after 1999 and 2002 as illustrated by Galati & Tsatsaronis (2003). A class of events, which blighted the sovereign debt market in this period of the observations, areextreme events inducing high systemic risks in the global financial markets such as the terrorist attacks of September 2001 as illustrated by chart 1 in Goldberg & Leonard (2003).

Moreover the evidence from the literature seem to be suggesting that the behaviour of volatility in the sovereign debt market during the crises period is influenced by two factors fundamentals and news. However, there is a separation with the weight of influenced being larger during the sovereign debt crisis with respect to the fundamentals. In contrast, the financial crisis is weighted towards news being the influencing factor, expected since throughout the sovereign debt crisis, the macroeconomic factors initiated and dictated the events, ashighlighted by a number of articles including Collignon (2012), Feldstein (2009) and section 2.3. Whereas the financial crisis was governed by news, a good example is the Lehman Brothers bankruptcy, from other financial markets (such as the equity, corporate bond and securitization, i.e. CDO and MBS, markets) transmitting volatility to the sovereign debt market. This is usually done thru the Knightian uncertainty mechanism, which induces systemic risk in a given market thus instigating a flight to safe or higher quality assets, e.g. the sovereign debt market as exemplified by Fratzscher (2009) and Caballero & Krishnamurthy (2009). In summary, the literature suggests that the particular period or point in time could have influenced the market efficiency. We therefore suggest testing the relationship of the market efficiency before, during and after the crises. The rationale is that if markets were efficient, any (arbitrary) period selection should not have any impact on the result, i.e. should show that markets are efficient. In turn, if this is not the case, then we can draw conclusions regarding permanent market efficiency.

While there, is a large and growing database of articles or papers on the volatility in the sovereign debt market. Yet past empirical studies had concentrated on the yields (Dotz & Fisher, 2011; Metui, 2011; Tamakoshi, 2011; Laopodis, 2010) or spreads (Mohl & Sondermann, 2013; Groba *et al.,* 2013; Favero & Missale, 2011; Missio & Watzka, 2011) in analysing the volatility in the sovereign debt market. However, as highlighted in section 2.1.1, we are testing the efficiency of the market; hence, the EMH dictates that prices should incorporate all available information. Therefore, in order to understand the reason why the market may or may not be efficient, there is a need to use the price to enable us to analyse the behaviour of volatility. Since the spreads are a measure of risks, i.e. liquidity or credit; and hence do not explain the efficiency of a market as well as the price. In essence, the yields are a derivative of the price.

Although the empirical evidence certainly does illustrates the impact from spillover effects and co-integrations on the sovereign debt market see (Pericoli & Sbracia, 2003; Abad *et al.,* 2010; Groba *et al.,* 2013). Yet the efficient market hypothesis as proposed by Malkiel (1962) and Fama (1965; 1970) is inconsistent with co-integration and hence spillover effect. Basically there are two key arguments: the first view, as argued by Baillie & Bollerslev (1989; 1994) and Masih & Masih (2001), states that co-integration in financial markets imply a violation of the efficient market hypothesis. Another view, according to Granger (1992) and Diebold *et al.,* (1994), is that there is an incompatibility between the predictability of co-integration and unpredictability of the efficient market hypothesis. Therefore, we do not use the multivariate GARCH models to analyse the behaviour of volatility. Since we want to understand what makes a market efficient or inefficient by analysing the information contained in the volatility. In other words, we are not interested in the transmission of volatility between the markets, studied by numerous articles and papers since the advent of the crises.

Of course, other univariate GARCH modelscan be of benefit in understanding the information contained in the volatility: GARCH-X, GARCH-Jump and spline-GARCH; however, these are usually complicated and involve coding because they have not been widely integrated into the econometrics packages. As illustrated previously, the GARCH models we have selected each determines a factor of market participant behaviour and test different aspects of the market efficiency.

Since the outbreak of the crises, most of the empirical evidence in the behaviour of volatility in the sovereign debt market hasinvolved the GIPS nations with the German market as the benchmark e.g. Missio & Watzka (2011), Tamakoshi (2011) and Mohl & Sondermann (2013). Since we are interested in how the crisis have affected the efficiency of the market in the aftermath of both the financial and sovereign debt crises, this means we must analyse the GIPS nations and the German market. However, the American market is by far the biggest sovereign debt market and regarded as the benchmark risk free and liquid market, hence any possible default by the US federal government is likely to have an impact on the efficiency of the global financial market. For thesereasons, we concentrate our research on these six markets.

In fairness, whichever you look at it, this is the influencing section underpinning the literature review. The GARCH family of volatility models underpin our variance bound tests and analysis of the behaviour of volatility. However, as we have illustrated during this section, as with the behaviour of market participants, there are many interpretations ofthe behaviour of volatility. It would be impossibleto analyse exactly the behaviour of volatility, which would involve many models. The fact issome of the models are complicated and require high computing power, a problem we have witnessed with the use of the Switching GARCH models, which caused us to use the SWARCH models.

3. Methodology

In essence, the key to our empirical evident is the behaviour of price volatility in the sovereign debt market over the period between 1st July 2002 and 31st March 2013, In effect analysing thebehaviour of price volatility in a changing global financial market environment. The basic idea influencing the research is does the behaviour of price volatility suggest that markets are not efficient. If so then what could be driving this deviation from market efficiency. However, if the markets are efficient then what makes price volatility behave in such a way that the market is efficient. The behavioural finance theory provides possible answers to these questions.

In order to test the null of the efficient market hypothesis, we test the key assumption underpinning the hypothesis: efficient market. To test the key assumption, we ask the question: does price volatility hint at inefficient markets? We also ask if the changing global financial market environment affects the efficiency of the market based on four fixed sub periods. We use the variance bound test proposed by Shiller (1979; 1981a) in testing the assumption of efficient market using two GARCH models of volatility:

- GARCH (1, 1) proposed by Bollerslev (1986)
- GJR-GARCH (1, 1) proposed by Glosten *et al.,* (1993)

In analysing the deviation from the efficient market hypothesis, we look at the models of volatility in an attempt to interpret the behaviour of price volatility in the changing market environment. The basis of the interpretation is the behavioural finance theory fundamentals such as the reactions to market shocks and volatility persistent, feedback, leverage and regime switching. We use two GARCH models in interpreting these behavioural effects:

- GARCH model (Bollerslev, 1986) for the reaction to market shocks and persistent of the price volatility in the market
- EGARCH-M (p, q) model (Nelson, 1991) for the feedback and asymmetrical effects

In concluding our analysis of the behavioural effects, we analyse for a possible regime structure. We use a SWARCH model, a combination of the ARCH model (Engle, 1982) and Markov Switching model (Hamilton, 1988), in analysing the regime structure of price volatility. We opt to use the Cai (1994) SWARCH model, mainly due to the model fitting our datasets best.

As this introductory illustrates, the methodology is divided into three sections. Each explaining the model we use and our interpretation. We also attempt to explain the theory and results influencing the models.

3.1. Model Specification for the Variance bound test

One of the main aims of this thesis is to test for the efficient market hypothesis (EMH) in the sovereign debt market. Therefore, we lay the foundation for the rest of the empirical section in order toexplain the behaviour of volatility in the sovereign debt market. We opt to use an extended version of the test originally proposed by Shiller (1979; 1981a), the Shiller volatility or variance bound test

Importantly, the variance bound test does not directly test the EMH, instead it tests the variance bound. Therefore, in testing the null hypothesis of the market being too volatile to be efficient, we could either reject or accept the EMH. At the heart of the Shiller volatility test, as stated by Shiller (1981a), is the key assumption that under the EMH prices incorporates the relevant market information efficiently, thus meaning excess volatility in the market is the result of inefficient markets as hinted by Bollerslev & Hodrick (1992) and Fama (1970). Hence, it is essentially a test of the null hypothesis ofexcess volatility in the market.

We test for the null of the EMH using both the 2002 and 2007 set of observed prices. In order to analyse the different effects on the EMH of the crises and bull periods, we test for different periods within the 2002 and 2007 issues. To test the EMH for these periods, we use four uniformed subsamples across all six markets and test them separately. In other words, we test the EMH for the whole sample as well as for the subsamples.

The interesting consequence of this is that if a subsample is efficient that does not necessarily mean that the entire sample is efficient. We could have a scenario where over the whole period the market could be efficient but during the subsamples, the market is inefficient. This then leads to the interesting question: whether financial markets can be efficient, if in some periods, they are efficient and in others, they are inefficient.

In essence, the influencing factor underpinning the variance bound test as highlighted by Shiller (1981a) is that on some occasions price volatility in the financial market exceeds that explained by the EMH. Hence, the markets are not efficient. Using the basis of the Shiller (1979) and LeRoy & Porter (1981) variance bound test methodology; we propose extending the test by using the GARCH and GJR-GARCH models in obtaining the key statistics. Although the variance bound test as used by Shiller (1979; 1981a) and LeRoy & Porter (1981) depends on the fundamental value to test the efficient market hypothesis. By using the GARCH and GJR-GARCH models, we omit the need for an optimal price and use the 5% critical value F-statistics to test the efficient market hypothesis. We then compare both sets of results.

In essence, the Shiller (1979; 1981a) and LeRoy & Porter (1981) variance bound test is really a test of whether the fundamental value as given by the present value equation, see equation 3.1.1, does determines the behaviour of the price. The basic argument, as put by Shiller (1992), is any excess volatility is evidence of inefficient markets. However, as we will illustrate now there is a big issue regarding the use of the present value model within the bond market. The present value model dictates that the price of a bond based on all coupons is as given by equation 3.1.1.

$$P = \sum_{t=1}^{T} \frac{C \times PV}{\left(1+\frac{r}{2}\right)^{2t}} + \frac{PV}{\left(1+\frac{r}{2}\right)^{2T}} \qquad 3.1.1.$$

Where C is the coupon rate, PV is the par value and r is the yield. The problem with this is from all these variables; the only time-varying variable is the yield. Whereas in the stock market the dividend is also time varying, hence the fundamental value of a stock is different from the price. However, since the price derives the yield in the bond market, this means that the price does not differentiate a lot from the fundamental value. So the problem in this model is that the price of the bond will always be approximating (if not equal to) the fundamental value. By omitting the need to calculate the fundamental value and using any appropriate econometric model, we could overcome this issue. Indeed Shiller does advocate this model specification to the volatility tests. Although Shiller does not specify a specific econometric model, yet he does set out a number of pre-requisite steps in the model specification of the test:

1. As illustrated by Shiller (1981a), the key factor underlyingany variance bound test is the variance calculation. We model the datasets in our test as a time varying lagged variance of the price using equation 3.1.2.

2.

$$\lim_{t\to T} var(Price_t) = \frac{\sum_{q=1}^{Q}(Price - \mu)^2}{Q} \qquad 3.1.2.$$

3. The first order autoregressive model estimates the residuals in the econometric model underpinning the test as illustrated by equation 3.1.3.

$$var(Price_t) = a + b_1 var(Price_{t-1}) + u_t \qquad 3.1.3.$$

$$u_t = \rho u_{t-1} + \epsilon_t$$

We set u_t to be equal to the residuals of the autoregressive model. Hence, the econometric model underpinning the test is estimated using equation 3.1.4.

$$var(Price_x) = a + b_1 var(Price_{t-1}) + u_t \qquad 3.1.4.$$

We opt to use the GARCH and GJR-GARCH models in our tests. In common with all our GARCH models, generally we use the t-student distribution. An influencing factor in the GJR-GAARCH model is the asymmetrical order, which we set to one. Hence, we estimate a t GARCH (1, 1) and t GJR-GARCH (1, 1) using the variance equations 3.1.5 and 3.1.6.

$$h_t = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1} \qquad 3.1.5.$$

$$h_{jt} = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1} + \gamma_1 k_{t-1} I(\varepsilon_{jt-1} < 0) \qquad 3.1.6.$$

An added and interesting factor with the GJR=GARCH is that we could see whether asymmetrical effect has any impact on the efficiency of the market. The key is the γ coefficient in equation 3.1.6 where $\gamma \neq 0$ then there is an asymmetrical effect; if $\gamma > 0$ then there is a leverage effect meaning negative shocks have greater effect than positive shocks

Key to our model are the coefficients of the GARCH and GJR-GARCH models of volatility. As mentioned earlier in this section, we derive our EMH test by using the f-statistics; for our observed samples, the f-statistics at the 5% level is 1.96. We calculate our test statistics using equation 3.1.7

$$EMHTest = \frac{\sum(coefficientsofvarianceequation \quad)-1}{standarddeviation \quad (var\,(x))} \qquad 3.1.7.$$

Since the market is efficient when the EMH test statistics is less than the F statistics, therefore by definition the market is efficient when the condition as set in equation 3.1.8 is true. Theoretically, the market is onlytruly efficient when the EMH test statistics is equal to the f-statistic. Hence, we reject the null hypothesis for the EMH if the condition in equation 3.1.8 is true but accept the null hypothesis of the market being too volatile to be efficient for anything else.

$$EMHTest \leq Fstatistics \qquad 3.1.8.$$

3.2. Model Specifications for the Univariate GARCH Models

One key objective of this research is to analyse the behaviour of pricevolatility in our six observed sovereign debt markets. Like many researches into volatility in the sovereign debt market, such as Bollerslev *et al.,* (2000), Christiansen (2007) and Dotz & Fisher (2011), we use time varying conditional variance to identify volatility in the sovereign debt markets. We obtain the conditional variance by using two alternatives GARCH models to find the best-fit estimation model for the observed prices of each market. We use the GARCH (p, q) model proposed by Bollerslev (1986). In addition, we use the EGARCH-M (p, q) model proposed by Nelson (1991).

In using the GARCH (p, q) and EGARCH-M (p, q), we could start to get an idea of the behaviour of volatility in the sovereign debt market. Since a key use of the ARCH/GARCH group of econometrics models as intended by Engle (1982) and Bollerslev (1986) is to model volatility clustering. We also analyse for leverage and feedback effects by using the EGARCH-M as noted by Brunner & Simon (1996).

The previous paragraph is interesting on a number of levels, since it does illustrate the key point in the use of the GARCH family in this research. As eluded previously, there are several features within an asset price bubble that can be picked up by the use of the GARCH models as pointed by Blanchard & Watson (1982) and Branch & Watson, (2011; 2013). Another point is according to Bollerslev & Hodrick (1992) there is evidence of seasonality and volatility clustering issues affecting the fundamental and prices. Hence, this implies the use of these GARCH models in order to understand the impact of bubbles on asset price. Another key factor in the use of the GARCH models is that they could help interpret the reaction and behaviour of market participants to price volatility. Indeed the reaction of market participants to market shocks and volatility persistent or the impact of feedback and asymmetrical effects could be analysed thru the use of the GARCH models.

In a research paper, Engle (1982) states that in the past the convention in econometric was for the conditional variance not to depend on the past value of the asset. Although it was widely assumed that the future value of an asset is dependent on the past value of the asset, therefore the conditional variance does depend on the past. In essence, this means the conditional variance follows a clustering behaviour. A standard approach for heteroskedasticity was to introduce an exogenous variable predicting the variance. However, the problem with this method is the requirement of specified causes of the changing variance rather than allowing the conditional mean and variance to evolve jointly over time. Another approach was to use the bi-linear model introduced by Granger & Andersen (1978), however this gave an unconditional variance of either zero or infinity.

Engle (1982) introduced a generalised model of the Granger & Andersen (1978) bi-linear model called autoregressive conditional heteroskedasticity or ARCH to overcome these problems. As defined by Engle (1982), at the heart of the specification of the ARCH model is the differentiation between conditional and unconditional variance; thus allowing the conditional variance to change over time as a function of past errors holding the unconditional variance constant. The basis of the model is a lagged autoregressive process with a vector data structure. However, mainly due to the problems with large number of lags, Engle (1982) specified the model to be arbitrary linearly declining lag length on an ARCH (4) thus restricting the number of parameters required to two rather than five. As stated by Engle (2001), the ARCH model uses a weighted average of past variances where the observed dataset provides the estimates for the weights. In essence, the ARCH model is a linear and stationary stochastic process with a fat tail distribution. The calculation of the estimate for the ARCH modeluses a maximum likelihood method.

In another research into volatility clustering models, Bollerslev (1986) introduced the Generalized Autoregressive Conditional Heteroskedasticity model; as the name suggests the GARCH model is a generalization of the ARCH model. As noted by Bollerslev (1986) a key different in the specification between an ARCH and GARCH model is the inclusion of a flexible lag structure and longer memory. The GARCH (p, q) specification uses a two lags structure whereby the q is the lags of the squared errors and p is the conditional variance lags. Thus meaning GARCH is a very parsimonious model allowing for an infinite number of past squared errors influencing the current conditional variance. At the basic level, the GARCH (p, q) means that by setting p to zero reduces a GARCH to an ARCH model.

A key assumption underpinning our conditional volatility models is that the error distribution follows a Student t distribution; otherwise known as a t-distribution, function where possible. If the estimated model encounters issues then we use the normal distribution. Thus, the basis of our univariate 1 lagged system is a t-distribution error distribution function. This means we estimate the coefficients for our model using the conditional t log likelihood function in calculating the Marquandt or BHHH maximum likelihood estimation method of the prices in the sovereign debt market.

The first order autoregressive model estimates the residuals in all our GARCH models as illustrated by equation 3.2.1.

$$\Delta Price_t = \omega + \alpha_1 \Delta Price_{t-1} + u_t$$
$$u_t = \rho u_{t-1} + \epsilon_t \qquad 3.2.1.$$

We set u_t to be equal to the residuals of the autoregressive model. Hence, all our GARCH models are estimated using equation 3.2.2.

The first model of price volatility we use is the GARCH (p, q) model first purposed by Bollerslev (1986). Due to the single time varying explanatory variable in our model, we use a univariate system to model the volatility. The basis of our lagged system is the one-day ahead volatility estimation, which means we use a one lagged GARCH (1, 1) model. This means we estimate the best fitting GARCH (p, q) model of the lagged time varying first order differentiated price volatility using equation 3.2.2.

$$\Delta Price_t = a + \sum_{j=1}^{J} b_j \Delta Price_{t-j} + P\varepsilon_t \qquad 3.2.2.$$

In reality, thebasis of the derivation of the GARCH model is two equations: the conditional variance and conditional mean. We model conditional variance in the price of sovereign debt by the univariate GARCH (1, 1) model as specified in equations 3.2.3. In equation 3.2.3, we follow the standard definition used by many others by denoting conditional variance to be h_t as σ_t^2 and denoting k_t as ϵ_t^2 where ϵ_t is the residual error term and derived from $\sigma_t z_t$ which is the product of the standard deviation and a stochastic variable. The conditional mean is the second equation in the GARCH model, denoted by equation 3.2.4. We use the simplest form of the conditional mean equation.

$$h_t = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1} \quad 3.2.3.$$
$$\Delta Price_t = \mu + \varepsilon_t \quad 3.2.4.$$
$$\hat{\sigma}^2 = \frac{\omega}{1-(\alpha+\beta)} \quad 3.2.5.$$
$$\alpha + \beta \quad 3.2.6.$$
$$-\frac{ln(2)}{ln(\alpha+\beta)} \quad 3.2.7.$$

As noted by Alexander (2008, p. 137) and Engle & Patton (2001), there is a story within any estimated GARCH (p, q) model influenced by the coefficients of the model. Thus meaning the coefficients of equation 3.2.3 naturally interprets the reaction and means reversion to market shocks of volatility.

- The conditional residual coefficient is a measure of the reaction of conditional volatility to market shocks, when α is relatively high (i.e. greater than 0.1) thus meaning volatility is very sensitive to market shocks.
- The conditional variance coefficient is a measure of the persistence of the conditional volatility irrespective of market conditions and status, when β is relatively large (i.e. greater than 0.9) thus meaning volatility takes longer to recover after a crisis in the market.
- Equation 3.2.5 measures the level of unconditional volatility in the GARCH model, otherwise known as the long-term average volatility, when it is relatively large thus meaning long term volatility in the market is relatively high.
- Equation 3.2.6 measures the convergence of the conditional volatility to the long-term average volatility i.e. mean reversion, when it is large (i.e. greater than 0.99) thus meaning that current information has no impact on the long run forecast.
- Equation 3.2.7 is the half-life of the volatility defined as the time it takes for the conditional volatility to move half way to the long-term average volatility. Of cause if $\alpha + \beta > 1$ then the volatility half-life is negative, thus the shock to volatility does not decay over time.

However, both theoretically and practically in finance, high risk assets have a high premium return; one way to model this theory is by extending the GARCH models to let the return be partly dependant on the risk. Sometimes referred to as the feedback effect where the higher the risk is the higher return is. Thus the ARCH-M model, introduced by Engle *et al.,* (1987) and extended to the GARCH-M model, extends the ARCH/GARCH to allow the conditional variance to become part of the conditional mean equation. In modelling the potential feedback effect in the price volatility of each sovereign debt, we use a t GARCH-M (1, 1).

As noted earlier, a key observation made primarily in stock markets, there is a negative correlation between returns and volatility. In order to model the leverage or asymmetrical effect, Nelson (1991) proposed the EGARCH. Unlike many other GARCH models, the EGARCH model uses the log of the conditional variance. The key to understanding the EGARCH model is a leverage effect hints at negative shocks having a larger impact than positive shocks on the behaviour of volatility.

As stated by Nelson (1991), the capture of the leverage and feedback effect by combining the EGARCH and GARCH-m could extend the EGARCH, thus deriving the EGARCH-m. Unlike the GJR-GARCH as proposed by Glosten *et al.,* (1993), the GARCH-m model isnot integrated into the EGARCH-m model and therefore derived from two separates models. This is helpful in analysing the feedback and leverage effects due to the separation of the effects coefficients. The model combines the conditional mean of the GARCH-M derived by Engle *et al.,* (1987) in equation 3.2.9 with the EGARCH model derived by Nelson (1991) in equation 3.2.8. We use a single lagged t EGARCH-M (1, 1) with a single asymmetrical order to analyse the leverage-feedback effect.

$$log(h_t) = \omega + \beta_1 log(h_{t-1}) + \alpha_1 \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma_1 \frac{\varepsilon_{t-1}}{\sigma_{t-1}} \qquad 3.2.8.$$

$$\Delta Price_t = \mu + \lambda_1 h_t + \varepsilon_t \qquad 3.2.9.$$

Note the conditional variance estimated from the logarithmic function in equation 3.2.8, thus implying that the leverage effect is estimated exponentially as oppose to the quadratic equation. Like the EGARCH (1, 1), the key is the γ coefficient in equation 3.2.8 where $\gamma \neq 0$ then there is an asymmetrical effect on the sovereign debt prices; if $\gamma > 0$ then there is a leverage effect meaning negative shocks have greater effects than positive shocks on the sovereign debt prices. In addition like the GARCH-M (1, 1), the key to interpreting the feedback effect is the λ coefficient in equation 3.2.9, thus meaning that a positive and statistically significant coefficient would suggest as risk increase the conditional return increases. However, a negative coefficient would suggest as risk increases the conditional return decreases. This means where both the leverage and feedback effect exist, the conditional volatility exhibit a risk/return relationship under an asymmetrical behaviour.

Look at the basic model underpinning the GARCH family in equation 3.2.2. The key factor in any GARCH model is that the coefficients must not be zero. As the name suggests, the GARCH model is a generalised model of the ARCH model of volatility; this is important because of one key factor if the β reduces to zero then the GARCH becomes a simple ARCH model. However, of more interest is if α reduces to zero thus resulting in equation 3.2.10. Of course, this means the unlikely probability that conditional volatility in our observed sovereign debt prices could follow a random walk model exemplified by equation 3.2.10. Essentially, in our case, this means that yesterday's prices have no bearing in assessing the distribution of today's prices as indicated by Fama (1970). Noteworthy, that the random walk model does not imply that past information on prices is not relevant to future price changes. Hence, this means that past volatility in the prices of sovereign debt can affect future volatility and therefore defining the behaviour of volatility. However, the random walk effect does make it difficult to interpret the results from the GARCH models.

$$h_t = \omega + \beta_1 h_{t-1} \qquad 3.2.10.$$

Given our observed periods and datasets, it is highly unlikely that any random walk effect in the conditional volatility of the sovereign debt prices could be cause by the observed period of time influencing the observed datasets This is mainly due to our observed period being over a long time scale incorporating episodes of constant high and low volatility. This means that any random walk effect in the conditional volatility is the product of an intentional split in the observed dataset into two observed periods due to an unprecedented hiked in the volatility rendering the period before and/or after meaningless, a possible scenario in the case of Greece or Portugal.

3.3. Model Specifications for Markov Switching ARCH

An interesting issue in the estimation of high frequency financial datasets is the apparent high persistence in the volatility as noted by Engle & Bollerslev (1986) resulting in the introduction of the Integrated GARCH (aka IGARCH) model by Engle & Bollerslev (1986). As Cai (1994) states the central concept of the

IGARCH model is that in certain time horizons current information effects the conditional variance for all future horizons. In essence, a test for IGARCH is a test for unit root in the variance. However, as Lamoureux & Lastrapes (1990) argue allowing deterministic shifts in the conditional variance intercept in GARCH counters the effect of high persistence in volatility. Diebold (1986) states that the inclusion of monetary-regime dummies in conditional variance intercept could explain the integrated-variance disturbances in interest rates. The SWARCH model proposed by Cai (1994) integrates the Markov Switching model first proposed by Hamilton (1988) and the ARCH model introduced by Engle (1982). The key to the Cai (1994) model is that the ARCH intercept is regime dependant, thus retaining volatility clustering and allowing the model to overcome spurious persistence. We use the Cai (1994) model to model the regime-switching behaviour of the price volatility without the regime dependent spurious high persistence volatility.

An influencing factor in the use of the SWARCH model is that on some occasions there can be the appearance of periodic collapsing bubbles, which can be analysed thru the use of a Markov process as alluded by Blanchard & Watson (1982), Evans (1991) and more recently Branch & Evans (2011) as modelled by the Markov Switching models (Hamilton, 1988). Since as illustrated by Blanchard & Watson (1982), the correlation between the innovations and asset returns points to the use of the ARCH/GARCH models, so hinting at the use of the SWARCH (Hamilton & Susmel, 1994; Cai, 1994) to model the impact of the bubble on the behaviour of price volatility. Another important factor is the assumption that market participants change their behaviour with the changing market environment. This means that market participants react differently, to high and low volatility regimes.

As stated by Hamilton (1989) a number of previous researches studying the relationship between the business cycle and GNP assume the observed data followed a linear stationary process. However, as a number of studies have proved the assumption of linearity and stationary in key macroeconomic datasets is weak. Hence, in an article on non-stationary time series and the business cycle, Hamilton (1989) introduced a regime-switching model based on an autoregression method using a discrete-state Markov process. Hamilton (1989) researched the non-stationarity and non-linearity of observed datasets, especially the non-linearity arising from datasets with changes in the dynamic behaviour of the series.

As a result of the research, Hamilton (1989) derives the Markov Switching Model (acknowledge as MSM hereafter) based on the Goldfield & Quandt (1973) Markov switching regression to characterized changes in the behaviour of the parameters of an autoregression process. Using the Kalman linear filter idea in Cosslett & Lee (1985), the MSM extends the Kalman to a filter and smoother providing a non-linear discrete unobserved state vector using the maximum likelihood method to identify the optimal unobserved regimes. However, as Hamilton (1990) hints a big problem with the previous specification was the maximizing of the likelihood method with respect to large number of parameters. Hence, Hamilton (1990) extends the previous specification by including an expectation maximization method. A key advantage of the expectation maximization method is the numerical robustness.

There are three key univariate[10] Markov regime-switching models: simple MSM (hereafter acknowledged as MS(s)), MSM autoregression model (hereafter acknowledge as MS(s)-AR (k)) and MSM dynamic regression (hereafter acknowledge as MS(s)-DR). Essentially, the bases of all three models are the four standard parameters organised in a vector structure. As defined in Hamilton (1989; 1990), the model is based on the conditional mean as the underlying measurements. Hamilton (2008), Piger (2011) and Guidolin (2012) provide a more descriptive analysis of the different Markov regime-switching models.

The basis of the regime shifts are an unobserved first order Markov variable within a matrix of transition probabilities attached to each regime and although the number of regimes is "unrestricted" depending on the research; yet the optimal number of regimes are two or three depending on the research. The optimal regimes are usually associated with periods of high, low and in some cases sTable. Essentially, there are three processes of updating the transition probability estimate influencing the regime switching: one-step (or period) ahead, filtering and smoothing. The one-step ahead process is where the estimation method weighs the density function of each regime by the one-step ahead probability of being in that regime to update the estimated regime probabilities. The filtering process adds to the one-step ahead by using the additional information provided by the dependant variable in a given period about the current regime to update the estimated regime probabilities. The final process, smoothing updates the filtering process by using all of the information in the

[10] Although the MSM can be extended to a multivariate model, see Krolzig (1997; 1999; 2000) for a description.

observed dataset to update the estimated regime probabilities. Hence, the process uses information about all future realization of the dependant variable to update the estimate.

Hamilton (1989) derived the MS(s)-AR (k) model from a combination of two or more first order autoregression models, each with a different intercept to highlight the change in the observed data at a certain time. However, as indicated by Hamilton (2008) the problem with that was priori knowledge of abrupt changes in the observed data. Hence, Hamilton (1989) introduced a multiple-state (i.e. two-state in this case) Markov chain with a system of probabilities attached to each state to model the changes in the observed data regime. The Markov Switching model as derived by Hamilton (1989), illustrated in equation 3.3.1.

$$y_t = \omega_{s_t} + a_1 y_{t-1} + \varepsilon_t \qquad 3.3.1.$$

$$s_t = \begin{cases} = 1\ if\ low\ regime \\ = 2\ if\ high\ regime \end{cases}$$

As previously stated, the literature and empirical evident on the Markov switching model in the sovereign debt market in the last few years have been strong, see (Georgoutsos & Migiakis, 2009; 2010 and 2012; Pozzi & Sadaba, 2013; and Schuster & Uhrig-Homburg, 2012). Although as Hamilton notes thelong-time acknowledgement that volatility seem to be following a high-low switching model, there is a lack of evident to the SWARCH or SWGARCH models. Given there is evident of changes in the volatility of sovereign debt prices over the past few years, hence a volatility switching model would help in identifying the behaviour of price volatility. Due to issues regarding the complexity, see (Cai, 1994) and (Guidolin, 2012), and the exaggerated high persistency in the volatility, see (Guidolin, 2012); we follow Christiansen (2008) and Abdymomunov (2013) in using a SWARCH model instead of a SWGRACH (i.e. Switching GARCH), in effect using the ARCH model of Engle (1982) to derive the volatility. Equation 3.3.2 uses a single lag ARCH model as proposed by Engle (1982).

$$h_t = \omega + \alpha_1 \varepsilon_{t-1}^2 where h_t = \sigma_t^2 \qquad 3.3.2.$$

The simplest method to estimate the integrated heteroskedasticity and switching effects in the volatility is by the use of a SWARCH model such as Hamilton & Susmel (1994) and Cai (1994). We opt for the Cai (1994) implementation mainly due to initial tests with our observed data raising a few estimation issues with respect to the Hamilton & Susmel (1994) implementation. In combining the Markov switching model as in equation 3.3.1 with the ARCH model in equation 3.3.2, it is easy to see how Cai (1994) integrated the two models. The Cai's model is derived from two equations, illustrated by equations 3.3.3 and 3.3.4, with the first equation being the integrated model and the second being the model of regime-switching probabilities. Analysing equation 3.3.3 closely reveals the beautiful simplicity in the construction of the model. Yet the model is powerful in its ability to model the regime switching in the volatility of the underlining observed dataset and complicated to estimate. The simplicity of the model is that it is a combination of the Hamilton (1989) Markov Switching model in equation 3.3.1 and ARCH model of Engle (1982) in equation 3.3.2 whereby the autoregression model in equation 3.3.1 substituted by the conditional heteroskedasticity model as derived by equation 3.3.2. However, since Cai (1994) uses a two-lagged ARCH model, this implies that the SWARCH model follows equation 3.3.3.

$$h_t = \omega_0 + \omega_1 s_t + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 \qquad 3.3.3.$$

$$s_t = \begin{cases} 0 \; if \; low \; volatility \\ 1 \; if \; high \; volatility \end{cases}$$

$$P(s_t = i|\widetilde{\varsigma_T}) = \sum_{j=1}^{M=2} P(s_t = i, s_{t+1} = j|\widetilde{\varsigma_T}) \qquad 3.3.4.$$

$$Pr_s = \frac{1}{1+Exp\left(\theta_{m,n}\right)} \qquad 3.3.5.$$

In the Cai (1994) model, the intercept for the low volatility regime is ω_0 and the high volatility regime calculated by multiplying ω_0 with the coefficient of the ARCH. Since the SWARCH model was originally proposed to highlight the issue of spuriously high persistence in the volatility of other models due to regime switching.

In a two-regime Markov switching model, we calculate the expected probabilities by using $\theta_{1,1}$ and $\theta_{1,2}$ logistic indices. Equation 3.4.5 illustrates the calculation; a key factor is that we substitute $\theta_{1,1}$ and $\theta_{1,2}$ into $\theta_{n,m}$ for the low and high regimes' probabilities respectively. We opt for the smoothing effect to figure the probabilities. This gives a more accurate figure of each probability, but requires extensive computing, due to the complex estimation method involving the entire history of filtered and predicted probabilities, see Hamilton (1994).

There are three main functions to estimate any Markov switching model: maximum likelihood, expectation maximization and Bayesian Markov Chain Monte Carlo. The maximum likelihood is the simplest but it is most likely to be the slowest. The method of estimation is key to any models successful estimation; there are essentially two key methods of estimating the ARCH component in the SWARCH: BHHH and BFGS.

4. Empirical Evidence

This section aims to provide empirical evidence of the impact of the crises on the efficiency of the financial market. The section will analysesix key sovereign debts markets over two 10-year notesobserved from 1st July 2002 to 31st December 2011 and from 1st July 2007 to 31stMarch 2013. The empirical section has two areas of interest, hence splitting this section into four subsections:

- Data Definition
- Statistical Analysis and Tests

The two areas of interest are:

- Testing the efficient market hypothesis
- Analysis of the changing behaviour in price volatility

In order to analyse the efficiency and behaviour of price volatility in the sovereign debt market under different global market conditions, we subdivide our observed markets into the following period:

1. 2012 issues
   a. All the observed markets: 1st July 2002 to 30th December 2011
   b. Pre-Crisis period: 1st July 2002 to 29th June 2007
   c. Financial crisis of the late 2000s: 2nd July 2007 to 30th October 2009
   d. Sovereign debt crisis of the 2010s: 2nd November 2009 to 30th December 2011
2. 2017 Issues
   a. All the observed markets: 2ndJuly 2007 to 29thMarch 2013

b. Financial crisis of the late 2000s: 2nd July 2007 to 30th October 2009

c. Sovereign debt crisis of the 2010s: 2nd November 2009 to 29th March 2013

With the exception of the Switching ARCH models, which used Estima WinRATS Pro 8.3, we used EViews 8.0 for our econometric modelling and statistical analysis. The reasoning being the comprehensive support for the econometric models we were using meant the use of two software packages.

An influencing factor in the structure of this section was the publishing of papers from the thesis, therefore where possible we report the results from each country separately within the section. Given this factor, we intend to conclude each section with a review of all the results.

4.1. Data Definition

As illustrated by Table 1, we use the daily 10-year sovereign debt, maturing in 20120F[11], end of day bid prices for Germany, Greece, Italy, Portugal, Spain and US obtained from Bloomberg. Importantly, the reference numbers are ISIN for all the markets, except the US, which uses CRSPID. In order to capture the price volatility during the sovereign debt crisis without the maturity effect, we extend our data to obtain a second group of sovereign bonds for the above-mentioned countries with the exception of Greece maturing in 2017 as illustrated in Table 2. We follow the norm by defining our week as Monday to Friday. In order to make the observed data uniformed across all six observed datasets, we substituteall missing observations with the last known price.

Table 1. *The 10-Year Sovereign Debt Prices Data with maturity in 2012*

	Reference Number	*Download Date*	*Issue Date*	*Maturity Date*
German	DE0001135192	16/07/2012	02/01/2002	31/12/2011
Greece	GR0124018525	17/12/2012	17/01/2002	18/05/2012
Italy	IT0003190912	16/07/2012	01/08/2001	01/02/2012
Portugal	PTOTEKOE0003	16/07/2012	12/06/2002	15/06/2012
Spain	ES0000012791	17/12/2012	14/05/2002	30/07/2012
US	9128277L0	16/07/2012	15/02/2002	15/02/2012

Mainly due to the last issue date, that of Portugal, and first maturity date, that of German, our observed sample is from 1st July 2002 to 30th December 2011. Thus meaning our sample has a uniformed total 2480 daily observations for each sovereign debt market.

[11] The exception is the German which matures at the end of 2011

Table 2. *The 10-Year Sovereign Debt Prices Data with maturity in 2017*

	Reference Number	*Download Date*	*Issue Date*	*Maturity Date*
German	DE0001135317	08/04/2013	17/11/2006	04/01/2017
Italy	IT0004164775	08/04/2013	01/08/2006	01/02/2017
Portugal	PTOTELOE0010	08/04/2013	18/06/2007	16/10/2017
Spain	ES00000120J8	08/04/2013	23/01/2007	31/01/2017
US	912828GH7	08/04/2013	15/02/2007	15/02/2017

In our second observed sample, we follow the same concept as before by using the Portuguese issue date to set the start. This means our observed sample is from 1st July 2007 to 31st March 2013, a total 1500 daily observations for each sovereign debt market.

4.2. Statistical Analysis and Tests

Since the basis of this research is the daily price in the six sovereign debt markets, we need to analyse the statistics and patterns of the prices of the elevenobserved government bonds. This should tell us a lot about the behaviour of the prices. In statistically analysing and testing the observed datasets, we analyse the pattern of the prices using various statistics (i.e. mean, median, maximum, minimum and standard deviation) for each sample period. We also use the par value to highlight the behavioural pattern; it is essential to note that in the bond market the par value acts as the long run equilibrium price. This is because at maturity the bond issuer only pays the bondholder the par value. In effect if the price is below the par value this means the market is oversupplied while the opposite means there is a high demand in the market.

However, we also need to analyse the statistics of the main variable in our test of the efficient market hypothesis. We calculate the daily variance in the price using equation 3.1.2 from the methodology. Two key factors influencing our choice of the lagged system in the calculation of the price variances were the uniformity across all observed datasets and the weekly (i.e. five day) increments limitationwe imposed on the lagged system (i.e. 5, 10, 15…). We opted to use the 20-lagged system inour test of the efficient market hypothesis due to two reasons: the first is that in primarily tests we encountered problems with the GARCH models using a 5-lagged system in some of our observed datasets. The second is that using a higher lagged system would have overlooked of the earlier part of the dataset. So we decided to use the four weekly (i.e. 20) lagged system, which is approximately a month.

We also statistically test the price and lagged variance for:

- Non-normality using the Jarque-Bera test proposed by Jarque & Bera (1980)
- Structural breaks using the Global L Breaks vs None proposed by Bai & Perron (1998)
- Stationarity using the augmented Dickey-Fuller test proposed by Dickey & Fuller (1979; 1981) and Lumsdaine-Papell test of stationarity with breakpoints as proposed by Lumsdaine & Papell (1997)
- Random Walk using the Variance Ratio Test proposed by Lo & MacKinlay (1988), we opt to use the optimal z-statistics as derived by Chow & Denning (1993)

4.2.1. Analysis of the Price

Before we can continue with the analysis of the price, it is worth remembering that the bond market is governed by the par value which in practice isset to 100, although the actual par value can be 1,000. This is important on a number of levels, firstly the price any bond isssuer pays the bond holder at maturity is the par value. Hence, making it the long term equilibruium price. And since theory dictate that the equilibrium price is governed by the demand and suplply curves, hence if the price falls below the par value than the market is over supplied and if the price rises above the par value then demand is high. Another key factor is that by definition the par value is when theyieldis equal to the coupon rate, this makes any increase/decreasein the required yield to above/below the coupon rate effectively a decrease/increase in the price to below/above the par value.

In this section, we will analyse the general pattern and statistics of the price of both the 2012 and 2017 bonds. The analysis will try to establish similarities and differences in the general pattern and statistis between the six sovereign debt markets. This will allow us to establish whether the markets are integrating or diversifying. It will also allow us to analyse the different impact on the markets during the crises.

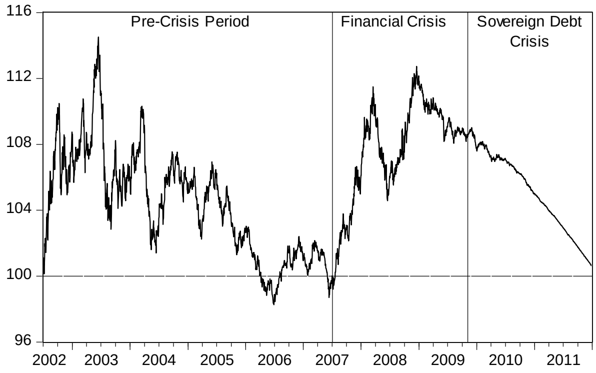

Figure 1. *US 2012 Price*

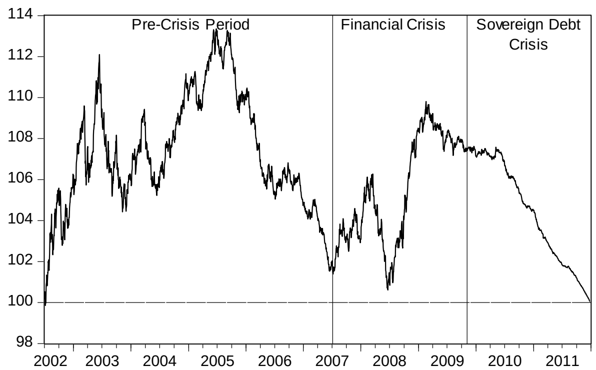

Figure 2. *German 2012 Price*

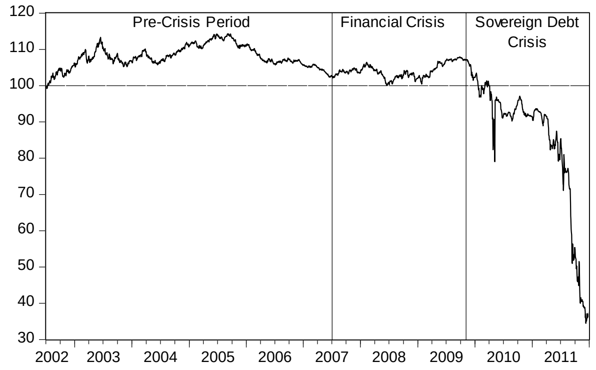

Figure 3. *Greek 2012 Price*

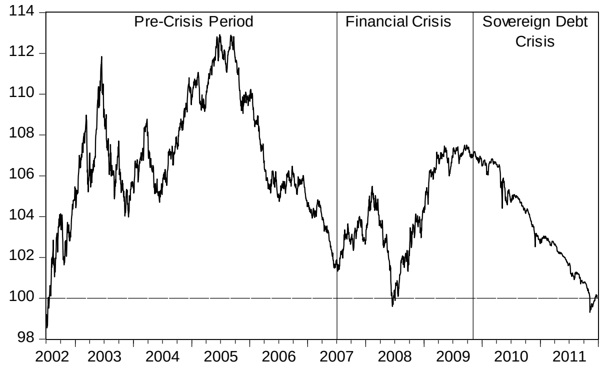

Figure 4: *Italian 2012 Price*

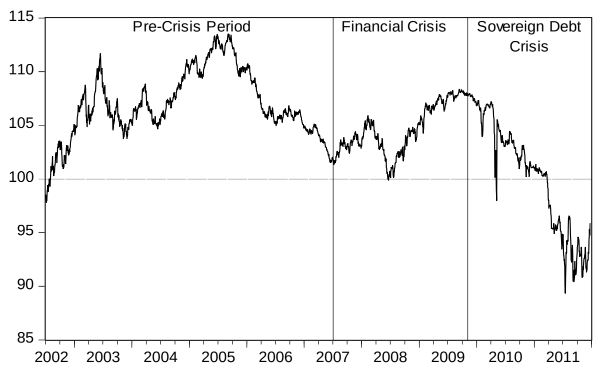

Figure 5. *Portuguese 2012 Price*

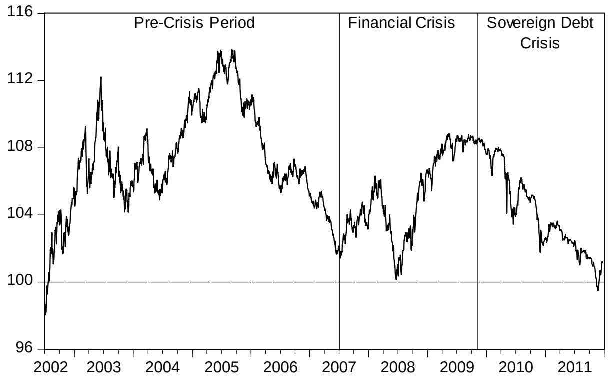

Figure 6. ***Spanish 2012 Price***

Table 3. *Price of the 2012 Bond (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	105.3247	106.2032	101.8065	105.4590	104.8485	106.0547
Median	105.6094	106.1945	105.4495	105.4310	105.4255	106.0650
Maximum	114.5156	113.3510	114.3290	112.9150	113.5220	113.8580
Minimum	98.26563	99.86200	34.50300	98.54900	89.35000	98.05300
Std. Dev.	3.277713	2.938535	12.98349	2.990753	4.423890	3.113044

Table 4. *Price of the 2012 Bond (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	104.3031	107.3011	107.9546	106.8508	106.9250	107.2933
Median	104.4844	106.7680	107.4250	106.3070	106.3740	106.7850
Maximum	114.5156	113.3510	114.3290	112.9150	113.5220	113.8580
Minimum	98.26563	99.86200	99.20000	98.54900	97.81700	98.05300
Std. Dev.	3.186893	2.801603	3.056214	2.917317	3.143961	3.087154

Table 5. *Price of the 2012 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	107.6985	105.4924	104.0667	104.2072	104.6122	105.1643
Median	108.6172	105.2095	103.8380	103.7700	104.3360	104.9510
Maximum	112.7344	109.8080	107.9360	107.5090	108.3660	108.8610
Minimum	99.20313	100.6090	100.0970	99.59800	99.89000	100.1480
Std. Dev.	2.976343	2.578907	1.902827	2.145335	2.249338	2.444874

Table 6. *Price of the 2012 Bond (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	105.1213	104.4349	85.16579	103.5959	100.3074	104.1552
Median	105.4219	104.6610	91.83500	103.1520	101.0650	103.4880
Maximum	109.0156	107.6220	107.2000	107.1950	107.9650	108.5780
Minimum	100.5625	100.0000	34.50300	99.31000	89.35000	99.47500
Std. Dev.	2.371351	2.481422	18.57523	2.239188	5.197018	2.466801

Overall, the six markets seem to be hinting at a changing underlying trend in the behaviour of market participants, which is inconsistent with the efficient market hypothesis. In general, the prices seem to be reacting to the financial and sovereign debt crises as illustrated by Figure 1 to Figure 6. Not surprisingly,

Table 3 is hinting at problems regarding the Greek and Portuguese market with both the standard deviation and minimum illustrating the issues underpinning these markets. However, the mean statistics are above the par value meaning demand for all these markets was generally high. This could be an indication that it was only during the sovereign debt crisis that demand fell in the Greek and Portuguese markets. However, remember an influencing factor in the pricing of bonds is that prices tend to move towards the par value as maturity approaches. Since the sovereign debt crisis occurred during the last part of these bonds lives, this could explain the fall in prices for the other four markets, especially the German and US markets.

Analysing Figure 2 to Figure 6 and statistics from

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	105.3247	106.2032	101.8065	105.4590	104.8485	106.0547
Median	105.6094	106.1945	105.4495	105.4310	105.4255	106.0650
Maximum	114.5156	113.3510	114.3290	112.9150	113.5220	113.8580
Minimum	98.26563	99.86200	34.50300	98.54900	89.35000	98.05300
Std. Dev.	3.277713	2.938535	12.98349	2.990753	4.423890	3.113044

Table 4 illustrates a certain similarity in the pattern of the prices between the five Eurozone 2012 bonds during the pre-crisis period, which seem to be hinting at an integrated market. Of course, this is a key policy in the introduction of the euro. The advantage of having such an integrated market is that market participants can invest in any market and the risks and returns are broadly similar. Giventhe Eurozone countries, fixed the coupon rate, this is not surprising. However, close inspections of the US market seem to be suggesting that integration in the global financial market was not as strong as in the Eurozone. As expected since the US and Eurozone markets are governed by different information. The introduction of the euro had a different impact on the US market. The problem is, as highlighted earlier, integration is not compatible with the random walk theory and hence the efficient market hypothesis.

According to Figure 2 to Figure 6, the prices of the Eurozone markets remained above the par value during the asset price bubble. This seems to be indicating that market participants in the Eurozone did not swap these "high quality" assets to high returns assets like CDOs or MBSs. Part of the reason for this was the high coupon rate in the Eurozone in comparison with the US. However, as illustrated by Figure 1, the US market did fall below the par value pointing towards a lack of demand in the market at the height of the asset price bubble. As expected since the asset price bubble initiated in the US housing market, and even though the housing market bubble burst long before the asset price bubble collapsed, market participants were investing in mortgage-backed securities as a consequence of the low rate of interests offered by high quality assets like US Treasuries. This leads to the bubble effecting the market, which is not consistent with the efficient market hypothesis.

Another factor highlighted by figures Figure 1 to Figure 6 is that market participants seem to be reacting to events and not just fundamental information during the pre-crisis period. In essence news and information regarding other market and while these sources are forms of information, the fundamental issue is that it is the reaction of market participants and not the fundamental information that is driving the price. This is the key explanation in some of the price changes in the markets illustrated by all the figures, especially in the US market, in the pre-crisis period. There were a number of highly reactive events, examples are:

- The "war on terror" with the Afghanistan and Iraq wars
- The asset price bubble backed by the housing market bubble in the US
- Introduction of the Euro

The statistics in,

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean	105.3247	106.2032	101.8065	105.4590	104.8485	106.0547
Median	105.6094	106.1945	105.4495	105.4310	105.4255	106.0650
Maximum	114.5156	113.3510	114.3290	112.9150	113.5220	113.8580
Minimum	98.26563	99.86200	34.50300	98.54900	89.35000	98.05300
Std. Dev.	3.277713	2.938535	12.98349	2.990753	4.423890	3.113044

Table 4 are interesting in that not only do they illustrate the uniformity of the prices and risks in the Eurozone during the pre-crisis period. The statistics also illustrate the interest of market participants in the GIPS nations bonds with the average prices similar to the German market and higher than the US market. And the key factor is the highest price of the Greek and Portuguse markets which seem to suggst a high demand for these bonds. However, the standard deviation, a key risk indicator seem to be suggesting that during the pre-crisis period the German market had the lowest risk factor. However, perhaps not surprisingly given the events duiring the pre-crisis period, the US market had the highest risk factor. This is illustrated by the movement of the price in the early stages of the pre-crisis period in Figure 1.

As illustrated by appendix A1 and Figure 1 to Figure 6, flights to the sovereign debt market from market participants reacting to events in other markets (i.e. stock, corporate debt and asset-backed securities) drove the financial crisis period. The asymmetrical information available on the financial assets compounded the problem, which were at the heart of the financial crisis (e.g. CDOs and MBSs). This led market participants to assume the worst-case scenario and fly from shares and debt issued by financial institutions to the safety of sovereign debt markets. This is reflected by the high statistics in

Table 5, which illustrates the flight to the US market with a higher average and maximum, mainly due to the intensity of the financial crisis in the US. Another issue is the response of the policy makers (i.e. Federal Reserve, ECB and central governments) during the crisis, which added to the confusions.

However,

Table 5 seems to be hinting at a decrease in the standard deviation and hence the risk factor in the sovereign debt market across all observed 2012 bonds. The main factor is the low levels of the standard deviations for the Greek and Portuguese markets; this is mainly due to the lowtrading volume in these two markets. Unlike the German and US markets that are high volume markets and under certain market conditions, like the ones during the financial crisis, market participants usual go to risk free liquid assets similar to the German and US markets.

Another possible explanation for the behaviour of prices illustrated bythe financial crisis period is that some market participants were short selling in order to survive, thus following the old Wall Street saying: "*If you can't sell what you want to sell, sell what you can sell*". This goes to the heart of the financial crisis because market participants were unable to sell these asset backed securities and forced to sell saleable assets, which could inevitably means sovereign debts. Therein lays the problem if distressed market participants were selling these high quality liquid financial assets in order to survive then the market must have been facing huge systemic risks. Moreover, these types of risks cannot be overcome using regular monetary policies, hence the introduction of the "non-standard" monetary policies such as quantitative easing by central banks. This resulted in a distorted market because central banks like the Federal Reserve poured trillions of new money into the global financial market; keeping the prices artificially high. This leads toa key question: were the markets efficient/inefficient due to the distorting of the price by the non-standard monetary policies?

As stated previously, an influencing factor ia the price of any "plain valinlla" type bond tends towards the par value as it approaches maturity. This is important due to the timing of the sovereign debt crisis coming towards the maturity of these bonds. The downwards trend in the price, as illustrated by figures Figure 1 to Figure 6, could be influenced by the maturity effect, especially the US, German, Italian and Spanish markets. This is evidence in Table 6 with all four markets having minimums approaching the par value and unsurprisingly, the minimum price of the German bond which matures on 30/12/2012 was at par value. Although the standard deviations of the Italian and Spanish markets did increase slightly from their levels during the financial crisis period, the evidence does not illustrate the true impact from the sovereign debt crisis. However, on close inspection of figures Figure 4 and Figure 6, there is limited evidence of the impact of the sovereign debt crisis on the Italian and Spanish bonds.

However, the key to the early stages of the sovereign debt crisis is the impact on the Greek and Portuguese markets. Certainly these two markets were at the centre of the sovereign debt crisis in the early stages. However, there is a diifferent in the impact on the two markets. As illustrated by Figure 3, in the aftermath of the Greek budget deficit revision the Greek market dipped below the par value for the first time since the initial stages of our observations. This led to a short spell of recovery to over the par value. As the crisis heated by the political indecision, the market participants became increasingly risk averse and the price of the Greek 2012 bond fell to a mininum of 34.50. The problem was that the rescue plan meant the market participants would to take a hit. Thus ignitinga downwards trending spiral which dictates that when mmarket participants are faced with huge risks they tend to sell the asset, this increases the risk aversions further and hence the price keeps going down i.e. increases in risk aversion leads to decrease in the price. The issue is that the political indecision within the Eurozone heightened the Greek problem and led to the spiral.

The market participants reaction led to a loss of trust in the GIPS markets, this led to the domino or contagion effectas the crisis envoloped the Portuguese market. However, as highlighted by Figure 5, the crisis did not impacted the Portuguese market as strongly as the Greek market. This is mainly because the Portuguese economic issues were not as deep rooted as the Greek. The second reason was the quick action by the IMF and European Communityto the Portuguese crisis. This means the price of these two bonds were reacting to the political environment and accounting for macroeconomic fundamentals during the crisis. In short this raises an interestng question, does the fact that the price of these bonds seem to be incorporating the information immediately mean they were efficient during the sovereign debt crisis?

Figure 7. *US 2017 Price*

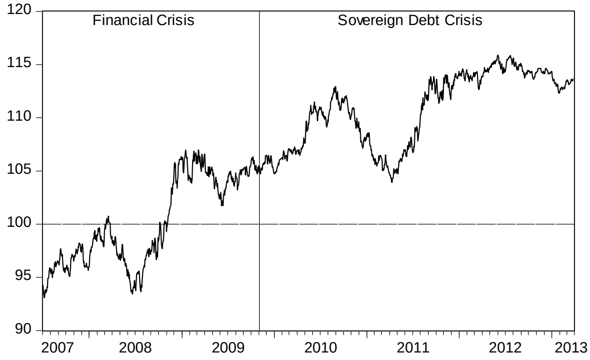

Figure 8. *German 2017 Price*

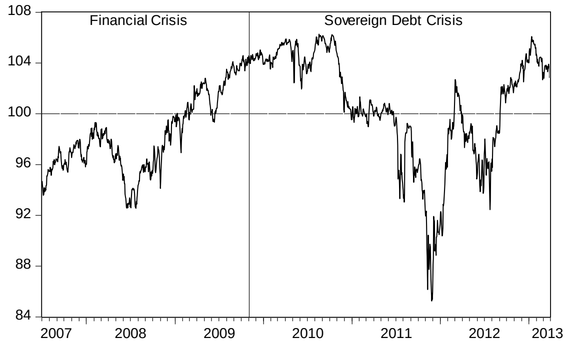

Figure 9. *Italian 2017 Price*

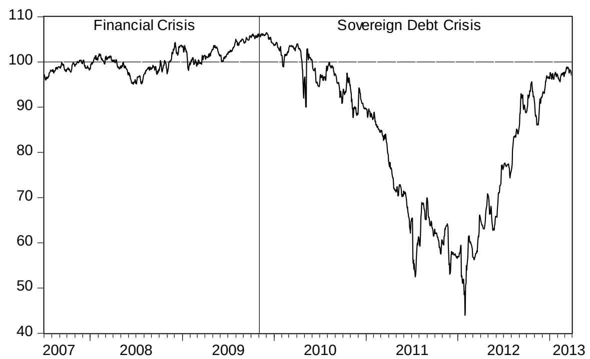

Figure 10. *Portuguese 2017 Price*

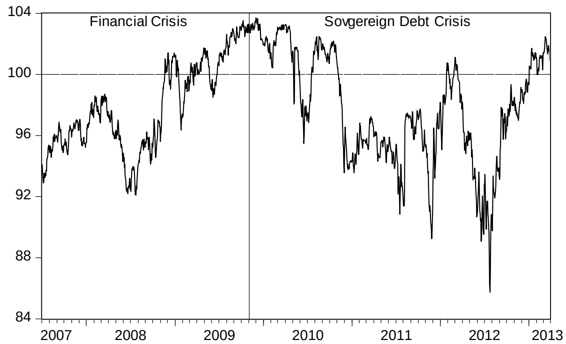

Figure 11. *Spanish 2017 Price*

Table 7. *Price of the 2017 Bond (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean	112.1776	106.4866	99.70470	90.12671	97.80271
Median	112.8281	106.4195	99.88400	97.39400	97.43350
Maximum	120.1719	115.8950	106.2640	106.4790	103.6990
Minimum	95.70313	93.08200	85.26000	43.96000	85.74000
Std. Dev.	5.464889	6.405270	4.041322	15.31369	3.343679

Table 8. *Price of the 2017 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean	107.7516	100.2182	98.32063	100.3050	97.84217
Median	107.5938	98.91050	97.80950	100.0090	97.25700
Maximum	120.1719	106.9890	104.5770	106.1740	103.5240
Minimum	95.70313	93.08200	92.55500	95.06900	92.10600
Std. Dev.	5.042972	4.124867	3.020674	2.525288	2.903542

Table 9. *Price of the 2017 Bond (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean	115.2112	110.7829	100.6533	83.15055	97.77567
Median	116.2344	111.7225	101.1400	88.59850	97.53750
Maximum	119.6875	115.8950	106.2640	106.4790	103.6990
Minimum	107.7500	103.9150	85.26000	43.96000	85.74000
Std. Dev.	3.206333	3.476175	4.367258	16.46953	3.615878

In general, Figure 7 to Figure 11 and Table 7 illustrates the diverse impact of both crises on the observed markets. This demonstrates the changing behaviour of market participants during a highly volatile period full of conflicting information. It would seem that the early stages of the financial crisis did not have a significant impact on the Eurozone markets as it did on the US. However, in general the sovereign debt crisis had a greater impact on the IPS[12] markets.

[12] IPS refers to Italy, Portugal and Spain

A key different between the 2012 and 2017 bonds isthe maturity effect, which had a large impacted on the effect of the sovereign debt crisis in the 2012 bonds. However, this introduced the “on-the-run” effect, which is likely to have affected the price during the financial crisis. Another factor is the Eurozone markets do tend to exhibit some co-movement in the 2017 bond prices hinting at an integrated Eurozone market during the financial crisis. Conversely, the sovereign debt crisis period seems to suggest that in the aftermath of the initial Greek crisis, the Eurozone markets were beginning to disintegrate.

Analysing Table 8 highlights the main issue in the global financial market during the crises, the wide dispersion and movement of the prices. In particular the US and German markets with a minimum of below 96 and maximum of above 115 illustrating the increasing demand for these bonds during the crises. However, regarded as high quality low risk assets these bonds were at the centre of a flight to safety during both crises were. Interestingly the German market only went above 100 in late 2008 acknowledging that demand was not high during the early parts of the financial crisis. However, the demand for the US market was high during both crises, backed by the higher statistics for the US market inTable 8. A possible explanation is that the early stages of the financial crisis had a bigger effect on the US financial market than the Eurozone; hence, Figure 8 to Figure 11 illustrating the price remained below 100 for much of the early stages of the financial crisis.

Interestingly, the statistics of the IPS markets in Table 8 hints at the Portuguese market performing better than the other observed markets. A possible explanation might be the size of the banking sector in Portugal, which means the government did not have to spend massive amounts bailing out the banking sector. However, asa percentage of GDP, it had a bigger impact on the economy. In reality, the financial crisis did not initially affect either Italy or Spain. A key factoraccording to the statistics from Eurostat, obtained on 17th March 2014, is the financial crisis did not directly influence the three IPS economies until late 2008 or early 2009. However, the Spanish economy suffered heavily when the crisis did hit with a total recapitalization cost of 13.67% of the debt as of 2008. Although the statistics revealed that the financial crisis did not affect the Italian economy, yet they reveal that the Italian economy was in stagnation long before the financial crisis. In a way, all the IPS nations had structural weaknesses in their economy long before the financial crisis, as indeed to a certain extent did the US according to the statistics obtained from the Federal Reserve Bank of St Louis on 17th March 2014.

As illustrated by Figure 7 to Figure 11 and Table 9, the sovereign debt crisis had a different impact on the IPS markets than both the US and German markets pointing to a flight to safety. The key statistics are the minimum values with the Portuguese market falling to 43.96 while the Italian and Spanish markets falling below 86, thus hinting at a crash in demand at the height of the crisis. It is noTable that the minimum values of the US and German markets remained above 100.00 for the duration of thesovereign debt crisis period, backed by the other statistics in Table 9, which seem to be hinting at market participants reacting to events. Note the rise and fall in the standard deviation for the IPS markets and US/German markets respectively; this is a sign of a hiked in the risk factors of the IPS markets. However, on close analysis of Figure 7 and Figure 8, both the US and German markets seem to have suffered a dip in the price during the early parts of the height of the sovereign debt crisis. The timing of the dips of both set of observed pricesprovides a clue. In the aftermath of the initial stages of the sovereign debt crisis, as flights to safety ensued with market participant overreacting this hiked up the prices of both markets. This resulted in a downwards trend to correct the overpricing. However, in the background there were a few issues regarding these two markets: the size of the US debt was causing a few political and fiscal issues, which initiated the so-called fiscal cliff and debt ceiling crises. The Eurozone crisis was giving rise to uncertainties about the future of the euro, whichaffected the German market.

In concluding, both the 2012 and 2017 group of bonds seem to be illustrating a change in the behaviour of the prices during both crises. It would seem to be the case that the market participants' reaction to events is influencing the pricing of these assets. However, this could results in efficient markets because of the immediate pricing of information. The problem is can markets overreact and still be efficient?

4.2.2. Test for Normality

A normal distribution has a Jarque-Bera statistic of zero, this means that the skewness and excess kurtosis must be zero given the equation $JB = \frac{n}{6}\left(S^2 + \frac{1}{4}(K-3)^2\right)$ as proposed by Jarque & Bera (1980) where S is the skewness and K is the kurtosis. Hence, any deviation from the normal distribution in the price or price variance would mean the use of an alternative distribution in the estimation of the models. The skewness can be negative where the left tail of the distribution is longer or positive where the right tail is longer. A positive excess kurtosis means the distribution is a leptokurtosis hinting at a tall distribution while a negative kurtosis is a platykurtic distribution hinting at a flat distribution.

Table 10. *Price of the 2012 Bond (01/07/2002-30/12/2011)*

	US	German	Greek	Italian	Portuguese	Spanish
Skewness	0.006672	0.114097	-3.155935	0.310764	-0.897185	0.247762
Kurtosis	2.229327	2.518666	14.25744	2.686866	4.263747	2.622968
Jarque-Bera	61.39190	29.32134	17212.21	50.04944	497.7379	40.06204

Table 11. *Price of the 2017 Bond (02/07/2007-29/03/2013)*

	US	German	Italian	Portuguese	Spanish	US
Skewness	-0.682903	-0.365043	-0.428285	-1.133068	-0.193150	-0.682903
Kurtosis	2.740363	1.977850	2.784800	2.875984	2.396806	2.740363
Jarque-Bera	120.8022	98.61347	48.75138	321.9222	32.06686	120.8022

As illustrated by both Table 10 and Table 11, the Jarque-Bera statistics seem to be hinting at non-normal distribution for the prices of the 2012 and 2017 bonds. The statistics for both the Greek and Portuguese 2012 bonds hint at a negatively skewed leptokurtosis distribution. Both markets seem to be suggesting that the crisis had a significant impact on the distribution of the prices. However, the Greek market seems to be significantly rejecting normality. This is due to the impact of the sovereign debt crisis on the prices, which caused a dramatic fall in the prices over a short period; a potential reason to explain the Portuguese market as well; however, the different is that the Portuguese market recovered some of the losses. This means that the Portuguese market does not reject the normality as significantly as the Greek market. Interestingly, the remaining 2012 bonds have a positive skew with a platykurtic distribution. With regard to the 2017 bonds as illustrated by Table 11, all the markets seem to be suggesting a negatively skewed platykurtic distribution. An interesting point is the increase in the Jarque-Bera statistic for the US and German market, this can be traced to the use of these two markets as safe havens in flights to safety episodes during both crises.

Table 12. *Price Variance of the 2012 Bond (01/07/2002-30/12/2011)*

	US	German	Greek	Italian	Portuguese	Spanish
Skewness	3.640635	3.286359	7.39\9076	3.283223	5.935009	2.899094
Kurtosis	20.06116	19.00135	66.76459	18.68907	45.61009	15.65636
Jarque-Bera	35298.93	30697.44	439560.1	29673.78	200706.0	19880.89

Table 13. *Price Variance of the 2017 Bond (02/07/2007-29/03/2013)*

	US	German	Italian	Portuguese	Spanish	US
Skewness	4.599066	2.154140	2.902400	2.578960	2.906014	4.599066
Kurtosis	31.82785	10.44338	11.81393	10.07871	12.86350	31.82785
Jarque-Bera	56503.28	4564.272	6873.136	4733.786	8088.004	56503.28

The statistics given by both Table 12 and

	US	German	Greek	Italian	Portuguese	Spanish
Skewness	3.640635	3.286359	7.39\9076	3.283223	5.935009	2.899094
Kurtosis	20.06116	19.00135	66.76459	18.68907	45.61009	15.65636
Jarque-Bera	35298.93	30697.44	439560.1	29673.78	200706.0	19880.89

Table 13 are significantly rejecting normality with low Jarque Bera statistics of 19,880.89 and 4,564.2 for the 2012 and 2017 bonds respectively. The skewness and kurtosis statistics for all the bonds point to a significantly leptokurtosis distribution with a large positive skew. The statistics from Table 12 highlight the impact of the sovereign debt crisis on the distribution of the price variance from the Greek and Portuguese markets. This is mainly because of the hike in the price variance towards the end of the observations, which meant that the tail is sparsely populated. This could occur during a highly volatile period, which has the properties of a sudden jump in the price variance to significantly high levels. This is exactly what happened to the Greek and Portuguese 2012 bonds during the sovereign debt crisis.

4.2.3. Test for Structural Breaks

In many ways, the existence of structural breaks could have huge implications on any test or model due to the sudden and/or dramatic change in the observed market. Hence, testing for the existence of breakpoints is essential, especially in a highly volatile environment as the past few years have been. Chow (1960) introduced a framework, which tested changes given a priori known date using the F–statistics. The problem was the requirement of priori knowledge of the break dates. Quandt (1960) modified the Chow test to include unknown priori knowledge of the break date; Andrews (1993) derived the Quandt-Andrews test by extending the Quandt test. The work of Bai (1997) and Bai & Perron (1998; 2003) extended the Quandt-Andrews test to include the detection of multiple unknown structuralbreak dates. We use the Bai & Perron (1998) Global L Breaks vs None test to identify a maximum of five break dates. The test is a generalization of the Quandt-Andrews test, which allows for the identification of multiple break points. For a more detailed overview of tests and models for multiple structural breaks, we refer you to Perron (2006).

The Bai & Perron (1998) framework is essentially a repeated test of the observed market for the null of no further breakpoints up to a maximum number of breakpoints. In common with all the previous tests for structural breaks, estimating an F-statistics for each breakpoint found. The influencing factor is the critical value of each breakpoint found. We opt to use a maximum number of five breakpoints and report the scaled f-statistics.

Table 14. *2012 Price Structural Breaks Statistics*

Breaks	*Critical Value*	*US*	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
1	11.47	23.95092	21.57173	13.57966	19.32178	15.06113	16.68173
2	9.75	18.10369	15.28463	12.63913	15.12658	13.28180	13.45311
3	8.36	13.78504	13.65211	8.983000	11.91132	11.62424	11.12479
4	7.19	12.96966	14.09152	7.121384	11.88558	10.46655	11.76886
5	5.85	10.18131	11.12317	5.568225	9.660592	8.495753	9.280339

Table 15. *2012 Price Structural Break Dates*

Breaks	*US*	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*	*US*
1	25/03/2004	22/04/2004	22/09/2005	29/07/2004	29/07/2004	22/04/2004	25/03/2004
2	06/09/2005	23/09/2005	12/02/2008	09/01/2006	18/01/2006	23/09/2005	06/09/2005
3	13/07/2007	15/03/2007	19/05/2010	09/07/2007	09/07/2007	15/03/2007	13/07/2007
4	17/12/2008	23/09/2008	No Break	15/12/2008	10/12/2008	23/09/2008	17/12/2008
5	21/05/2010	26/02/2010	No Break	19/05/2010	13/05/2010	19/04/2010	21/05/2010

Table 16. *2017 Price Structural Breaks Statistics*

Breaks	*Critical Value*	*US*	*German*	*Italian*	*Portuguese*	*Spanish*	*Critical Value*
1	11.47	8.976054	17.10608	16.56933	35.03087	4.440264	11.47
2	9.75	8.979260	15.96320	12.61822	22.96561	8.681674	9.75
3	8.36	8.301646	15.55006	10.98181	16.87322	8.779958	8.36
4	7.19	6.847645	12.89369	9.715446	13.99067	6.861368	7.19
5	5.85	6.286869	10.04540	5.465509	11.33912	4.178000	5.85

Table 17. *2017 Price Structural Break Dates*

Breaks	*US*	*German*	*Italian*	*Portuguese*	*Spanish*	*US*	*German*
1	No break	16/10/2008	05/11/2008	24/07/2008	No Break	No break	16/10/2008
2	No Break	16/10/2009	11/09/2009	12/06/2009	No Break	No Break	16/10/2009
3	No Break	6/08/2010	28/07/2010	12/05/2010	No Break	No Break	6/08/2010
4	No Break	6/07/2011	30/11/2011	22/03/2011	No Break	No Break	6/07/2011
5	No Break	7/05/2012	No Break	31/01/2012	No Break	No Break	7/05/2012

As illustrated by Table 14 to Table 17, the statistics seem to be hinting at the existence of five break points in all the markets for the 2012 bonds with the exception of the Greek market. Interestingly, the evidence from Table 15 seem to be pointing at the acceptance of the null hypothesis of no further breaks during the sovereign debt crisis for the Greek 2012 bond. Yet in general, the evidence from the other 2012 bonds seems to be hinting at a break point before the outbreak of the financial crisis in 2007. The evidence also seem to be hinting attwo break points during the financial and sovereign debt crisis hinting at a change in the market participants attitudes towards all the markets. However, this does not lend itself to a change between the pre-crisis and post-crisis periods, the evidence also suggest the existence of two structural breaks before 2007. This hints at a change in the market structure during the "bubble" period. Not surprisingly, with the exception of the Greek 2012 bond, the evidence is pointing at a break point in the aftermath of the Lehman Brothers bankruptcy. However, there seem to be a delayed reaction to the initial stage of the sovereign debt crisis.

Interestingly, Table 16 and Table 17 hint at the non-existence of structural breaks in both the US and Spanish markets. The evidence also seems to be pointing at only four structural breaks in the Italian market. Analysing the evidence for the German, Italian and Portuguese markets, there seem to be a similar trend of a break in each year. This hints at a very volatile market in general with a high number of breaks during the sovereign debt crisis.

The existence of breaks in the datasets means that we have to be very careful in analysing and interpreting the results. As section 4.2.5 on the analysis of stationarity in the datasets will demonstrate, there is a need to include structural breaks in any test of the dataset. Hence, omitting structural breaks in any test can lead to wrong conclusions.

4.2.4. Variance Ratio Test of the Random Walk Model

The interesting findings of the previous outcomes leads to a key question: could rational arbitrageurs take advantage of market conditions to make excess returns on the market? However, as Fama (1965) and Malkiel (2003) state an influencing factor is the efficient market hypothesis dictates that the price in the short run should follow a random walk model. As Fama (1970) hints this means that prices are unpredicTable in the short run. However, as pointed by Malkiel (2005) in the long run prices are partially predicTable. Although the random walk model dictates that arbitrage opportunities do not exists for long. However, as Fama (1965) indicates a key assumption of the efficient market hypothesis is the existence of well-informed wealthy rational arbitrageurs who push the prices back towards the fundamental value. Nevertheless, as Abreu & Brunnermeier (2003) argue these rational arbitrageurs sometimes take advantage of the circumstances. Hence, market prices may not be random, if rational arbitrageurs could benefit from circumstances.

In order to test if the market does follow a random walk model and is unpredicTable, we use the variance ratio test proposed by Lo & MacKinlay (1988). The variance ratio test is in essence a test of whether the distribution of the residuals in our sovereign debt markets follows a random walk model. We use the multiple comparison test by Chow & Denning (1993) which essentially states that if the optimal z-statistics is significantly greater than one then we reject the null hypothesis of a random walk model in the observed sovereign debt market.

Table 18: *2012 Price Variance Ratio Test of Random Walk Hypothesis*

	01/07/2002 – 30/12/2011	*01/07/2002 – 29/06/2007*	*02/07/2007-30/10/2009*	*02/11/2009-30/12/2011*
US	3.194503	1.654971	3.105259	2.136958
German	1.602747	0.983499	1.045396	3.733599
Greek	3.787044	0.867388	2.740936	1.763757
Italian	1.618343	0.762173	1.176205	3.832282
Portuguese	7.122426	1.236545	1.592191	5.700823
Spanish	2.232194	0.744564	0.690423	4.669596

Table 19: *2017 Price Variance Ratio Test of Random Walk Hypothesis*

	02/07/2007 – 29/03/2013	*02/07/2007-30/10/2009*	*02/11/2009-29/03/2011*
US	3.399660	2.330855	1.898576
German	2.608126	2.215527	1.220798
Italian	6.512701	2.685879	5.495046
Portuguese	9.934657	2.623884	8.094835
Spanish	7.272041	1.208776	6.837078

Table 18 and Table 19 illustrate the results and analysis of the Lo & MacKinlay (1988) variance ratio test of the random walk hypothesis for the price in the observed samples and subsamples. The evidence is relatively conclusive in rejecting the null hypothesis of the existence of random walk in the markets. Of cause the key word is relatively, there are arguably six subsample exceptions as listed below:

- German 2012 subsample from 1st July 2002 to 29th June 2007
- Greek 2012 subsample from 1st July 2002 to 29th June 2007
- Italian 2012 subsample from 1st July 2002 to 29th June 2007
- Spanish 2012 subsample from 1st July 2002 to 29th June 2007
- German 2012 subsample from 2nd July 2007 to 30th October 2009
- Spanish 2012 subsample from 2nd July 2007 to 30th October 2009

The evidence from Table 18seem to be hinting that duringthe pre-crises period of 1st July 2002 to 29th June 2007 with the exception of the Portuguese market, the Eurozone markets all accepted the random walk hypothesis. Therefore, giving rise to the question: does a crisis such as the recent financial and sovereign debt crises make the financial markets reject the random walk hypothesis? The evidence from the Spanish and to a certain extent German markets during the financial crisis period (i.e. 002/07/2007 – 30/10/2009) seem to be suggesting that is not the case. The answer may lay in the reaction of the market participants to the events and information, a key factor in these two markets was the delayed impact of the financial crisis on their financial sector. Remember these 2012 bonds were in the middle of their lives. Hence, these two factors meant the German and Spanish markets gave the impression that the financial crisis did not influence them, mainly because of the continued economic and financial upturn during the early stages of the financial crisis. Another key issue is does a market reject the random walk hypothesis even if there are periods of random walk. The key is in the sample and subsample notation, the German and Spanish markets accept the random walk hypothesis in two subsamples; however, the whole sample rejects the random walk hypothesis. Given that the weight of influence is with the sample then, we reject the random walk hypothesis. Of course, in our case, if all the subsamples were to accept the random walk hypothesis then the outcome would have been different.

The evidence from Table 19seems to be backing our previous observation from Table 18that in general the market did change in the aftermath of the financial crisis. All the 2017 bonds seem to be rejecting the random walk hypothesis, remember that the issuance of the 2017 bonds was just before the financial crisis. So in essence, this seems to be suggesting that the markets do follow a pattern during a period of crisis.

In concluding, the fact that four of the six 2012 bonds accepted the random walk hypothesis during the pre-crisis period means that the financial market can be random during "sTable" times. However, an interesting factor is that a crisis can change the behaviour of the financial market. Conversely, although this means that there is a pattern during a crisis period, yet it does not mean that arbitrage opportunities exist regularly.

4.2.5. Stationarity Tests

In essence, although GARCH models should be able to model the conditional variance using any observed markets; yet to be able to model the optimal conditional variance the data need to be stationary. The test we chose to use is the augmented Dickey-Fuller or ADF test of stationarity as proposed by Dickey & Fuller (1979; 1981). The key to understanding the ADF tests is in the test statistics, which must be lower than the test critical value at the chosen confidence level, which in our case is the 5% level. Under most circumstances, the prices are likely to be non-stationary at level order difference; hence, the prices tend to be differentiated to first and in some cases second order. However, as stated earlier we also use a 20-lag variance of the prices, hence these tend to be stationary at the level order.

As illustrated in section 4.2.3, the markets do have structural break issues. Therefore, the ADF test may not accurately reflect the stationarity of the markets. In such cases, it is essential to test for the existence of stationarity in markets with one or more breakpoints in the structure. We use the Lumsdaine-Papell test proposed by Lumsdaine & Papell (1997), which generalised the ADF test to account for two or more breakpoints at unknown dates.

We restrict the breakpoint(s) in the test to occur in the trend. Due to the amount of computing power required to run any test with more than two breakpoints, we restrict the tests to just two breakpoints. It is worth remembering that the number of iterations of the unit root test required goes up exponentially with the number of breaks, so in a dataset with more than 1,400 observations as we have it is likely that we will have millions of iterations. One key point worth noting is that we use Estima RATS 8.3 to estimate both tests.

Table 20. *2012 Price ADF Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*1st Order*
US	-2.866437	1.263962	-24.65435
German	-2.862506	-1.742036	-48.22283
Greek	-2.862512	4.935023	-15.07865
Italian	-2.862506	-1.996735	-48.20681
Portuguese	-2.862507	-1.744868	-29.79928
Spanish	-2.862506	-2.414818	-47.61661

Table 21. *2017 Price ADF Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*1st Order*
US	-2.863265	-2.772514	-31.16835
German	-2.863262	-1.588765	-36.20650
Italian	-2.863266	-2.325404	-24.30151
Portuguese	-2.863264	-1.269721	-29.80293
Spanish	-2.863264	-3.307542	

Table 22. *2012 Price Variance ADF Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*
US	-2.862516	-7.736530
German	-2.862525	-4.468008
Greek	-2.862526	-4.985577
Italian	-2.862525	-4.636672
Portuguese	-2.862525	-6.259515
Spanish	-2.862515	-11.07297

Table 23. *2017 Price Variance ADF Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*
US	-2.863301	-4.876033
German	-2.863288	-9.479041
Italian	-2.863291	-7.136924
Portuguese	-2.863299	-5.367470
Spanish	-2.863290	-7.135752

Tables Table 20 to Table 23 illustrate the results from the ADF test of stationarity in the prices and price variances of the observed 2012 and 2017 government bonds. As expected, the results seem to be different with Tables Table 22 and Table 23 hinting at the price variances accepting the null hypothesis of non-stationarity at level order for the 5% critical level. While with the exception of the Spanish 2017 dataset, the prices seem to be hinting at the acceptance of the null hypothesis at the first order level. The Spanish 2012 prices seem to be indicating an acceptance of the null hypothesis at the level order.

Table 24. *2012 Price Lumsdaine-Papell Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*1st Order*	*Break Date 1*	*Break Date 2*
US	-6.62	-5.68	-17.25	08/06/2006	19/10/2007
German	-6.62	-3.03	-17.35	28/12/2006	07/10/2008
Greek	-6.62	-3.21	-16.46	03/03/2006	03/08/2010
Italian	-6.62	-3.17	-17.54	04/04/2006	05/01/2009
Portuguese	-6.62	-3.76	-17.08	05/03/2009	03/08/2010
Spanish	-6.62	-3.21	-17.37	28/12/2006	23/10/2008

Table 25. *2017 Price Lumsdaine-Papell Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*1st Order*	*Break Date 1*	*Break Date 2*
US	-6.62	-3.45	-14.75	27/05/2009	07/05/2010
German	-6.62	-2.94	-15.98	29/10/2010	05/09/2011
Italian	-6.62	-4.38	-16.20	03/08/2009	26/11/2010
Portuguese	-6.62	-5.97	-13.57	07/07/2011	24/05/2012
Spanish	-6.62	-4.11	-15.96	13/11/2008	19/11/2010

Table 26. *2012 Price Variance Lumsdaine-Papell Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*Break Date 1*	*Break Date 2*
US	-6.62	-10.88	10/01/2006	16/01/2008
German	-6.62	-13.15	19/11/2004	08/08/2008
Greek	-6.62	-11.26	16/02/2009	03/08/2010
Italian	-6.62	-12.87	31/12/2004	01/08/2008
Portuguese	-6.62	-8/19	31/12/2004	21/05/2009
Spanish	-6.62	-12.23	02/11/2004	08/06/2010

Table 27. *2017 Price Variance Lumsdaine-Papell Unit Root Test Statistics*

	Critical Value 5% Level	*Level Order*	*Break Date 1*	*Break Date 2*
US	-6.62	-14.75	27/05/2009	07/05/2010
German	-6.62	-15.98	29/10/2010	05/09/2011
Italian	-6.62	-16.20	03/08/2009	26/11/2010
Portuguese	-6.62	-13.57	07/07/2011	24/05/2012
Spanish	-6.62	-15.96	13/11/2008	19/11/2010

As with the ADF test, Tables Table 24 to

	Critical Value 5% Level	*Level Order*	*Break Date 1*	*Break Date 2*
US	-6.62	-10.88	10/01/2006	16/01/2008
German	-6.62	-13.15	19/11/2004	08/08/2008
Greek	-6.62	-11.26	16/02/2009	03/08/2010
Italian	-6.62	-12.87	31/12/2004	01/08/2008
Portuguese	-6.62	-8/19	31/12/2004	21/05/2009
Spanish	-6.62	-12.23	02/11/2004	08/06/2010

Table 27 illustrate the different results between the prices and price variances with respect to the Lumsdaine-Papell test of stationarity. With the exception of the prices from the Spanish 2017 bond, the results seem to be confirming the ADF tests of first and level order acceptance of the null hypothesis in the prices and price variances respectively. Accounting for non-stationarity in the prices means there is a significant different between the resulting break dates of the Bai-Perron (see section 4.2.3) and Lumsdaine-Papell structural breaks tests. The only possible exception is the German 2012, which recorded a 14 days different. Although using the Lumsdaine-Papell test, we did managed to find two break dates in the US and Spanish markets which previously resulted in no break points using the Bai-Perron test.

In concluding, with the exception of the prices for the Spanish 2017 bond, both tests yielded similar results. This means that the structural breaks do not have any impact on the tests in our case. However, in accounting for non-stationarity, the structural break test did result in a significantly different set of result than the Bai-Perron test hinting at non-stationarity having an impact on the structural breaks.

4.3. Testing the Sovereign Debt Market for the Efficient Market Hypothesis

Since the influencing assumption of the efficient market hypothesis is that prices must reflect the relevant information efficiently, thus excess volatility points at inefficient markets as hinted by Fama (1970) and Bollerslev & Hodrick (1992). Therefore, in testing for the efficient market hypothesis, we derive a test based on the volatility or variance bound test of Shiller (1979; 1981a). As illustrated by the model specification of the test in section 3.1 of the methodology, Shiller does not dictate which model to use as the basis of the volatility test.

We follow Shiller's two basis pre-requisites by using a lagged variance system and a first order lagged autoregressive model to estimate the residuals. In general, the summary of the results and tests of the estimated autoregression model hint at high serial correlations 1F [13] and ARCH effects 2F [14] with a non-normal distributed 3F[15] residuals. However, the high R^2 and adjusted R^2 for our observed markets seem to hint at both the lagged price variances and autoregressive model being highly able to explain

[13] Using the Breusch-Godfrey serial correlation LM test proposed by Breusch (1979) and Godfrey (1978)

[14] Using the ARCH LM test proposed by Engle (1982)

[15] Using the Jarque-Bera test proposed by Jarque & Bera (1980)

the movement in the price variance throughout our observed markets.

As illustrated by the model specification in section 3.1 of the methodology, we opt to use the GARCH family of models as the basis of our tests in order to account for the ARCH effects. The GARCH models allow us to test for excess volatility in the price variance from our observed markets. We opt to use the GARCH (1, 1) and single asymmetrical order GJR-GARCH (1, 1) models to compare our results.

As noted by Alexander (2008, p.137) and Engle & Patton (2001), there is a story within any member of the GARCH family of volatility models influenced by the coefficients in the variance equation. This means the reaction and mean reversion ofthe market shocks to volatility, naturally interpreted by the two key coefficients in equations 3.1.5 and 3.1.6 in the methodology. The α coefficient is a measure of the reaction of conditional volatility to market shocks, when α is relatively high (i.e. greater than 0.1) thus meaning volatility is very sensitive to market shocks. The β coefficient is a measure of the persistence of the conditional volatility irrespective of market conditions and status, when β is relatively large (i.e. greater than 0.9) thus meaning volatility takes longer to recover after a crisis in the market. However, due to the use of the variance of the price as the independent variable in the mean equation, we cannot use the true definition. This means the use of the price variance had the impact of hiking the α coefficient leading to a massive increase in the volatility's sensitivity to market shocks. In contrast, the β coefficient decreased significantly leading to massive downgrade in the persistence of the volatility in the aftermath of a crisis in the market.

As highlighted by section 3.1 of the methodology, the key to our variance bound test lies in the variance equation part of the GARCH model. Remember equation 3.1.7 dictates that the basis of our EMH test is the coefficients of the GARCH and GJR-GARCH models and standard deviation of the price variance. However, there is another important factor in section 4.3.2; by using the GJR-GARCH model, we could combine the EMH test results with the asymmetrical effect to see whether the asymmetrical effect has any impact on the efficiency of the market.

Four tests of the model are the basis of the statistical analysis. The first is testing the goodness of the model using the R^2 and adjusted R^2. The second is the normality test using the Jarque-Bera statistic proposed by Jarque & Bera (1980). We then test for serial correlation using the Q-statistics of the correlogram as proposed by Ljung & Box (1979). The last type of test is for the heteroskedasticity, we opt for the ARCH LM test introduced by Engle (1982).

4.3.1. Volatility Test of the EMH using GARCH

As indicated by section 3.1 in the methodology, we implement the variance bound test to test the efficient market hypothesis in the sovereign debt market. We use a GARCH (1, 1) in order to obtain the key variables for the test. It is essential to remember that there are two parts for any GARCH model, the mean equation and variance equation:

$$var(Price_t) = a + b_1 var(Price_{t-1}) + \epsilon_t$$

$$h_t = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1}.$$

Our variance bound test uses the following equation:

$$EMH\ Test \leq F\ statistics$$

Where

F statistics = 1.96

$$EMH\ Test = \frac{(\alpha + \beta) - 1}{standard\ deviation\big(var(x)\big)}$$

In essence, the key variablesfor the Shiller volatility test are the α and βcoefficients in the variance equation of the GARCH model and the standard deviation of the price variance.

Throughout the test, the model is a single lagged GARCH (1, 1) model with a Student t distribution estimated using the Maximum Likelihood method with a BHHH optimization algorithm where possible. Although due to estimations errors in Tables 34/35 for the Greek and Portuguese markets, we used a normal distribution with a Marquandt optimization algorithm.

Table 28 and Table 29 illustrate the statistical analysis and estimated models for the entire sample observation of the 2012 issued bonds. This combines the impact on market efficiency from the three-subsample periods: pre-crisis, financial crisis and sovereign debt crisis.

Table 28. *2012 Bond GARCH EMH Residuals Statistics (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.987422	0.983304	0.987032	0.983508	0.987587	0.982010
Adjusted R^2	0.987412	0.983291	0.987022	0.983495	0.987577	0.981995
Jarque-Bera	4324.66	5702.64	5545.99	26818.10	2561.71	9767.13
Q-Statistics (Correlogram)	611.65	730.76	803.94	651.94	745.49	692.07
F-Statistics (ARCH Test)	2.216885	3.088917	3.473037	0.727817	2.030977	0.421659

As illustrated by the estimated models in Table 28, a key factor to note is the high $R^2$and adjusted R^2. The R^2 is above 0.98 through all the estimated GARCH models hinting at the lagged price variance with the estimated residuals being highly able to explain the movement in the price variance. Another factor is the high adjusted R^2 pointing at the estimated GARCH model being a good fit to the dependent variable across all the markets. These two statistics partly illustrates our GARCH model is correctly specified to testthe null hypothesis of the market being too volatile to be efficient in all the markets.

The Jarque-Bera test for all the markets seem to be hinting at an acceptance ofthe null hypothesis of non-normality in the distribution of the residuals. We found all our markets seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera statistics seem to be hinting at a varied set of results with the Italian and Spanish being significantly greater than the other markets. Conversely, the Portuguese market is significantly lower than all the others are. Under certain circumstances, we can consider the existence of non-normal residuals as an indicator for non-efficient markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at a high correlation. At the single lagged level, the Q-statistic for all our markets does not drop below 611.65 as observed by the US. Considering that, ideally the Q-statistics should be zero, the importance of these statistics for the estimated models highlighted in Table 28. Hence, these statistics hint at a significant amount of serial correlation in the residuals. The existence of autocorrelated residuals usually implies the omission of important variables from the regression. In the current framework, the fact that other variables may be important to determine bond prices seems to be indicatinginefficient markets.

In essence, the test for the heteroskedasticity is a test for remaining ARCH effect in the residuals. Therefore, the lower the F-statistic, the lower the remaining ARCH effect in the residuals. The F-statistics seem to be wielding very widely between approaching no ARCH effect to a significant ARCH effect remaining. In essence, the two lowest are the Italian and

Spanishmarketswith F-statistics below one, thus meaning a significantly low ARCH effect remaining. The highest is the Greek market hinting at a significant ARCH effect remaining.

Table 29. *GARCH EMH Test Statisticsof the 2012 Bond (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation A	0.004720 (4.24E-05)	0.001963 (2.46E-05)	0.015070 (0.000256)	0.002078 (3.64E-05)	0.005322 (0.000151)	0.002763 (8.80E-05)
B	0.981295 (0.000642)	0.990089 (0.000685)	1.001164 (0.000728)	0.991657 (0.000793)	0.984827 (0.000740)	0.991356 (0.000858)
ϵ	0.714328 (0.006116)	0.710886 (0.006884)	0.752249 (0.006803)	0.729164 (0.006826)	0.760523 (0.006955)	0.742471 (0.007016)
Variance Equation Ω	3.23E-08 (9.73E-09)	3.25E-08 (8.60E-09)	1.45E-05 (1.83E-06)	1.42E-07 (3.62E-08)	5.70E-06 (7.77E-07)	1.17E-06 (1.95E-07)
α	1.609716 (0.124186)	1.68348 (0.113878)	1.673333 (0.116096)	1.861907 (0.145773)	1.780045 (0.131446)	1.803619 (0.135187)
B	0.282801 (0.015724)	0.23705 (0.014322)	0.131313 (0.013700)	0.214033 (0.013940)	0.150484 (0.013768)	0.189778 (0.014138)
Statistics Log Likelihood	7556.608	8507.083	5101.819	8145.527	6369.352	7120.501
Standard Deviation	0.560344	0.216199	5.963928	0.202834	0.806295	0.235362
EMH Test EMH Test Statistics	1.592802	4.25779	0.134919	5.304535	1.15408	4.22072
Efficiency	Accept	Reject	Accept	Reject	Accept	Reject

As illustrated by Table 29, the b coefficients and residuals, ϵ dictates the mean equation. Since we use a simple single lagged autoregressive model, we use the interpretation of Alexander (2008, p. 203). With all our b coefficients being greater than 0.98 with a standard error of less than 0.0009, thus hinting at the price variance taking longer to revert back to the unconditional mean after a shock. However, the white noise dictated by ϵ is high with all the markets standing in the low to mid 0.7s with a low standard error. It is worth remembering the mean equation is not the focal point of our research.

In essence, the variance equation reflects the impact from the use of the price variance in the estimation of the GARCH model using the full 2012 sample observations. Conversely, due to the use of the price variance both coefficients are not within normal GARCH bounds. Therefore, we cannot use the full coefficients' interpretation of Alexander (2008, p.137) and Engle & Patton (2001). Therefore, we concentrate on the analysis of the α and β coefficients relative to the other observed markets.

The α coefficients hint at a relatively high level of sensitivity to market shocks in the volatility of the markets, this could be due to the over- and underreactionof the markets to news, which if the markets were efficient should not happen. However, analysing the α coefficients closely would suggest a split in the observed markets with the Italian, Portuguese and Spanish markets having relatively high levels of sensitivity to market shocks with a higher standard error. While the other observed markets seem to have lower sensitivity to market shocks and standard errors. However, the α coefficients hint at a closer levels of sensitivity among the observed markets than most subsequent observational periods suggesting that the markets were similar in their reactions to market shocks. This hints at the obvious different reactions to the shocks during the two crises periods between the markets levelling out over the duration of the dataset.

In terms of the volatility persistence in the markets, the β coefficients seem to be suggesting that shocks in the US market are relatively persistence in the aftermath of a crisis. In fact, it is the highest level of persistence observed in all the samples estimated using the GARCH model. The German and Italian volatility also seem to be relatively persistence. However, considering the Greek and Portuguese markets were at the heart of the early stages of the Eurozone sovereign debt crisis, their β coefficients seem to be hinting at a relatively low level of persistence. A possible explanation is the persistence in the volatility seems to be low throughout the early part of the observational period in these two markets. This seems to be suggesting persisting crisis does not affect these two markets. Another possible explanation is the relatively small size and liquidity of the Greek and Portuguese markets.

In essence, the standard deviation is a measure of how volatile the observed markets are. Consequently, the standard deviation seem to be suggesting that generally, with the exception of the Greek market, the sovereign debt market was sTable with the observed price variances disperse close to the expected price variance. However, the significant standard deviation of the Greek market seems to be hinting that the impact from the sovereign debt crisis towards the end of the observational period was large. This creates the appearance of a large dispersion in the Greek market due to the collapse of the price towards the end of the observation. In a way, this also explains the high standard deviation in the Portuguese market relative to the other observed markets. The US market is interesting due to the opposite effect on the price illustrating that a market does not need downwards pressures on the price to have an impact on the standard deviation. Certainly the upwards pressures from both crises had the same effect of increasing the dispersion of the price variance.

It is worth noting that the test of the market efficiency states that we accept the null hypothesis of the market being too volatile to be efficient, if the EMH test statistic is greater than 1.96. Thus meaning we accept the efficient market hypothesis for anything else. When consideringthis, picture is confused, with three markets accepting market efficiency: US, Greek and Portuguese markets. However, what is surprising is that the three markets are the same ones, which had the largest standard deviation and thus dispersion from the expected price variance. In contrast, the significant EMH test statistics of the German, Italian and Spanish markets seem to be strongly accepting the null hypothesis of the market being too volatile to be efficient. These results seem to be suggesting that the dispersion of the price variances has a role in the acceptance of the efficient market hypothesis, which was accepted because of the equation underpinning the EMH test statistics. However, another explanation is since the efficient market hypothesis dictates that in order for markets to be efficient they need to be random and unpredicTable. Therefore, the standard deviation has to be constant even in the presence of shocks.

Table 30 and Table 31illustrate the statistical analysis and estimated model for the pre-crisis period. Two different issues highlighted the period; the first issue being the highly volatile period of the early parts which was the combination of a number of events as hinted in sections 2.4.4 and 4.2.1. The evidence seems to suggest two different impacts influenced the period. The first impact occurred during the early parts of the pre-crisis subsample and was mainly due to the introduction of the euro and extreme events, which lead to Knightian uncertainty such as the 11 September 2001 terrorist attacks. The second impact occurred during the later stages of the pre-crisis subsample and was mainly due to the asset price bubble. The different between these two impacts on the sovereign debt market is the first impact had the impression of a highly volatile market whereas during the asset price bubble the impression was of low volatility and prices in the sovereign debt market.

Table 30. *2012 Bond GARCH EMH Residuals Statistics(01/07/2002–29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.985536	0.979538	0.979487	0.980571	0.980036	0.980981
Adjusted R^2	0.985513	0.979506	0.979455	0.980541	0.980005	0.980951
Jarque-Bera	844.25	525.97	769/99	1001.30	1087.33	724.11
Q-Statistics (Correlogram)	355.85	479.46	491.55	429.90	451.85	440.35
F-Statistics (ARCH Test)	0.445786	2.844207	2.638146	2.975284	2.062553	1.714021

In essence, as illustrated byTable 28previously, the high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Although the Jarque-Bera tests seem to be significantly lower, yet the statistics still accept the null hypothesis of non-normality in the distribution. Conversely, the Q-statistics are also lower but similarly seem to be hinting at a significant serial correlation. With the exception of the US market, the F-statistics are hinting athighly significant ARCH effect.

Table 31. *GARCH EMH Test Statistics of the 2012 Bond 01/07/2002–29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.002192 (0.000432)	0.001080 (0.000333)	0.014016 (0.000421)	0.001452 (0.000320)	0.005095 (0.000365)	0.002972 (0.000388)
b	1.002683 (0.001139)	1.010122 (0.001977)	0.992232 (0.001909)	1.006916 (0.001861)	0.990671 (0.001888)	0.985159 (0.001778)
ϵ	0.749997 (0.007591)	0.729650 (0.011164)	0.683685 (0.011067)	0.773139 (0.010820)	0.748951 (0.010518)	0.777070 (0.010728)
Variance Equation ω	2.68E-05 (5.19E-06)	1.03E-05 (1.72E-06)	1.22E-05 (2.09E-06)	9.35E-06 (1.76E-06)	1.28E-05 (2.13E-06)	1.73E-05 (2.60E-06)
α	1.517380 (0.145895)	1.355465 (0.129580)	1.370290 (0.124556)	1.309422 (0.144706)	1.376901 (0.130443)	1.346987 (0.131897)
β	0.168458 (0.022045)	0.171189 (0.025036)	0.166205 (0.023499)	0.209803 (0.028309)	0.171778 (0.022900)	0.165501 (0.024569)
Statistics Log Likelihood	2716.990	3435.158	3329.469	3475.344	3331.977	3296.506
Standard Deviation	0.699244	0.257346	0.260240	0.243392	0.260696	0.273801
EMH Test EMH Test Statistics	0.98	2.05	2.06	2.13	2.10	1.87
Efficiency	Accept	Reject	Reject	Reject	Reject	Accept

Table 31 hints at a high b coefficients during the pre-crisis period, with the exception of the Portuguese and Spanish markets, this seem to be suggesting that the observed markets do not revert back to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 1.0 with a standard error of greater than 0.0011. However, the Portuguese and Spanish markets with b coefficients of less than 1.0 and standard errors of higher than 0.0017 do slowly revert back to the unconditional mean. The residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the market except for the US.

Despite this period being governed by some highly volatile events, the α coefficients hint at relatively low levels of sensitivity to market shocks throughout the observed markets in general. More specifically with α coefficients not higher than 1.38, the Eurozone markets seem to be illustrating the stability of the euro effect on the market. While the US is markedly higher, the assumption is the consideration that the US market is the "risk free" market; hence, it observed some flights to safety during the period. A possible explanation for the low α coefficients is that the stability of the asset price bubble countered the earlier effects of the introduction of the euro and the highly volatile events like the Iraq war. Since during any period of sustained economic upturn, market participants are likely to opt for high earning risky assets such as asset-backed securities, i.e. MBS or CDO, or the equity market.

With the exception of the Italian market, the β coefficients are hinting at relatively moderate levels of volatility persistence in the aftermath of a crisis. This is not surprising since in general highly persisting events did not affect this period, of course, the moderate levels accounted for some persisting events like the "war on terror". At first glance, the persistence level in the Italian market is rather interesting, however it must be remembered that until 2004 Italy had the biggest debt to GDP ratio of all the observed markets and problems adjusting economically to the introduction of the euro. It could be said that Greece had the same problems but remember the size and liquidity of the Italian market far outweighs the Greek market.

The standard deviation, which does not go above 0.28, provides further evidence of the stability in the Eurozone markets. As stated previously, initially the introduction of the euro caused markets to be highly volatile. However, in the longer-term market participants began to adjust to the introduction of the euro. Over time, the stability within the Eurozone markets as hinted by the standard deviations highlighted by Table 31. However, as previously stated, the US market regarded as the risk free market and therefore any news or information would heightened volatility. Another explanation for the high standard deviation is that many of the highly volatile events such as the "war on terror" and the accountancy problems of WorldCom and Enron were largely associated with the US market.

Interestingly only two markets, the US and Spanish, accept the efficient market hypothesis. However, what is interesting about the EMH test statistics of all other markets is not that they accept the null hypothesis of the market being too volatile to be efficient but that their statistics are close to accepting the efficient market hypothesis. Furthermore, these markets are closer to the f-statistics of 1.96 than the US market. However, the Spanish market is the closest to true efficiency in that it is the closest to the key statistic. A possible explanation for the result is the market was efficient for large parts of the pre-crisis period, given that the Spanish banking sector was in the first instance not involved in the US sub-prime mortgage market. Interestingly it is the Eurozone markets that are closer to the key f-statistics, so the difference between being efficient and not is maybe the reaction to a certain event or events. Although the US market is further away from the key statistic, yet it is efficient. A key explanation for this is the standard deviation, whichis higher than all the other markets. As explained earlier the larger the standard deviation is the more unpredicTable the market, hence the US market was the most unpredicTable during the pre-crisis period. Since one of the key assumptions of the efficient market hypothesis is that markets are unpredicTable that means that the US market had satisfied one of the key assumptions.

Table 33 are associated with the financial crisis of the late 2000s. Although the first hint of theend of the bubble in the housing market came long before the financial crisis. Yet the financial markets continued riding the bubble until mid-2007 when a number of international banks (e.g. Bear Stearns and BNP Paribas) recorded losses on their off-balance sheet activities associated with the MBS or CDO, which resulted in flights to liquidity and quality. In essence, this meant an increase in market activities in the observed markets as market participants sought the safety of the sovereign debt market.

Table 32. *2012 Bond GARCH EMH Residuals Statistics (02/07/2007–30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.979268	0.979426	0.976536	0.980445	0.978760	0.978049
Adjusted R^2	0.979200	0.979358	0.976459	0.980381	0.978690	0.977977
Jarque-Bera	1311.57	97.56	83.44	354.28	84.28	2376.50
Q-Statistics(Correlogram)	92.106	218.51	229.71	179.20	198.04	147.00
F-Statistics (ARCH Test)	0.082282	3.249124	4.975770	0.157189	1.287693	0.025320

The financial crisis seems to have had the impact of lowering the R^2 and adjusted R^2 through all the estimated models hinting at the model being less of a good fit in comparison with the pre-crisis period as illustrated by Table 30; however, both statistics are still highly significant at above 0.97. With the exception of the US and Spanish markets, the financial crisis seem to have reduced the Jarque-Bera statistic hinting at the residuals approaching normality during the period. Conversely, the Q-statistics also reduced hint at a lower serial correlation for all the observed markets. Additionally, with the exception of the German and Greek markets, the F-statistics are hinting at a reduced ARCH effect.

Table 33. *GARCH EMH Test Statistics of the 2012 Bond (02/07/2007–30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation						
a	0.004776 (0.000202)	0.002287 (0.000271)	0.015968 (0.000477)	0.001986 (0.000252)	0.005228 (0.000394)	0.002256 (0.000248)
b	0.975373 (0.001567)	0.973174 (0.001752)	0.998039 (0.001763)	0.997611 (0.001729)	0.991573 (0.001812)	1.000609 (0.001605)
ϵ	0.702917 (0.011493)	0.741932 (0.015975)	0.781440 (0.012187)	0.799874 (0.011807)	0.818953 (0.013470)	0.715137 (0.013922)
Variance Equation						
ω	1.73E-06 (7.57E-07)	3.71E-06 (8.48E-07)	1.49E-05 (2.93E-06)	4.52E-06 (9.01E-07)	1.50E-05 (2.52E-06)	4.33E-06 (1.10E-06)
α	2.739762 (0.722247)	1.314567 (0.175964)	1.540484 (0.199140)	1.787047 (0.256983)	1.416167 (0.202024)	2.169304 (1.10E-06)
β	0.191036 (0.031928)	0.198202 (0.037437)	0.089209 (0.026096)	0.060629 (0.023431)	0.073715 (0.023395)	0.096187 (0.027979)
Statistics						
Log Likelihood	1621.194	1908.073	1675.784	2016.488	1817.379	1794.027
Standard Deviation	0.223842	0.133095	0.189977	0.116066	0.157186	0.141228
EMH Test						
EMH Test Statistics	8.625718	3.852654	3.314575	7.303396	3.116575	8.960624
Efficiency	Reject	Reject	Reject	Reject	Reject	Reject

Table 33 hints at a mixed picture regarding the b coefficients during the financial crisis period. Although the b coefficients seem to be suggesting mean reversion throughout the observed markets, yet the GIPS markets seem to be approaching perfect mean reversion. Interestingly these are the markets with an increasing b coefficient. Furthermore, the Spanish market with a b coefficient of 1.0 is hinting at a perfect mean reversion. The impact from the financial crisis on the b coefficients of the German and US markets seem to be hinting at the crisis having a positive effect with respect to mean reversion. The b coefficients seem to be confirming the split between these two groups. Conversely, the standard errors for the b coefficients are between 0.0016 and 0.0019 thru all the observed markets. The residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.02 thru all the markets. As the α coefficients hint, the onslaught of the financial crisis led to an increase in the sensitivity levels to market shocks. Especially in the US and Spanish markets where the impact from the financial crisis was felt most among the observed markets. However, with the possible exception of the Italian market, the sensitivity levels of the remaining markets did not increase significantly. As explained previously, the Greek and Portuguese markets are not as liquid as the other observed markets. To a certain extent the German market was not affect by the financial crisis, which may explain the relatively low α coefficients. The β coefficients seem to be pointing at a high level of persistence in the US and German markets while all the GIPS markets have a low level of persistence. As expected since the US and German markets were regarded as high quality and liquid markets, hence during the financial crisis these markets experienced a constant flight to safety. This leads to high levels of persistence since the volatility is consistently high. In contrast the GIPS nations were not only perceived to be of a lower quality or liquid but also due to the German market being the key market in the Eurozone, this meant many Eurozone market participants were likely to go to the German market.

The standard deviation does reflect a significant decrease in the volatile market during the financial crisis in comparison with the pre-crisis period. This seems to be stating that the observedmarkets were not highly volatile during a period of highly volatile global financial markets. In essence, this is not surprising since the prices of these assets were generally following an upwards trend due to the global financial crisis and this does not make them volatile but this does make them predicTable. The key to understanding the rejection of the efficient market hypothesis is to consider what the EMH test really implies. The EMH test implies that the market is deviating from the fundamental value. Since the financial crisis meant that market participants were engaging in flights to liquidity or quality, this meant that prices were trending upwards faster than the fundamental value. This meant that the EMH test statistics significantly rejected the efficient market hypothesis for all the observed markets. A key factor in the deviation from the fundamental value was that market participants were reacting to events instead of the fundamentals. Furthermore as explained in the previous paragraph the continued upwards trend meant that in essence the markets were predicTable to a certain extent. Table 34 and Table 35 are associated with the Eurozone sovereign debt and US fiscal cliff crises. In order to provide liquidity and boost the economy, many central banks embarked onnon-standard monetary policies. However, it became clear that monetary policy alone was not going to be enough save the banking system and avert a deep recession turning into a full-scale depression. Essentially, the sovereign debt crises was the product of the governments providing much needed capital for the banking system and following a fiscal stimulus policy to support the economy after the financial crisis. This added a substantial amount to the total debt. However, it is worth remembering that these assets are fixed term contacts, which mature at a certain date, hence an influencing factor to bear in mind is the maturity effect.

Table 34. *2012 Bond GARCH EMH Residuals Statistics (02/11/2009–30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.984793	0.985310	0.985119	0.983549	0.986188	0.984302
Adjusted R^2	0.984739	0.985257	0.985066	0.983491	0.986138	0.984246
Jarque-Bera	105.76	416.19	3391.42	167.13	203.66	196.36
Q-Statistics (Correlogram)	182.89	203.53	44.41	189.04	214.28	157.03
F-Statistics (ARCH Test)	2.601891	5.379326	0.340019	5.855812	6.982726	0.277941

The sovereign debt crisis seems to have had the impact of raising the R^2 and adjusted R^2 through all the estimated models. This hints at the model being a good fit in comparison with the financial crisis period, as illustrated by Table 32, with both statistics above 0.98. With the exception of the US and Spanish markets, the sovereign debt crisis seem to have increased the Jarque-Bera statistic hinting at the residuals accepting the null hypothesis of non-normality. Interestingly, although the reductions for the US and Spanish markets were significantly large, they still seem to beaccepting the null hypothesis of a non-normal distribution. Conversely, with the exception of the US and Greek markets, the Q-statisticsare hinting at a relatively limited change in serial correlation between the financial and sovereign debt crisis periods. However, with the exception of the Greek market, the F-statistics are hinting at a significant increase in the ARCH effect.

Table 35. *GARCH EMH Test Statistics of the 2012 Bond (02/11/2009–30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation						
a	0.004641 (0.000122)	0.002091 (5.53E-05)	0.022285 (0.001814)	0.002514 (4.28E-05)	0.005038 (0.000144)	0.003195 (7.74E-05)
b	0.981840 (0.003607)	0.993474 (0.001796)	0.981985 (0.001511)	0.969182 (0.001580)	0.982596 (0.000598)	1.001468 (0.001531)
ϵ	0.702702 (0.018872)	0.763513 (0.019155)	1.276555 (0.002463)	0.829925 (0.012519)	0.744887 (0.012284)	0.857096 (0.012099)
Variance Equation						
ω	1.57E-08 (8.68E-09)	4.53E-08 (9.45E-09)	0.000860 (6.27E-05)	1.51E-07 (3.32E-08)	5.75E-07 (2.44E-07)	4.33E-07 (1.49E-07)
α	0.991745 (0.148589)	1.383852 (0.193950)	2.526172 (0.119999)	1.869897 (0.243632)	1.74503 (0.135819)	2.316483 (0.437554)
β	0.243627 (0.047824)	0.113232 (0.029609)	0.140287 (0.016319)	0.04853 (0.025347)	0.251716 (0.014035)	0.099802 (0.022945)
Statistics						
Log Likelihood	3305.380	3233.428	-37.37380	2731.215	1224.056	2077.784
Standard Deviation	0.01774	0.013194	11.4855	0.064861	1.51737	0.190863
EMH Test						
EMH Test Statistics	13.26787	37.675	0.145092	14.15993	0.656891	7.420427
Efficiency	Reject	Reject	Accept	Reject	Accept	Reject

With the possible exception of the Spanish market, the markets are hinting at strong mean reversion during the sovereign debt crisis. Although the b coefficient of the Italian market is pointing at a weak mean reversion in comparison. As with the financial crisis, the Spanish b coefficient is above 1.0, howeverit is slightly greater than 1.0 in comparison with Table 33. Conversely, the standard errors for the b coefficients vary widelyfrom approximately 0.0006 for the Portuguese market to approximately 0.0036for the US market. The residuals seem to be hinting at a significant amount of white noise especially for the Greek and Portuguese markets with ϵ coefficients of greater than 0.7. However, again the standard errors vary widely, although not as widely as the standard errors of b coefficients.

The α coefficients seem to be reflecting the diverse impact of the sovereign debt crisis on the observed markets. In essence, the US and to a lesser extent German markets were not effect by the early stages of the crisis, hence the low levels of sensitivity to market shocks. Remember that both markets at the time were seen as safe haven from the crisis. However, the significant α coefficients of the Greek and Spanish markets are hinting at high levels of sensitivity to market shocks. Notably the Greek market was at the centre of the Eurozone sovereign debt crisis. Although the Spanish market did not feel the impact of the sovereign debt crisis until the later parts, yet a combination of a weakening economy, continuation of the financial crisis and weak local government finance at a time when the spotlight was on government spending did make the Spanish market highly sensitivity to market shocks. Even before the financial crisis, the Italian debt to GDP ratio was the highest in the Eurozone, hence with such a high ratio the Italian market was highly sensitive to market shocks. Although the α coefficients of the Portuguese market were high, however they are not that high. As previously suggested, a possible explanation is size and liquidity of the market. Another explanation is the quick reaction of the Portuguese government, IMF and European Community to the Portuguese crisis.

The β coefficients seem to be hinting at mixed picture underpinning the level of volatility persistence. The US and Portuguese markets seem to be interesting due to the high volatility persistence providing a further explanation as to why the sensitivity to market shocks were relatively low. However, with the exception of the German and Greek markets, all the remaining observed markets seem to be hinting at a low level of volatility persistence. A possible explanation ismainly due to the indecision of the politicians both within Greece and the Eurozone, the Greek market was a highly reactive to every decision and statement by the politicians. As illustrated in the financial crisis period, the German market was the safe haven for all Eurozone market participants.

The standard deviations seem to be hinting at a split market with the US, German and Italian markets pointing at a sTable market. However, the Greek and Portuguese markets are highly volatile. Interestingly the Greek market seems to be very significantly volatile, as expected since the Greek market was at the centre of the sovereign debt crisis in the Eurozone. Although the Spanish market does seem to suggest stability in comparison to some of the observed standard deviations, yet it also suggests a volatile market relative to other standard deviations. Hence, the Spanish market, seem to be suggesting indecision on the part of market participants.

As hinted previously, during the financial crisis the market participants were reacting to events instead of the fundamentals. Interestingly, the fundamentals of the sovereign debt markets were already highlighting many issues such as high longer-term unemployment and high debt/deficit. However, hindsight is a lovely tool to have but unfortunately; during any crisis, human nature dictates that market participant react to events rather than the fundamentals of the asset, which was the case during the financial crisis and to a certain extent the sovereign debt crisis. This is the key to understanding the significant acceptance of the null hypothesis of the markets being too volatile to be efficient with regards to the US, German, Italian and to a lesser extent the Spanish markets. During the early stages of the sovereign debt crisis, these markets were seen as risk free and liquid markets, hence the upwards trend continued making them more predicTable. However, of greater interest is the Greek and Portuguese markets acceptance of the efficient market hypothesis. A possible explanation is that market participants had no option other than to accept the price as given by the fundamentals because the market was no longer dictating the price. In other words, the market participants were increasingly reacting to the fundamental information rather than events, which especially in the case of Greece shows that market participants obviously were not aware or did not take into account thereliability of the Greek national accounts.

Table 36 and Table 37 illustrate the statistical analysis and estimated model of the entire observation for the 2017 issued bonds. In essence, these government bonds were issued just before the financial broke out which mean we analyse the full influences from both crises on the efficiency of the observed markets. Additionally, with the exception of the Portuguese market, the impact from the sovereign debt crisis did not hit some of the observed markets until the later stages. However, although this helps overcome the maturity effect on the analysis of the sovereign debt crisis. Yet it does introduce another issue in the form of the "on-the-run" effect during the financial crisis. In a way, the combination of the financial and sovereign debt crisis should make the market highly volatile and reactive.

Table 36. *2017 Bond GARCH EMH Residuals Statistics (02/07/2007–29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.987786	0.981807	0.985123	0.984973	0.982754
Adjusted R^2	0.987769	0.981783	0.985103	0.984953	0.982731
Jarque-Bera	16546.91	1392.45	1351.47	1438.45	1711.09
Q-Statistics (Correlogram)	287.04	468.74	456.76	417.17	433.94
F-Statistics(ARCH Test)	0.000144	1.382685	2.704764	0.731502	2.040020

As illustrated by the estimated models in Table 36, a key factor of note is the high $R^2$and adjusted R^2. The $R^2$is significantly high and approaching one, above 0.98, through all the estimated GARCH models hinting at the lagged price variance with the estimated residuals being highly able to explain the movement in the price variance. Another factor is the significantly high adjusted R2 pointing at the estimated GARCH model being a good fit to the dependent variable across all the markets. These two statistics partly illustrates our GARCH model is correctly specified to test all the markets for the null hypothesis of the market being too volatile to be efficient.

The Jarque-Bera test for all the markets seem to be hinting at a significant acceptance ofthe null hypothesis of non-normality in the distribution of the residuals. We found all our markets seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, apart from the US, the Jarque-Bera statistics seem to be hinting at uniformed results across all the observed markets. Although the Spanish statistic is higher, yet it is within the range of the other Eurozone markets. Conversely, the US statistic is significantly higher than all the others are; in fact, it is higher by a factor of approximately 10 from the Spanish statistics, hinting at a significant acceptance of the null hypothesis of non-normality. Rememberunder certain circumstances the consideration of the existence of non-normal residuals as an indicator for non-efficient markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at a high serial correlation in the residuals. At the single lagged level, the Q-statistic for all our samples does not drop below 287.04 as observed by the US. Remember the existence of autocorrelated residuals usually imply the omission of important variablesfrom the regression. In the current framework, the fact that other variables may be important to determine bond prices seems to be indicating inefficient markets.

The F-statistics seem to be wielding very widely between approaching no ARCH effect to a relatively significant ARCH effect remaining. In essence, the two lowest F-statistics are the US and Portuguesemarkets with an F-statistics below one, thus meaning a significantly low ARCH effect remaining. The highest F-statistic is that of the Italian market hinting at a relatively significant ARCH effect remaining.

Table 37 hints at a high b coefficients; with the exception of the German market, this seem to be suggesting that the observed markets do revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 0.97with a standard error of less than 0.00095. However, the German market with b coefficient greater than 1.0 and standard errors higher than 0.0011 does not revert back to the unconditional mean. The residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.0075 thru all the market except for the US. Conversely, the Portuguese market has the highest amount of white noise.

Table 37. *GARCH EMH Test Statistics of the 2017 Bond (02/07/2007–29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation					
a	0.009329 (0.000173)	0.004452 (0.000380)	0.009859 (0.000336)	0.042697 (0.000791)	0.008246 (0.000496)
b	0.993947 (0.000883)	1.003136 (0.001126)	0.995940 (0.000783)	0.974538 (0.000623)	0.993566 (0.000937)
ϵ	0.717657 (0.007993)	0.747491 (0.010197)	0.742892 (0.008919)	0.838409 (0.009546)	0.717486 (0.009254)
Variance Equation					
ω	1.38E-06 (4.27E-07)	2.05E-05 (3.46E-06)	2.01E-05 (3.51E-06)	0.000124 (2.21E-05)	5.78E-05 (9.13E-06)
α	1.933987 (0.224059)	1.52365 (0.154555)	1.764853 (0.164880)	1.876973 (0.182783)	1.898960 (0.195272)
β	0.246653 (0.224059)	0.179062 (0.021962)	0.140782 (0.018864)	0.131443 (0.017092)	0.113456 (0.017045)
Statistics					
Log	2926.421	3350.473	2840.106	1037.013	2494.552

Likelihood					
Standard Deviation	1.067295	0.344854	1.070745	4.984212	1.102358
EMH Test					
EMH Test Statistics	1.106198	2.037709	0.845799	0.202322	0.918409
Efficiency	Accept	Reject	Accept	Accept	Accept

With the exception of the German market, the α coefficients seem to be hinting at high levels of sensitivity to market shocks. Although the Italian market is lower than the others are, yet it is high. However, the German market seem to be portraying a sTable market throughout as also observed by Table 39 and Table 41, explained by the fact that German debt is largely held domestically. Moreover, the crises did not really affect the German market, as German government bonds were a safe haven. In contrast, the US market has a high level of sensitivity to shocks; this could be due the use of the US market as a safe haven during both crises. Another plausible explanationis the on-going fiscal-cliff and debt ceiling crises. Interestingly, the IPS markets range between 1.76 for the Italian market and 1.89 for the Spanish market. A plausible explanation is the impact of both crisis on the markets. Although the Spanish market did not feel the impact of the sovereign debt crisis until the later stages of the crisis, yet it banking system was the biggest problem throughout the observed period. There were signs of the weakness in the Italian economy before the advent of any crisis but the full extent of the sovereign debt crisis did not affect the Italian market until the later stages. This along with the limited impact from the financial crisis meant that the sensitivity to market shocks was lower than the remaining IPS markets. The Portuguese market is a tale of two crises while the impact from the financial crisis was limited. However, the sovereign debt crisis was highly damaging, and as a result, the sensitivity to market shocks is high.

The β coefficient illustrates the difference in the volatility persistence between the IPS and US/German markets. As stated previously mainly due to flights during both the financial and sovereign debt crises, the US and German markets had high levels of volatility persistence in the aftermath of events during both crises. However, another explanation with respect to the US market is the on-going US fiscal cliff and debt ceiling crises. In contrast, the impact on the IPS markets was usually short shocks hiking the volatility.

Again mainly due to both crises not having an impact on the German market, the standard deviation did not increase in the German market as it did in the remaining observed markets. The standard deviation seems to be hinting at highly volatile IPS markets, especially the Portuguese. As expected since the sovereign debt crisis did directly affect these markets. As mentioned earlier, mainly due to flights during both crises in addition to the impact from the two crises, the US market had high volatility throughout the observed period. Whereas to a certain extent the strongest influence the German market came from flights.

Interestingly, the EMH test statistics seem to be hinting at the acceptance of the efficient market hypothesis. However, the German market narrowly accepted the null hypothesis of the market being too volatile to be efficient. Of more interest are the Portuguese and Spanish markets, the reason being that these two 2017 government bonds seem to be accepting the efficient market hypothesis in all observed periods. As previously hinted, both crises made the environment too volatile that market participants had no option other than to accept the price as given because the market was no longer dictating the price. In other words, the market participants were accepting the fundamental information.

Tables 38 and 39 are associated with the financial crisis of the late 2000s. As stated previously, the main impact was the flight to safety from the risky assets at the heart of the financial crisis to the sovereign debt market. In essence the sovereign debt market, especially the US and German, were considered safe haven from the financial crisis. However, of more interest is the impact from the on-the-run effect, since the 2017 bonds were issued just before the financial crisis heated up. With this in mind, we will compare the statistics in these two Tables with the statistic from Tables 32 and 33.

Table 38: *2017 Bond GARCH EMH Residuals Statistics (02/07/2007–30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.984827	0.976877	0.974911	0.979995	0.979447
Adjusted R^2	0.984775	0.976798	0.974825	0.979927	0.979377
Jarque-Bera	75.00	198.89	378.23	212.48	36.11
Q-Statistics (Correlogram)	180.94	203.72	196.13	178.77	236.10
F-Statistics(ARCH Test)	2.027137	1.025226	1.773055	0.224477	6.305451

In comparison both Tables 38 and 32 seem to be hinting at the R^2 and adjusted R^2 being significant. This means that the estimated models are good fit for both the observed datasets. Although there are slight differences between both observed datasets, the differences do not have any significant impact. With the exception of the US and Spanish markets, the 2017 bonds seem to have larger

Jarque-Bera statistic hinting at the residuals moving away from normality. Interestingly, the Jarque-Bera statistics of theUS and especially Spanish marketsare approaching normality. Conversely, with the exception of the German and Portuguese markets, the increase of Q-statistics hints at a higher serial correlation. Additionally, only the German and Portuguese markets have reduced F-statistics hinting at low ARCH effects. The Spanish market is interesting in thatfrom approaching zero to significantly large ARCH effects this has dramatically hiked upthe F-statistic.

Table 39 is hinting at a split picture, with the exception of the Italian and Portuguese markets, the b coefficients seem to be increasing on those in Table 33. This is interesting because these three markets also seem to be hinting at a change from displaying strong to no mean reversion to the unconditional mean. The standard errors for all the observed markets are significantly higher. However, with the exception of the German and Portuguese markets, the residuals seem to be hinting at a reduction in the white noise.

Table 39. *GARCH EMH Test Statistics of the 2017 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	-0.000564 (0.003340)	0.006665 (0.001545)	0.011000 (0.000833)	0.042407 (0.001197)	0.006207 (0.000926)
b	1.006598 (0.003128)	1.005106 (0.002573)	0.995054 (0.002496)	0.971872 (0.001474)	1.007520 (0.002517)
ϵ	0.703845 (0.014809)	0.789827 (0.018080)	0.744826 (0.014066)	0.811311 (0.013325)	0.707078 (0.017994)
Variance Equation ω	0.000763 (0.000151)	0.000143 (2.52E-05)	5.28E-05 (1.13E-05)	0.000203 (3.45E-05)	5.81E-05 (1.11E-05)
α	1.238184 (0.181054)	1.379988 (0.224340)	1.636521 (0.228196)	1.461788 (0.206918)	1.352788 (0.192634)
β	0.126311 (0.045353)	0.097725 (0.034010)	0.060077 (0.025787)	0.003933 (0.023586)	0.105089 (0.027438)
Statistics Log Likelihood	633.739	1083.302	1299.831	1110.215	1231.439
Standard Deviation	1.444623	0.397085	0.308165	0.552783	0.461169
EMH Test EMH Test Statistics	0.252312	1.20305	2.260471	0.842502	0.992862
Efficiency	Accept	Accept	Reject	Accept	Accept

With the exception of the Italian and Portuguese markets, the financial crisis does not appear to have impacted on the α coefficients of the observed markets. In comparison with Table 33, the level of sensitivity to market shocks was higher in Table 33with the exception of the Portuguese and German markets.

Interestingly, the US had the lowest α coefficients whereas the Italian had the highest. This is a complete reversal of the α coefficients for these two markets from those sensitivity levels reported in Table 33.

Although the β coefficients point towards a low volatility persistence in all the observed markets; yet there seem to be a different in the persistence of volatility. While the Italian and Portuguese markets seem to have very low levels of persistence, the US market does hint at a relatively higher level of persistence. Contrasting with Table 33, whichseems to be hinting at higher levels of persistence for all 2012 bonds during the financial crisis.

There seems to be a differentiation between the US market and the Eurozone markets with the US hinting at a high standard deviation and therefore a highly volatile market. As expected, this is due to the financial crisis having the biggest impact on the US financial market. However, this does not explain why the Eurozone markets, especially the Spanish market, seem to be low. One possible explanation is unlike the US the financial crisis did not really affect the observed Eurozone markets, especially the Spanish, until the later stages. Obviously, given these government bonds were issued just before the financial crisis and hence they react to events quicker than bonds in the middle of their lives, these bonds, especially the US, seem to be more volatile than the 2012 bonds as illustrated by Table 33.

Interestingly, the EMH test statistics seem to be hinting at the observed markets accepting the efficient market hypothesis during the financial crisis. The exception is the Italian market, which accepts the null hypothesis of markets being too volatile to be efficient. Conversely, in contrast to Table 31 with exception of the German and Portuguese markets, the efficiency status of the other observed markets remained unchanged. This seems to be suggesting that during the financial crisis the "on-the-run" effect did have the impact of increasing the efficiency.

Tables 40 and 41 are associated with the Eurozone sovereign debt and US fiscal cliff crises. One influencing factor to bear in mind is that the 2012 bonds did not cover the later stages of the sovereign debt crisis while the 2017 bonds do cover the majority of the crisis. However, another factorworth remembering is that the 2012 bonds were at the end of their lives during the sovereign debt crisis; hence, an influencing factor to bear in mind is the maturity effect. Conversely, the 2017 bonds were in mid-life during the crisis, hence it is interesting to see what impact the maturity effect had on the markets during the sovereign debt crisis.

Table 40. *2017 Bond GARCH EMH Residuals Statistics (02/11/2009 –29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.984020	0.982091	0.984568	0.981909	0.981416
Adjusted R^2	0.983984	0.982051	0.984533	0.981868	0.981374
Jarque-Bera	11650.69	108.16	159.90	699.10	2219.34
Q-Statistics (Correlogram)	172.50	315.52	302.62	259.33	254.70
F-Statistics(ARCH Test)	0.003594	5.054297	7.962822	0.662548	0.511039

In comparison both Tables 40 and 34 seem to be hinting at the R^2 and adjusted R^2 being significant. This means that the estimated models are good fit for the 2017 observed datasets. Although there are slight differences between both observed datasets, the differences do not have any significant impact. With the exception of the Germanand Italian markets, the 2017 bonds seem to have larger Jarque-Bera statistic hinting at the residuals moving away from normality. Interestingly, the Jarque-Bera statistics of the US and Spanish markets are significantly larger. Conversely, with the exception of the US market, the increase in Q-statistics hints at a higher serial correlation. Additionally, only the Italianmarket has greater F-statistics and with the exception of the German and Italian markets, the F-statistics are hinting at low ARCH effects. The US market is interesting in that the reduction of the F-statistic means ARCH effects of effectively zero.

Table 41. *GARCH EMH Test Statistics of the 2017Bond (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.009385 (0.000177)	0.005924 (0.000346)	0.010160 (0.000367)	0.042367 (0.001466)	0.008436 (0.000639)
b	0.987676 (0.000946)	0.975723 (0.001524)	0.989713 (0.001113)	0.974749 (0.000795)	0.983830 (0.001460)
ϵ	0.707102 (0.010624)	0.739618 (0.012980)	0.746453 (0.011486)	0.855308 (0.012212)	0.698492 (0.012982)
Variance Equation ω	1.61E-06 (4.73E-07)	7.84E-06 (1.84E-06)	9.32E-06 (2.43E-06)	0.000163 (5.02E-05)	3.62E-05 (8.56E-06)
α	2.317501 (0.354558)	1.321697 (0.152443)	1.673335 (0.205084)	1.982929 (0.244304)	2.023975 (0.263779)
β	0.164934 (0.021917)	0.238089 (0.027270)	0.192224 (0.023514)	0.153943 (0.021813)	0.140932 (0.022178)
Statistics Log Likelihood	2335.037	2307.666	1557.962	-61.15424	1275.555
Standard Deviation	0.41962	0.257374	1.312213	5.824118	1.320804
EMH Test EMH Test Statistics	3.532803	2.17499	0.659618	0.195201	0.881968
Efficiency	Reject	Reject	Accept	Accept	Accept

Table 41 is hinting at a split picture, with the exception of the US and Italian markets, the b coefficients seem to be decreasing on those in Table 35. The Spanish market is interesting due to the reduction meaning a change from no mean reversion to strong mean reversion. The standard errors for all the observed markets are lower with the exception of the Portuguese market. Additionally with the exception of the Portuguese market, the residuals seem to be hinting at a reduction in the white noise.

With the exception of the German and Italian markets, the α coefficients seem to be pointing at a significantly highlevel of sensitivity during the sovereign debt crisis. Although the Italian market is also displaying a relatively high level of sensitivity, however it is not as significant as the other observed markets. As with all previous observations concerning the 2017 bonds, the German market continues to display a low level of sensitivity in comparison to the other observed markets. However, in contrast to Table 35, it seem that the maturity effect had a varying impact on the levels of sensitivity, with the US and Portuguese markets hinting at an increase while the others are pointing towards a decrease. The hike in the US market is significant; a possible explanation is that the fiscal cliff and debt ceiling crises did not fully affect the US market until the later stages.

Interestingly, the volatility persistence levels seem to be displaying the reverse impact on the observed markets with the German and Italian markets displaying high levels of volatility persistence. In contrast, the remaining observed markets seem to be pointing at relatively low volatility persistence levels. This would point at a fast changing environment in the observed markets during the sovereign debt crisis. However, contrasting with Table 35 seem to be suggesting that the maturity effect had a varying impact on the level of volatility persistence with the US and Portuguese markets hinting at a decrease, while the otherspointing towards an increase. An interesting point is the significant increase in the German and Italian markets pointing to the main impact of the sovereign debt crisis coming in the latter stages. In a way, this would explain the decrease in the β coefficient of the Portuguese market, since as the Eurozone sovereign debt crisis continued the Portuguese market became relatively susceptible to shocks rather than persisting volatility.

With the exception of the US and German markets, the standard deviations seem to be hinting at a highly volatile market. The Portuguese market seems to be significantly volatile. This seems to be hinting at a different impact during the sovereign debt crisis on the GIPS markets. As expected, this is due to the emphasis of the sovereign debt crisis on the GIPS markets. Conversely, in comparison with Table 35, it would seem that the later stage of the sovereign debt crisis was significantly more volatile with all the observed markets recording a higher standard deviation.

The EMH tests seem to be hinting at the acceptance of the efficient market hypothesis for all observed markets with the exception of the US and German markets. The other key factor is once again the huge impact of the maturity effect makes on the observed markets. As illustrated by the fact that the EMH test accepted the null hypothesis of the market being too volatile to be efficient in all but the Portuguese and Greek markets in Table 35. Another explanation is that not until the later stages of the crisis were the full impact of the sovereign debt crisis observed, hence the different in the market efficiency ofthe Italian and Spanish markets.

4.3.2. An Alternative Volatility Test of the EMH using GJR-GARCH

As indicated earlier, the keys to the EMH test statistic are the coefficients and standard deviation of the model of volatility. Hence, in essence, the model used determines the EMH test statistic; in the previous section, we used a GARCH (1, 1) model. In this section, we propose an alternative model to estimate the coefficients and standard errors, the GJR-GARCH model. An influencing factor in the used of the GJR-GARCH is the use of the asymmetrical effect to analyse whether our EMH test responses differently to negative and positive shocks.

We use a single lagged GJR-GARCH model with a single asymmetrical order. As stated earlier in section 5.3.1, the estimation of any GARCH model is from two equations, namely the mean and variance equations. In essence, for any EMH test the mean equation does not change, hence we use the same equation as the one used in the 5.3.1 section. However, the variance equation is as following:

$$var(Price_t) = a + b_1 var(Price_{t-1}) + \epsilon_t$$
$$h_{jt} = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1} + \gamma_1 k_{t-1} I(\varepsilon_{jt-1} < 0)$$

As explained in the methodology section 3.1, the key to the asymmetrical effect is the γ coefficient when it is positive any shock to the market has an impact on the EMH test. However, of more importance, a negative γ coefficients means a negative shock has a greater impact than a positive shock on the EMH test. This has great implications, if the efficient market hypothesis does follow a certain asymmetrical effect in any market. Does this mean that the sign of the market shock determines the efficiency of the market? Hence, this means the test of the efficient market hypothesis then becomes:

$$EMH\ Test = \frac{(\alpha + \beta + \gamma) - 1}{standard\ deviation\big(var(x)\big)}$$

A key part of the analysis of the test is a comparison with the test of efficiency used previously. Since the only different is the model underpinning the test, hence this essentially is a test of the goodness of the GARCH and GJR-GARCH models. In essence, we use the following reported statistics in our comparison:

- Akaike information criterion (AIC) introduced by Akaike (1974)
- Hannan–Quinn information criterion (HQC) proposed by Hannan & Quinn (1979)
- Bayesian information criterion or Schwarz criterion (SBC) derived by Schwarz (1978)

With three exceptions, the model is a single lagged and asymmetrical order GJR-GARCH model with a student t distribution estimated using the Maximum Likelihood method with a BHHH optimization algorithm. However, due to errors in three markets with the estimation we used the following:

- In Tables 42/43, we used normal distribution and Marquandt optimization for the Greek market and Marquandt optimization for the Spanish market.
- In Tables 54/55, we used normal distribution and Marquandt optimization for the Portuguese market.

Tables 42 and 43 illustrate the statistics analysis of the estimated model for the entire 2012 issued bonds sample observations. As mentioned previously, the observational period combines the impact from the pre-crisis, financial crisis and sovereign debt crisis periods on the efficiency of the market. The interesting addition is the asymmetrical effect; could a positive or negative asymmetrical effect have an impact on the efficiency of the market?

Table 42. *2012 Bond GJR-GARCH EMH Residuals Statistics (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.987427	0.983318	0.986942	0.983489	0.987577	0.982004
Adjusted R^2	0.987417	0.983305	0.986932	0.983475	0.987567	0.981989
Jarque-Bera	4142.43	5272.05	782.52	27601.75	2557.55	12.92
Q-Statistics (Correlogram)	616.39	742.50	1097.04	660.91	755.28	706.95
F-Statistics(ARCH Test)	2.151315	2.842148	39.26778	0.546006	1.980954	0.472439

As illustrated by the estimated models in Table 42, a key factor of note is the high R^2 and adjusted R^2. The R^2 is above 0.98 through all the estimated GJR-GARCH models hinting at the lagged price variance with the estimated residuals being highly able to explain the movement in the price variance. Another factor is thehigh adjusted R^2pointing at the estimated GJR-GARCH model being a good fit to the dependent variable across all the markets. These two statistics partly illustrates our GJR-GARCH model is correctly specified to test all the markets for the null hypothesis of the market being too volatile to be efficient. Interestingly, with the exception of the US and German markets the R^2 and adjusted R^2 seem to favour the GARCH model as illustrated by Table 28. This is interesting due to the GIPS countries favouring one model and the benchmark countries, i.e. the US and Germany, favouring another model.

The Jarque-Bera test for all the markets seem to be hinting at an acceptance of the null hypothesis of non-normality in the distribution of the residuals. We found all our marketsseem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera statistics seem to be hinting at a varied set of results with the Italian being significantly greater than the other countries. Conversely, the Spanish is significantly lower than all the others are. However, the evidence seem to be suggesting with the exception of the Italian, the Jarque Bera statistics are lower than those for the GARCH model in Table 28. Interestingly the Spanish and to a lesser extent Greek markets seem to have decreased the most. As noted earlier, under certain circumstances one can consider the existence ofnon-normal residuals is an indicator for non-efficient markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at a high correlation. At the single lagged level, the Q-statistic for all our samples does not drop below 616.39 as observed by the US. Considering that, ideally the Q-statistics should bezero, the importance of these statistics for the estimated models highlighted in Table 42. Hence, the statistics hint at a significant amount of serial correlation in the residuals. The interesting factor is that these statistics highlight a rise in the series correlation from the GARCH model in Table 28. As previously stated, the existence of autocorrelated residuals usually implies the omission of important variables from the regression. In the current framework, the fact that other variables may be important to determine bond prices seems to be indicating inefficient markets.

In essence, the test for the heteroskedasticity is a test for remaining ARCH effect in the residuals. The F-statistics seem to be wielding very widely between approaching no ARCH effect to a significant ARCH effect remaining. In essence, the two lowest are the Italian and Spanish markets with F-statistics below one, thus meaning a significantly low ARCH effect remaining. The highestisthe Greek market hinting at a significant ARCH effect remaining. The increasesin the Greek and to a certain extent then Spanish markets on the results from Table 28 seem to be hinting that a large percentage of the ARCH effect is due to the GJR-GARCH model. However, all the other observed markets are hinting at a reduction in the ARCH effect.

Table 43. *GJR-GARCH EMH Test Statistics of the 2012 Bond (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation						
a	0.004718 (4.28E-05)	0.001971 (2.46E-05)	0.014725 (0.000252)	0.002074 (3.59E-05)	0.005314 (0.000153)	0.002776 (8.83E-05)
b	0.981760 (0.000756)	0.990280 (0.000788)	0.991871 (0.000796)	0.992199 (0.000878)	0.985286 (0.000837)	0.991562 (0.000925)
ϵ	0.713804 (0.006172)	0.712868 (0.006878)	0.717175 (0.004099)	0.727280 (0.006702)	0.757204 (0.006929)	0.742174 (0.006981)
Variance Equation						
ω	3.13E-08 (9.68E-09)	3.11E-08 (8.33E-09)	1.47E-05 (1.00E-06)	1.31E-07 (3.40E-08)	5.42E-06 (7.46E-07)	1.13E-06 (1.87E-07)
α	1.796321 (0.167025)	1.878929 (0.156243)	1.481097 (0.086233)	2.078245 (0.194462)	1.987364 (0.181877)	2.025392 (0.181242)
β	0.29755 (0.016376)	0.247206 (0.014669)	0.235425 (0.008610)	0.220256 (0.014229)	0.158464 (0.014091)	0.197475 (0.014350)
γ	-0.47366 (0.173375)	-0.46492 (0.178392)	-0.41363 (0.111463)	-0.47485 (0.202053)	-0.46603 (0.200808)	-0.50504 (0.195955)
Statistics						
Log Likelihood	7562.003	8512.469	5023.944	8149.936	6373.905	7125.949
Standard Deviation	0.560344	0.216199	5.963928	0.202834	0.806295	0.235362
EMH Test						
EMH Test Statistics	1.106845	3.058381	0.050788	4.060725	0.843117	3.049893
Efficiency	Accept	Reject	Accept	Reject	Accept	Reject

As illustrated by Table 43, all our b coefficients are greater than 0.98 with a standard error of less than 0.0009, thus hinting at the price variance taking longer to revert to the unconditional mean after a shock to the market. However, the white noise dictated by ϵ is high with all the markets standing in the low to mid 0.7s with a low standard error. It is worth remembering the mean equation is not the focal point to this part. In comparison with Table 29, the b coefficients seem to be hinting at the price variance taking longer to revert to the unconditional mean with the GJR-GARCH in all but the Greek market. However, this means a reduction in the white noise with the exception of the German market.

As illustrated by Table 43, all the markets have an advantage effect hinting at negative shocks having a greater impactthan positive shocks. With the exception of the Greek and Spanish markets, the evidence on the individual markets seems to be suggesting a uniformed leverage effect among the markets. Interestingly, the Greek market has a lower asymmetrical coefficient than the others do. A possible explanation is the size and liquidity of the Greek market may have an impact, since the market is relatively small, the reaction to events affecting the sovereign debt market is not likely to be large. In contrast to the Greek market, the Spanish market has a higher asymmetrical coefficient than the others do. Table 55 portrays a possible explanation for the leverage effect underpinning the GIPS markets, since this observational period encapsulates the sovereign debt crisis period. Additionally, thefinancial and sovereign debt crises could also explain the high asymmetrical coefficient of the US as illustrated by Tables 51 and 55. However, subsequent observational periods do not explain the relatively high asymmetrical coefficient of the German market.

With the exception of the Greek market, the α coefficients seem to be hinting at relatively high levels of sensitivity to market shocks. Furthermore, the remaining observed Eurozone markets have a higher sensitivity levels than the US market. Interestingly, with the exception of the Greek market the inclusion of the asymmetrical effect had the impact of raising the sensitivity levels as illustrated by Table 29. The Greek market is interesting because it would seem that the asymmetrical effect had made the market less reactive to market shocks, even though the asymmetrical effect is a leverage effect like all the other observed markets. This seems to be suggesting the asymmetrical effect can account for some of the shocks to the volatility.

Apart from the Portuguese and Spanish markets, the β coefficients seem to be hinting at relatively high levels of persisting volatility in the market and moreover the US market has the highest persisting volatility among the observe markets. As illustrated by Table 29, to a certain extent, the impact from the inclusion of the asymmetrical effect has not increased the persistence of the volatility in the aftermath of a shock to the market by much. Interestingly, this statement does not apply to the Greek and, to a lesser extent, Portuguese markets where the impact from the inclusion of the asymmetrical effect certainly made the volatility increasingly persistence in the aftermath of a crisis. Hence, like the α coefficient for the Greek market, the β coefficient seems to be illustrating the affinity of the Greek market to the impact from the asymmetrical effect with a sharp increase.

It is worth noticing that three markets do accept the efficient market hypothesis: US, Greek and Portuguese markets. In contrast, the significant EMH test statistics of the German, Italian and Spanish markets seem to be strongly accepting the null hypothesis of the market being too volatile to be efficient. However, rather interestingly the inclusion of the asymmetrical effect has decreased the EMH test statistics for all the observed markets. Yet despite this reduction, the efficiency of the observed markets remains the same as illustrated by Table 29.

Table 44. *2012 Bond GARCH(EMH) ModelAnalysis (01/07/2002-30/12/2011)*

	US	*German*	*Greek**	*Italian*	*Portuguese*	*Spanish*
AIC	-6.137893	-6.910637	-4.142129	-6.616689	-5.172644	-5.783334
SBC	-6.121366	-6.894110	-4.125603	-6.600162	-5.156118	-5.766807
HQC	-6.131888	-6.904632	-4.136125	-6.610684	-5.166639	-5.777329

Table 45. *2012 Bond GJR-GARCH (EMH) ModelAnalysis (01/07/2002-30/12/2011)*

	*US**	*German**	*Greek*	*Italian**	*Portuguese**	*Spanish**
AIC	-6.141466	-6.914203	-4.078816	-6.619460	-5.175532	-5.786951
SBC	-6.122578	-6.895315	-4.062290	-6.600572	-5.156645	-5.768063
HQC	-6.134603	-6.907340	-4.072811	-6.612597	-5.168669	-5.780088

According to Tables 44 and 45, the information criterions seem to be hinting at the best model to explain the information contained within the price variance is the GJR-GARCH model with the exception of the Greek market. This means that the addition of the asymmetrical effect has the advantage of the GJR-GARCH model fully explaining the information contained in the five observed markets and since we are testing the efficiency of the market, it is important that the model does reflect the information contained. However, the Greek market is hinting at the GARCH model being able to explain the information contained in the price variance.

Tables 46 and 47 illustrate the statistical analysis and estimated model for the pre-crisis period. Two different issues highlighted the period: the first issue being the highly volatile period of the early parts, which was the combination of a number of events as hinted in sections 2.4.4 and 4.2.1. The evidence seems to suggest two different impacts influenced the period. The first impact occurred during the early parts of the pre-crisis subsample and was mainly due to the introduction of the euro and extreme events, which lead to Knightian uncertainty such as the 11 September 2001 terrorist attacks. The second impact occurred during the later stages of the pre-crisis subsample and was mainly due to the asset price bubble. The different between these two impacts on the sovereign debt market is the first impact had the impression of a highly volatile market whereas during the asset price bubble the impression was of low volatility and prices in the sovereign debt market.

As illustrated by Tables 46 and 30, the R^2 and adjusted R^2 remain relatively unchanged hinting at all the models being a good fit to the dependent variable. With the exception of the Greek market, the Jarque-Bera tests seem to be pointing at a slight increase hinting at the statistics still accepting the null hypothesis of non-normality. Conversely, the Q-statisticsalso seem to be hinting at a significant serial correlation. Although there is a significant reduction in the F-statistics of the Portuguese and Spanish markets, yet with the exception of the US market, the F-statistics remain high.

Table 46. *2012 Bond GJR-GARCH EMH Residuals Statistics (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.985531	0.979528	0.979454	0.980530	0.979993	0.980953
Adjusted R^2	0.985508	0.979496	0.979422	0.980500	0.979961	0.980923
Jarque-Bera	899.84	548.97	766.72	1112.87	1225.63	765.16
Q-Statistics (Correlogram)	355.03	479.30	495.56	432.50	450.94	442.92
F-Statistics(ARCH Test)	0.384849	2.237703	2.447778	2.465125	1.620070	1.712269

Table 47. *GJR-GARCH EMH Test Statistics of the 2012 Bond (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.002250 (0.000434)	0.001103 (0.000327)	0.013936 (0.000417)	0.001479 (0.000317)	0.005014 (0.000363)	0.002960 (0.000388)
b	1.002679 (0.001199)	1.010206 (0.002170)	0.992984 (0.002117)	1.006970 (0.002011)	0.992200 (0.002003)	0.985914 (0.001873)
ϵ	0.749415 (0.007641)	0.729584 (0.011159)	0.679615 (0.011011)	0.768757 (0.010708)	0.745118 (0.010372)	0.772916 (0.010728)
Variance Equation ω	2.61E-05 (5.13E-06)	9.50E-06 (1.65E-06)	1.15E-05 (2.02E-06)	8.60E-06 (1.68E-06)	1.20E-05 (2.03E-06)	1.64E-05 (2.52E-06)
α	1.617939 (0.207861)	1.519302 (0.191128)	1.516549 (0.186904)	1.477531 (0.205162)	1.519331 (0.197461)	1.458529 (0.189148)
β	0.171466 (0.022344)	0.178823 (0.025907)	0.171924 (0.023894)	0.217932 (0.028624)	0.178277 (0.023354)	0.172782 (0.025086)
γ	-0.189597 (0.243610)	-0.301126 (0.226530)	-0.298920 (0.226349)	-0.316765 (0.220031)	-0.282134 (0.225726)	-0.236220 (0.220606)
Statistics Log Likelihood	2717.475	3436.803	3331.135	3477.286	3333.378	3297.518
Standard Deviation	0.699244	0.257346	0.260240	0.243392	0.260696	0.273801
EMH Test EMH Test Statistics	0.857795	1.542666	1.496899	1.555912	1.593711	1.442986
Efficiency	Accept	Accept	Accept	Accept	Accept	Accept

As with Table 31, Table 47 hints at high b coefficients during the pre-crisis period. With the exception of the Greek, Portuguese and Spanish markets, this seem to be suggesting that the observed markets do not revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 1.0 with a standard error of greater than 0.0011. However, the three remaining markets with b coefficients of less than 1.0 and standard errors of higher than 0.0017 do slowly revert back to the unconditional mean. Also like Table 31, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the market except for the US.

As illustrated by Table 47, the asymmetrical coefficients for the entire observed markets hint at anegative asymmetrical or leverage effectmeaning negative shocks have a greater impact on the market than positive shocks of the same magnitude. It is worth noting that a key factor underpinning the impact of an asymmetrical or leverage effect is the decision of the market participants on whether information has a positive or negative impact on the asset. Hence, a possible explanation for the negative asymmetrical coefficients is the indecision of the market participants with respect to the major event of the time; in essence, the introduction of the euro caused a lot of confusion among the market participants. It is worth remembering high volatility blighted the early part of this period and although there were many highly volatile factors, influencing theearly parts of this period. Nonetheless, the main factor was the introduction of the euro. Another influencing factor is the asset price bubble in the later stages of the period associated with the sTable sovereign debt markets and low prices towards the end of the pre-crisis period; hence any negative event amplifies the reaction of the market participants due to their perspectives.

With the exception of the US market, the α coefficients are hinting at relatively low levels of sensitivity to market shocks. In truth, the US market does not hint at a high level of sensitivity to market shocks. However, the five Eurozone markets do seem to be hinting at relatively low sensitivity levels. Although on the face of it, the asymmetrical effect does not seem to have had an impact on the α coefficient, yet on closer inspection as illustrated by Table 31, the asymmetrical effect seem to have had a decreasing impact on the sensitivity levels of all the markets.

The β coefficients seem to be hinting at relatively low volatility persistence in the aftermath of a crisis in the market, especially the US, Greek and Spanish markets. Although in comparison, the persistence in the Italian market does seem to be large. Yet the Italian market does hint at a low persistence level. As pointed by Table 31, the addition of the asymmetrical effect does seem to have affected the levels of persistence in the observed markets.

Essentially, the asymmetrical effect had increased the persistent levels thru all the observed markets.

It is worth noticing that all the observed markets accept the efficient market hypothesis. However, interestingly the inclusion of the asymmetrical effect has decreased the EMH test statistics for all the observed markets as pointed by Table 31. Conversely, this reduction led to the acceptance of the efficient market hypothesis by all the markets. This is due to the Eurozone markets with the exception of the Spanish narrowly rejecting the efficient market hypothesis in Table 31.

Table 48. *2012 Bond GARCH(EMH) ModelAnalysis (01/07/2002-29/06/2007)*

	*US**	*German**	*Greek**	*Italian**	*Portuguese**	*Spanish**
AIC	-4.217883	-5.335655	-5.171159	-5.398201	-5.175061	-5.119853
SBC	-4.189782	-5.307554	-5.143058	-5.370100	-5.146960	-5.091752
HQC	-4.207334	-5.325105	-5.160609	-5.387652	-5.164511	-5.109303

Table 49. *2012 Bond GJR-GARCH (EMH) ModelAnalysis (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
AIC	-4.217081	-5.336659	-5.172195	-5.399667	-5.175686	-5.119872
SBC	-4.184966	-5.304544	-5.140080	-5.367552	-5.143571	-5.087757
HQC	-4.205025	-5.324602	-5.160139	-5.387611	-5.163629	-5.107815

According to Tables 48 and 49, the information criterions seem to be hinting at the best model to explain the information contained within the price variance is the GARCH model for all observed markets. This means that the omission of the asymmetrical effect has the advantage of the GARCH model fully explaining the information contained in the all the observed markets. This is interesting due to the GJR-GARCH model being able to accept the efficient market hypothesis for all observed markets. However, another interesting factor is that the AIC seem to be accepting the GJR-GARCH for all the observed markets in contrast to the SBC and HQC.

Tables 50 and 51 illustrate the impact from the financial crisis of the late 2000s. In mid-2007 a number of international banks (e.g. Bear Stearns and BNP Paribas) recorded losses on their off-balance sheet activities associated with the MBS or CDO, which resulted in flights to liquidity and quality. As the financial crisis spread, the credit market froze therefore non-financial corporations could not find the money required and hence the crisis spread to the equity and corporate bonds market. In essence, this meant an increase in market activities in the observed markets as market participants sought the safety of the sovereign debt market.

As illustrated by Tables 50 and 32, the R^2 and adjusted R^2 remain relatively unchanged hinting at all the models being a good fit to the dependent variable. And with the exception of the increases in the US and German markets, the Jarque-Bera tests seem to be pointing at a relatively slight increase hinting at the markets still accepting the null hypothesis of non-normality.

Table 50. *2012 Bond GJR-GARCH EMH Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.979223	0.979485	0.976535	0.980444	0.978762	0.978033
Adjusted R^2	0.979155	0.979418	0.976458	0.980379	0.978692	0.977961
Jarque-Bera	1745.37	473.09	81.05	333.76	77.13	2278.62
Q-Statistics (Correlogram)	89.31	208.20	230.11	179.79	199.75	148.57
F-Statistics(ARCH Test)	0.106963	0.884602	4.926133	0.156402	1.488080	0.019445

Conversely, with the exception of the decreases in the US and German markets, the Q-statistics seem to be hinting at a slight increase. Yet all of the observed markets hint at significant serial correlation. Although there is a slight increase in the F-statistics of the Portuguese and Spanish markets, however, with the obvious exception of the Greek market, the F-statistics are low hinting at a very low ARCH effect. The German market is interesting because the F-statistic is much lower using the GJR-GARCH than the GARCH model.

Table 51. *GJR-GARCH EMH Test Statistics of the 2012 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.004796 (0.000204)	0.001772 (0.000190)	0.015970 (0.000487)	0.001989 (0.000257)	0.005261 (0.000405)	0.002262 (0.000248)
b	0.974958 (0.001581)	0.987673 (0.001896)	0.998053 (0.001793)	0.997661 (0.001765)	0.991626 (0.001820)	1.000558 (0.001707)
ϵ	0.699719 (0.011537)	0.683483 (0.015206)	0.781356 (0.012194)	0.799973 (0.011800)	0.819527 (0.013501)	0.713470 (0.013905)
Variance Equation ω	1.63E-06 (7.11E-07)	1.30E-06 (4.37E-07)	1.49E-05 (2.94E-06)	4.49E-06 (9.00E-07)	1.49E-05 (2.50E-06)	4.19E-06 (1.08E-06)
α	3.361139 (0.941532)	1.682167 (0.305531)	1.56118 (0.245778)	1.844676 (0.335691)	1.51262 (0.275942)	2.257028 (0.462730)
β	0.205077 (0.033263)	0.208921 (0.034590)	0.089461 (0.026248)	0.061464 (0.023683)	0.075603 (0.023654)	0.098107 (0.027931)
γ	-1.334381 (0.712667)	-0.324735 (0.358297)	-0.044722 (0.368074)	-0.113284 (0.430284)	-0.209147 (0.331943)	-0.177109 (0.520074)
Statistics Log Likelihood	1624.479	1912.030	1675.797	2016.549	1817.726	1794.128
Standard Deviation	0.223842	0.133095	0.189977	0.116066	0.157186	0.141228
EMH Test EMH Test Statistics	5.503145	4.255254	3.189433	6.831079	2.41164	8.341306
Efficiency	Reject	Reject	Reject	Reject	Reject	Reject

As with Table 33, Table 51 hints at relatively high b coefficients during the financial crisis period. With the exception of the Spanish market, this seem to be suggesting that the observed markets do revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than

0.97 with a standard error of less than 0.0019. However, the Spanish market with a b coefficients of greater than 1.0 and standard errors of higher than 0.0017 does not revert to the unconditional mean. Also like Table 33, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the markets except for the US and German. The US and German marketsare hinting at a reduction to below 0.7 in comparison with Table 33.

During the financial crisisperiod, the asymmetrical coefficients were hinting at a leverage effect for all the observed markets as illustrated by Table 51. With the exception of the Greek market, the effect seems to be significant. However, the asymmetrical coefficient of the US market is significantly high hinting at a large movement in the market volatility following a negative shock to the market. Given that during the financial crisis the prices of sovereign debt did consistently deviate from the expected price due to market participants engaging in flight to safety from risky assets such as MBS, CDO and shares and bonds of financial firms. It is worth remembering that the prices of these assets plummeted, especially in the aftermath of the Lehman Brothers bankruptcy on 15th September 2008, an example is the Dow Jones Average index, which fell from 13,950 on 16th July 2007 to 6,547 on 9th March 2009. This partly explains the high leverage effect in the US market and to a lesser extent the German market that as stated previously is the risk free market in the Eurozone. It must be noted that as previously stated the size and liquidity of the Greek market meant that the impact from any event during the financial crisis did not have a large impact on the asymmetrical coefficient which meant a near zero leverage effect.

The α coefficients are interesting because they truly reflect the different impact of the financial crisis on the observed sovereign debt markets, and whereas the α coefficient seem to be illustrating the obviously high levels of sensitivity to market shocks in the US market during the financial crisis. What is more interesting with the α coefficient of the US market is that it is the highest of all the observations. This points to a huge impact on the levels of sensitivity to market shocks. Equally interesting is the Spanish market, which was to a certain degree the most affected country by the financial crisis within the Eurozone, does point to a significantly large level of sensitivity to market shocks. The remaining observed markets seem to be hinting at a limited impact from the financial crisis. However, as illustrated by Table 33, certainly the asymmetrical effect had the impact of raising the levels of sensitivity to shocks inall the observed markets.

With the exception of the US and German markets, the β coefficients hints at a low level of volatility persistence in the observed markets during the financial crisis. In contrast the US and German markets seem to be confirming the high levels of volatility persistence in the advent of the financial crisis. Not surprisingly during the financial crisis as illustrated by Table 33, the asymmetrical effect had the impact of rising the β coefficients of all the observed markets and hence the levels of persistence in the markets.

The EMH test statistics seem to be hinting at the acceptance of the null hypothesis of the market being too volatile to be efficient in all the observed markets. With the exception of the Portuguese market, the EMH test statistics are significantly greater than the F-statistic. As Table 33 hints, the inclusion of the asymmetrical effect did not have a significant impact on the EMH test statistics. Having said that, the EMH test statistic for the German market seem to be going against the norm for this period in deviating further from the efficient market.

Table 52. *2012 Bond GARCH(EMH) Model Analysis (02/07/2007-30/10/2009)*

	US	*German*	*Greek**	*Italian**	*Portuguese**	*Spanish**
AIC	-5.292438	-6.233026	-5.471423	-6.588486	-5.935669	-5.859106
SBC	-5.241792	-6.182380	-5.420776	-6.537840	-5.885023	-5.808460
HQC	-5.272737	-6.213325	-5.451722	-6.568785	-5.915968	-5.839405

Table 53. *2012 Bond GJR-GARCH (EMH) Model Analysis (02/07/2007-30/10/2009)*

	*US**	*German**	*Greek*	*Italian*	*Portuguese*	*Spanish*
AIC	-5.299932	-6.242723	-5.468187	-6.585406	-5.933527	-5.856157
SBC	-5.242050	-6.184841	-5.410305	-6.527525	-5.875645	-5.798276
HQC	-5.277417	-6.220207	-5.445671	-6.562891	-5.911011	-5.833642

According to Tables 52 and 53, the information criterions seem to be hinting at the best model to explain the information contained within the price variance is the GARCH model with the exception of the US and German markets. This means that the addition of the asymmetrical effect has the advantage of the GJR-GARCH model fully explaining the information contained in the US and German markets and since we are testing the efficiency of the market, it is important that the model does reflect the information contained. However, the remaining observed markets are hinting at the GARCH model being able to explain the information contained in the market.

Tables 54 and 55 are associated with the Eurozone sovereign debt and US fiscal cliff crises. Essentially, the sovereign debt crises was the product of the governments providing much needed capital for the banking system and following a fiscal stimulus policy to support the economy after the financial crisis. This added a substantial amount to an already large total debt. However, as previously explained an influencing factor to bear in mind is the maturity effect. Another influencing factor is in order to provide liquidity and boost the economy, many central banks embarked on a quantitative easing policy; this helped maintain the artificially high prices and more importantly low yields in some markets especially the US.

Table 54. *2012 Bond GJR-GARCH EMH Residuals Statistics (02/11/2009-30/12/2011)*

	0.984772	0.985281	0.985480	0.983567	0.986223	0.984275
R^2	0.984718	0.985229	0.985428	0.983509	0.986174	0.984219
Adjusted R^2	86.41	347.59	1069.56	143.20	212.12	238.64
Jarque-Bera	184.91	207.21	217.15	192.05	215.62	161.11
Q-Statistics (Correlogram)	2.223018	4.788012	110.0445	5.560962	7.049023	0.131579
F-Statistics(ARCH Test)	0.984772	0.985281	0.985480	0.983567	0.986223	0.984275

As illustrated by Tables 54 and 34, the R^2 and adjusted R^2 remain relatively unchanged hinting at all the models being a good fit to the dependent variable. With the exception of the increase in the Portuguese and Spanishmarkets, the Jarque-Bera tests seem to be pointing at a reduction. Interestingly the GJR-GARCH model seems to be hinting at a significant reduction to the Greek Jarque-Bera statistics. Nevertheless, the test is stillhinting at the acceptanceof the null hypothesis of non-normality for all observed markets. Conversely, the Q-statisticsfor all the observed markets seem to be hinting at an increase especially the Greek market meaning all the observed markets hint at significant serial correlation. Although with the exception of the Greek and Portuguese markets, there is a reductionin the F-statistics. However, with the exception of the Spanish market, the F-statistics arehinting at a high ARCH effect. The Greek market is interesting because the F-statistic is much higher using the GJR-GARCH than the GARCH model.

As with Table 35, Table 55 hints at relatively high b coefficients during the sovereign debt crisis period. This seem to be suggesting that the observed markets do revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 0.97 (except for the Greek market) with a standard error of less than 0.0019 (except for the US market). However, the Spanish market, with a b coefficientof greater than 1.0 in Table 35, does nowrevert to the unconditional mean. Like Table 35, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the markets except for the US market. The US markets is hinting at a reduction to below 0.7 in comparison with Table 35. Interestingly, the increase in the white noise of the Greek market is significant.

Table 55. *GJR-GARCH EMH Test Statistics of the 2012 Bond (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.004611 (0.000125)	0.002081 (5.62E-05)	0.034489 (0.100328)	0.002517 (4.29E-05)	0.005097 (0.000137)	0.003162 (8.54E-05)
b	0.982766 (0.003688)	0.993686 (0.001894)	0.982734 (0.004985)	0.969560 (0.001634)	0.984177 (0.000865)	0.999832 (0.001766)
ϵ	0.698886 (0.019263)	0.759687 (0.019821)	1.138810 (0.038076)	0.829390 (0.012387)	0.745970 (0.012060)	0.836750 (0.012703)
Variance Equation ω	3.43E-08 (8.72E-09)	4.38E-08 (9.19E-09)	0.697604 (0.104858)	1.46E-07 (3.20E-08)	4.42E-07 (2.02E-07)	5.17E-07 (1.55E-07)
α	1.104164 (0.198694)	1.548027 (0.270511)	0.711551 (0.179001)	2.093871 (0.318346)	2.195565 (0.236310)	2.775620 (0.592585)
β	0.256096 (0.048658)	0.120869 (0.029296)	-0.00614 (0.000157)	0.055148 (0.026693)	0.267627 (0.014937)	0.094363 (0.024345)
γ	-0.25853 (0.223850)	-0.34541 (0.328236)	-0.02664 (0.256421)	-0.50411 (0.423612)	-0.95724 (0.285304)	-1.00184 (0.551071)
Statistics Log Likelihood	3306.247	3234.314	-581.148	2732.289	1230.006	2080.447
Standard Deviation	0.017740	0.013194	11.48550	0.064861	1.517370	0.190863
EMH Test EMH Test Statistics	5.734724	24.51766	-0.02797	9.942986	0.333442	4.548493
Efficiency	Reject	Reject	Accept	Reject	Accept	Reject

The asymmetrical coefficients in Table 55 are indicating a leverage effect during the period accounting for the sovereign debt crisis. With the exception of the Greek market, the evidence seems to be pointing at a significant leverage effect. Interestingly, the asymmetrical coefficient of the Greek market is insignificantly low considering the Greek sovereign debt crisis. As highlighted on numerous times previously, the size and liquidity of the Greek market may provide a partial explanation. However, the asymmetrical coefficients for the remaining observed markets hint at a mixed picture with the Portuguese and Spanish markets hinting at a highly significant leverage effect. The argument is as discussed earlier the Portuguese market is of a similar in size and liquidity to the Greek market and therefore should response to events in similar fashion. The answer probably lays in the timing of the crises in both markets while the Greek crisis occurred at the start of the subsample period, the impact of the crisis did not spread to the Portuguese market until mid-2010. It is worth noting that the price of the Portuguese bond was not consistently below 100 until end of March 2011 while the price of the Greek bond was consistently below 100 from the end of January 2010. Another key factor is since for the asymmetrical coefficient to be insignificant, the market has to be indifferent between the positive and negative impact. This is the key issue underpinning the Greek market over the duration of this period; the impact on the volatility from the Greek crisis was short and had sharp negative and positive impacts. Althougha hike in volatility affected the Portuguese market, it was not as sharp and short as the Greek market; hence, the estimated GJR-GARCH model was able to observe a high leverage effect in the Portuguese market. However, another key explanation as to the significant of the asymmetrical coefficient in the Portuguese market is in the estimation model, due to an error in the estimation we had to use the BHHH optimization. This had a bigger impact on the asymmetrical coefficient.

Not surprisingly, the α coefficients seem to be split along the impact of the sovereign debt crisis with the US and German markets hinting at a relative low levels of sensitivity to market shocks. However, with the exception of the Greek market, the GIPS nations are pointing at a high level of sensitivity to market shocks. Conversely, the interesting factor is the significantly low α coefficient of the Greek market, which seems to be contradicting Table 35. The Greek α coefficient seems to be suggesting the lowest level of sensitivity to market shocks observed in both models thru all observations. The other key statistics observed in the Greek market provide a clue, which seem to be pointing at an insignificantimpactthroughout Table 55. Hence, the impact from the inclusion of the asymmetrical effect seems to have rendered allcoefficients of the Greek market insignificant during the sovereign debt crisis. However, the asymmetrical effect did have an impact on the α coefficients for the remaining markets raising the levels of sensitivity to market shocks.

Since all the coefficients of the Greek market rendered insignificant by the GJR-GARCH model, the β coefficients for the remaining observed markets seem to be painting a rather mixed picture. Whilethe US and Portuguese markets seem to be suggesting a high level of persistence in the market. The Italian and Spanish markets are hinting at insignificant β coefficients. Interestingly this means that three of the four GIPS markets have insignificant levels of persistence. As illustrated by Table 35, with the exception of the Spanish market, the inclusion asymmetrical effect seems to have increased the volatility persistence of the observed markets in the aftermath of a shock.

With the exception of the Greek and Portuguese markets, the EMH test statistics seem to be hinting at the acceptance of the null hypothesis of the market being too volatile to be efficient. All the observed inefficient markets have EMH test statistics that are significantly greater than the F-statistic. Interestingly the Greek market is the only market with a negative EMH test statistic; however, the negative EMH test statistic is still within the range of acceptance. Hence, the Greek market rejects the null hypothesis. Although the inclusion of the asymmetrical effect did not have an impact on the resulting efficiency of the market, however it did decrease the EMH test statistics. Conversely, the EMH test statistic for the German market is still significantly higher than the observed markets, with the inclusion of the asymmetrical effect hinting at a large deviation from the efficient market.

Table 56. *2012 Bond GARCH(EMH) Model Analysis (02/11/2009-30/12/2011)*

	*US**	*German**	*Greek**	*Italia**	*Portuguese*	*Spanish*
AIC	-11.67568	-11.42098	0.153536	-9.643240	-4.311702	-7.330210
SBC	-11.62195	-11.36725	0.199590	-9.589509	-4.265647	-7.276480
HQC	-11.65471	-11.40001	0.171512	-9.622268	-4.293726	-7.309238

Table 57. *2012 Bond GJR-GARCH (EMH) Model Analysis (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese**	*Spanish**
AIC	-11.67521	-11.42058	2.085480	-9.643500	-4.329227	-7.336095
SBC	-11.61380	-11.35917	2.146886	-9.582094	-4.275496	-7.274689
HQC	-11.65124	-11.39661	2.109448	-9.619532	-4.308254	-7.312127

According to Tables 56 and 57, the information criterions seem to be hinting at the best model to explain the information contained within the price variance is the GARCH model, with the exception of the Portuguese and Spanish markets. This means that the addition of the asymmetrical effect has the advantage of the GJR-GARCH model fully explaining the information contained in the Portuguese and Spanish markets and since we are testing the efficiency of the market, it is important that the model does reflect the information contained.

Tables 58 and 59 illustrates the full impact from both crises on the efficiency of the observed sovereign debt markets. As hinted previously, the extended observations allow us to analyse thefuller impactof the sovereign debt crisis. Conversely, as stated earlier it also allows us to overcome the maturity effect, yet it also introduces the “on-the-run” effect. In a way, the combination of the financial and sovereign debt crises should make the market highly volatile and reactive meaning the asymmetrical effect is interesting.

Table 58. *2017 Bond GJR-GARCH EMH Residuals Statistics (02//07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.987775	0.981802	0.985126	0.984982	0.982759
Adjusted R^2	0.987758	0.981778	0.985106	0.984961	0.982736
Jarque-Bera	16412.36	1387.75	1137.92	1555.60	1697.91
Q-Statistics (Correlogram)	294.54	468.83	416.13	418.10	435.88
F-Statistics(ARCH Test)	5.14E-05	1.396875	2.706063	0.582979	1.791602

As illustrated by Table 58, a key factor is the high R^2 and adjusted R^2. The R^2 is above 0.98 through all the estimated GJR-GARCH models hinting at the lagged price variance with the estimated residuals being highly able to explain the movement in the price variance. In addition, the significantly high-adjusted R^2 seem to be pointing at the estimated GJR-GARCH model being a good fit to the dependent variable across all the markets. These two statistics partly illustrates our GJR-GARCH model is correctly specified to testall the markets for the null hypothesis of the market being too volatile to be efficient. Interestingly, with the exception of the US and German markets, the $R^2$and adjusted R^2 seem to have increasedin comparison with Table 36. This is interesting due to the GIPS countries favouring one model and the benchmark countries, i.e. the US and Germany, favouring another model.

The Jarque-Bera test for all the markets seem to be hinting at a significant acceptance of the null hypothesis of non-normality in the distribution of the residuals. Additionally, the Jarque-Bera statistics seem to be hinting at the US marketbeing significantly greater than the other countries. Conversely, the Italianmarket is lower than all the other markets. However, the evidence seem to be suggesting with the exception of the Portuguese market, the Jarque Bera statistics are lower than those for the GARCH model in Table 36. Remember under certain circumstances the consideration of existence of non-normal residuals as an indicator for non-efficient markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at a high correlation. At the single lagged level, the Q-statistic for all our samples does not drop below 294.54 as observed by the USA. The interesting factor is that with the exception of the Italian these statistics highlight a rise in the series correlation from the GARCH model in Table 36. Remember the existence of autocorrelated residuals usually implies the omission of important variables from the regression. In the current framework, the fact that other variables may be important to determine bond prices seems to be indicating inefficient markets.

The F-statistics seem to be wielding very widely between approaching no ARCH effect tosignificant ARCH effect remaining. In essence, the two lowest F-statistics are the US and Portuguese markets with an F-statistics below one, thus meaning significantly low ARCH effect remaining. The highest F-statistic is that of the Italian market hinting at a significant ARCH effect remaining. In comparison with Table 36, the observed markets hint at a reduction in the ARCH effect except for the German and Italia markets.

Table 59. *GJR-GARCH EMH Test Statistics of the 2017 Bond (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.009322 (0.000173)	0.004464 (0.000382)	0.009899 (0.000344)	0.042894 (0.000805)	0.008362 (0.000509)
b	0.994000 (0.000985)	1.003184 (0.001175)	0.996090 (0.000819)	0.974679 (0.000633)	0.993579 (0.000973)
ϵ	0.715953 (0.008007)	0.747434 (0.010223)	0.743969 (0.008990)	0.838783 (0.009540)	0.718223 (0.009307)
Variance Equation ω	1.34E-06 (4.20E-07)	2.02E-05 (3.47E-06)	2.00E-05 (3.46E-06)	0.000123 (2.20E-05)	5.80E-05 (9.09E-06)
α	2.100291 (0.272322)	1.558723 (0.200247)	1.936111 (0.212740)	2.122838 (0.249824)	2.088818 (0.255098)
β	0.251858 (0.020892)	0.180358 (0.022155)	0.144515 (0.019124)	0.13376 (0.017633)	0.115353 (0.017244)
γ	-0.39551 (0.267432)	-0.06761 (0.225540)	-0.36191 (0.248899)	-0.51457 (0.266990)	-0.41596 (0.275646)
Statistics Log Likelihood	2927.945	3350.545	2841.688	1040.093	2496.294
Standard Deviation	1.067295	0.344854	1.070745	4.984212	1.102358
EMH Test EMH Test Statistics	0.896326	1.947123	0.671234	0.148875	0.715023
Efficiency	Accept	Accept	Accept	Accept	Accept

As with Table 37, Table 59 hints at relatively high b coefficients which seem to be suggesting that with the exception of the German market the observed markets do revert back to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 0.99(except for the Portuguese market) with a standard error of less than 0.001 (except for the US market). However, the German market with b coefficients of greater than 1.0 does not revert to the unconditional mean. An interesting factor in Tables 37 and 59 is that in general the b coefficients remain relatively similar. Also like Table 35, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.0089 thru all the markets except for the US market.

The asymmetrical coefficients in Table 59 are indicating a leverage effect in markets. It must be noted that the observed period only coverthe financial and sovereign debt crises. This is essential because what it is mean is during the period covering both crises negative shocks had a greater impact than positive shocks. However, although the German market is hinting at a leverage effect, the asymmetrical coefficients seem to be hinting at an indifferent reaction to a shock to the market. Analysing the impact from both crises on the German market provides an explanation; the asymmetrical coefficients in Tables 63 and 67 seem to be hinting at both the financial and sovereign debt crises periods acting as counter balance. This would suggest in the German market, the cancellation of the strong leverage effect during the sovereign debt crisis by the asymmetrical effect of the financial crisis. Although the German sovereign debt was downgraded during the Eurozone sovereign debt crisis, an influencing factor is the financial and sovereign debt crises did not really have a negative impact on the German market. The reason is the strength of the German economy and industrial output, which at the time was mainly responsible for holding the value of the euro. In contrast, the GIPS markets had a triple impact from the crises: a weak economy including a huge issue with respect to the industrial output, an increasing total debt and political upheaval. Although, the financial crises had a large negative impact on the US economy but it did not have a significantly negative impact on the US Treasuries market. The main reason why the US market held its value well despite the huge increase in the total debt was itsposition as a safe haven asset. However, the fiscal cliff crisis and hence disagreements in federal government leading to the near shutdown of the federal government 6F[16] meant the US market increasingly experienced a negative impact. These factors meant that behavioural theories dictated any negative shock to the market from news or information has a greater impact than positive shocks.

With the exception of the German market, the α coefficients seem to be hinting at high levels of sensitivity to market shocks. Although the Italian market is lower than the others are, yet it is significantly high. However, the German market seem to be portraying a sTable market throughout as also observed by Tables 63 and 67, as expected and illustrated earlier due to the German market not really being effect by the crises. It must be noted that

[16] Although the US federal government did shutdown from 1st October 2013 to 16th October 2013, the shutdown came after our observational period.

the inclusion of the asymmetrical effect had the impact of increasing the levels of sensitivity to market shocks in all observed markets, therefore making the US, Portuguese and Spanish markets increasingly sensitivity to shocks in the market as illustrated by Table 37.

The βcoefficients illustrate the difference in the volatility persistence between the GIPS and US/German markets. As stated previously mainly due to flights during both the financial and sovereign debt crises, the US and German markets had high levels of volatility persistence in the aftermath of shocks during both crises. However, the impact on the GIPS markets was usually short shocks hiking the volatility. Nevertheless, the asymmetrical effect seems to have had the impact of increasing the volatility persistence of all the observed markets as illustrated by Table 37.

Interestingly, the EMH test statistics seem to be hinting at the acceptance of the efficient market hypothesis. However, only the German market may be close to being truly efficient as it is approximately equal to the F-statistics. Since, the inclusion of the asymmetrical effect had a decreasing impact on the EMH test statistics of all the observed markets see Table 37. Considering that using the GARCH model, the German market narrowly accepted the null hypothesis of the market being too volatile to be efficient. This illustrates a key point in testing the hypothesis of any economic model; the acceptance of the model could depend on the slightest differences within the tests. In essence, this means that one test could narrowly reject the model while the other test could accept the model. Another point of interest concerning the German market is that the German 2017 government bond seems to be accepting the efficient market hypothesis under the GJR-GARCH model thru all observed periods. Of more interest are the Portuguese and Spanish markets, the reason being that these two 2017 government bonds seem to be accepting the efficient market hypothesis under both models in all observational periods.

Table 60. *2017 Bond GARCH(EMH) ModelAnalysis (02/07/2007-29/03/2013)*

	*US**	*German**	*Italian**	*Portuguese**	*Spanish**
AIC	-3.947830	-4.521262	-3.831110	-1.392850	-3.363830
SBC	-3.922750	-4.496182	-3.806029	-1.367770	-3.338750
HQC	-3.938480	-4.511912	-3.821760	-1.383500	-3.354480

Table 61. *2017 Bond GJR-GARCH (EMH) ModelAnalysis (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
AIC	-3.948540	-4.520007	-3.831897	-1.395663	-3.364833
SBC	-3.919876	-4.491344	-3.803234	-1.367000	-3.336169
HQC	-3.937854	-4.509322	-3.821211	-1.384977	-3.354147

According to Tables 60 and 61, the information criterions seem to be hinting at the GARCH model being the best model to explain the information contained within the price variance for all observed markets. This means that the omission of the asymmetrical effect has the advantage of the GARCH model fully explaining the information contained in the all the observed markets. This is interesting due to the GJR-GARCH model being able to accept the efficient market hypothesis for all observed markets. However, another interesting factor is that with the exception of the German market, the AIC seem to be accepting the GJR-GARCH for all the observed markets in contrast to the SBC and HQC. Interestingly in the 2012 bonds, the same markets accepted the GJR-GARCH model.

Tables 62 and 63 are associated with the financial crisis of the late 2000s. As stated previously, the main impact was the flightfrom the risky assets at the heart of the financial crisis to the sovereign debt market. In essence the sovereign debt market, especially the US and German, were considered safe haven from the financial crisis. However, a relevant factor, as previously discussed, is the impact of the on-the-run effect, since the 2017 bonds were issued just before the financial crisis heated up.

Table 62. *2017 Bond GJR-GARCH EMH Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.984815	0.976944	0.974909	0.979897	0.979443
Adjusted R^2	0.984763	0.976865	0.974824	0.979828	0.979373
Jarque-Bera	68.16	181.78	375.73	184.59	35.57
Q-Statistics (Correlogram)	182.84	204.96	196.09	180.20	236.08
F-Statistics(ARCH Test)	2.429012	1.014540	1.762716	0.407571	6.037451

As illustrated by Tables 62 and 38, the R^2 and adjusted R^2 remain relatively unchanged hinting at all the models being a good fit to the dependent variable. The Jarque-Bera tests seem to be pointing at a reduction, however stillhinting at an acceptance of the null hypothesis of non-normality for all observed markets. Conversely, with the exception of the Italian and Spanish markets, the Q-statistics seem to be hinting at an increase in serial correlation. Although with the exception of the US and Portuguese markets, there is a reduction in the F-statistics, yet the Italian and certainly Spanish markets are hinting at a high ARCH effect.

Table 63. *GJR-GARCH EMH Test Statistics of the 2017 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	-0.000445 (0.003378)	0.006568 (0.001563)	0.011004 (0.000836)	0.042020 (0.001229)	0.006134 (0.000923)
b	1.006716 (0.003380)	1.004785 (0.002627)	0.995071 (0.002625)	0.970640 (0.001307)	1.007695 (0.002630)
ϵ	0.703304 (0.015093)	0.791480 (0.017962)	0.744794 (0.014088)	0.808195 (0.011742)	0.707212 (0.018087)
Variance Equation ω	0.000742 (0.000150)	0.000146 (2.55E-05)	5.29E-05 (1.13E-05)	0.000252 (3.81E-05)	5.82E-05 (1.11E-05)
α	1.32636 (0.251253)	1.222606 (0.282780)	1.654902 (0.313631)	1.59663 (0.279844)	1.316892 (0.251679)
β	0.136396 (0.047082)	0.09753 (0.033691)	0.059969 (0.025826)	-0.036693 (0.019637)	0.10437 (0.027778)
γ	-0.198894 (0.299086)	0.261166 (0.340134)	-0.035996 (0.412166)	-0.330976 (0.363664)	0.070649 (0.316510)
Statistics Log Likelihood	634.068	1083.834	1299.838	1111.013	1231.482
Standard Deviation	1.444623	0.397085	0.308165	0.552783	0.461169
EMH Test EMH Test Statistics	0.182651	1.463923	2.202959	0.414197	1.066661
Efficiency	Accept	Accept	Reject	Accept	Accept

As with Table 39, Table 63 hints at relatively high b coefficients during the financial crisis. This seems to be suggesting that with the exception of the Italian and Portuguese markets the observed markets do not revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 1.0 with a standard error of greater than 0.002. However, the Italian and Portuguese markets with b coefficients of less than 1.0dorevert to the unconditional mean. An interesting factor in Tables 39 and 63 is that in general the b coefficients remain relatively similar. Also like Table 39, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the markets.

It is worth noting that, as previously stated, this observational period is associated with the financial crisis. Hence, the period give us the opportunity to compare the impact of a highly volatile financial market on the efficiency of two governments bonds at different stages in their life given the inclusion of asymmetrical effects. Although the asymmetrical coefficients in Table 63 seem to be suggesting a split picture with the German and Spanish markets pointing towards an asymmetrical effect while the other observed markets are hinting at a leverage effect. In reality, the asymmetrical coefficients paints a rather mixed picture, on close inspections the Italian and Spanish markets seem to have insignificant asymmetrical coefficients. In contrast, the Portuguese market has a relatively high asymmetrical coefficient and the two remaining observed markets have a relatively low asymmetrical coefficient. Thus signalling the different impact the financial crisis had on the sovereign debt market. As illustrated by Tables 51 and 63, the rather interesting factor is the differentiation of the asymmetrical effect on the 2012 and 2017 government bondsduring this period. One of the fundamental rules of the bond market can provide an explanation for the difference: any information or news has varying impact on the bond over the duration of its life. This means an asymmetrical effect could have a varying impact throughout the life of a bond. Given both the 2012 and 2017 bonds were at different stages of their life, the different in the age is likely to have had an impact on the asymmetrical effect. Another explanation is the "on-the-run" effect, which is due to the high number of transactions until the next issue is released. A key factor in these explanations is that the 2017 bonds were issuedjust before the financial crisis. This made the bonds highly reactive to changes in the market leading to different asymmetrical effects among the observed markets.

With the exception of the Italian and Portuguese markets, the financial crisis does not appear to have impacted on the α coefficients of the observed markets. Even the Italian and Portuguese markets do not appear to have a relatively high level of sensitivity to market shocks. Interestingly as eluded to previously, the German market had the lowest α coefficients. Of course, the inclusion of the asymmetrical effect did have a relatively significant impact on the markets with the possible exceptions of the Italian and Spanish markets. The asymmetrical effect did decrease the α coefficients of the German and Spanish markets, while increasing them to the other observed markets as illustrated by Table 39.

Although the β coefficients point towards a low volatility persistence in all the observed markets, yet there seem to be a different in the persistence of volatility while the Italian and Portuguese markets seem to have very low levels of persistence, the US market does hint at a relatively higher level of persistence. Contrasting with Table 39, the inclusion of the asymmetrical effect did influence the levels of volatility persistence. With the exception of the US market, the level of volatility persistence seems to have decreased. Interestingly, the β coefficient of the Portuguese market is negative.

Interestingly, the EMH test statistics seem to be hinting at the observed markets accepting the efficient market hypothesis during the financial crisis. The exception, as with the GARCH model, is the Italian market, which accepts the null hypothesis of markets being too volatile to be efficient. Essentially, the results from the efficiency tests seem to be reflecting the results in Table 39. Although the inclusion of the asymmetrical effect does influence the EMH test statistics with the German and Spanish markets having an increasing effects while the other observed markets had a decreasing effect.

Table 64. *2017 Bond GARCH(EMH) Model Analysis (02/07/2007-30/10/2009)*

	*US**	*German**	*Italian**	*Portuguese**	*Spanish**
AIC	-2.128145	-3.654676	-4.389920	-3.746060	-4.157687
SBC	-2.076109	-3.602640	-4.337884	-3.694024	-4.105652
HQC	-2.107872	-3.634402	-4.369646	-3.725787	-4.137414

Table 65. *2017 Bond GJR-GARCH (EMH) Model Analysis (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
AIC	-2.125867	-3.653085	-4.386548	-3.745376	-4.154437
SBC	-2.066398	-3.593616	-4.327079	-3.685907	-4.094967
HQC	-2.102698	-3.629916	-4.363379	-3.722207	-4.131267

According to Tables 64 and 65, the information criterions seem to be hinting at the best model to explain the information contained within the price variance is the GARCH model for all observed markets. This means that the omission of the asymmetrical effect has the advantage of the GARCH model fully explaining the information contained in the all the observed markets. This is interesting due to the GJR-GARCH model being able to accept the efficient market hypothesis for all observed markets with the exception of the Italian market; however, it is also true for the GARCH model.

Tables 66 and 67are associated with the Eurozone sovereign debt and US fiscal cliff crises. One influencing factor is that the 2017 bonds do cover the majority of the crisis. However, another factor worth remembering is that the 2012 bonds were at the end of their lives during the sovereign debt crisis; hence, an influencing factor to bear in mind is the maturity effect. Conversely, the 2017 bonds were in mid-life during the crisis, hence it is interesting to see what impact the maturity effect had on the markets during the sovereign debt crisis.

Table 66. *2017 Bond GJR-GARCH EMH Residuals Statistics (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.984000	0.982162	0.984607	0.981901	0.981474
Adjusted R^2	0.983963	0.982122	0.984572	0.981860	0.981432
Jarque-Bera	10229.62	104.65	113.80	798.51	2306.60
Q-Statistics (Correlogram)	178.16	317.68	312.26	258.50	255.03
F-Statistics(ARCH Test)	0.008930	5.078602	6.785071	0.474670	0.269662

As illustrated by Tables 66 and 40, the R^2 and adjusted R^2 remain relatively unchanged hinting at all the models being a good fit to the dependent variable. With the exception of the Portuguese and Spanish markets, the Jarque-Bera tests seem to be pointing at a reduction. However, all the markets are still hinting at an acceptance of the null hypothesis of non-normality.

Table 67. *GJR-GARCH EMH Test Statistics of the 2017 Bond (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.009374 (0.000176)	0.005949 (0.000346)	0.010297 (0.000373)	0.042438 (0.001450)	0.008533 (0.000653)
b	0.987700 (0.001009)	0.976898 (0.001641)	0.989804 (0.001197)	0.974871 (0.000807)	0.984917 (0.001467)
ϵ	0.704801 (0.010476)	0.742831 (0.012988)	0.752617 (0.011471)	0.852081 (0.012345)	0.702770 (0.012874)
Variance Equation ω	1.57E-06 (4.61E-07)	7.32E-06 (1.78E-06)	9.36E-06 (2.32E-06)	0.000152 (4.91E-05)	3.68E-05 (8.63E-06)
α	2.564097 (0.435636)	1.462187 (0.208775)	1.931614 (0.257805)	2.275183 (0.337703)	2.391783 (0.361685)
β	0.166534 (0.022048)	0.250852 (0.028026)	0.206225 (0.023736)	0.158652 (0.022781)	0.145523 (0.022969)
γ	-0.56507 (0.426030)	-0.3394 (0.226951)	-0.64715 (0.279677)	-0.61827 (0.356660)	-0.81629 (0.363280)
Statistics Log Likelihood	2336.351	2309.224	1561.647	-58.637	1279.294
Standard Deviation	0.419620	0.257374	1.312213	5.824118	1.320804
EMH Test EMH Test Statistics	2.777668	1.451747	0.373942	0.140033	0.545891
Efficiency	Reject	Accept	Accept	Accept	Accept

Conversely, with the exception of the Portuguese market, the Q-statistics seem to be hinting at an increase in the serial correlation. Althoughwith the exception of the US and German markets, there is a reduction in the F-statistics. Yet the ARCH effect of the Greek and Italian markets remains high. However, theUS market is hinting at an ARCH effect-approaching zero.

As with Table 41, Table 67 hints at relatively high b coefficients during the sovereign debt crisis. The b coefficients seem to be suggesting that the observed markets do revert to the unconditional mean after a shock to the price variance. These markets all have b coefficients greater than 0.97 with a standard error of greater than 0.0016. An interesting factor in Tables 41 and 67 is that in general the b coefficients remained relatively similar. Also like Table 41, the residuals seem to be hinting at a significant amount of white noise with ϵ coefficients of greater than 0.7 and standard errors greater than 0.01 thru all the markets.

Remember Table 67 is associated with the sovereign debt crisis and covers more of the crisis timeline than Table 55. Hence, this period give us the opportunity of not only analysing the full impact of the sovereign debt crisis on the efficient market hypothesis but also whether the maturity effect canhave a changing influence on the results. The asymmetrical coefficients in Table 67 certainly hint at a leverage effect influencing all the observed markets. While this observation is similar to Table 55, however one noticeable different is the leverage effect in both the US and Italian markets have increased whereas it had decrease in the remaining observed markets. It is hard not to notice the changes in the asymmetrical coefficient of the Portuguese and Spanish markets. One possible explanation is the impact of the maturity effect but this does not explain the dissimilar impact on the other observed markets. A key factor in any crisis is that market participants tend to overreact during the initial stage. Notably the end date to the observed 2012 bonds is 31st December 2011; in contrast, the end date to the observed 2017 bond is 31st March 2013. Hence, a more plausible explanation is that at the start of the crisis Portuguese and Spanish markets' participants were responding with greater intensity to negative shocks. However, the continuation of the crisis had the effect of balancing out the impact. This could also explain the differences in the leverage effect of the US and Italian markets, since in essence, the crisis did not hit the US and Italian markets until the later stages of the sovereign debt crisis, not observed by the 2012 bonds. The leverage effect for the German market hints at an insignificant change between Tables 55 and 67, suggesting that as the sovereign debt crisis continued the market participants did not act differently in response to negative shocks in the German market.

With the exception of the German and Italian markets, the α coefficients seem to be pointing at a significantly high sensitivity levels for the observed markets during the sovereign debt crisis. Although the Italian market is also displaying a relatively high sensitivity level, however it is not as significant as the other observed markets. As with all previous observations concerning the 2017 bond, the German market continues to display a low sensitivity level in comparison to the other observed markets. The results from Table 41 seem to be suggesting that the inclusion of the asymmetrical effect seem to have increased the sensitivity levelsto market shock for all the observed markets. However, a more mixed picture is emerging in comparison with Table 55. It seem that the maturity effect had a varying impact on the sensitivity levels with the US and Portuguese markets hinting at an increase, while the others are pointing towards a decrease.

Interestingly, the volatility persistence levels seem to be displaying the reverse impact on the observed markets with the German and Italian markets displaying high levels of volatility persistence. Incontrast, the remaining observed markets seem to be pointing at relatively low volatility persistence kevels. This would point at a fast changing environment in the remaining observed markets during the sovereign debt crisis. The results from Table 41 seem to be suggesting that the inclusion of the asymmetrical effect seem to have slightly increased the level of volatility persistence for all the observed markets. However, a more mixed picture is emerging in comparison with Table 55. It seem that the maturity effect had a varying impact on the level of volatility persistence with the US and Portuguese markets hinting at a decrease, while the others are pointing towards an increase.

As hinted by Table 67, the EMH tests seem to be pointing at the acceptance of the efficient market hypothesis for all observed markets but the US market. Interestingly Table 41 seem to be hinting at the inclusion of the asymmetrical effect lowering the EMH test statistics, which enabled the German market to accept the efficient market hypothesis. The other key factor is once again the huge different the maturity effect makes on the EMH test statistics, illustrated by the fact that the EMH test significantly accepted the null hypothesis of the market being too volatile to be efficient in all but the Portuguese and Greek markets in Table 55.

Table 68. *2017 Bond GARCH(EMH) Model Analysis (02/11/2009-29/03/2013)*

	*US**	*German**	*Italian*	*Portuguese*	*Spanish*
AIC	-5.231544	-5.170036	-3.485307	0.153156	-2.850686
SBC	-5.193860	-5.132352	-3.447623	0.190839	-2.813002
HQC	-5.217140	-5.155632	-3.470904	0.167559	-2.836283

Table 69. *2017 Bond GJR-GARCH (EMH) Model Analysis (02/11/2009-29/03/2013)*

	US	*German*	*Italian**	*Portuguese**	*Spanish**
AIC	-5.232250	-5.171289	-3.491341	0.149745	-2.856841
SBC	-5.189183	-5.128222	-3.448274	0.192813	-2.813774
HQC	-5.215790	-5.154828	-3.474880	0.166206	-2.840380

According to Tables 68 and 69 the information criterions seem to be hinting at the best model to explain the information contained within the price variance for the US and German markets is the GARCH model. This means that the addition of the asymmetrical effect has the advantage of the GJR-GARCH model fully explaining the information contained in the IPS markets. Since we are testing the efficiency of the market, it is important that the model does reflect the information contained.

4.3.3. Concluding Review

In concluding, the EMH tests do hint at a mixed result regarding the efficiency of the observed sovereign debt markets. Notablythe observed period and/or estimated model influenced the efficiency of the market. In essence, there are only two observed bonds, both issued in 2017, that fully reject the null hypothesis of the market being too volatile to be efficient: the Portuguese and Spanish. And while the German 2017 bond does accepts the efficient market hypothesis under the GJR-GARCH model, the Portuguese and Spanish government bonds accept the efficient market hypothesis under both estimated models. Interestingly none of the sample observationsseems to be accepting the efficient market hypothesis through all the observed markets under both models. Thereare only two sample observations that seem to be accepting the efficient market hypothesis thru all observed market as illustrated by Tables 47 and 59. Conversely, both only accept the efficient market hypothesis under the GJR-GARCH model.

An influencing factor is that all 2012 government bonds seem to be accepting the null hypothesis of the market being too volatile to be efficient in both models during the financial crisis period. This does seem to be suggesting that the market is more likely to accept the efficient market hypothesis at the initial stage of a bond's life than at any other stage. It is important to remember that the research used a strict strategy of fixed observational periods to analyse the behaviour of volatility in the sovereign debt market. Conversely, it could be argued that a more relax strategy of varying observational periods could find that more markets accept the efficient market hypothesis.

A relevant factor raised by our empirical evidence regarding the efficient market hypothesis is that during some highly volatile periods some markets seem to be rejecting the null hypothesis of the market being too volatile to be efficient. As hinted by Kirchler (2009), the underreaction hypothesis provides one possible explanation, which suggests that market participants' reaction leads to overvaluation or undervaluation during bulls or bears market respectively. Hence, a highly volatile period with instances of both a bear and bull market would give the impression of an efficient market. This is what seems to have happened during these periods as market participants reacted to the information and news.

The interesting factor is our evidence seems to suggest that the use of different models of volatility could produce varying results of efficiency, highlighted in several periods where one or more markets accept the efficient market hypothesis under the GJR-GARCH model but reject it under the GARCH model. It seems that the GARCH model is more likely to accept the null hypothesis of the market being too volatile to be efficient than the GJR-GARCH model. Therefore, in theory it could be possible to find a model of volatility that would suit whichever side of the argument you are on. Interestingly although the GJR-GARCH model seems more likely to accept the efficient market hypothesis, the evidence from the information criterion seem to suggest that the GARCH is morelikely to be selected, due to the model being highly able to explain the information contained in the dependent variable. However, as is always the case, it is dangerous to say that therefore the GARCH model is the best model for the EMH test because under certain periods and markets the GJR-GARCH seems to perform better. The choice of model is dependent on the dataset and observed periods.

In the end the acceptance of the efficient market hypothesis could depend on various factors, e.g. EMH test, dataset, model and observed period. However, this would overlook the essential fact that in general the market does accept the null hypothesis of being too volatile to be efficient. This is true as based on one or more observational periods the market may not be partly efficient. In addition, the market cannot be efficient just because one asset is efficient. Hence, it is either wholly efficient or not efficient at all. Therefore, the observed sovereign debt markets seem to be suggesting they are too volatile to be efficient.

If the observed sovereign debt markets seem to be accepting the null hypothesis of being too volatile to be efficient then what could be explaining the behaviour of volatility in these markets. An explanation already hinted at previously in this section is the changing reaction of market participant to information and news in different market environments over time. This leads to the use of the behavioural finance theory to be able to explain the behaviour of price volatility in the sovereign debt market given a changing market environment.

4.4. The Behaviour of Price Volatility in the Sovereign Debt Market

Behavioural finance dictates that market participants' reaction to news and information influences the price and since in general each market participant interprets the information individually, hence the price deviates from the fundamental value. A possible method of understanding the reactions of market participants to any news or information is to analyse the behaviour of volatility in the market. Since the behaviour of volatility is in essence the reaction of the market participants to events such as news and information announcements. Therefore, the use of the figures and interpretations of the volatility in the observed markets explains the reaction of market participants to events in a changing environment.

The empirical evidence of both volatility tests in the previous section points to the use of the behavioural finance theory in explaining the price volatility in the sovereign debt market. As pointed by Blanchard & Watson (1982) and Branch & Evans (2011; 2013), a possible method of interpretingbehavioural finance is using the GARCH family. Firstly, we use the GARCH as devised by Bollerslev (1986) to interpret the volatility clustering effect. In addition, we use the EGARCH-m as proposed by Nelson (1991) to interpret the feedback and asymmetrical effects. We also use the SWARCH model of Cai (1994) to interpret the regime-switching effect.

Mainly due to the estimated GARCH and EGARCH-m models providing a better fit and explaining the movement better, we follow Shiller's advice in using a first order single lagged autoregressive model to estimate the residuals. In general, the summary of the results and tests of the estimated autoregression model hint at high serial correlations 7F[17] and ARCH effects 8F[18] with a non-normal distributed 9F[19] residuals. Although some may have a low serial correlation while others may have a low ARCH effect. However, the low R^2 and adjusted R^2 for our observed markets seem to hint at both the lagged first order differentiated price and autoregressive model being unable to explain the movement in the price throughout our observed markets.

As illustrated by the model specification in section 3.2 of the methodology, we opt to use the GARCH family of models as the

[17] Using the Breusch-Godfrey serial correlation LM test proposed by Breusch (1979) and Godfrey (1978)

[18] Using the ARCH LM test proposed by Engle (1982)

[19] Using the Jarque-Bera test proposed by Jarque & Bera (1980)

basis of our tests in order to account for the ARCH effects. The GARCH models allow us to interpret the behaviour of volatility in the prices from our observed markets. We opt to use the GARCH (1, 1) and single asymmetrical order EGARCH-m (1, 1) model specifications.

With regard to the SWARCH model after testing for the optimal model specification, we opted for a single lagged, single ARCH effect, dual regime model. Where possible, we use the maximum likelihood BFGS estimation method with a normal distribution. However, we may be forced to use another estimation method like the maximum likelihood BHHH method in some estimations due to incompatibility issues concerning our markets.

It is worth remembering that equation 3.2.3 in the methodology gives the GARCH model. The key to the interpretation of the GARCH model is in the coefficients of the model of conditional variance. As illustrated in section 3.2 of the methodology, we will concentrate on just thefour, which allow us to determining the behaviour of the market participants: market shocks sensitivity, volatility persistence, long term volatility and volatility convergence to the long term volatility. Remember as Alexander (2008, p.137) notes an ARCH effect coefficient of greater than 0.1 is interpreted as a high level of sensitivity to market events or shocks, while a GARCH coefficient of greater than 0.9 means volatility is highly persistence following a crisis in the market. We also calculate the volatility half life expectancy.

In essence as illustrated by equations 3.2.6 and 3.2.7 in the methodology, the two models: EGARCH and GARCH-m derive the EGARCH-m. Essentially, this means that equation 3.2.6 gives the asymmetricaleffect and equation 3.2.7 gives the feedback effect. The key to the interpretation of the asymmetricaleffect in our model is in the γ coefficient of equation 3.2.7. The key to the interpretation of the feedback effect in our model is in the λ coefficient of equation 3.2.7.

The basis of the statistical analysis is the same five statistics used to test the models in section 4.3:

- R^2
- adjusted R^2
- Jarque-Bera statistic proposed by Jarque & Bera (1980)
- ARCH LM test introduced by Engle (1982)
- Q-statistics of the correlogram as proposed by Ljung & Box (1979)

4.4.1. The GARCH Model of Price Volatility

As indicated by section 3.2 in the methodology, we use a simple GARCH model of volatility to analyse the behaviour of volatility in the sovereign debt market. We use a GARCH (1, 1) to estimate the conditional variance of the first order-differentiated price. It is essential to remember the conditional variance equation of the GARCH model:

$$\Delta Price_t = a + \sum_{j=1}^{J} b_j \Delta Price_{t-j} + \epsilon_t$$

$$h_t = \omega + \alpha_1 k_{t-1} + \beta_1 h_{t-1}.$$

We analyse for market shocks and volatility persistent by using the α and β coefficients as stated in the methodology section 3.2. We use the $\alpha + \beta$ to analyse the convergence or mean reversion of the volatility to the long-term average volatility. Finally, we analyse the half-life of the volatilityusing $-\frac{ln(2)}{ln(\alpha+\beta)}$.

With the exception of a number of observations, the model is a single lagged GARCH (1, 1) model with a student t distribution estimated using the Maximum Likelihood method with a BHHH optimization algorithm. However, due to an error with the optimization algorithm, we used the Marquandt rather than the BHHH to estimate the US period 2 and German 2012 period 3 observations. We also encountered errors regarding the distribution of the residuals in the model; hence, we used the normal distribution to estimate the German 2012 period 3 and the 2012 period 2 for the Greek, Portuguese and Spanish. We also encountered errors with the lagged system, which mean the use of two lags in the estimation model with respect to all the US 2012 and Italian market and sample periods.

Table 70. *2012 Bond GARCH Residuals Statistics (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999899	0.999331	0.999999	0.999639	0.999990	0.999906
Adjusted R^2	0.999899	0.999331	0.999999	0.999639	0.999990	0.999906
Jarque-Bera	226.41	135.04	1509.64	8794.87	694.85	378.69
Q-Statistics (Correlogram)	0.0196	0.0243	1.2662	1.4406	0.7944	0.0182
F-Statistics(ARCH Test)	1.402221	0.010843	0.409324	0.009807	1.588620	2.820865

As illustrated by Table 70, a key factor of note is the high R^2 and adjusted R^2. The R^2 is above 0.99 through all the estimated GARCH models, thus hinting at the lagged price differential with the estimated residuals being highly able to explain the movement in the price differential. Another factor is the significantly high adjusted R^2 pointing at the estimated GARCH models being a good fit to the dependent variable across all the markets.

The Jarque-Bera test for all the markets seem to be hinting at an acceptance of the null hypothesis of non-normality in the distribution of the residuals. We found all our markets seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera statistics seem to be hinting at a varied set of results with the Greek and Italian being significantly greater than the other markets. Conversely, the German is significantly lower than all the other markets.

With regard to the serial correlation, the Q-statistics seem to be hinting at a significantly low correlation. At the single lagged level, the Q-statistic for all our samples does not rise above 1.4406as observed by the Italian. Considering that, the Q-statistics must be approximately zero, the importance of these statistics for the estimated models highlighted by Table 70. Withthe exception of the Greek and Italian, the Q-statistics seem to be approaching zero.

The F-statistics seem to split between approaching no ARCH effect and low ARCH effect remaining. In essence, the three lowest F-statistics are the German, Greek and Italian with an F-statistics below one, thus meaning approximatelyno ARCH effect remaining. The highest F-statistic is that of the Spanish hinting at a relatively low amount of ARCH effect remaining.

Table 71. *GARCH Statisticsof the 2012 Bond (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	7.03E-05 (1.18E-05)	-0.000545 (2.99E-05)	-0.023059 (4.94E-06)	0.000228 (4.00E-05)	-0.000431 (1.26E-05)	0.000944 (3.11E-05)
b_1	-0.054232 (0.000190)	0.033025 (0.000481)	0.075436 (1.74E-05)	0.032879 (0.000312)	0.145161 (5.40E-05)	0.045026 (0.000172)
b_2	-0.042572 (0.000191)					
ϵ	1.000174 (0.000194)	0.998966 (0.000494)	1.000017 (1.88E-05)	0.999406 (0.000300)	1.000014 (5.50E-05)	0.999813 (0.000166)
Variance Equation ω	-4.34E-11 (9.22E-11)	-9.12E-10 (6.25E-10)	5.43E-09 (1.01E-09)	6.20E-09 (5.70E-09)	1.72E-08 (4.37E-09)	1.87E-08 (8.66E-09)
α	0.041664 (0.006897)	0.034731 (0.005779)	0.178422 (0.021970)	0.032879 (0.008580)	0.108132 (0.014886)	0.084401 (0.011024)
β	0.957897 (0.005939)	0.964909 (0.005122)	0.805469 (0.014884)	0.999406 (0.007213)	0.87876 (0.013736)	0.918665 (0.009532)
$\frac{\omega}{1-(\alpha+\beta)}$	-9.89E-08	-2.53E-06	3.37E-07	-7.06E-03	1.31E-06	-6.10E-06
$\alpha+\beta$	0.999561	0.99964	0.983891	1.032285	0.986892	1.003066
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	1579	1925	43	-22	53	-226
Log Likelihood	11960.16	10428.95	16382.07	10816.12	14265.95	11934.73

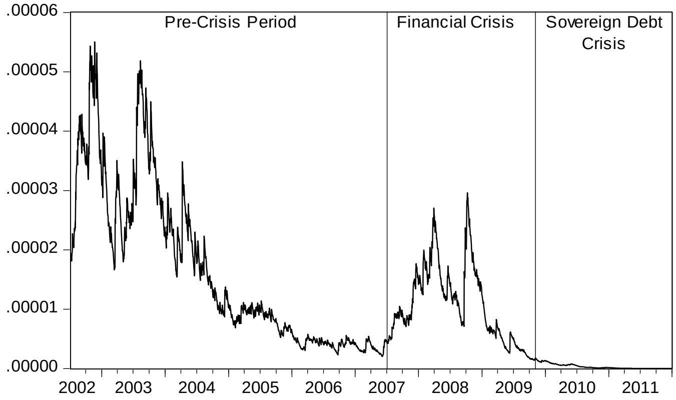

Figure 12. *US 2012 (GARCH)*

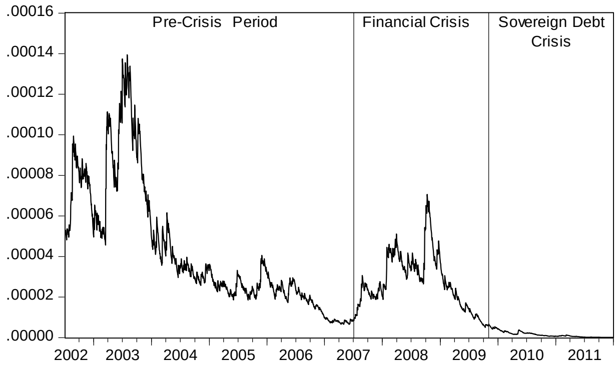

Figure 13. *German 2012 (GARCH)*

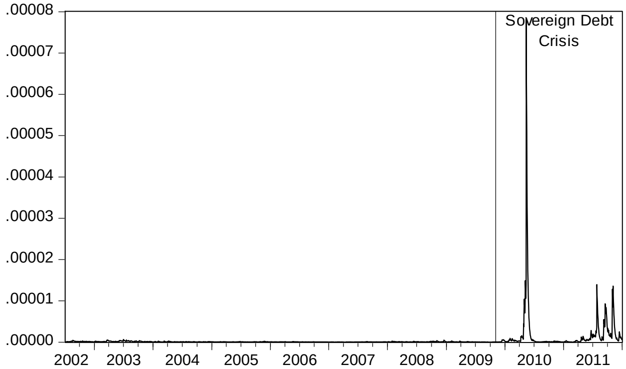

Figure 14. *Greek 2012 (GARCH)*

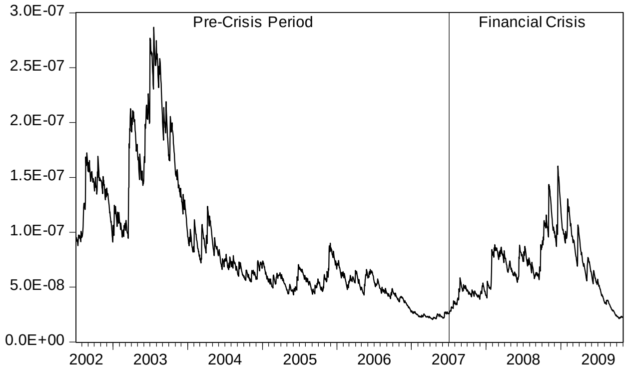

Figure 15. *Greek 2012 w/o Sovereign Debt Crisis (GARCH)*

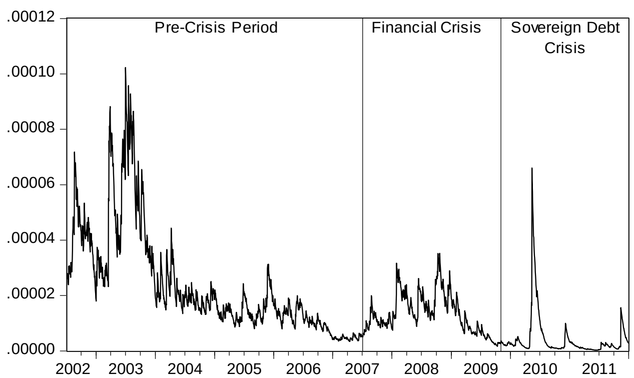

Figure 16. *Italian 2012 (GARCH)*

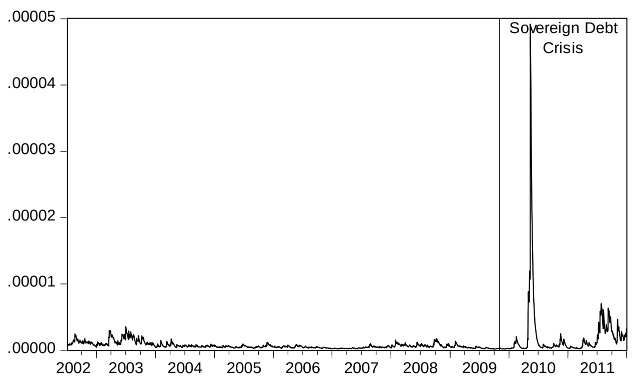

Figure 17. *Portuguese 2012 (GARCH)*

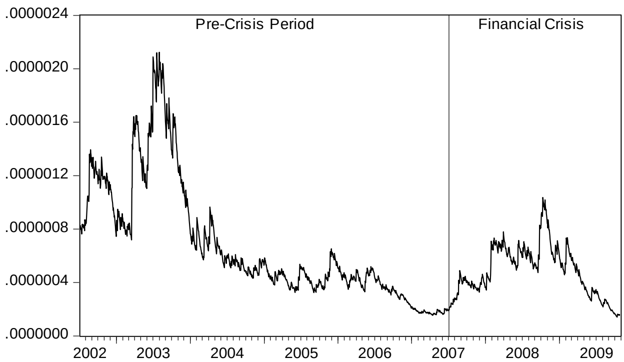

Figure 18. *Portuguese 2012 w/o Sovereign Debt Crisis (GARCH)*

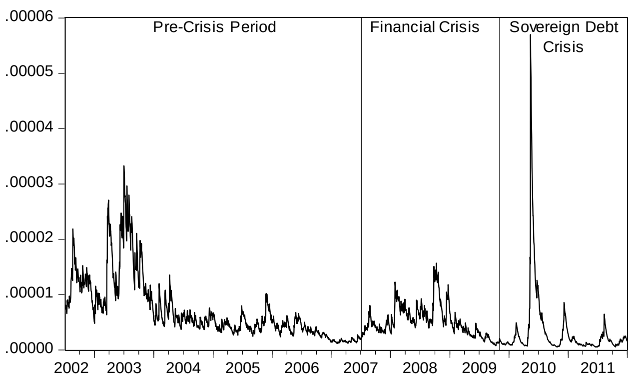

Figure 19. *Spanish 2012 (GARCH)*

Since unlike the efficient market hypothesis tests, we use the price differential to estimate our GARCH models we could use the full coefficients' interpretation of Alexander (2008, p.137) and Engle & Patton (2001).

It is worth remembering Table 71 covers the period between 1st July 2002 and 31st December 2011 for the 2012 bonds, thus meaning it illustrates the behaviour of volatility during a period of changing market environment. In essence, this observed period included the two crises and an extended period of economic upturn, which led to the asset price bubble of the mid-2000s. Essentially, the statistics in Table 71 are the generalised pointers to the behaviour of volatility in the observed 2012 government bonds. It must be noted that as illustrated by Table 29 the GARCH variant of our EMH test accepted the market efficiency for the observed

US, Greek and Portuguese markets. However, it did also significantly accept the null hypothesis of the market being too volatile to be efficient for the remaining markets.

The level of sensitivity to market shocks seems to be hinting at a differentiated picture. Thus, meaning with the exception of the Greek and Portuguese markets, the observed markets seems to be hinting at a low level of sensitivity to market shocks. However, the α coefficient for the Spanish market seems to be relatively high suggesting that a relatively high shock to the market was observed at some point. The Greek and Portuguese markets are pointing at a significant level of sensitivity to market shocks. Looking at figures 14, 17 and 19 would suggest the shock in the Greek, Portuguese and Spanish markets came during the sovereign debt crisis. And although the Italian market as illustrated by figure16 seem to be also pointing at a hike in the price volatility during the sovereign debt crisis, yet the evidence from the figure and Table seem to be suggesting that it was not significant. In fact, the α coefficients hints at the Italian market having the lowest level of sensitivity to market shocks of all the observed markets. The US and German markets seem to be pointing at a low level of sensitivity to market shocks, however as illustrated by figures 12 and 13 there seem to be some evidence of market shocks.

With the exception of the Greek and Portuguese markets, the β coefficients are pointing at highly persistence levels of volatility in the aftermath of a shock in the observed markets. Conversely, the Spanish market seems to be hinting at a relatively lower persistence level of volatility than the remaining markets. Figures 14 and 17 seem to be illustrating the reason why the Greek and Portuguese markets seem to have a low level of volatility persistence. As illustrated previously, significant hikes in the volatility blighted the Greek and Portuguese markets during the sovereign debt crisis, which hint at a reactive market. However, as illustrated by figures 15 and 18 when the sovereign debt crisis is taken out of the equation, both the Greek and Portuguese markets look to be more persistence. A known factor is that when the market is highly reactive to market shocks, the levels of persistence is relatively low and the opposite is equally true. This is important because it explains the other observed markets, since as previously illustrated these market are not reactive. Therefore, they are persistent and with the possible exception of the Spanish market, the β coefficients seem to be hinting at highly persistence volatility in the aftermath of any shock to the market. The Italian market seems to be displaying the highest persistence level.

With the exception of the US and Italian markets, the unconditional volatility seemsto be relatively low, however it is worth considering the subsequent levels. A glance at Tables 73, 75 and 77 seem to be confirming our initial suspicions. Conversely, the unconditional volatility for the US market is significantly low and the Italian market seems to be significantly high. It is important to know if the volatility from our observed markets does revert to the long-term mean volatility after a rise or fall. The evidence seems to be suggesting that with the exception of the Italian and Spanish markets, the observed markets do revertto the unconditional volatility in the aftermath of a crisis. Interestingly, given that the Italian and Spanish markets had the highest unconditional volatility, the statistics seem to be hinting at these two markets not reverting to the unconditional volatility. However, the volatility half-life seem to be suggesting that the volatility in the Greek and Portuguese markets does tend to decay to half their levels quicker in the aftermath of a shock to the market than any of the other observed markets. In contrast, the US and German markets seem to be hinting at a very long duration for the volatility to decay to half its value in the aftermath of a shock to the market. Moreover, the negative half-life of the Italian and Spanish markets seems to be hinting that volatility does not decay over time.

As pointed earlier, the EMH test statistics in Table 29 hint at the rejection of the null hypothesis of the markets being too volatile to be efficient for the US, Greek and Portuguese markets. However, interestingly according to Table 71, the Greek and Portuguese markets seem to be very reactive to market shocks and exhibit low volatility persistence in aftermath of a crisis with a low half-life. In contrast, the US market seems to be very phlegmatic to market shocks and highly persistence with a high half-life. However, both the US and Greek markets seem to exhibit a relatively low expected long-term volatility as does the Portuguese to a certain extent.

Table 72. *2012 Bond GARCH Residuals Statistics (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.998056	0.999334	0.999999	0.999639	0.999990	0.999906
Adjusted R^2	0.998053	0.999333	0.999999	0.999639	0.999990	0.999906
Jarque-Bera	56.24	34.23	38.47	45.67	42.41	32.75
Q-Statistics (Correlogram)	63.19	0.15	0.22	0.19	0.24	0.22
F-Statistics(ARCH Test)	0.087923	1.051006	1.117249	1.028082	1.578360	1.349344

In essence, as illustrated by Table 70 previously, the high R^2 and adjusted R^2 hint at all the models being a good fit to the dependent variable through all the estimated GARCH models.

Although the Jarque-Bera tests seem to be significantly lower, yet the statistics accept the null hypothesis of non-normality in the distribution. However, the Q-statistics seem to be suggesting that with the significant exception of the US, the observed markets have a very low serial correlation. With the exception of the US market, the F-statistics arehinting at a relatively low ARCH effect. Conversely, the US market is hinting at the ARCH effect-approaching zero.

Table 73. *GARCH Statisticsof the 2012 Bond (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.000108 (0.000344)	-0.000348 (0.000138)	-0.023063 (6.51E-06)	0.000298 (0.000101)	-0.000440 (1.81E-05)	0.000939 (5.64E-05)
b	-0.053343 (0.001193)	0.032485 (0.000702)	0.075351 (3.11E-05)	0.032450 (0.000508)	0.145021 (8.82E-05)	0.044426 (0.000265)
ϵ	1.000856 (0.001151)	0.999128 (0.000699)	0.999983 (3.11E-05)	0.999384 (0.000509)	0.999957 (8.74E-05)	0.999872 (0.000261)
Variance Equation ω	1.81E-07 (2.27E-07)	2.36E-08 (4.62E-08)	8.11E-11 (1.19E-10)	3.42E-08 (3.62E-08)	6.26E-10 (9.07E-10)	5.59E-09 (8.60E-09)
α	0.020376 (0.006254)	0.023517 (0.006845)	0.024717 (0.007077)	0.027906 (0.008255)	0.023590 (0.006908)	0.024142 (0.006939)
β	0.977578 (0.006273)	0.974707 (0.006830)	0.973301 (0.007174)	0.969251 (0.008423)	0.974321 (0.007009)	0.973883 (0.006980)
$\frac{\omega}{1-(\alpha+\beta)}$	8.85E-05	1.33E-05	4.09E-08	1.20E-05	3.00E-07	2.83E-06
$\alpha+\beta$	0.997954	0.998224	0.998018	0.997157	0.997911	0.998025
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	338	390	349	243	331	351
Log Likelihood	3615.632	4869.476	8872.661	5274.899	7535.686	6056.229

Remember that Table 73 covers the pre-crisis period between 1st July 2002 and 29th June 2007. Highly volatile events and a prolonged period of stability in the sovereign debt market blighted the period. Looking at the section of figures 12 to 19 marked "*Pre-Crisis period*" would seem to suggest that this is the case. The pre-crisis period came in the aftermath of a period of highly volatile events like the introduction of the Euro and the 11 September 2001 terrorists' attacks. However, notably the period also saw a prolonged economic upturn, which initiated the asset price bubble of the mid-2000s. Conversely, it must be noted that as illustrated by Table 31 the GARCH variant of our EMH test accepted the market efficiency for the observed US and Spanish markets. However, it did also insignificantly accept the null hypothesis of the market being too volatile to be efficient for the remaining markets.

The α coefficients seem to be hinting at a very low level of sensitivity to market shocksthroughout. On close analysis, the US market seems to be pointing at a lower level of sensitivity to market shocks. In contrast, the Italian market seems to be hinting at a slightly higher level of sensitivity to market shocks.

The β coefficients seem to be pointing at low levels of volatility persistence in the aftermath of a shock in the observed markets, although the US market seems to be indicating a slightly higher persistence level of volatility than the other markets. Conversely, theItalianmarket seems to besuggesting a lower level of persistence in the aftermath of a shock to the market.

With the exception of the Greek and Portuguese markets, the unconditional volatility seems to be relatively high. Conversely, the unconditional volatility for the Greek and Portuguese is significantly low. The statistics seems to be suggesting that all the observed markets do revert to the unconditional volatility in the aftermath of a crisis. However, the volatility half-life seems to be suggesting that the volatility in all the observed markets do tend to decay to half their levels relatively slowly in the aftermath of a shock. The German market in particular seems to be hinting at a long duration for the volatility to decay to half its value. Moreover, the Italian marketseems to be hinting that volatility decays quicker over time.

As pointed earlier, the EMH test statistics in Table 31 hint at the rejection of the null hypothesis of the markets being too volatile for the US and Spanish markets during the pre-crisis period. However, interestingly according to Table 73, the US and Spanish as with all the observed markets seem to be very phlegmatic to market shocks butexhibit high volatility persistence in aftermath of a crisis with a relatively high half-life. Conversely, both markets seem to exhibit high-expected long-term volatility but this is true to all the remaining markets with the exception of the Greek.

Table 74. *2012 Bond GARCH Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999902	0.999337	0.999999	0.999641	0.999990	0.999907
Adjusted R^2	0.999902	0.999335	0.999999	0.999640	0.999990	0.999906
Jarque-Bera	215.20	64.15	130.90	40.62	38.26	35.61
Q-Statistics (Correlogram)	0.0201	0.0480	0.0129	0.2316	0.1806	0.1233
F-Statistics(ARCH Test)	0.010680	0.018199	0.032501	0.005342	0.003746	0.155048

As illustratedby Table 74, the high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Although with the exception of the US and possibly Greek markets, the Jarque-Bera tests seem to be slightly higher indicating a slightly significant acceptance of the null hypothesis of non-normality in the distribution. Yet the Jarque-Bera statistics of the US and to a certain extent Greek market seem to be indicating a significantly higher acceptance of the null hypothesis. However, the Q-statistics seem to be hinting at significantly low serial correlations thru all markets. Of course, the Q-statistics of the Italian market is higher than in Table 72. Conversely, the US market is significantly lower. The F-statistics are hinting at significantly lower ARCH effect with all the markets pointing at the ARCH effect-approaching zero.

Table 75. *GARCH Statistics of the 2012 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	-0.000127 (9.67E-05)	-1.66E-05 (0.000166)	-0.023049 (8.64E-06)	0.000538 (0.000115)	-0.000393 (2.31E-05)	0.001103 (7.17E-05)
b_1	-0.054001 (0.000374)	0.032834 (0.000928)	0.075420 (4.06E-05)	0.032899 (0.000689)	0.145090 (0.000117)	0.044436 (0.000346)
b_2	-0.042549 (0.000372)					
ϵ	0.999498 (0.000384)	0.999313 (0.000970)	1.000048 (4.20E-05)	1.000148 (0.000712)	1.000099 (0.000120)	0.999859 (0.000366)
Variance Equation ω	1.95E-08 (4.02E-08)	-2.80E-08 (8.23E-08)	4.53E-10 (5.54E-10)	-2.23E-08 (3.51E-08)	-5.77E-10 (1.83E-09)	-9.87E-09 (1.51E-08)
α	0.061735 (0.018886)	0.035012 (0.011952)	0.031907 (0.013695)	0.036275 (0.012664)	0.032787 (0.012117)	0.032688 (0.011630)
β	0.93849 (0.018154)	0.966376 (0.012133)	0.961225 (0.017336)	0.9659 (0.012603)	0.968648 (0.012990)	0.969625 (0.012139)
$\frac{\omega}{1-(\alpha+\beta)}$	-8.67E-05	2.02E-05	6.60E-08	1.03E-05	4.02E-07	4.27E-06
$\alpha+\beta$	1.000225	1.001388	0.993132	1.002175	1.001435	1.002313
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	-3081	-500	101	-319	-483	-300
Log Likelihood	2702.523	2389.583	4221.184	2622.947	3608.588	2914.310

It is worth noting that Table 75 is associated with the financial crisis and hence some markets may have experienced flights to them. In essence, the statistics in Table 75 are reflecting the mixed reaction associated with such a crisis. Looking at the section of figures 12 to 19 marked "*Financial Crisis Late 2000s*" would seem to suggest that although there was a uniformed hike in volatility, the levels of the volatility seem to be telling. Remember the GARGH variant of our EMH test hints at the significant acceptance of the null hypothesis of the market being too volatile to be efficient for all the observed markets during the financial crisis as illustrated by Table 33. The α coefficients seem to be hinting at a slightly increasing but still low level of sensitivity to market shocks. Unsurprisingly the US market seems to be pointing at a significantly higher level of sensitivity to market shocks than the other observed markets. The Greek, Portuguese and Spanish markets are pointing at a relatively low level of sensitivity to market shocks. In contrast, the German and Italian markets seem to besuggesting a higher level of sensitivity to market shocks. The β coefficients seem to be pointing at a reduction in the alreadylow levels of volatility persistence in the aftermath of a shock thru all the observed markets. Yet the US market seems to be indicatinga significantly lower persistence level of volatility than the other markets. In addition, the Greek market is pointing at a relatively lower level ofvolatility persistence. In contrast, the Portuguese and Spanish markets seem to be suggesting a slightly higher level of persistence in the aftermath of a shock to the market.

With the exception of the US and Italian markets, the unconditional volatility seems to have been slightly increased. Conversely, the unconditional volatility for the Greek and Portuguese markets remains significantly low. With the exception of the Greek market, the mean reversion statistics seem to have increased hinting at the observed markets notreverting to the unconditional volatility in the aftermath of a crisis. However, the Greek market is pointing at a slight reduction hinting at the market reverting to the unconditionalvolatility. Conversely, with the exception of the Greek market, the volatility in all the observed markets does notdecay to half their levels in the aftermath of a shock. Moreover, the Greek market seems to be hinting that volatility decays quicker over time in comparison with Table 73. As pointed earlier, the EMH test statistics in Table 33 hint at the acceptance of the null hypothesis of the markets being too volatile for all the observed markets during the financial crisis period. However, interestingly according to Table 75, all the observed markets seem to be very phlegmatic to market shocks but exhibit relatively low volatility persistence in the aftermath of a crisis with a negative half-lifewith the exception of the Greek market. Conversely, with the exception of the Greek and Portuguese markets, all the other markets seem to exhibit relatively high-expected long-term volatility.

Table 76. *2012 Bond GARCH Residuals Statistics (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999892	0.999323	0.999999	0.999650	0.999990	0.999910
Adjusted R^2	0.999891	0.999321	0.999999	0.999648	0.999990	0.999910
Jarque-Bera	9.95	85.04	435.82	10034.14	467.63	427.76
Q-Statistics (Correlogram)	0.0054	0.9895	5.0920	0.2818	0.0782	0.0007
F-Statistics(ARCH Test)	0.596262	8.710481	0.262242	0.125176	0.688975	0.845092

As illustrated by theprevious Tables, the high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Although with the exception of the US market, the Jarque-Bera tests seem to be higher indicating a significant acceptance of the null hypothesis of non-normality in the distribution especially for the Italian market. Yet the Jarque-Bera statistic of the US market seems to be indicating a significantly lower acceptance of the null hypothesis. However, with the exception of the Greek and to a certain extent German markets, the Q-statistics seem to be hinting at the serial correlations remaining significantly low through all markets. Of course, the Q-statistics of the Greek market is significantly higher than in Table 74. Conversely, the US and Spanish markets are significantly low. Moreover, the F-statistics are hinting athigh ARCH effect with all the markets pointing at increases in the ARCH effect, especially the German market.

Table 77. *GARCH Statistics of the 2012 Bond (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation a	0.000148 (1.55E-05)	-0.000564 (3.29E-05)	-0.023090 (1.88E-05)	0.000213 (4.02E-05)	-0.000467 (2.77E-05)	0.000912 (3.91E-05)
b_1	-0.053207 (0.000431)	0.033556 (0.000949)	0.075427 (1.71E-05)	0.034483 (0.000519)	0.145640 (7.88E-05)	0.046724 (0.000294)
b_2	-0.041162 (0.000413)					
ϵ	1.001457 (0.000434)	0.998025 (0.001017)	1.000176 (2.10E-05)	0.999474 (0.000481)	1.000000 (8.83E-05)	0.999129 (0.000269)
Variance Equation ω	1.86E-10 (1.17E-10)	4.81E-10 (1.12E-09)	4.30E-08 (9.52E-09)	1.64E-07 (6.97E-08)	5.03E-08 (1.26E-08)	1.06E-07 (3.22E-08)
α	0.036449 (0.013434)	0.030325 (0.012292)	0.478738 (0.069965)	0.26082 (0.087970)	0.185152 (0.032247)	0.136323 (0.032971)
β	0.952777 (0.013183)	0.964401 (0.010887)	0.410825 (0.046510)	0.749416 (0.052414)	0.714817 (0.036883)	0.770618 (0.044902)
$\frac{\omega}{1-(\alpha+\beta)}$	1.73E-08	9.12E-08	3.89E-07	-1.60E-05	5.03E-07	1.14E-06
$\alpha+\beta$	0.989226	0.994726	0.889563	1.010236	0.899969	0.906941
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	64	131	6	-68	7	7
Log Likelihood	3738.922	3185.039	3352.444	2979.818	3158.551	3025.912

It is worth noting that Table 77 is associated with the sovereign debt crisis and hence as expected, there is a difference between the GIPS group of markets and the other two. In essence, the statistics in Table 77 and the section of the figures 50 to 57 marked "*Sovereign Debt Crisis Early 2010s*" seem to be reflecting this different. Interestingly Table 35illustrates the GARCH variant of our EMH test accepted the market efficiency for the observed Greekand Portuguese markets. However, it did also significantly accept the null hypothesis of the market being too volatile to be efficient for the remaining markets. The observed markets seem to be hinting at a significantly higher level of sensitivity to market shocks in all observed GIPS markets. The Greek and Italian markets, in particular, seem to be pointing at significantly higher levels of sensitivity to market shocks than other observed markets.

Additionally, the α coefficients of the Portugueseand Spanish markets are also pointing at a high level of sensitivity to market shocks. In contrast, the US and German markets seem to be lower suggesting a significantly low level of sensitivity to market shocks, in fact both markets are approaching zero.

The β coefficients seem to be pointing at significantly lower levels of volatility persistence in the aftermath of a shock in the observed GIPS markets. Yet the Greek market seems to be indicatinga significantly lower persistence level of volatility than the other GIPS markets. However, as expected the US and German markets are pointing at relatively high levels ofvolatility persistence in the aftermath of a shock to the market. Conversely, the US and German markets are slightly higher and lower respectively than previously indicated in Table 75.

With the exception of the Spanish market, the unconditional volatility seems increased for all theGIPS markets. Conversely, the unconditional volatility for the US and German markets is lower. The evidence from the statistics seems to be painting a weak picture with respect to the mean reversion among the GIPS markets. However, the US and German markets seem to be suggesting that in the long run volatility does reverts to the average long term volatility after a positive or negative shock to the market. Interestingly, the Italian market's statistic for the mean reversion is greater than one hinting at a negativehalf-lifesuggesting that volatility does not decay over time. However, the other GIPS markets seem to be hinting at a significant change in the volatility half-life to 6 or 7 working days. In contrast, the US and German markets seem to be also hinting at change but with volatility half-lives of 64 and 131 working days respectively, they remain high.

As noted earlier rather surprisingly, the EMH test statistics in Table 35 hint at the rejection of the null hypothesis of the markets being too volatile for the Greek and Portuguese markets during the sovereign debt crisis period. However, interestingly according to Table 77, the Greek and to lesser extent Portuguese markets seem to be very reactive to market shocks and exhibit a low volatility persistence in aftermath of a crisis with a significantly low half-life. Conversely, both markets seem to exhibit a relatively low expected long-term volatility. However, notably that to a certain extent this is true of a number of other GIPS markets.

Table 78. *2017 Bond GARCH Residuals Statistics (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990780	0.999976	0.999918
Adjusted R^2	0.999999	0.999999	0.990761	0.999976	0.999918
Jarque-Bera	96.87	26.84	2264.50	4681.58	1552.97
Q-Statistics (Correlogram)	0.0010	0.0948	0.2811	0.3268	0.1235
F-Statistics(ARCH)	0.566707	0.950073	0.744441	0.905307	1.254261

As illustrated by Table 78, a key factor to note is the high R^2 and adjusted R^2. The R^2 is above 0.99 through all the estimated GARCH models, thus hinting at the lagged price differential with the estimated residuals being highly able to explain the movement in the price differential. Another factor is the significantly high adjusted R^2pointing at the estimated GARCH model being a good fit to the dependent variable across all the markets. An interesting point to note is the$R^2$and adjusted R^2 of the IPS[20] markets are lower than the US and German markets

The Jarque-Bera test for all the markets seem to be hinting at a significant acceptance ofthe null hypothesis of non-normality in the distribution of the residuals. We found all our samples seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera tests for the IPS markets seem to be excessively high, especiallythe Portuguese market. Yet the Jarque-Bera statistic of the US and German markets seem to be indicating a significantly lower acceptance of the null hypothesis in comparison with the observed IPS markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at low serial correlations thru all markets. Of course the Q-statistics of the US and German markets are significantly lower than the other observed markets.

In essence, with the possible exception of the Spanish, the F-statistics are hinting at low ARCH effect in all the markets. However, the observed Eurozone markets seem to be hinting at a higher ARCH effect.

[20] Italy, Portugal and Spain

Table 79. *GARCH Statistics of the 2017 Bond (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation a	0.013447 (6.04E-06)	0.012487 (7.86E-06)	0.005179 (0.000702)	0.000288 (5.47E-05)	0.004129 (8.14E-05)	0.013447 (6.04E-06)
b_1	-0.060876 (2.15E-05)	0.067354 (2.67E-05)	0.175965 (0.001926)	0.255124 (7.69E-05)	0.190727 (0.000208)	-0.060876 (2.15E-05)
b_2			-0.069594 (0.002063)			
ϵ	1.000047 (2.31E-05)	1.000030 (2.85E-05)	0.994172 (0.001839)	0.999879 (8.58E-05)	1.000336 (0.000200)	1.000047 (2.31E-05)
Variance Equation ω	-3.28E-11 (5.58E-11)	8.80E-11 (2.16E-10)	4.10E-05 (1.21E-05)	7.09E-07 (1.42E-07)	6.20E-07 (1.85E-07)	-3.28E-11 (5.58E-11)
α	0.047406 (0.008881)	0.0467 (0.009079)	0.117162 (0.021872)	0.206489 (0.030734)	0.105298 (0.019833)	0.047406 (0.008881)
β	0.953587 (0.007923)	0.953682 (0.008871)	0.867571 (0.018727)	0.716505 (0.031543)	0.859003 (0.022424)	0.953587 (0.007923)
$\frac{\omega}{1-(\alpha+\beta)}$	3.30E-08	-2.30E-07	2.69E-03	9.21E-06	1.74E-05	3.30E-08
$\alpha+\beta$	1.000993	1.000382	0.984733	0.922994	0.964301	1.000993
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	-698	-1815	45	9	19	-698
Log Likelihood	9781.492	9820.607	2948.889	6771.308	6295.678	9781.492

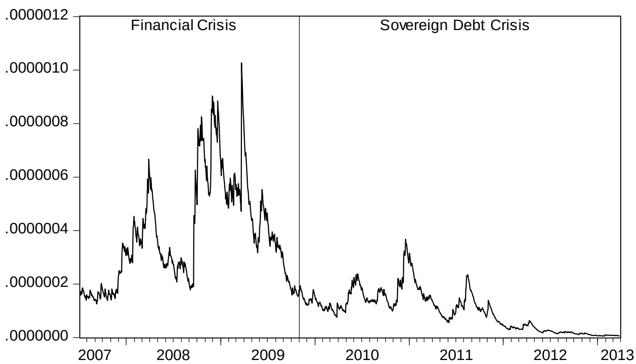

Figure 20. *US 2017 (GARCH)*

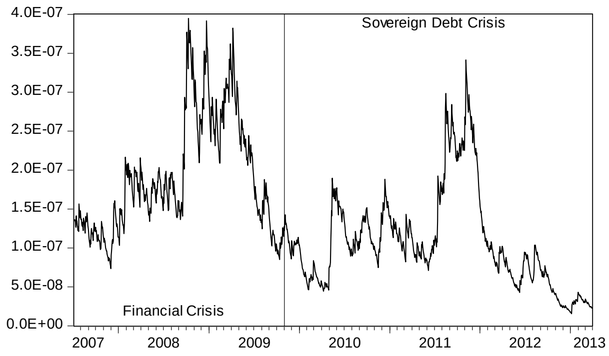

Figure 21. *German 2017 (GARCH)*

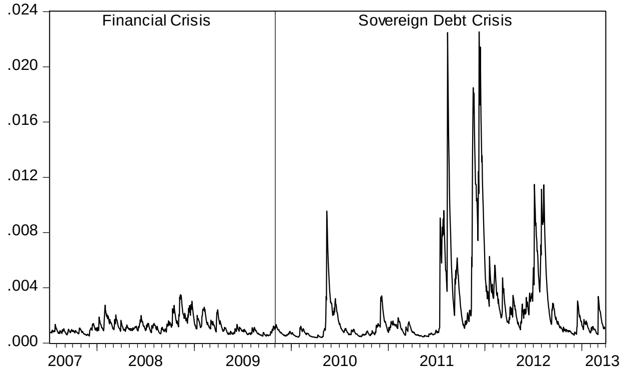

Figure 22. *Italian 2017 (GARCH)*

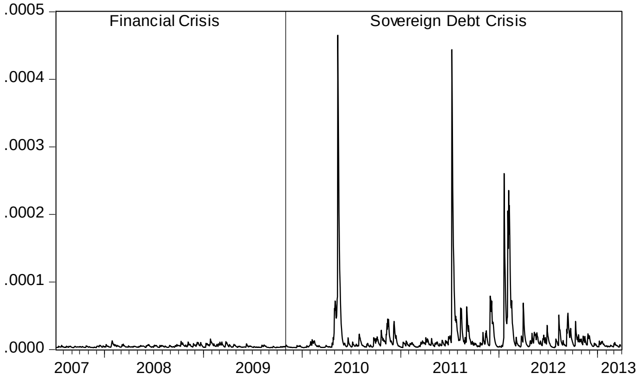

Figure 23. *Portuguese 2017 (GARCH)*

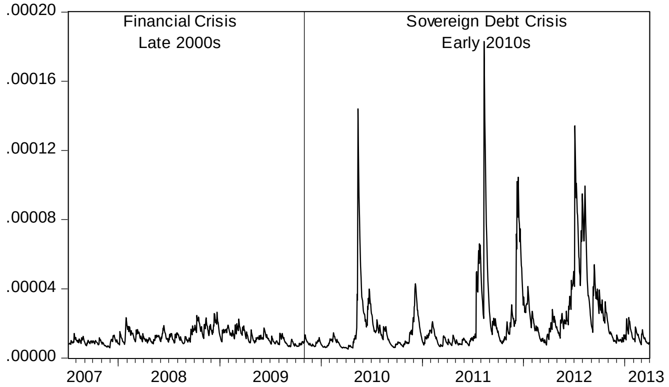

Figure 24. *Spanish 2017 (GARCH)*

It is worth remembering that the 2017 bonds cover the period between 1st July 2007 and 31st March 2013, thus meaning they illustrate the behaviour of volatility in a highly volatile market environment based on the financial and sovereign debt crises. In essence, the statistics in Table 79 are the generalised pointers to the behaviour of volatility during the crises period. As figures 20 to 24 seem to be illustrating, the observed markets are generally, subdivided into the IPS markets, which were at the heart of the sovereign debt crises and the US, and Germany markets. An influencing factor is by analysing the behaviour of volatility in these 2017 bonds, we could overcome the maturity effect and thus extend our analysis of the sovereign debt crisis. Remember the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the observed markets except for the German as illustrated by Table 37.

The level of sensitivity to market shocks seems to be pointing at a differentiated picture with the IPS markets hinting at a high level of sensitivity to market shocks. As illustrated by figures 22 to 24, more than two significant hikes in the volatility dominate the IPS markets. However, the α coefficient for the Portuguese market seem to be hinting at a significantly higher level of sensitivity to market shocks than the other observed IPS markets. In contrast, the US and German markets seem to be hinting at significantly low levels of sensitivity to market shocks.

Like the α coefficients, the β coefficients also seem to be pointing at a differentiated picture with the IPS markets hinting at a significantly low level of volatility persistence in the aftermath of market shocks. However, the Portuguese market seems to be hinting at a lower level of volatility persistency than the other observed IPS markets. In contrast, the US and German markets seem to be hinting at a significantly high level of volatility persistence in the aftermath of a market shock.

The differentiated picture continues with the IPS markets demonstrating a high unconditional volatility. Conversely, the unconditional volatility for the Italian market is significantly high. In contrast, boththe US and German markets have low unconditional volatility. The evidence from the statistics seems to be painting a weak picture with respect to the mean reversion among the IPS markets. Interestingly, both the US and German markets' statistics for the mean reversion are greater than one meaning that both markets do not revertto the unconditional volatility. These high statistics seems to be suggesting that volatility does not decay over time. However, the IPS markets seem to be hinting at a low volatility half-life with the Portuguese market having a low volatility half-life of only 9 working days.

As pointed earlier, the EMH test statistics in Table 37 hint at the rejection of the null hypothesis of the markets being too volatile for all the observed markets except for the German. However, interestingly according to Table 79, the IPS markets seem to be very reactive to market shocks but exhibit low volatility persistence in aftermath of a crisis with a low half-life (except to a certain extent for the Italian). The US market hints at a phlegmatic market shock but exhibit relatively high volatility persistence in aftermath of a crisis with a negative half-life. Conversely, all the IPS markets seem to exhibit relatively high-expected long-term volatility but the US has a low unconditional volatility.

Table 80. *2017 Bond GARCH Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990621	0.999975	0.999916
Adjusted R^2	0.999999	0.999999	0.990574	0.999975	0.999915
Jarque-Bera	90.21	3.82	7.66	3.66	0.73
Q-Statistics (Correlogram)	0.0512	0.0129	0.0319	0.0425	0.0204
F-Statistics(ARCH Test)	0.008514	0.093090	0.264138	0.005975	0.006336

The high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Like Table 78, there is a split between the IPS and US/German markets with the IPS markets hinting at lower R^2 and adjusted R^2. Although the Jarque-Bera tests, for the US market seem to be excessively high in comparison with the Eurozone markets indicating a significant acceptance of the null hypothesis of non-normality in the distribution, yet the Eurozone markets, especiallythe Spanish, seem to be significantly low hinting at a distribution approaching normality. Additionally, the Q-statistics seem to be pointing at significantly low serial correlation for all the observed markets. Conversely, the F-statistics are hinting at an ARCH effect-approaching zero with all the markets.

Table 81. *GARCH Statistics of the 2017 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation a	0.013419 (2.26E-05)	0.012478 (1.66E-05)	0.004676 (0.001163)	0.000192 (6.83E-05)	0.004016 (0.000122)	0.013419 (2.26E-05)
b_1	-0.060859 (3.49E-05)	0.067302 (4.49E-05)	0.169176 (0.003771)	0.255791 (0.000198)	0.191675 (0.000372)	-0.060859 (3.49E-05)
b_2			-0.062907 (0.003837)			
ϵ	1.000119 (3.75E-05)	1.000051 (4.93E-05)	0.991894 (0.003730)	0.999880 (0.000198)	0.999988 (0.000394)	1.000119 (3.75E-05)
Variance Equation ω	4.83E-09 (3.69E-09)	8.14E-09 (5.37E-09)	1.32E-05 (1.16E-05)	3.51E-08 (3.42E-08)	8.11E-08 (9.00E-08)	4.83E-09 (3.69E-09)
α	0.043325 (0.016580)	0.044572 (0.019666)	0.034996 (0.016369)	0.032077 (0.014663)	0.025297 (0.012058)	0.043325 (0.016580)
β	0.943928 (0.021698)	0.912228 (0.041023)	0.952196 (0.023159)	0.957466 (0.020752)	0.966583 (0.017502)	0.943928 (0.021698)
$\frac{\omega}{1-(\alpha+\beta)}$	3.79E-07	1.88E-07	1.03E-03	3.36E-06	9.99E-06	3.79E-07
$\alpha+\beta$	0.987253	0.9568	0.987192	0.989543	0.99188	0.987253
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	54	16	54	66	85	54
Log Likelihood	3660.356	3848.062	1257.029	2984.073	2636.353	3660.356

It is worth noting that this subsample is associated with the financial crisis and hence some markets may have experienced flights to them. In essence, the statistics in Table 81 are reflecting the mixed reaction associated with such a crisis. Looking at the section of figures 20 to 24 marked "*Financial Crisis Late 2000s*" it would seem to be giving the impressionthat the US/German market are more volatile than the IPS markets. However, this seems to be an illusion with the high levels of volatility during the sovereign debt crisis effecting the IPS markets. Remember the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the observed markets except for the Italian as illustrated by Table 39.

The observed markets seem to be hinting at a low level of sensitivity to market shocks. Moreover, the α coefficients of the IPS markets are pointing at a lower level of sensitivity to market shocks. Additionally, the Spanish market seems to be pointing at significantly low level of sensitivity to market shocks. In contrast, the US and German markets seem to be suggesting a higher level of sensitivity to market shocks.

The β coefficients seem to be pointing at relatively low levels of volatility persistence in the aftermath of a shock in the observed markets. Yet the Germanmarket seems to be indicating at a significantly lower persistence level of volatility than the other markets. The US market is pointing at a relatively low level ofvolatility persistence. However, the IPS markets, especially the Spanish, have higher β coefficients suggesting a relatively high level of volatility persistence.

The differentiated picture continues with the IPS markets demonstrating a high unconditional volatility. Conversely, the unconditional volatility for the Italian is significantly high. In contrast both the US and German markets have low unconditional volatility. The evidence from the statistics seems to be painting amorecoherentpicture with respect to the mean reversion among the markets with the exception of the German market. However, the Spanish market seem to be suggesting that in the long run volatility does reverts to the average long term volatility after a shock to the market. Interestingly, the German market's statistic for the mean reversion is significantly below 0.99. This means the German market has the lowest volatility half-life of 16 working days. However, the other markets seem to be hinting at a relatively high volatility half-life with the Spanish market hinting at a volatility half-life of 85 working days.

As pointed earlier, the EMH test statistics in Table 39 hint at the rejection of the null hypothesis of the markets being too volatile for all the observed markets except for the Italian. However, interestingly according to Table 81, all the markets seem to be very reactive to market shocks but exhibit low volatility persistence in aftermath of a crisis with a low half-life with the exception to a certain extent of the German market. Conversely, all the markets seem to exhibit relatively low expected long-term volatility.

Table 82. *2017 Bond GARCH Residuals Statistics (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990868	0.999977	0.999919
Adjusted R^2	0.999999	0.999999	0.990837	0.999976	0.999919
Jarque-Bera	27.75	32.79	3394.59	1048.06	1822.18
Q-Statistics (Correlogram)	0.1404	0.1574	0.1542	0.0001	0.1081
F-Statistics(ARCH Test)	1.436519	0.269539	1.020956	2.844755	0.930503

The high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Like Tables 78 and 80, there is a split between the IPS and US/German markets with the IPS markets hinting at lower R^2

and adjusted R^2. These splits continue with the Jarque-Bera test, the IPS markets seem to be excessively high indicating a significant acceptance of the null hypothesis of non-normality in the distribution. Yet the US and German markets seem to be hinting at a relatively low acceptance of the null hypothesis. Additionally, the Q-statistics seem to be pointing at significantly low serial correlation for all the observed markets with the Portuguese market-approaching zero. Conversely, the F-statistics are hinting at a relatively low ARCH effect in all the observed markets with the possible exception of the Portuguese and possibly German markets. While the German market is approaching zero arch effect, the Portuguese market seems to be hinting at a high ARCH effect in comparison.

Table 83. *GARCH Statistics of the 2017 Bond (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation a	0.013447 (6.21E-06)	0.012489 (8.96E-06)	0.005548 (0.000861)	0.000428 (8.21E-05)	0.004218 (0.000118)	0.013447 (6.21E-06)
b_1	-0.060881 (2.77E-05)	0.067377 (3.40E-05)	0.180145 (0.002265)	0.254807 (9.54E-05)	0.190026 (0.000267)	-0.060881 (2.77E-05)
b_2			-0.074069 (0.002350)			
ϵ	0.999998 (2.99E-05)	1.000018 (3.58E-05)	0.994877 (0.002076)	0.999958 (0.000101)	1.000908 (0.000205)	0.999998 (2.99E-05)
Variance Equation ω	-6.42E-13 (7.44E-11)	3.92E-10 (3.65E-10)	7.82E-05 (2.79E-05)	2.63E-06 (9.23E-07)	4.95E-07 (1.37E-07)	-6.42E-13 (7.44E-11)
α	0.052876 (0.012626)	0.068465 (0.015843)	0.252176 (0.061072)	0.46313 (0.142701)	0.127816 (0.015907)	0.052876 (0.012626)
β	0.94665 (0.011165)	0.929266 (0.015319)	0.771994 (0.032014)	0.586524 (0.063846)	0.844498 (0.014821)	0.94665 (0.011165)
$\frac{\omega}{1-(\alpha+\beta)}$	-1.35E-09	1.73E-07	-3.24E-03	-5.30E-05	1.79E-05	-1.35E-09
$\alpha+\beta$	0.999526	0.997731	1.02417	1.049654	0.972314	0.999526
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	1462	305	-29	-14	25	1462
Log Likelihood	6127.453	5973.276	1707.772	3826.701	3653.535	6127.453

It is worth noting that Table 83 is associated with the sovereign debt crisis and hence as expected, there is a difference between the IPS markets and US/German markets. In essence, the statistics in Table 83 and the section of the figures 58 to 62 marked "*Sovereign Debt Crisis Early 2010s*" seems to be reflecting this different. The2017 bonds allow us to extend the period of analysis in the sovereign debt crisis and to overcome the maturity effect of the 2012 bonds in Table 77. Interestingly the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the IPS markets as demonstrated by Table 41.

The α coefficients of the IPS markets seem to be pointing at high level of sensitivity to market shocks. However, the Portuguese market seems to be hinting at a higher level of sensitivity to market shocks than the other observed IPS markets. In contrast, the US and German markets seem to be hinting at relatively low levels of sensitivity to market shocks.

The β coefficients also seem to be hinting seem to be pointing at a differentiated picture with the IPS markets hinting at a significantly low level of volatility persistence in the aftermath of market shocks. However, the Portuguese market seems to be hinting at a lower level of volatility persistency than the other observed IPS markets. In contrast, the US and German markets seem to be hinting at a significantly high level of volatility persistence in the aftermath of a market shock.

The differentiated picture continues with the IPS markets demonstrating a high unconditional volatility. Conversely, the unconditional volatility for the Italian is significantly high. In contrast both the US and German markets have low unconditional volatility with the US market significantly low. With the exception of the Spanish market, the evidence seems to be painting a weak picture with respect to the mean reversion among the IPS markets. However, the US and German markets seem to be suggesting that in the very long run volatility does reverts to the average long term volatility after a shock to the market. Interestingly, both the Italian and Portuguese markets' statistic for the mean reversion is greater than one meaning both market do not revert to the unconditional volatility. These high statistics results in a negative half-life of the volatility, whichsuggests that volatility does not decay over time, however, the Spanish market seem to be hinting at a relatively low volatility half-life. In comparison, the US and to a lesser extent Germanmarkets seem to pointing at a significantly high volatility half-life.

As pointed earlier, the EMH test statistics in Table 41 hint at the rejection of the null hypothesis of the markets being too volatile for all the observed IPS markets. However, interestingly according to Table 83, all the IPS markets seem to be very reactive to market shocks but exhibit low volatility persistence in aftermath of a crisis with no half-life(except for the Spanish market which has a low half-life). Conversely, all the markets seem to exhibit relatively high-expected long-term volatility.

4.4.2. The EGARCH-m Model of Volatility

We use an EGARCH–m model of volatility to analyse the feedback and asymmetrical effects on the behaviour of price volatility in our observed sovereign debt markets. In essence, the basis of the EGARCH-m is the integration of two models: the asymmetrical effect obtained by the EGARCH, which is the first equation, and the feedback effect obtained by the GARCH-m, which is the second equation. The key coefficients are the γ in the EGARCH portion of the model and the λ in the GARCH-m portion of the model:

$$log(h_t) = \omega + \beta_1\, log(h_{t-1}) + \alpha_1 \left|\frac{\varepsilon_{t-1}}{\sigma_{t-1}}\right| + \gamma_1 \frac{\varepsilon_{t-1}}{\sigma_{t-1}}$$

$$\Delta Price_t = \lambda_1 h_t + a + \sum_{j=1}^{J} b_j\, \Delta Price_{t-j} + \epsilon_t$$

With the exception of a number of observations, the model is a single lagged EGARCH –m (1, 1) model with a student t distribution estimated using the Maximum Likelihood method with a Marquandt optimization algorithm. However, due to an error with the optimization algorithm, which meant we used the BHHH rather than the Marquandt to estimate the US period 2 and German 2012 period 3 observations. We also encountered errors with respect to the distribution of the residuals in the model; hence, we used the normal distribution to estimate four of the sample periods 12F[21] and the Generalized Errors Distribution for the US 2012 period 4. Just like the GARCH model in section 4.4.1, we encountered errors with the single lagged system, which meant the use of two lags in the estimation model with respect to all the US 2012 with the exception of the pre-crisis period and Italian 2017 sample periods. However, looking at the German and Portuguese markets during the financial crisis closely, the statistics seem to be suggesting an error in the estimation of the β coefficients for both markets. We tried to use different estimation settings but couldnot get the correct estimation. Conversely, the use of new settings introduced in EViews 9 could solve theseissues. However, we did not have time to test the new settings, hence we just display the German and Portuguese estimated statistics obtained thru the use of EViews 8.1.

[21] German 2012 Period 3, Greek 2012 Period 2, Greek 2012 Period 4 and Spanish 2017 period 3

Table 84. *2012 Bond EGARCH-M Residuals Statistics (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999900	0.999331	0.999999	0.999638	0.999990	0.999906
Adjusted R^2	0.999899	0.999330	0.999999	0.999638	0.999990	0.999906
Jarque-Bera	241.92	164.05	1377.57	12622.57	783.95	524.20
Q-Statistics (Correlogram)	0.0005	0.0637	2.2926	0.2546	1.3633	0.0472
F-Statistics(ARCH Test)	0.198796	0.187648	3.221562	0.028781	0.018891	1.515810

As illustrated by Table 70, a key factor of note is the high R^2, which are above 0.99 through all the estimated EGARCH-M models, thus hinting at the lagged price differential with the estimated residuals being highly able to explain the movement in the price differential. Another factor is the significantly high adjusted R^2pointing at the estimated EGARCH-M model being a good fit to the dependent variable across all the markets. The Jarque-Bera test for all the samples seem to be hinting at a significant acceptance of the null hypothesis of non-normality in the distribution of the residuals. We found all our samples seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera statistics seem to be hinting at a varied set of results with the Greek and Italian markets being significantly greater than the other markets. Conversely, the German market is significantly lower than all the other markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at a significantly low correlation. At the single lagged level, the Q-statistic for all our samples does not rise above 2.2926 as observed by the Greek. Withthe exception of the Greek and Portuguese, the Q-statistics seem to be approaching zero, especially the US.

The F-statistics seems split between approaching no ARCH effect and low ARCH effect remaining. In essence, the two highest F-statistics are the Greek and Spanish markets. However, the other observed markets all have F-statistics lower than one, thus meaning approximately no ARCH effect remaining. Of note is the F-statistic of the Portuguese market, whichseems to be hinting at near zero ARCHeffect remaining.

Table 85. *EGARCH-M Statistics of the 2012 Bond (01/07/2002-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation λ	-19.48992 (5.659459)	16.55045 (3.578849)	-19.56909 (37.60378)	16.83725 (4.911288)	33.60185 (28.79731)	29.39833 (10.80412)
a	0.000073 (9.97E-06)	-0.0005740 (2.68E-05)	-0.0230610 (5.85E-06)	0.000163 (4.36E-05)	-0.000452 (1.95E-05)	0.000859 (4.38E-05)
b_1	-0.054230 (0.000189)	0.0328620 (0.000475)	0.0754340 (1.74E-05)	0.033158 (0.000310)	0.145163 (5.34E-05)	0.044967 (0.000169)
b_2	-0.042543 (0.000187)					
ϵ	1.000150 (0.000192)	0.9987240 (0.000490)	1.0000150 (1.86E-05)	0.999563 (0.000301)	1.000006 (5.48E-05)	0.999751 (0.000167)
Variance Equation ω	-0.064846 (0.014351)	-0.048553 (0.011806)	-0.572891 (0.078216)	-0.116668 (0.022977)	-0.420401 (0.082646)	-0.210595 (0.042733)
α	0.090640 (0.014472)	0.076715 (0.011699)	0.243006 (0.024986)	0.139255 (0.015247)	0.187736 (0.022564)	0.161352 (0.017858)
γ	-0.005809 (0.007984)	0.012944 (0.006829)	-0.067240 (0.016017)	-0.021769 (0.011059)	-0.033638 (0.014437)	-0.029898 (0.012182)
β	1.000578 (0.000634)	1.001075 (0.000621)	0.974899 (0.004581)	0.998887 (0.001615)	0.979996 (0.005318)	0.992713 (0.002990)
$\frac{\omega}{1-(\alpha+\beta)}$	0.710890	0.6241548	2.6290861	0.8445513	2.5063852	1.3669231
$\alpha+\beta$	1.091218	1.0777900	1.2179050	1.1381420	1.1677320	1.1540650
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	8	9	4	5	4	5
Log Likelihood	11962.04	10441.59	16408.25	10840.49	14287.56	11950.83

It is worth remembering Table 85 covers the period between 1st July 2002 and 31st December 2011 for the 2012 bonds, thus meaning it illustrates the behaviour of volatility during a period of changing market environment. In essence, the statistics in Table 85 are the generalised pointers to the behaviour of volatility in the observed 2012 government bonds. It must be noted that as illustrated by Table 29, the GARCH variant of our EMH test accepted the market efficiency for the observed US, Greek and Portuguese markets. However, it did also significantly accept the null hypothesis of the market being too volatile to be efficient for the remaining markets.

With the exception of the US and Greek markets, the λ coefficients seem to be hinting at a positive feedback effect. Remember a positive feedback hints at the returns increase with the risks; given that for long periods the risks in these markets were low, this does suggest that the returns were low. However, the opposite also holds true, when the risks are decreasing the returns are also decreasing. This may be the key to understanding the crises, especially the sovereign debt crisis, in the later part of the observational period. However, the US and Greek market have a negative feedback effect meaning as risk increases (decreases) returns decrease (increase). During the economic upturn/asset price bubble the risk on these bonds decreased, this meant that returns increased. Conversely, this may have continued during the financial crisis. However, during the sovereign debt crisis, the risk increased and hence the returns decreased, especially in the Greek market.

With the exception of the German market, the γ coefficients seem to be hinting at a leverage effect. This means that a negative shock carry greater impact than a positive shock to the market. This seems to be hinting at a number of influential events causing negative shocks in the observed markets. As will be illustrated later, this means the sovereign debt crisis conveys more weight with the GIPS markets while the pre-crisis period seem to be more influential with the US market. Since the financial and sovereign debt crisis did not have a significant negative impact on the US market during the observation. Since theory dictate that some markets, mainly risk free markets like the German market, experience an increase in the volatility from a positive shock to the pricing during a crisis. Thus, a possible explanationfor the positive asymmetrical effect in the German market is both crises increased the price and thus made the market highly volatile.

The level of sensitivity to market shocks seems to be hinting at a differentiated picture. Thus meaning with the exception of the US and German markets, the observed markets seem to be hinting at a relatively high level of sensitivity to market shocks. As previously hinted the shock to the price volatility in the GIPS markets came during the sovereign debt crisis. The α coefficients of the US and Germanmarkets are pointing at a low level of sensitivity to market shocks. As illustrated previously, we assume much of the shock to the US and German markets came from individual events causing Knightian uncertainty.

With the exception of the Greek and Portuguese markets, the β coefficients are pointing at highly persistence levels of volatility in the aftermath of a shock in the observed markets. As illustrated previously, significant hikes in the volatility blighted the Greek and Portuguese markets during the sovereign debt crisis hinting at a reactive market. However, by the omission of the sovereign debt crisis from the equation, both the Greek and Portuguese markets look to be more persistence. A known factor is that when the market is highly reactive as in high sensitivity to market shocks, the levels of persistence is relatively low and the opposite is equally true. This is importance because it explains the other observed markets, since as previously illustrated these market are not as reactive as the Greek or Portuguese markets. Therefore, the β coefficients seem to be hinting at highly persistence volatility in the aftermath of any shock to the market. In particular, the US and

German markets seems to be displaying the highest persistence levels.

The unconditional volatility seems to be hinting at a divided picture with regard to the observed markets. Whereas the US, German and Italian markets have relatively low unconditional volatility; the remaining observed markets seem to be pointing at significant levels of unconditional volatility. However, the unconditional volatility is significantly high for all the observed market. An explanation could be find in the ωcoefficient, which is significantly higher than previously observed. Conversely, all the observed markets do not revertto the unconditional volatility after a rise or fall. The evidence seems to be suggesting that with the exception of the US and German markets, the statistics are significantly higher than previously observed. However, the volatility half-life seem to be suggesting that the volatility in all observed markets tend to decay to half their levels significantly fast in the aftermath of a shock to the market.

It would seem to be that the negative feedback effect influenced the efficiency of both the US and Greek markets. However, if this is the case then, why did not the Portuguese market accept the null hypothesis, after all it is hinting at a highly positive feedback effect. The explanation is not with the asymmetrical or feedback effect, it is to do with the behaviour of market participants during the observation. It is obvious that the highly volatile events of the sovereign debt crisis in the later part of the observation played an influential part in the overall picture of the Greek and Portuguese markets. Conversely, the high volatility of the later stages of the observation did counter the effect of the low volatility in the rest of the observations. Since volatility is essentially the movement of the price, this would suggest that these two counter balances were significant enough to make the prices of these two markets accept the EMH. This could also explain the acceptance of the EMH by the US market, since the high volatility of the earlier period and the financial crisis counter balanced the low volatility during the asset price bubble and the maturity effect. The other observed markets may have been too volatile at some point of the observation to be efficient. This would hint at the overreaction/underreaction hypothesis playing a role in the efficiency of the market.

Table 86. *2012 Bond EGARCH-M Residuals Statistics (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.998055	0.999333	0.999999	0.999638	0.999990	0.999906
Adjusted R^2	0.998051	0.999331	0.999999	0.999637	0.999990	0.999906
Jarque-Bera	55.86	40.86	44.05	47.36	48.98	38.27
Q-Statistics (Correlogram)	60.63	0.16	0.11	0.20	0.20	0.19
F-Statistics(ARCH Test)	0.041863	0.258298	0.348886	0.136401	0.552330	0.371671

In essence, as illustrated by Table 86, the high R^2 and adjusted R^2 through all the estimated EGARCH-M models hint at all the models being a good fit to the dependent variable. Although the Jarque-Bera tests seem to be low, yet the statistics accept the null hypothesis of non-normality in the distribution. However, the Q-statistics seem to be suggesting that with the significant exception of the US, the observed markets have a very low serial correlation. The F-statistics are hinting at a very low ARCH effect. Conversely, the US market is hinting at the ARCH effect-approaching zero.

Table 87. *EGARCH-M Statistics of the 2012 Bond (01/07/2002-29/06/2007)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation λ	-3.149173 (2.210038)	18.98865 (6.997839)	427.4147 (163.1040)	28.22693 (9.840331)	163.5715 (58.79183)	49.10407 (18.64287)
a	0.000548 (0.000502)	-0.000827 (0.000232)	-0.023086 (1.15E-05)	-9.09E-05 (0.000175)	-0.000510 (3.25E-05)	0.000736 (9.96E-05)
b	-0.053412 (0.001175)	0.032208 (0.000695)	0.075342 (3.09E-05)	0.032224 (0.000507)	0.144987 (8.74E-05)	0.044319 (0.000262)
ϵ	1.000703 (0.001157)	0.999143 (0.000695)	0.999985 (3.10E-05)	0.999407 (0.000510)	0.999957 (8.66E-05)	0.999861 (0.000260)
Variance Equation ω	-0.036435 (0.016058)	-0.029680 (0.018290)	-0.030912 (0.030303)	-0.030242 (0.020236)	-0.031741 (0.026106)	-0.031495 (0.022706)
α	0.044060 (0.013495)	0.043634 (0.012487)	0.045550 (0.013406)	0.043850 (0.012861)	0.043774 (0.013049)	0.043995 (0.012837)
γ	-0.010118 (0.007872)	0.012498 (0.008243)	0.014311 (0.008381)	0.013259 (0.008170)	0.012619 (0.008415)	0.014061 (0.008274)
β	0.999847 (0.001146)	1.000527 (0.001409)	1.000327 (0.001631)	1.000448 (0.001515)	1.000221 (0.001570)	1.000315 (0.001585)
$\frac{\omega}{1-(\alpha+\beta)}$	0.829822	0.672086	0.673802	0.682694	0.721468	0.710788
$\alpha+\beta$	1.043907	1.044161	1.045877	1.044298	1.043995	1.04431
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	-16	-16	-15	-16	-16	-16
Log Likelihood	3617.665	4871.735	8875.005	5277.896	7538.044	6058.830

Remember that Table 87 covers the pre-crisis period between 1st July 2002 and 29th June 2007. Highly volatile events and a prolonged period of stability in the sovereign debt market blighted the period. The pre-crisis period came in the aftermath of a period of highly volatile events like the introduction of the Euro and the 11 September 2001 terrorists' attacks. However, notably the period also saw a prolonged economic upturn, which initiated the asset price bubble of the mid-2000s. Conversely, it must be noted that as illustrated by Table 31 the GARCH variant of our EMH test accepted the market efficiency for the observed US and Spanish markets. However, it did also acceptthe null hypothesis of the market being too volatile to be efficient for the remaining markets.

With the exception of the US market, the λ coefficients seem to be hinting at a positive feedback effect. Notably that a positive feedback hints at the returns increasing with the risks; given that for long periods, the risks in these markets were low, this does suggest that the returns were low. In many ways, the positive feedback effect was inherent due to the factors influencing the Eurozone economy and financial market. An important factor to note is that the high risks of the aftermath of the introduction of the euro influenced the early stage of the pre-crisis period. The implications were that market participants were unsure about the euro and did not want to invest in other Eurozone markets; this caused the prices to increase as risk increase. Another factor is that a prolonged economic upturn highlighted the later stages of the pre-crisis period, which led to an asset price bubble in some Eurozone markets. During prolonged economic upturns, market participants tend to go after high returns increasing their risk holdings and "safe" assets like sovereign debts tend to have low returns in comparison. A key factor to remember is the positive feedback effect also implies that the prices decrease as risks decrease.

However, the λ coefficient hints at the US market having a negative feedback effect meaning as risk increases (decreases) returns decrease (increase). Rather surprisingly, this implies that during the economic upturn and hence asset price bubble of the mid 2000s risk on these bonds decreased, this meant that returns increasedor to put it another way, risk increased and hence returns decreased. Whichever way you put it; this means that an illogical behaviour in the price blighted the asset price bubble during the pre-crisis period. Since, theory would suggestthat during a prolonged economic upturn or asset price bubble, prices and risks of so-called "safe" assets like sovereign debt would decrease. Of course, a possible explanation is that highly volatile events blighted the pre-crisis period, which led to increased risk in the US, and global financial market, thus decreasing risk and increasing prices in the observed US market. The overreaction/underreaction theory then dictates that a period of correction occurs, which decreases the price and increases the risk.

With the exception of the US market, the γ coefficients seem to be hinting at a positiveasymmetrical effect. Essentially, this hints at a positive shock to the market having an impact on the volatility, hence increasing the volatility. As hinted previously this seems to be the result of a number of factors influencing the Eurozone market. Essentially the aftermath of the introduction of the Euro and a number of highly volatile events like the 11 September 2001 terrorist attacks and following "war on terror" created Knightian uncertainty which made some market participants go on flight to safety to the five observed Eurozone markets. This also may explain the negative asymmetrical effect in the US market, the highly volatile events and asset price bubble during the pre-crisis period led to themarket participants leaving the US Treasuries market, which led to a negative shock to the market.

As illustrated by the GARCH model in Table 73, the α coefficients seem to be hinting at uniformly low levels of sensitivity to market shocks across the observed markets. Although there were some highly volatile events inducing Knightian uncertainty, yet the levels of sensitivity to market shocks were low throughout the observed markets. A key issue is how these statistics account for the aftershocks of some highly volatile events like the introduction of the Euro and the terrorist attacks of 11 September 2001. The behaviour of homo-sapiens to news with respect to time provides a possible explanation; the initial event causes shock but subsequent events decrease the level of sensitivity with time. Since both key sources of shocks to the market during the early parts of the decade occurred before our observational period i.e. the 1999 introductionof the Euro and 2001 terrorist attacks. While the aftershocks of these events, like "the war on terror" or the highly volatile financial markets in the aftermath of the euro, continued to provide volatility to the market. Yet the levels of sensitivity to these shocks were decreasing with time because market participants were accounting for them.

With the possible exception of the US market, the β coefficients are pointing at highly persistence levels of volatility in the aftermath of a shock in the observed markets. As already explained in the previous paragraph, with time the market participants were accounting for the aftershocks of both highly volatile events in the early part of the 21st century. This meant that the volatility was highly persistent in the aftermath of these two events. Of course looking at the pre-crisis period in figures 12 to 19 would tell us the persistent in the volatility eventually died during the asset price bubble/economic upturn.

The unconditional volatility is relatively low during the pre-crisis period. This does mean that the sovereign debt market was sTable. Although the US market seems to be higher than the observed Eurozone markets, yet it is still lower than all the observed periods in our EGARCH-m model. However, the unconditional volatility is still significantly high for all the observed market. As explained previously, the ω coefficient, which is still significantly higher than, previously observed in the GARCH model. Conversely, all the observed markets do not revert to the unconditional volatility after a rise or fall. This does seem to be suggesting that the volatility in all observed markets do not decay to half their levels in the aftermath of a shock to the market.

Interestingly, Table 31 seems to be hinting at the acceptance of the null hypothesis of the market being too volatile to be efficient for all the markets except the US and Spanish. However, the EMH test statistics of the markets that accept the null hypothesis seem to be suggesting that the different between the acceptance and rejection is significantly small. Conversely, Table 47; seem to be hinting at the GJR-GARCH variant of the EMH test rejecting the null hypothesis thru all the observed markets. This would suggest that the reaction of the market participants to the events influenced the efficiency of the market during the pre-crisis period. As stated earlier the key to understanding the behaviour of market participants is the reaction to theaftershocks of the two most influential events: the introduction of the euro and 2001 terrorist attacks. These seem to be consistent with the addition of the asymmetrical effect and hint at the overreaction/underreaction hypothesis, since as time goes by the overreaction to these aftershocks seem to be morphing into an underreaction. This would suggest that the efficiency of the market depends on a simple different between the over- and under-reactionof the market participants.

Table 88. *2012 Bond EGARCH-M Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Po0rtuguese*	*Spanish*
R^2	0.999902	0.999347	0.999999	0.999641	0.999990	0.999907
Adjusted R^2	0.999901	0.999344	0.999999	0.999639	0.999990	0.999906
Jarque-Bera	190.09	90.86	394.60	35.91	62.40	34.2620
Q-Statistics (Correlogram)	0.0033	0.0073	0.2284	0.1782	0.0021	0.0685
F-Statistics(ARCH Test)	1.302303	0.006349	0.173096	0.001792	0.001125	0.20583

As illustrated by Table 88, the high R^2 and adjusted R^2 through all the estimated EGARCH-M models hint at all the models being a good fit to the dependent variable. Although with the exception of the US and Greek markets, the Jarque-Bera tests seem to be slightly high indicating a slightly significant acceptance of the null hypothesis of non-normality in the distribution. Yet the Jarque-Bera statistics of the US and Greek markets seem to be indicating a significantly higher acceptance of the null hypothesis. However, the Q-statistics seem to be hinting at significantly low serial correlations thru all the markets. Of course, the Q-statistic of the Italian market is higher than the other observed markets. Conversely, the US market is significantly lower. The F-statistics are hinting at significantly low ARCH effect with the German Italian and Portuguese markets pointing at the ARCH effect-approaching zero.

Table 89. *EGARCH-M Statistics of the 2012 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation λ	-22.288 (18.96065)	-322.1832 (140.12960)	-2191.51 (1713.178)	16.63086 (22.10678)	-2264.027 (5473.716)	46.85389 (38.53333)
a	-0.000059 (0.000153)	0.008639 (0.003613)	-0.02291 (1.10E-04)	0.000404 (0.000239)	0.00073 (2.72E-03)	0.000948 (0.000159)
b_1	-0.054030 (0.000383)	0.035436 (0.000896)	0.075404 (3.84E-05)	0.032793 (0.000691)	0.14504 (0.000111)	0.044377 (0.000348)
b_2	-0.042537 (0.000369)					
ϵ	0.999494 (0.000392)	0.998562 (0.000889)	1.000039 (4.01E-05)	1.00006 (0.000712)	1.000153 (0.000114)	0.999791 (0.000368)
Variance Equation ω	-0.0940 (0.072465)	-15.667860 (1.838161)	-4.789022 (9.88E-01)	-0.063721 (0.07376)	-18.360070 (8.383459)	-0.039629 (0.074717)
α	0.089066 (0.03107)	0.092854 (0.043000)	0.110245 (7.08E-02)	0.088110 (0.027815)	0.045862 (0.099951)	0.076519 (0.025648)
γ	-0.042200 (0.019978)	0.065322 (0.027464)	0.008634 (0.035056)	-0.000977 (0.018781)	-0.001888 (0.021283)	-0.003653 (0.019013)
β	0.997937 (0.005467)	-0.480180 (0.175129)	0.715590 (0.059910)	1.000418 (0.005652)	-0.262267 (0.578161)	1.001584 (0.005378)
$\frac{\omega}{1-(\alpha+\beta)}$	1.080101	-11.293568	-27.497	0.719784	-15.093715	0.507394
$\alpha+\beta$	1.087003	-0.387326	0.825835	1.088528	-0.216405	1.078103
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	8	Error	-4	8	Error	9
Log Likelihood	2704.064	2348.729	4215.287	2623.282	3593.078	2915.544

It is worth noting that Table 89 is associated with the financial crisis and hence some markets may have experienced flights to them. In essence, the statistics are reflecting the mixed reaction associated with such a crisis. The crisis seems to suggest that although there was a uniformed hike in volatility, the levels of the volatility seem to be telling. Remember the GARGH variant of our EMH test hints at the significant acceptance of the null hypothesis of the market being too volatile to be efficient for all the observed markets during the financial crisis as demonstrated by Table 33. As pointed earlier there was problem with the estimation of the

German and Portuguese markets, which meant that the statistics displayed in Table 89 did not paint the full picture.

With the exception of the Italian and Spanish markets, the λ coefficients seem to be hinting at a negative feedback effect. This means that during the financial crisis the observed markets were displaying decreasing risks and increasing returns. As demonstrated earlier, the financial crisis meant that market participants went on a flight to safety from the risky assets (such as equities, corporate bonds and asset-backed securities i.e. MBS and CDO) to presumed "risk free" assets such as sovereign debt and commodities i.e. Gold and Oil. This increased the price leading to a decrease in the yield in the sovereign debt market. However, more interestingly is the US Federal Reserves' response to the financial crisis, which came in the shape of Quantitative Easing. This had the impact of further increasing the price of the US Treasury and decreasing the yields. This is important because the yields are a key measure of risk in the bond market. The ECB did not introduce quantitative easing until the later stages of the sovereign debt crisis but did introduce a number of monetary easing policies. Conversely, it was obvious that monetary policy on its own was never going to be enough to counter the huge systemic issues in the economy. Hence, many central governments introduced fiscal stimulus policies, which increased the supply dramatically. Under the circumstances of the financial crisis, there was a huge demand for these assets, so the increase in supply matched the increase in demand.

In general, the Italian and Spanish markets seem to be hinting at risks increasing with the returns during the financial crisis. This is due to deep-rooted problems in their economies, according to statistics from the European Central Bank and Eurostat obtained on 17 March 2014, both had structural problems in their economies before the financial crisis, in particular the Italian economy, which was weak and highly indebted for a long period before the financial crisis. Although the Spanish economy was performing much better than most of the Eurozone economies, yet it had grown at a faster rate than was sustainable and was relying on the financialsector more heavily than usual. Hence, with the advent of the financial crisis, these issues highlighted in Table 89. However, although the risks increased the prices continued to increase during this period, this is mainly due to market participants fleeing other financial markets. The sad thing is that the financial crisis left many market participants in such a state of freight that they could not see the obvious weakness of the fundamentals underpinning the sovereign debt market in general. This seem to be pointing at the underreaction theory,it is important to note that due to the financial crisis many market participants underreacted to the fundamentals in the sovereign debt market in general with the possible exception of the German market.

Rather surprisingly with the exception of the German and Greek markets, the γ coefficients are pointing at a negative asymmetrical effect during the financial crisis. This would suggest a negative shock to the market would increase volatility, whichseems to be hinting at a move away from the market. However, during the financial crisis market participants were reacting to events influencing other markets, whichwould hint at a positive shock to the market influencing the volatility consistent with the German and Greek markets. A possible explanation as hinted previously is since a key behavioural factor influencing market participants as with any homo-sapiens dictates that shock levelsin the aftermath of a major event decrease with time. This means that as time goes by the market participants seem to overlook any associated event mainly due to accounting to risk factors. This would suggest that at some stage the fundamentals became more important in the sovereign debt market. Since these fundamentals are the economic indicators in the sovereign debt market, hence towards the end of the financial crisis period attention turned to the economic recession and large debts of the countries. The German and Greek markets displayed a positive asymmetrical effect because the market participants were either already accounting for the weakness of the economy as in the Greek market or were assured by the strength of German economy. Another issue is with the financial sector and many corporations in need of huge capital injection to survive, the governments of the observed markets were forced to follow a capital inject policy. This did not have a significant impact on the German economy as illustrated by statistics from the Competition division of the European Commission.

With the exception of the Greek market, the α coefficients seem to be hinting at a low level of sensitivity to market shocks. However, the coefficients of the US, German and Italian markets seem to be hinting at a higher level of sensitivity to market shocks than the Spanish and certainly the Portuguese markets. Although the German and Portuguese market have estimation issues which discounts them. The other observed markets are interesting because they seem to be backing the earlier findings in the GARCH model that in general the sovereign debt market was not sensitive to the financial crisis. As previously explained, this could be due to market participants becoming accustomed and accounting for the events during the financial crisis with time. Although the α coefficients still seem to be hinting at market participants reacting to major events, such as the Lehman Brothers bankruptcy, during the financial crisis. This could be hinting at a weakening in the aftermath of these major events with respect to time. However, the Greek market is surprising; nevertheless, a look at the recapitalization statistics from the Competition division of the European Commission would illustrate the extent of the impact on the Greek financial sector.

The influencing factor to bear in mind is that the statistics for the German and Portuguese markets were estimations that seem to contain errors. The β coefficients of the remaining markets are hinting at a significantly high level of persistent in the aftermath of a shock in all the remaining observed markets except for the Greek market. As explained previously, the sovereign debt markets were the subjects of a flight to safety and in the case of the US market quantitative easing policy in the later stages. These made volatility highly persistent in the aftermath of crises such as the Lehman Brothers bankruptcy and the near collapse of the global banking system. The long lasting recession in the economies of the observed markets made the impact on the persisting volatility worse. This is the key to understanding the persisting volatility an unprecedented cocktail of three crises in a short period: Financial crisis, freezing of credit and economic downturn. As illustrated by the α coefficient, the Greek market was highly reactive to market shockshence the low volatility persistent in the aftermath of a crisis.

As previously explained, we omit the German and Portuguese markets. However, the Greek market also seems to be hinting at a negative unconditional volatility, which is inconsistent with both practice and theory. Looking at the unconditional variance equation, there is a combination of two factors leading to the negative unconditional variance: the negative intercept ω and a low β coefficient. Conversely, the remaining observed markets seem to be hinting at a low unconditional volatility during the financial crisis except for the US market. This does mean that these two sovereign debt markets weres Table during the financial crisis. A key factor influencing the high volatility in the US market is the significant ω coefficient. Conversely, all the observed markets do not revert to the unconditional volatility after a rise or fall. However, thestatistics seem to be suggesting that the volatility in all these markets tend to decay to half their levels rather quicker than expected under the circumstances in the aftermath of a shock to the market.

A key factor during the financial crisis is the significant acceptance of the null hypothesis of the markets being too volatile to be efficient throughout the observed markets using both GJR-GARCH and GARCH models. This would suggest that market participants were reacting to events like the Lehman Brothers bankruptcy hinting at flights to safety being the paramount movement of the price volatility. However, as we discovered that earlier the problem is that with the exception of the Greek market, the sensitivity to market shock was relatively low. This seems to be pointing to the persistent as the main source of the high volatility in the markets. The assumption that during deep crisis market participants start accounting provides a clue for the worst-case scenario. This means that they become less willing to take risksand hence persist with their strategy of investing in "risk-free" assets, which push prices further from the fundamental value. The influencing factor is that market participants are reacting to event rather than information, which is not consistent with the efficient market hypothesis. Another influencing factor is that the fundamentals by the policies of the central banks and governments such as quantitative easing distorted markets, especially the US.

Table 90. *2012 Bond EGARCH-M Residuals Statistics (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999874	0.999329	0.999999	0.99966	0.999990	0.99991
Adjusted R^2	0.999873	0.999326	0.999999	0.999658	0.999990	0.99991
Jarque-Bera	6.94	88.12	95.84	3901.59	295.16	304.55
Q-Statistics (Correlogram)	1.3116	0.1691	4.8436	0.6149	1.4748	0.039
F-Statistics(ARCH Test)	0.425887	6.171794	0.099635	0.077604	0.708057	1.897639

As illustrated by the previous Tables, the high R^2 and adjusted R^2 through all the estimated EGARCH-M models hint at all the models being a good fit to the dependent variable. Although with the exception of the US market, the Jarque-Bera tests seem to be indicating a significant acceptance of the null hypothesis of non-normality in the distribution especially for the Italian market. Yet the Jarque-Bera statistic of the US market seems to be indicating a significantly lower acceptance of the null hypothesis. However, with the exception of the Greekmarket, the Q-statistics seem to be hinting at the serial correlations being significantly low thru all markets. Of course, the Q-statistics of the Greek market is significantly higher. Conversely, the Spanish market is significantly low. The F-statistics are hinting at a mixed picture with the German market pointing at a highly significant ARCH effect. The remaining markets hinting at low ARCH effects, especially the Greek and Italianmarkets with F-statistics approaching zero.

Table 91. *EGARCH-M Statistics of the 2012 Bond (02/11/2009-30/12/2011)*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation λ	378.5658 (79.34670)	31.6328 (42.03145)	0.517743 (18.04759)	42.19234 (25.50394)	6.055649 (16.24672)	1.167815 (28.53369)
a	0.000127 (1.69E-05)	-0.000575 (0.000039)	-0.02311 (1.47E-05)	0.000104 (5.34E-05)	-0.000477 (2.69E-05)	0.000897 (5.05E-05)
b_1	-0.053556 (0.000399)	0.033785 (0.000947)	0.075498 (1.89E-05)	0.034393 (0.000561)	0.145388 (8.28E-05)	0.046627 (0.0003)
b_2	-0.041101 (0.000385)					
ϵ	1.001373 (0.000416)	0.997818 (0.001033)	1.000305 (1.71E-05)	0.998909 (0.000518)	1.000004 (9.16E-05)	0.999325 (0.000301)
Variance Equation ω	-0.042546 (0.071134)	-0.088817 (0.045426)	-1.709489 (1.91E-01)	-0.494382 (0.156981)	-0.971962 (0.261689)	-1.077196 (0.342525)
α	0.063626 (0.024713)	0.080527 (0.027834)	0.836698 (6.18E-02)	0.115269 (0.043459)	0.526789 (0.171264)	0.355526 (0.085266)
γ	0.041296 (0.017134)	0.013751 (0.015021)	-0.055593 (4.33E-02)	-0.188233 (0.037287)	-0.130850 (0.069734)	-0.142718 (0.046638)
β	1.000725 (0.003537)	0.998406 (0.002739)	0.923878 (0.012182)	0.969247 (0.011095)	0.947865 (0.017802)	0.937737 (0.023615)
$\frac{\omega}{1-(\alpha+\beta)}$	0.661155	1.125220	2.247624	5.849567	2.047727	3.673140
$\alpha+\beta$	1.064351	1.078933	1.760576	1.084516	1.474654	1.293263
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	-11	9	1	9	2	3
Log Likelihood	3717.960	3188.029	3337.761	2996.474	3193.632	3040.268

It is worth noting that Table 91 is associated with the sovereign debt crisis and hence as expected, there is a difference in general between the Eurozone markets and US. In essence, the statistics seem to be reflecting this different. Interestingly Table 35 illustrates the GARCH variant of our EMH test accepted the market efficiency for the observed Greek and Portuguese markets. However, it did also significantly accept the null hypothesis of the market being too volatile to be efficient for the remaining markets.

The λ coefficients seem to be hinting at a positive feedback effect for all the observed markets. Unlike the financial crisis period, this means that all observed markets were hinting at the return increasing with the risks during the sovereign debt crisis, with the increase in debt due to the recapitalization programs and fiscal stimulus policies in the advent of the financial crisis and economic recession. In the aftermath of the Greek revision market participants became increasingly aware of the weaknesses in the economy of many of the observed markets. This heightened the risk aversion to sovereign debt markets as fear spread of the quality and more importantly ability of many of these countries to service the debt. Against this background, the feedback effect observed in the markets seems to be suggesting market participants were reacting to news as well as the fundamentals. Yet surprisingly, the λ coefficients seem to be pointing at a positive feedback effect in the GIPS markets. There are two explanations for this and both are linked with the timing of the observed period, the first is as explained earlier the maturity effect which dictates as any plain vanilla type bond approaches maturity the price approaches par value. The second is the 2012 bond matured in 2012 and thus ignoringthe full impact of the sovereign debt crisis, since the crisis did not affect the Italian and Spanish markets until the later stages. Although the Greekand to a lesser extent Portuguese markets seem to be hinting at a positive feedback effect, the coefficient is insignificantly low. This seem to be hinting at indifferent and hence uncertainty underpinning the Greek and Portuguese markets.

In essence, the positive feedback effect in theUS and German markets seem to be consistent with a flight, asdemand increased the price increased and hence volatility increases since as explained previously volatility is the movement of the price. However, the USmarket was at the centre of a deepening crisis with the high and increasing federal debt and deepest recession for over 80 years, market participants were concerned about the high ratings. Of course, an influencing factor mentioned previously is the continuation of the quantitative easing policy by the Federal Reserve, whichmay have distorted the market by decreasing supply. In addition, the weakness of the global financial market and economy meant that not until later were these concerns illustrated. Conversely, the maturity effect meant that prices move towards par value by default towards the end and hence volatility was falling, although as the statistics from Eurostat on 17 March 2014 would illustrate the German sovereign debt was the highest in the Eurozone. Yet the strength of the German economy and the relatively insignificant impact of the financial crisis on the German economy meant the visualisation of the Bund market as the risk-free asset in the Eurozone financial market.

With the exception of the German and US markets, the γ coefficients seem to be hinting at a leverage effect. This would suggest a negative shock to the market would increase volatility, which hints at a move away from the GIPS markets. In essence, construed as what actually happened in the GIPS markets during the sovereign debt crisis. As hinted previously, the Greek crisis of late autumn 2009 made market participants increasingly aware of the systemic issues underpinning theeconomies of the GIPS markets. However, there was another factor influencing the behaviour of market participants in the aftermath of the financial crisis, Kimball (1993) states that market participants bearing one risk are less likely to bear another risk. Hence, as Diamond & Stiglitz (1974) argue increasing risks leads to an upward shift in risk aversion. This would suggest that market participants who already had a heightened risk aversion from the financial crisis reacted to the sovereign debt crisis strongly. There is a hint of the overreaction hypothesis in that market participant were overreacting due to the events of the financial crisis. However, the fundamentals would suggest this is not the case, since as mentioned earlier the economies of the GIPS nations were systematically weak and their debt had increased causing the market participant to doubt whether they would be able to pay it. In the end, it is a combination of the two factors that gave rise to the sovereign debt crisis and hence the domino effect.

Theoretically, the positive asymmetrical effect of the US and German markets seem to be reflecting the norm. In essence, the presumption isthese two markets being risk-free and hence as theory dictate that during a crisis market participants usually invest in risk free assets. However, at the time the US economy was weak and the total debt high and increasing according to statistic from the Federal Reserve Bank of St Louis. So the fundamental information underpinning the US market was hinting at a weak market. Essentially, this goes back to the upward shift in the risk aversion to the financial market and especially the Eurozone sovereign debts. This highlights the market participants' reaction to the fundamental information at the centre of the US market, which points at the underreaction hypothesis. Conversely, the action of the market participants seems to suggest that the Eurozone crisis was of greater concern than the US economy. Essentially, the US Fiscal Cliff crisis did not affect the US market until the later stages and hence it did not affect the observed US 2012 bond. Since the sovereign debt crisis did not affect the German market and the economy remained strong throughout the observed period despite some concerns about the size of the debt. This seems to be hinting the market participants saw the German market as the risk free asset of the Eurozone. Hence, the positive asymmetrical effect during the sovereign debt crisis seem to be a reaction to the hike in the risk factors of the GIPS markets, in short a flight to the safety of the German market.

The level of sensitivity to market shocks seems to be hinting at a differentiated picture. Thus meaning with the exception of the US and German markets, the observed markets seem to be hinting at a significantly high level of sensitivity to market shocks. As previously hinted the shock to the price volatility in the GIPS markets came during the sovereign debt crisis. The α coefficients of the US and German markets is pointing at a low level of sensitivity to market shocks. As illustrated previously, we assume much of the shock to the US and German markets came from individual events causing Knightian uncertainty in other markets such as the GIPS markets. The resulting shocks from the flight to safety to the US and German markets were low because as already illustrated the markets were already high from the financial crisis.

With the exception of the US and German markets, the β coefficients are pointing at low persistence levels of volatility in the aftermath of a shock in the observed markets. As illustrated previously, significant hikes in the volatility blighted the GIPS markets throughout the sovereign debt crisis hinting at a highly reactive market. Essentially, the GIPS markets were at the centre of the Sovereign debt crisis, so they are more likely to be reactive as each event lead to an increase in the volatility. Hence, as explained previously, a highly reactive market means the levels of persistence is relatively low and the opposite is true. Conversely, this explains the persistent levels in the US and German markets, since as previously illustrated these markets were not reactive. Hence, their β coefficients seem to be hinting at highly persistence levels of volatility in the aftermath of any shock to the market. A possible explanation is that market participants tend to hold these assets for the longer periods during a long lasting crisis. Of course, another possible explanation, especially with the US market, is the distortion of the monetary policy.

The unconditional volatility seems to be hinting at a divided picture with regard to the observed markets. Whereas the US and to a lesser extent German markets have relatively low unconditional volatility; the observed GIPS markets seem to be pointing at significant levels of unconditional volatility. Conversely, all the observed markets do not revert to the unconditional volatility after a rise or fall. However, with the exception of the US market, the volatility half-life seem to be suggesting that the volatility in the observed markets tend to decay to half their levels significantly fast in the aftermath of a shock to the market, especially the Greek and Portuguese markets. The negative half-life of the US market is pointing at a very persistingvolatility, which does not revert to half–life.

As noted earlier rather surprisingly, the EMH test statistics in Table 35 and 55 hint at the rejection of the null hypothesis of the markets being too volatile for the Greek and Portuguese markets during the sovereign debt crisis period. However, Table 91 seem to be backing the evident found using the GARCH model, as illustrated by Table 77, which the Greek and Portuguese markets seem to be very reactive to market shocks and exhibit a low volatility persistence in aftermath of a crisis with a significantly low half-life. However, to a certain extent this is true of the other GIPS markets. The efficiency test seem to be hinting that during the sovereign debt crisis, the high reaction of the market participants to the crisis in the observed Greek and Portuguese markets may have played a role in the efficiency. This would seem to be plausible since at the basic level the market participants were reacting to the fundamental information.

Table 92. *2017 Bond EGARCH-M Residuals Statistics (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990836	0.999976	0.999918
Adjusted R^2	0.999999	0.999999	0.990811	0.999976	0.999918
Jarque-Bera	101.24	21.09	932.62	18710.23	601.13
Q-Statistics (Correlogram)	0.1433	0.0758	0.2582	1.5301	0.0183
F-Statistics(ARCH Test)	1.439902	1.299904	0.430832	0.76054	0.252997

As illustrated by Table 92, a key factor of note is the high $R^2$and adjusted R^2. The R^2 is above 0.99 through all the estimated EGARCH-M models, thus hinting at the lagged price differential with the estimated residuals being highly able to explain the movement in the price differential. The significantly high adjusted R^2 seem to be pointing at the estimated EGARCH-M model being a good fit to the dependent variable across all the samples. An interesting point to note is that the $R^2$and adjusted $R^2$of the IPS markets are lower than the US and German markets.

The Jarque-Bera test for all the markets seem to be hinting at an acceptance of the null hypothesis of non-normality in the distribution of the residuals. We found all our samples seem to follow a leptokurtic distribution, which hints at the Student t distribution model. However, the Jarque-Bera tests for the IPS markets seem to be excessively high indicating a significant acceptance of the null hypothesis of non-normality in the distribution especially for the Portuguese market. Yet the Jarque-Bera statistic of the US and German markets seem to be indicating a significantly lower acceptance of the null hypothesis in comparison with the observed IPS markets.

With regard to the serial correlation, the Q-statistics of the correlogram seem to be hinting at low serial correlations thru all markets. Of course, the Q-statistics of the German and Spanish markets are lower than the other observed markets.

The F-statistics arediverting between approaching no ARCH effect and low ARCH effect remaining. In essence, the F-statistics are approaching zero ARCH effect with all the IPS markets.

Table 93. *EGARCH-M Statistics of the 2017 Bond (02/07/2007-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation λ	-84.018 (63.56287)	-93.06015 (128.28010)	-1.288607 (0.783721)	-1.586273 (8.039033)	-15.68134 (10.39978)	-84.018 (63.56287)
a	0.013452 (6.63E-06)	0.012495 (1.53E-05)	0.007147 (0.001016)	0.000307 (7.57E-05)	0.004415 (1.40E-04)	0.013452 (6.63E-06)
b_1	-0.060865 (2.12E-05)	0.067351 (2.68E-05)	0.175976 (0.002000)	0.255225 (8.24E-05)	0.190713 (0.000211)	-0.060865 (2.12E-05)
b_2			-0.069482 (0.002097)			
ϵ	1.000047 (2.29E-05)	1.000034 (2.85E-05)	0.994131 (0.001885)	0.99985 (8.90E-05)	1.000358 (0.000206)	1.000047 (2.29E-05)
Variance Equation ω	-0.1008 (0.035905)	-0.141980 (0.062205)	-0.268611 (0.051102)	-0.783723 (0.156946)	-0.314152 (0.081069)	-0.1008 (0.035905)
α	0.115993 (0.020021)	0.093484 (0.018273)	0.161890 (0.028096)	0.287761 (0.041443)	0.115877 (0.022235)	0.115993 (0.020021)
γ	-0.003760 (1.30E-02)	-0.019726 (0.012436)	0.102326 (0.019389)	0.060384 (0.023675)	0.104314 (0.01639)	-0.003760 (1.30E-02)
β	0.999443 (0.001796)	0.995706 (0.003470)	0.977291 (0.006321)	0.949239 (0.012393)	0.979625 (0.006749)	0.999443 (0.001796)
$\frac{\omega}{1-(\alpha+\beta)}$	0.873125	1.591882	1.929940	3.306848	3.289481	0.873125
$\alpha+\beta$	1.115436	1.089190	1.139181	1.237000	1.095502	1.115436
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	6	8	5	3	8	6
Log Likelihood	9781.605	9818.658	2965.985	6783.002	6319.375	9781.605

It is worth remembering that the 2017 bonds cover the period between 1st July 2007 and 31st March 2013, thus meaning it illustrates the behaviour of volatility during a highly volatile market environment based on the financial and sovereign debt crises. In essence, the statistics in Table 93 are the generalised pointers to the behaviour of volatility in the observed 2017 sovereign debt markets during the crises period. As previously hinted, there was a division inthe observed markets between the IPS markets, which were at the heart of the sovereign debt crises, and the US/Germany markets. An influencing factor is by analysing the behaviour of volatility of these 2017 bonds, we could overcome the maturity effect and thus extend our analysis of the sovereign debt crisis. Remember the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the observed markets except for the German as demonstrated by Table 37.

As illustrated by Tables 85 and 93, the λ coefficients are hinting at a change in the feedback effect of the observed Eurozone markets from positive to negative during the crisis. There are a number of explanations for the change, chief among these is the 2017 bonds were issued just before the 2007/2008 financial crisis and do not mature until 2017. In other words, the maturity effect will not distort the results; however, this does introduce the "on the run" effect, whicheven under normal market conditions heightens volatility. Conversely, the 2017 bonds cover more of the Eurozone sovereign debt crisis and the impacton the Italian and Spanish markets. Not surprisingly, the US market remains negative; the key to this is the expansion of the period to cover a major part of the fiscal cliff crisis.

As illustrated by Tables 85 and 93, the points highlighted by the previous paragraph also changed the γ coefficients thru all the observed Eurozone markets with the US market remaining negative. This seem to be suggesting that with the exception of the German market, the full impact of the crisis did make market participants react more to negative shock than positive shocks. This in reality is more in common with human nature; homo-sapiens always overreact more to negatives events than to positive events. In fact, they seem to underreact to positive events. Coincidentally, for reason explained earlier, the German market did not have any significant negative impact during the crises period.

With the exception of the Spanish market, the crises period also saw an increase in the level of sensitivity to market shocks observed by the markets. However, the levels of sensitivity in the German market remained insignificant. Notably the Spanish market did not feel the impact until the later stages of the crises as explained earlier. This means during the on the run stage of the Spanish 2017 bond, the market was under normal condition and since the on the run stage of the 2012 bond came in the aftermath of the introduction of the Euro, this may have played a part inthe different levels of sensitivity observed in the Spanish market.

The β coefficients are pointing at the reduction of persistence levels of volatility in the aftermath of a shock in all observed markets. This hints at the market participants in the IPS markets exhibiting an increasingly reactivebehaviour during the crisis period. Although the persistence levels of the US and German markets were reduce, yet they are still significant. This is due to these two markets acting as safe havens from the financial and to a certain extent the sovereign debt crisis. The reduction in the sensitivity was mainly due to the extended period of the sovereign debt crisis. In essence, with the possible exception of the Portuguese market, the impact from the worse stage of the sovereign debt crisis did not hit the observed markets until the later stages especially the US, Italian and Spanish markets.

The unconditional volatility seems to be hinting at an increase in all observed markets. Although with the exception of the US market, the increased does signify a significantly more volatile market in the long term. This is mainly due to the indecision and communication issues by the politicians during the sovereign debt crisis in the Eurozone. Unsurprisingly all the observed markets still do not revert to the unconditional volatility after a rise or fall. Although, the volatility half-life seem to be suggesting that the volatility in all observed markets tend to decay to half their levels significantly fast in the aftermath of a shock to the market. However, the Spanish market did show an increase in the half-life.

According to Table 37, with the exception of the German market, the EMH test statistics seem to be pointing at the acceptance of the EMH under the GARCH model. However, even the German market only narrowly rejects the EMH. Yet according to Table 59, all observed markets accept the EMH under the GJR-GARCH Model. As explained earlier, the key to understanding the reaction lays with the behaviour of market participants during the observation. It is obvious that the highly events volatile of the later stages in the sovereign debt crisis played an influential part in the overall picture of the markets. In general, psychological behavioural theories dictates that homo-sapiens take one of two routes when faced with uncertainty; either they accept the information or reject the information. For reasons explained previously, during the crises period, the market participants took the first option, which led to an efficient market.

Table 94. *2017 Bond EGARCH-M Residuals Statistics (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990702	0.999975	0.999916
Adjusted R^2	0.999999	0.999999	0.99064	0.999975	0.999915
Jarque-Bera	122.07	11.49	16.10	9.18	0.8
Q-Statistics (Correlogram)	0.0593	0.0474	0.2373	0.3428	0.0003
F-Statistics(ARCH Test)	0.44949	0.405597	0.031952	0.034316	0.004194

The high R^2 and adjusted R^2 hint at all the models being a good fit to the dependent variablethrough all the estimated EGARCH-M models. Although the Jarque-Bera tests for the US market, seems to be high in comparison with the Eurozone markets indicating a significant acceptance of the null hypothesis of non-normality in the distribution. Yet the Eurozone markets, especially the Spanish, seem to be low hinting at a distribution approaching normality. Additionally, the Q-statistics seem to be pointing at significantly low serial correlation for all the observed markets. Conversely, the F-statistics are hinting at an ARCH effect-approaching zero with all the markets, especially the IPS markets.

Table 95. *EGARCH-M Statistics of the 2017 Bond (02/07/2007-30/10/2009)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation λ	1514.000 (1078.532)	-264.5028 (843.95850)	-8.761215 (4.504204)	392.3102 (283.82)	-14.54099 (51.0342)	1514.000 (1078.532)
[a	0.012870 (3.84E-04)	0.01252 (1.57E-04)	0.013265 (0.004255)	-0.001086 (9.43E-04)	0.004183 (5.10E-04)	0.012870 (3.84E-04)
b_1	-0.060832 (3.28E-05)	0.06731 (4.31E-05)	0.167389 (0.003780)	0.255873 (1.91E-04)	0.191746 (3.80E-04)	-0.060832 (3.28E-05)
b_2			-0.063313 (0.003842)			
ϵ	1.000097 (3.53E-05)	1.000056 (4.56E-05)	0.990627 (0.003685)	0.999906 (1.95E-04)	1.00002 (3.94E-04)	1.000097 (3.53E-05)
Variance Equation ω	-21.6580 (3.268085)	-23.291120 (6.718371)	-0.381878 (0.180604)	-2.036129 (0.04983)	-0.140734 (0.111448)	-21.6580 (3.268085)
α	0.143334 (0.083335)	0.154669 (0.111639)	0.080846 (0.038253)	0.087042 (0.052679)	0.056298 (0.026393)	0.143334 (0.083335)
γ	0.063527 (0.041879)	-0.007164 (0.057158)	0.070786 (0.034224)	0.019270 (0.026072)	0.004552 (0.019458)	0.063527 (0.041879)
β	-0.452525 (0.221569)	-0.495539 (0.434989)	0.953762 (0.0245)	0.844046 (0.005432)	0.991611 (0.008789)	-0.452525 (0.221569)
$\frac{\omega}{1-(\alpha+\beta)}$	-16.543010	-17.370155	11.034385	-29.546799	2.937527	-16.543010
$\alpha+\beta$	-0.309191	-0.340870	1.034608	0.931088	1.047909	-0.309191
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	Error	Error	20	-10	15	Error
Log Likelihood	3649.347	3845.962	1259.379	2974.306	2635.723	3649.347

It is worth noting that this period is associated with the financial crisis and hence some markets may have experienced flights to them. In essence, the statistics in Table 95 are reflecting the mixed reaction associated with such a crisis. The crisis seems to be giving the impression that the US/German markets are more volatile than the IPS markets. However, this seems to be an illusion with the high levels of volatility during the sovereign debt crisis affectedIPS markets. Remember the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the observed markets except for the Italian as demonstrated by Table 39. The Influencing factor is the impact of the "on the run" effect on the observed markets during the financial crisis. And as noted by Tables 89 and 95 whereas the German and Portuguese markets were not sTable in the observed 2012 bonds, the 2017 bonds seem to be hinting at the US and German markets being unsTable. So in essence, the EGARCH-M estimated model seems to be hinting at the inclusion of the asymmetrical effect making the German market too unsTable during the financial crisis.

Tables 89 and 95 are hinting that apart from Germany, the λ coefficients seem to be pointing at a change in the feedback effect with the US and Portuguese markets changing to a positive feedback. In contrast, the Italian and Spanish markets now exhibit a negative feedback effect. Since the period is the same, a possible explanation is that the "on the run" effect may have affected the markets during the financial crisis.

With the exception of the German market, the γcoefficients are pointing at a change to a positive asymmetrical effect in Table 95 from a negative in Table 89. Interestingly the German market changed from a positive to a negative effect. However, during the financial crisis market participants were reacting to events influencing other markets, which would hint at a positive shock to the market influencing the volatility consistent with all the observed markets except for the German. A possible explanation as hinted previously is the financial crisis occurred during the early stages of the observation and hence the on the run effect must account for the majority of the change.

With the exception of the Italian and Spanish markets, the α coefficients are hinting at an increase in the levels of sensitivity. Since the US and German markets are benchmark markets, in essence this means during the on the run stage the markets are highly reactive and during the initial stages of a financial crisis there was a high amount of uncertainties. This means that during the financial crisis market participants were going on flights to safety by investing in these highlyliquid markets. Notably these markets are highly liquid when new as time goes by they become less liquid. As previously stated, the IPS markets are more risky, hence although they are highly liquid during the "on the run" stage relative to other stages. Yet the financial crisis meant that they were not as reactive as the US and Germanmarkets.

Although one would suspect that the persistent levels as hinted by the β coefficients for the US and German markets would be low given the high sensitivity levels. However, the insignificant β coefficients of these two markets seem to be the result of an error in the estimation of the models as hinted at previously. Conversely, the Portuguese market seems to have overcome the estimation error in the 2012 bond. The Italian and Spanish markets are hinting at a reduction in the persistent levels, yet both the Italian and Spanish markets are still highly persistent, especially the Spanish.

As previously explained, we omit the US and German markets. However, as with the Greek market in Table 89, the unconditional volatility in the Portuguese market is inconsistent with both practice and theory. Conversely, the two remaining observed markets seem to be hinting at a high unconditional volatility during the financial crisis. This does mean that these two sovereign debt markets were highly volatile during the financial crisis. Conversely, like Table 89 both markets do not revert to the unconditional volatility after a rise or fall. However, thestatistics seem to be suggesting that the volatility in both markets tend to decay to half their levels rather longer than illustrated in Table 89 in the aftermath of a shock to the market.

A key factor during the financial crisis is the significant rejection of the null hypothesis of the markets being too volatile to be efficient throughout the observed markets except the Italian market using both GJR-GARCH and GARCH models. This would suggest that market participants react differently to on the run bonds than off the run bonds. Since the basis of these bonds, being more liquid and the financial crisis is illiquidity issues within the major financial firms. Notably these firms are also the key market participants in the sovereign debt market[22]. Another influencing factor is that the fundamentals by the policies of the central banks and governments such as quantitative easing and fiscal stimulus distorted these markets, especially the US. This may have made them efficient. However, the Italian market accepted the null hypothesis. A possible explanation is that unlike the other markets, the financial crisis did not affect the Italian market. This means that the Italian financial sector remained unaffected and the Italian market not was the subject of flight to safety. In fact the statistics on government aid to the financial sector obtained from the European Commission on 21st April 2014 points to this, the Italian financial sector had the lowest state aid of all the observed countries in our research.

Table 96. *2017 Bond EGARCH-M Residuals Statistics (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
R^2	0.999999	0.999999	0.990919	0.999977	0.99992
Adjusted R^2	0.999999	0.999999	0.990878	0.999976	0.99992
Jarque-Bera	28	27.29	1242.22	1873.52	613.82
Q-Statistics (Correlogram)	0.4432	0.1514	0.6138	0.0119	0.0801
F-Statistics(ARCH Test)	1.628148	0.522260	1.067903	3.795833	0.383171

The high R^2 and adjusted R^2 through all the estimated GARCH models hint at all the models being a good fit to the dependent variable. Like Table 94, there is a split between the IPS and

[22] Sovereign wealth funds such as the Chinese and governmental departments such as the social security departments tend to hold these bonds until they mature likewise many insurance firms.

US/German markets with the IPS markets hinting at lower R^2 and adjusted R^2. These splits continue with the Jarque-Bera test, the IPS markets seem to be excessively high indicating a significant acceptance of the null hypothesis of non-normality in the distribution. Yet the US and German markets seem to be hinting at a relatively low acceptance of the null hypothesis. Additionally, the Q-statistics seem to be pointing at significantly low serial correlation for all the observed markets with the Portuguese and Spanish markets approaching zero. Conversely, the F-statistics are hinting at a relatively low ARCH effect in all the observed markets with the exception of the Portuguese.

Table 97. *EGARCH-M Statistics of the 2017 Bond (02/11/2009-29/03/2013)*

	US	*German*	*Italian*	*Portuguese*	*Spanish*
Mean Equation λ	-191.734 (127.999)	-97.94969 (183.56640)	-0.682855 (0.702502)	-5.610844 (6.64732)	-11.78626 (9.43112)
a	0.013456 (7.28E-06)	0.012498 (1.65E-05)	0.006974 (0.001115)	0.000512 (1.15E-04)	0.004504 (1.56E-04)
b_1	-0.060869 (2.76E-05)	0.067374 (3.35E-05)	0.180347 (0.002385)	0.254856 (9.67E-05)	0.190259 (2.48E-04)
b_2			-0.072917 (0.002504)		
ϵ	1 (2.95E-05)	1.000018 (3.54E-05)	0.994986 (0.002193)	0.999969 (1.02E-04)	1.000654 (2.52E-04)
Variance Equation ω	-0.1412 (6.28E-02)	-0.326749 (0.136113)	-0.360104 (0.07546)	-1.565741 (0.373943)	-0.223885 (0.081842)
α	0.129854 (0.028087)	0.149947 (0.031578)	0.246714 (0.047805)	0.521541 (0.094207)	0.099157 (0.025453)
γ	0.012500 (0.019126)	-0.005638 (0.021434)	0.121808 (0.029254)	0.031044 (0.045657)	0.143802 (0.021689)
β	0.997778 (0.003155)	0.987174 (0.007611)	0.970829 (0.009338)	0.886332 (0.031595)	0.986141 (0.00695)
$\frac{\omega}{1-(\alpha+\beta)}$	1.106078	2.382925	1.655323	3.838795	2.624739
$\alpha+\beta$	1.127632	1.137121	1.217543	1.407873	1.085298
$-\frac{\ln(2)}{\ln(\alpha+\beta)}$	6	5	4	2	8
Log Likelihood	6129.576	5972.090	1720.483	3830.002	3702.262

It is worth noting that Table 97 is associated with the sovereign debt crisis and hence as expected, there is a difference between the IPS group of markets and the other two observed markets. In essence, the statistics in Table 97 seems to be reflecting this differenced. The 2017 bonds allow us to extend the period of analysis in the sovereign debt crisis and to overcome the maturity effect of the 2012 bonds in Table 91. Interestingly the GARGH variant of our EMH test hints at the rejection of the null hypothesis of the market being too volatile to be efficient for all the IPS markets as demonstrated by Table 41.

As illustrated by Tables 91 and 97, the λ coefficients seem to be pointing at a change from a positive feedback effect to a negative feedback effect for all the observed market. One could presume that a plausible explanation would be the maturity effect on the estimationsfrom Table 91. However, another influential explanation is that the 2012 observation end in December 2011, hence the impact from the sovereign debt crisis on the observed markets was at the initial stage. In the case of the US market, this means that not until the later stages of the sovereign debt crisis period was the full impact fiscal cliff and debt ceiling crises felt. With the possible exception of the Portuguese market, the full impact from the Eurozone crisis did not affect the observed Eurozone markets until the later stages. In fact,the combinations of both may have affected the feedback effect in the markets.

With the exception of the US market, the γ coefficients are pointing at a change in the asymmetrical effectwith the IPS markets changing to positive asymmetrical effects. Interestingly the German market changed from a positive to a negative effect. However, during the later stages of the sovereign debt crisis, the uncertainty within the Eurozone spread to the German market. At the heart of this issue was the question should Germany contribute more to avert the euro from collapsing given that the German economy was by far the biggest in the Eurozone. The political environment in Italy and to a certain extent Spaindid not help either. In addition, the Italian economy was weak even before the crisis and the Spanish financial sector still required government aid in the form of recapitalization as late as autumn 2012. These factors made the market participants generally nervous about the euro and Eurozone markets. Conversely, although the fiscal cliff and debt ceiling crises affected the US market, yetthe weakness of the financial market and the Eurozone crisis overshadowed the American problems until late 2013 when the US federal government came close to a default on its interest payment. This meant that the US market continued to act as the risk free market and as explained previously many market participants[23] held onto these assets for the long term.

Although, with the exception of the Spanish and Portuguese markets, the α coefficients are hinting at an increase in the levels of sensitivity; however, it does seem to be that both the maturity and

[23] For example: US Local and Federal Governments, US Federal Reserve, Insurance and Pensions firms and Sovereign Wealth Funds e.g. Chinese.

observation effect did not have a large impact on the level of sensitivity inthe Portuguese market. This is mainly due to the Portuguese crisis comingearly in the sovereign debt crisis; hence, Table 91 accounts for much of the impact. Interestingly the Spanish market seems to be hinting at a low level of sensitivity given that the full impact from the financial and sovereign debt crisis came in the later stages. A key note is that the financial crisis did not fully effect Spain until the later parts of the sovereign debt crisis and hence may have overshadowed the impact from the sovereign debt crisis. However, this does not explain the high levels of sensitivity in Table 91. A possible explanation is contrary to our earlier statement, the observation did have larger impact than initially thought. Only until the later stages werethe full impact of the Spanish financial crisis felt, the effect did not appear in the 2012 Spanish bond. Conversely, as explained earlier the delayedimpact of the sovereign debt crisis on the remaining observed markets seem to have affect the level of sensitivity making these market increasingly reactive.

With the exception of the Italian and Spanish markets, the β coefficients seem to be hinting at a reduction in the market persistence. This would point towards the extension of observation making these markets less persistence because of the events, pointed to previously, in the later stages of the sovereign debt crisis making the markets increasingly reactive. However, with respect to the Italian and Spanish markets, the increase in the persistence levels seem to be suggesting that the delayed influence of the crises may have made these markets increasingly persistence. Certainly both markets seem to have had a delayed reaction to the sovereign debt crisis, however as hinted earlier the Spanish market also experienced a delayed reaction to the financial crisis. This would suggest a longer spell of high volatility in these two markets.

Except for the Italian and Spanish markets, Table 97 seem to be hinting at an increase in the unconditional volatility on Table 91. This would suggest that the inclusion of the later stages of the crisis raise the expected long term volatility and as previously stated there are influencing factors explaining this increase. Conversely, as previously stated the extension of the observed period did decrease the long-term expected volatility in the Italian and Spanish markets due to the delayed impact of the crises. Like Table 89 all our observedmarkets do not revert to the unconditional volatility after a rise or fall. However, thestatistics seem to be suggesting that with the exception of the Spanish and Portuguese markets, the volatility in the markets tend to decay to half their levels faster than illustrated in Table 91 in the aftermath of a shock to the market. Interestingly the Portuguese market seems to be pointing to an indifferent in the half-life.

Interestingly, during the sovereigndebt crisis the IPS markets significantly rejected the null hypothesis of the markets being too volatile to be efficient using boththe GJR-GARCH and GARCH based variance bound tests. This would suggest that the extension of the observation period to cover the later stages of the sovereign debt crisis made the IPS markets efficient. This would further strengthen the argument that market participants were increasingly reacting to the fundamental information during the crisis. This would also suggest that under extreme market uncertainty, market participants in certain sovereign debt market would react to the fundamental information. Conversely, the German market only accepts the EMH under the GJR-GARCH model suggesting that the asymmetrical effect made the market efficient. This seems to be hinting at the direction of the volatility seemingly important to the EMH.

4.4.3. The SWARCH Model of Volatility Switching

We use the variant of the SWARCH model proposed by Cai (1994) as indicated by section 3.3 in the methodology to analyse the regime-switching behaviour of volatility in the sovereign debt market. We derive a single lagged two states SWARCH to model the switching conditional variance of the first order-differentiated price. The SWARCH model is below:

$$h_t = \omega_0 + \omega_1 s_t + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2$$

$$s_t = \begin{cases} 1 \; if \; low \; volatility \\ 2 \; if \; high \; volatility \end{cases}$$

It is worth remembering that the key to the Cai (1994) SWARCH model is the ARCH intercept. By analysing the ARCH intercept for each of the regimes, we could get an idea of the volatility in each regime. However, a more revealing factor is the probabilities of each regime.

In estimating our SWARCH model, we use the maximum likelihood with normal distribution. With the exception of the US and German 2017 datasets, we use the BHHH method. However, due to errors in the estimation with these two datasets, we opted to use the BFGS method in the estimation. Due to errors with the estimations, we used various sample periods.

Table 98. *SWARCH Statistics of the 2012 Bond*

	US	*German*	*Greek*	*Italian*	*Portuguese*	*Spanish*
Mean Equation M	-1.58E-02 (1.06E-03)	-1.33E-02 (1.60E-03)	4.93E-03 (4.82E-03)	-9.22E-03 (2.19E-03)	2.38E-03 (4.22E-03)	-7.25E-03 (3.50E-03)
Variance Equation ω_0	5.01E-04 (4.15E-05)	8.29E-04 (1.31E-04)	3.74E-02 (1.96E-03)	4.21E-03 (3.24E-04)	3.64E-02 (1.79E-03)	9.20E-03 (8.39E-04)
$\omega_{s=1}$	0.293810 (0.021568)	0.253356 (0.035551)	0.335285 (0.043909)	0.158109 (0.032121)	0.033347 (0.020498)	0.085378 (0.026087)
$\omega_{s=2}$	0.314870 (0.029868)	0.092030 (0.021645)	0.105865 (0.022795)	0.092066 (0.021929)	-0.002624 (0.001148)	0.113403 (0.022369)
α	166.038529 (13.727654)	48.809924 (7.388534)	43.495632 (9.503578)	11.191042 (0.851123)	10.619878 (1.049327)	6.523605 (0.550924)
$\theta_{(1.1)}$	7.018339 (1.062313)	4.815815 (0.679569)	4.380112 (0.272185)	4.840678 (0.453747)	3.846200 (0.274914)	4.530508 (0.429168)
$\theta_{(1.2)}$	-7.752714 (0.592539)	-5.930005 (0.607668)	-1.846393 (0.311306)	-5.598055 (0.456174)	-2.164589 (0.314784)	-5.352082 (0.440106)
$Pr_{s=1}$	8.95E-04	8.04E-03	1.24E-02	7.84E-03	2.09E-02	1.07E-02
$Pr_{s=2}$	0.99957	0.99735	0.8637	0.99631	0.89702	0.99528
Log Likelihood	187.0060	1097.1737	-530.0750	837.6236	-91.3807	362.2630

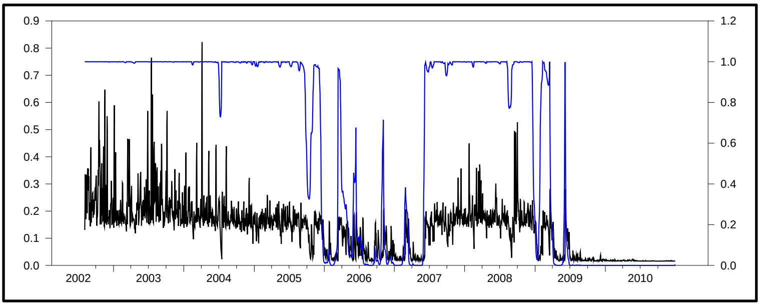

Figure 25. *US 2012 High Volatility Regime*

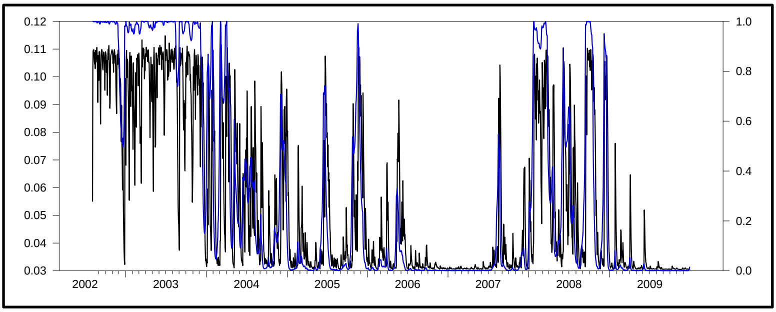

Figure 26. *German 2012 High Volatility Regime*

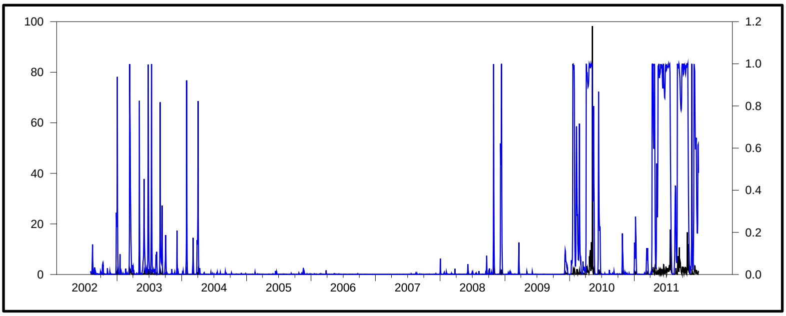

Figure 27. *Greek 2012 High Volatility Regime*

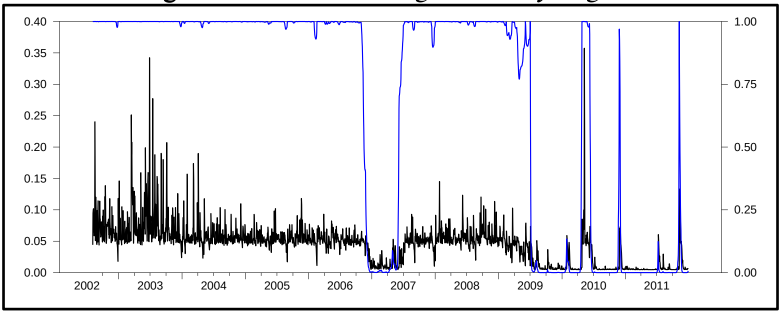

Figure 28. *Italian 2012 High Volatility Regime*

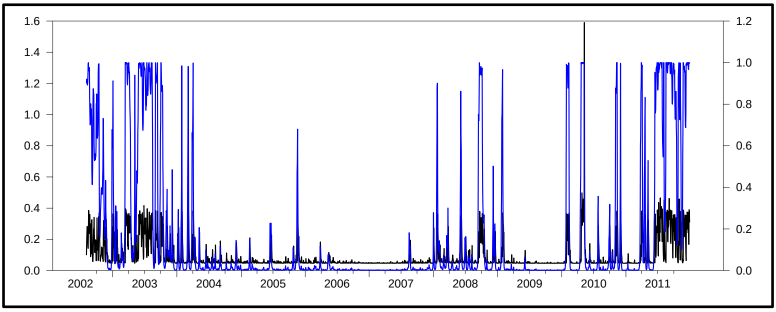

Figure 29. *Portuguese 2012 High Volatility Regime*

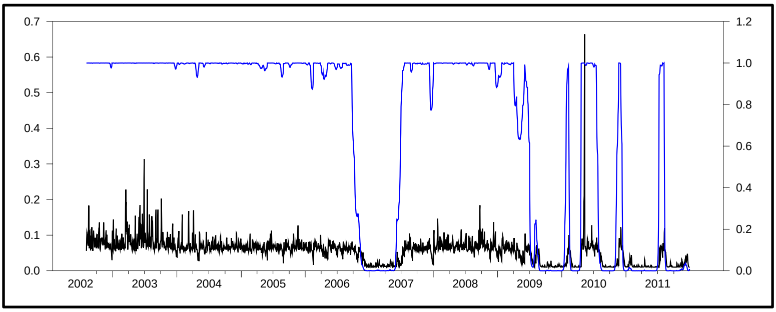

Figure 30. *Spanish 2012 High Volatility Regime*

In essence, the 2012 bonds were associated with a period of changing market environment in the global financial market. Of course the later stages of the period were associated with the financial and sovereign debt crises, yet it was also governed by a number of events which changed the market environment during the earlier stages such as the asset price bubble and accountancy issues leading to the bankruptcy of Enron and WorldCom. However, two events, which had an influential impact during the early stages, were the introduction of the euro andthe terrorist attacks of 11 September 2001 leading to a number of wars. Although these two events occurred before the observed period, yet the persistency in their aftermath had a big impact on the behaviour of market participant.

The evidence from figures 25 to 30 certainly points towards the existence of a regime-switching behaviour influencing the pattern of price volatility in the sovereign debt market. While the figures illustrate the extent to which the sovereign debt market in general is highly volatile within the 2012 bonds, further illustrated by analysing the probabilities of the high volatility regime in Table 98, in essence regime 2. Surprisingly for our observed markets, this is highly significant with a minimum probability of 0.8637 as observed by the Greek market, backed by the probability for the low volatility regime, which is regime 1, with a maximum probability of 0.0209 for thePortuguese market. This would suggest it is more likely that the next regime will be highly volatile. With the exception of the Greek and Portuguese markets, the probabilities are in the high 0.90s, which are hinting at the other observed markets being more volatile. Notably the Greek and Portuguese markets also point to a significant probability of a high volatility regime.

In general, the ARCH interceptsseem to be hinting at a three way split in the markets. This is consistent with our previous observation of the behaviour of volatility in the sovereign debt market. The ARCH intercepts in both regimes for the Italian and Spanish markets seem to be hinting at very low levels of volatility, understandable as the high volatility until the later stages as illustrated by figures 28 and 30 affected neither market. Both these figures also illustrate that the highly volatile period of the early 2000s did not really influence the volatility levels. An influencing factor is that the early stages of the crises did not affect either the Italian or the Spanish markets. Arguably, the financial crisis did not affect the Spanish market until later on and the Italian market remained unaffected.

The US and German markets seem to be portraying a more volatile market than the other observed markets. However, as illustrated by figures 25 and 26, at the highest level their volatility levels are below the Greek and Portuguese markets. A counter argument is during some spells the level of volatility for the German and especially the US markets seem to be higher than the Greek and Portuguese markets. As mentioned previously, a possible explanation is the quality and liquidity factors of the US and German markets making them the benchmark markets for both the dollar and euro currencies. This makes them prime markets for flights to safety during crises or extreme events i.e. Knightian uncertainty. Another influencing factor with respect to both markets is that the Basel II regulations to hold sovereign debt on their balance sheets as capital are a requirement of many financial institutions. Hence, many of these organizations choose to hold either US or German sovereign debt depending on their "home" currency.

The Greek and to a lesser extent Portuguese markets were in the "eye of the hurricane" during the sovereign debt crisis, hence the high levels of volatility, as illustrated by figures 27 and 28, which had an impact on the regime 2 ARCH intercepts. However, as the figures also illustrates there are long periods of low volatility in both the Greek and Portuguese markets. As highlighted previously an influencing factor is that both these markets are not liquid and more importantly are not large markets. Hence, as illustrated by the figures, during "normal" market environment these markets do not have a high number of transactions, which gives the appearance of Table markets.

Table 99. *SWARCH Statistics of the 2017 Bond*

	US	*German*	*Italian*	*Portuguese*	*Spanish*	*US*
Mean Equation μ	-7.64E-04 (6.83E-03)	1.18E-02 (7.39E-03)	5.38E-03 (8.20E-03)	-1.46E-02 (1.15E-02)	-1.68E-03 (8.93E-03)	-7.64E-04 (6.83E-03)
Variance Equation ω_0	1.95E-02 (2.02E-03)	2.88E-02 (7.77E-03)	6.68E-02 (3.95E-03)	1.34E-01 (9.01E-03)	1.04E-01 (4.93E-03)	1.95E-02 (2.02E-03)
$\omega_{s=1}$	0.135506 (3.18E-02)	0.0897424 (4.07E-02)	0.0063287 (1.69E-02)	0.014309 (3.30E-02)	0.076919 (3.42E-02)	0.135506 (3.18E-02)
$\omega_{s=2}$	0.071336 (3.46E-02)	-0.0269799 (4.62E-03)	0.0710576 (3.13E-02)	0.096304 (3.28E-02)	-0.006101 (5.47E-04)	0.071336 (3.46E-02)
α	12.987887 (1.250402)	4.5921499 (0.839103)	10.1028920 (1.137037)	16.841144 (2.236902)	7.764033 (0.977439)	12.987887 (1.250402)
$\theta_{(1.1)}$	6.571102 (1.492712)	3.2786740 (0.393502)	3.7757628 (0.274308)	3.331685 (0.257237)	4.512419 (0.402756)	6.571102 (1.492712)
$\theta_{(1.2)}$	-7.203025 (1.235778)	-4.0878472 (0.570678)	-2.2659541 (0.283508)	-1.738651 (0.351140)	-2.670022 (0.382444)	-7.203025 (1.235778)
$Pr_{s=1}$	1.40E-03	3.63E-02	2.24E-02	3.45E-02	1.09E-02	1.40E-03
$Pr_{s=2}$	0.99926	0.98350	0.90602	0.85052	0.93523	0.99926
Log Likelihood	-761.8270	-352.5236	-590.8467	-1242.7689	-749.8844	-761.8270

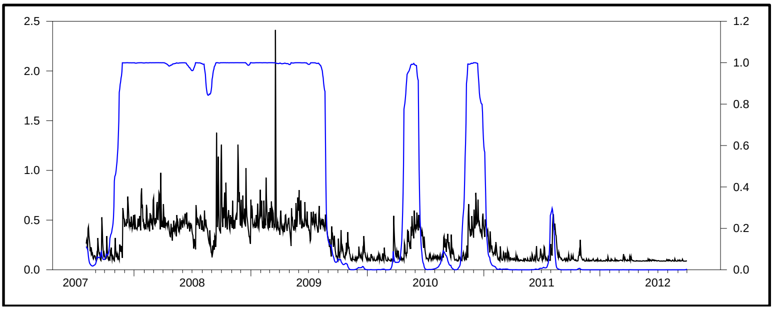

Figure 31. *US 2017 High Volatility Regime*

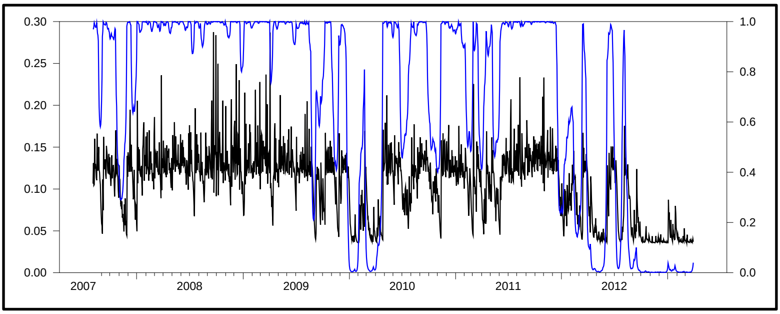

Figure 32. *German 2017 High Volatility Regime*

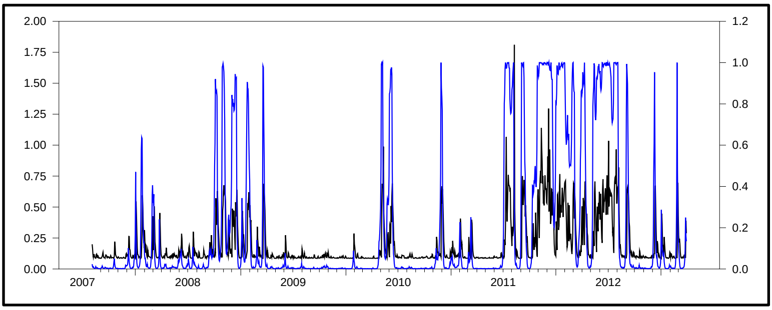

Figure 33. *Italian 2017 High Volatility Regime*

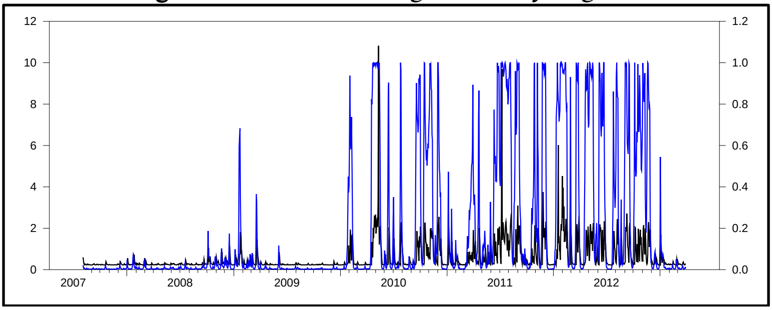

Figure 34. *Portuguese 2017 High Volatility Regime*

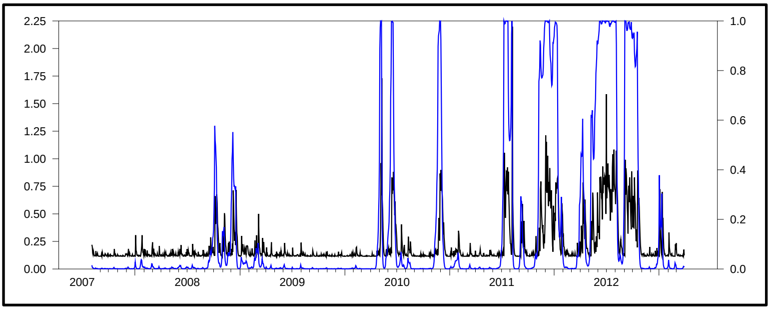

Figure 35. *Spanish 2017 High Volatility Regime*

In essence, the 2017 bonds are associated with a highly volatile period in the global financial market mainly due to the financial and ensuing sovereign debt crises. Although, this in itself is interesting, mainly due to the differing impact on the observed markets of each crisis; however, as hinted previously, another influencing factor is the different impact from the on the runand maturity effects on the financial and sovereign debt crises respectively. The final factor is the extended observed period; therefore allowing us to analyse the full impact of the sovereign debt crisis. Thesefactors may have had an effect on the SWARCH model.

The evidence from Table 99 is pointing at a mixed picture with respect to the probabilities. The high probability of regime 2 suggests that there is a significant probability of a highly volatile regime throughout our observed markets. With the exception of the Portuguese market, the observed markets are hinting at a significant probability of above 0.9 that the next regime is highly volatile. With the US and German markets approaching 1.0, this seem to be indicating that the US and German markets were highly volatile throughout the observed period, although the probabilities of both the Italian and Spanish markets were also significantly high.

Like the probabilities, the ARCH intercept for regimes 1 and 2, points at a rather mixed picture in terms of the level of volatility in the observed markets. As illustrated by figures 31 to 34, it would seem that the German market had the lowest level of volatility in both regimes. An influencing factor is that both crises did not really affect the German economy or financial market, despite the downgrade of the German sovereign debt ratings. However, the evidence from figure 32 seems to suggest that the market was highly volatile and backed by the probability of regime 2 as hinted earlier. A possible explanation isdue to the status of the German market as the benchmark market for the Eurozone; hence, the persistency of the high volatility regime is the result of flights to safety during both crises. Similarly, the persistency of the high volatility regime during the early stages of the US market observations was the result of a flight from the financial assets to the US market during the financial crisis. Since the financial crisis had its origin in the US; hence, these flights to safety as illustrated by figure 31significantly affected the US market. However, the timings of the two hikes in volatility during the sovereign debt crisis period seem to be hinting at the Eurozone sovereign debt crisis, hence a plausible explanation is that the US market was at the centre of a flight from the euro to the US dollar. It must be remembered that due to problems with the estimation of the SWARCH model, we had to limit our observed dataset to 1st October 2012, which meant the full impact of the US fiscal cliff, and debt-ceilingcrises on the US market was not captured.

To a certain extent figures 33 to 35 seem to be hinting at the limited impact of the financial crisis on the IPS markets. Although there is some evidence ofhigh volatility regimes during the financial crisis period, yet this evidence seems to be telling. Certainly, the evidence seems to be pointing at jumps rather than changes in the volatility regime effecting the markets during the financial crisis, especially around the period of the Lehman Brothers bankruptcy. This seems to be hinting at a period of reactive behaviour by the market participants to events during the financial crisis period. However, during the sovereign debt crisis, the regime changes became increasingly persistence and frequent. An interesting factor is the lag between the Greek deficit revision and the reaction of the market participants leading to the contagion in the IPS markets.

4.4.4. Concluding Review

Summarising the results, we find low levels of sensitivity to market shocks using the GARCH model in general throughout all the observed markets during the pre-crisis and financial crisis periods. However, asexpected, the GIPS markets were highly sensitive to market shocks during the sovereign debt crisis with the US and German markets pointing to low levels of sensitivity, reversed when accounting for the levels of persistence in the aftermath of a shock. With the exception of the GIPS markets during the sovereign debt crisis, the levels of persistence were high.

Although in general, the statistics from the EGARCH-m do confirm the sensitivity and persistence levels throughout the observed markets. Yet it is the feedback and asymmetrical effects, which are of importance in the EGARCH-m. In general the observed markets seem to be hinting at a positive feedback effect throughout the pre-crisis period with exception of the US market. However, during the financial crisis the majority of the observed markets were pointing towards a negative feedback effect. Conversely, there is a split picture during the sovereign debt crisis, with the 2012 bonds registering a positive feedback and 2017 bonds pointing towards a negative feedback effect. The asymmetrical effect is rather interesting; in general, it signifies the change in the reaction from a positive asymmetrical effect during the pre-crisis period to a negative asymmetrical effect during both crises. However, rather surprisingly in the 2017 bonds, the generality was for positive asymmetrical effect during both crises.

Certainly, the SWARCH model seems to point to a regime-switching behaviour in the price volatility of the sovereign debt market. Ingeneral, the high volatility regime in both the 2012 and 2017 bonds governed the SWARCH model. The SWARCH model also seemsto highlight an interesting factor in the 2012 bonds, the observed markets seem to be generally divided into three groups depending on the pattern of the volatility and regimes: the US and German markets, Greek and Portuguese markets and Italian and

Spanish markets. Another factor observed in the patterns of volatility in the 2017 bonds is that IPS markets do follow a similar pattern of volatility while the US and German markets seem to be dictated by individual pattern of volatility. A relevant factor in our research is that SWARCH model seems to be picking on the changing environment for each of the observed markets. Since each of the markets was effected by a number of different factors.

The interesting factor is that all the estimated modelshad various issues with the observed datasets, some serious. Some of theseissues led to changes in the estimation methods and distributions systems. Additionallywith the SWARCH, the issue was that the full-observed datasets of certain markets were incompatible with the SWARCH model, so we had to re-estimate the model using a reduced datasets.

However, not all the issues were because of the dataset or estimated model, the two keyissues were the result of the fundamental structure of the sovereign debt market. In essence the 2012 bonds were affected by the maturity effect while the 2017 bonds were affected by the on the run effect. Theory dictates that when bonds approaches maturity the price approaches the par value, this generally leads to low volatility, as the market participants tend to hold these bonds until they mature. In contrast, when the bond is issued, it is said to be on the run until another similar bond is issued. Theoretically, the expectation is these on the run sovereign debts are benchmark bonds, which means they are seen as liquid assets and to a certain extent risk free. This makes them very volatile since they have a high volume of trading at the initial stage. Another important issue is the policies of the governments and central banks during the resulting recession in the aftermath of the financial crisis. Essentially, this links to the fiscal stimulus policies which increase and quantitative easing policies, which decrease the supply in the sovereign debt market, thus distorting the markets from their true value. Another issue is that the high volatility exhibited in the Greek and Portuguese markets during the sovereign debt crisis distorted the rest of the observations so much that it reduced the volatility in the rest of the observation to insignificance levels.

The events of the last few years led to a fast changing and highly volatile market environment increasing uncertainty in the global financial market. Our empirical evidence highlightsthe fact that the fast changing market environment had a big impact on the observed sovereign debt markets. The evidence seems to suggest that the behaviour of price volatility changed significantly in the aftermath of both the financial and sovereign debt crises. As illustrated by the GARCH and SWARCH graphs of the 2012 bonds, the pre-crisis period is evidence of how external eventscould change the market environment. The early stages of the pre-crisis period were highly volatile due to a number of events not directly linked to the sovereign debt market, although debatably the introduction of the euro did change the fundamentals in the observed Eurozone markets. However, the economic upturn and asset price bubble during the later stages of the pre-crisis period did change the market environment and as illustrated by the graphs this reduced the volatility towards the end of the pre-crisis period in the observed market.

Coincidentally, the high risk taking and leverage during the asset price bubble of the later years in the pre-crisis period meant that the problems were a combination of deleveraged and re-pricing of risk. This combination caused the financial crisis, which led to massive upheavals in the global financial market environment and changed the behaviour of price volatility in the observed markets. In general, the observed markets witnessed a flight to safety from other markets, which pushed the prices higher as market participants sought more liquidity and risk free assets, obviously reflected in the behaviour of price volatility during the financial crisis period in both 2012 and 2017 bonds.

In the aftermath of the Lehman Brothers crisis and with a deepening economic downturn turning into a possible depression, many countries were force to recapitalisetheir banking systems and implement a fiscal stimulus policy, which led to a dramatic increase in the total sovereign debt. However, mainly due to the uncertainty in the global financial market the observed markets were still seen as safe risk free assets, even though the fundamental information (i.e. economic indicators) underpinning these markets were hinting at a weakening market. On the face of it, it was the Greek fiscal deficit revision, which caused market participants to reassess the fundamental information underpinning the sovereign debt market. However, as already stated this market was already showing signs of weakness in the fundamentals long before the Greek revision. The financial crisis not only raised the expenditure but also reduced the revenue as a result even before the advent of the fiscal stimulus the fundamentals were showing signs of a weakness. This made market participants less confident in the observed GIPS market as time went by and thus resulting in flights from these markets to the US and German markets as illustrated by the statistics. Although the sovereign debt crisis did affect the US market in the form of the fiscal cliff and debt ceiling crises, yet not until the later stages of the sovereign debt crisis wasthe true impact felt.

In general, the market environment can be an influential factor on the market participants in the global financial market. However, in a fast changing and highly volatile market environment, the interesting factor is the behaviour of market participants. Our empirical evidence seems to be suggesting that market participants tend to overreact or underreact to information and events depending on the general market environment. In general, market participants tend to overreact during a crisis period and underreact during a bubble period. Although this is not technical true under all circumstances, yet the evident during the early stages of the pre-crisis period is highlighting an overreaction to the uncertainty in the market due to a number of events not least the introduction of the euro and the accountancy issues of 2002/2003. In contrast, the underpricing of sovereign debts reflected the underreaction of the market participants during the asset price bubble of the later stages of the pre-crisis period meant that the inflated prices of the stocks and securitizations markets, indicated by the low volatility in the observed markets towards the end of the pre-crisis period.

Eventually the asset price bubble of the mid-2000s did burst in the summer of 2007 with the Bear Stearns and BNP Paribas loses. Since in general market participants tend to overreact to negative news, this led to a flight from the securitized assets at the centre of the crisis and financial sector to safe havens like the observed sovereign debt markets. As illustrated by the asymmetrical effect, in general the negative impact on the global financial market, seen asrisk free liquid assets, transmitted to a positive impact on the 2017 bonds. An influencing factor to note during the financial crisis is the liquidity issue at the heart of the problems facing the market participant, there in lays the different in the asymmetrical effect between the 2012 and 2017 bonds.

However, as the financial crises worsened, it became clear that many market participants needed an injection of capital and the resulting economic recession was getting deeper. Hence, in the aftermath of the Lehman Brothers bankruptcy, many central governments did invest in their banking system in order to inject much needed capital. The thing is that by investing capital in their banking system and implementing huge fiscal stimulus policy, they were increasing the total debt at a time when the recession was already increasing their debt. In addition, in theory, the increase in supply would decrease the price of an asset but the financial crisis meant that these assets were in high demand. However, another distorting factor is the policies of the central banks, in providing short term liquidity they did exchange liquidity for assets like sovereign debts. Some central banks, such as the Federal Reserve, also implementeda large quantitative easing policy of buying assets like sovereign debts in the attempt of boasting their economy. This further distorted the price from the fundamental value bydecreasing supply; however, although the ECB was not allowed to implement such a policy until the later stages of the sovereign debt crisis. This did not stop the ECB providing liquidity for the market participants, who were the banks, in the shape of short-term asset backed loans, which were usually Eurozone sovereign debts.

The issues with the economy and size of the total debt relative to the GDP in many of the observed markets, especially the GIPS nations were a cause for concern long before the onslaught of the sovereign debt crisis. However, the financial crisis had overshadowed these issues. As previously stated, mainly due to the requirement of the market participants for liquid and risk free assets during the financial crisis the prices went up in the observed markets. The Greek deficit revision in autumn 2009 did make market participants highly reactive to the issues in the economy and sovereign debt market. This led to a contagion in the GIPS markets as market participants fled these markets to the safe haven of the German and US markets during the sovereign debt crisis, illustrated by the high prices of the US and German markets. Yet to a certain extent, the US market was suffering from a similar issue with the fiscal cliff and debt ceiling crises. A key factor is the assumption that the US government would not risk the consequences; another influencing factor is the crisis in the Eurozone overshadowed the US crises. Of course thecrises did eventual effect the US market with the closure of the US government, however this was out of observation. During the financial crisis, a possible explanation is available as to why the US market did not suffer from any negative effect on the price volatility. The Federal Reserve was implementing a huge quantitative easing policy, which distorted the market to a certain extent. However, the main factor was the overreaction to the Eurozone crises and underreaction to the US crises. Coincidentally, the overreaction to the GIPS crises also made market participants overlook the economic weakness and credit rating downgrade of the German market. However, an influencing behavioural factor is that during a crisis, market participants are highly reactive; this is the crucial factor influencing the markets responses to the policy communication by many influentialpoliticians.

Theoretically, the efficiency of a market depends only on the market participants' accessibility and analysis of information. However, in thispart of the empirical evidence, we considered and analysed the possibility of the reaction of the market participants making the markets efficient. A possible explanation is available in the overreaction/underreaction hypothesis. As hinted by our empirical evidence, generally market participants were over- or under-reactionto information or events. This leads to the overreaction/underreaction cancelation states. Where there are periods of underreaction and other periods of overreaction from the market participants, these two periods could cancel each other out and the resulting steady state in the market seems to suggest to participants that the market is efficient. This could explain why during a highly volatile period such as the financial and sovereign debt crises, a number of the observed markets seem to accept the efficient market hypothesis. It could also explain why during a period of low volatility the markets seem to accept the null hypothesis of the market being too volatile to be efficient. The key is if market participants overreact (underreact) more than they underreact (overreact) then the market is deemed to be too volatile to be efficient. Of course, another explanation is the correction to the over- or under-reactionerror. Nevertheless, this also seems to point at the overreaction/underreaction state since in the aftermath of a reaction from the market participants the market always readjusts cancelling out the reaction. This correction pushes the reaction towards the overreaction/underreaction steady state and hence makes the markets efficient.

In concluding, it is hard to capture the impact from the behaviour of volatility in a dynamic and highly volatile environment using one model. While this is true for any market, not just the sovereign debt market, yet what is interesting is the possible distortion of the sovereign debt market by factors other than market participants. Hence, the price may not be determined by the reaction of the market participants to information or news, it could be determinedby supply side players like the central banks and governments implementing extenuating policies such as quantitative easing or fiscal stimulus. In truth, these are rare and need special environmental circumstances like the recent financial crisis and following deep recession. Interestingly, it is these distortions that could provide one possible explanation to the efficiency of the market during the highly volatile environment of the financial and sovereign debt crises. However, another more intruding explanation is the idea of the overreaction/underreaction state whereby the market efficiency is determined by the reaction of the market participants cancelling each other out during any period. Essentially, this means that market participants reactions to information is the key factor whether the market is efficient or not.

5. Conclusions

The efficient market hypothesis has been the mainstream of finance for nearly 50 years. However, as highlighted in the review, there are many issues with this theory and it does throw up a basic flawed idea. The concept is that the price always incorporates all the information at the time and hence the price reflects the given information. This idea is at the centre of the debate surrounding the efficient market hypothesis in the aftermath of the financial crisis. The other key issue is that it relies on key assumptions made in neoclassical economics, which do not always hold in the real world, i.e. the existence of rational market participants and perfectly competitive markets. In truth, both theefficient market hypothesis and neoclassical economics view which underpins it are essentially just models of the financial market and are therefore best used as benchmarks and not observations of the real world.

The keyissue of this thesis is that does a crisis such as the financial and sovereign debt crises change the efficiency of a financial market. We do know the crisis did change the environment within the global financial market is operating. However, did the change in the market environment lead to a change in the efficiency of the market? Effectively, does new information spread efficiently and do market participants react rationally to new information or events during a highly volatile period? In analysing the impact of a changing environment, on the efficiency of the sovereign debt market; we extendedthe variance bound test of Shiller (1979) to include the GARCH models of volatility; proposing a GJR-GARCH based variance bound test to analyse the impact of different asymmetrical effects in a changing market environment on the efficiency of the sovereign debt market.

In essence, the evidence seems to point at over- or under-reaction of market participants to new information and new events, considered (rightly or wrongly) to play an influential role in the pricing of financial assets. This leads tobehavioural finance theories to explain the pricing of assets. At the centre of the behavioural finance theory is the idea that in order to understand the movement in the price, we need to understand the reaction of the market participants to all the information in the market, since as stated many times previously market participants are homo-sapiens and not homo economics. This leads to different interpretations on the information, made worse by the existence of asymmetrical information, which leads to different reactions. This can sometimes lead to underreaction while on other occasions it could lead to overreaction.

The problem isthis could lead to a deviationin the price from its markedly efficient value, which in the longrun could lead to fads such as rational price bubbles. As a bubble by nature isunpredicTable, regulators who act too fast could cause a market crash. On the other hand, acting too slow could lead to a crisis just like the recent financial crisis and market participants could lose billions. A problem with the behavioural finance theoryis the limited number of tested models, unlike the efficient market hypothesis. Hence, until such models become widely available the theory will be need to be continued to be tested as thereisstill few empirical evidence for the behavioural finance theory.

In the conclusion, we will review our literature and empirical findings. This includes a brief overview of our findings in the key areas of efficient market hypothesis, behavioural finance theory and models of volatility. We will review the objectives. We follow this by looking at the contributions and recent developments in the field of research. We then look at the limitations of the research and suggest areas of extension and ideas for future research resulting from our research. We concludea reflection on the thesis statement.

5.1. A Review of the Research Objectives

The research objectives were:

1. Objective (1) was to test the efficient market hypothesis using the variance bound test during the pre-crisis, financial crisis and sovereign debt crises periods.

a. This meant researching the efficient market hypothesis and behavioural finance theory

b. Researching the tests of the efficient market hypothesis

c. Deriving the tests:

i. The first test was a GARCH variant of the variance bound test

ii. We also wanted to analyse the impact of a negative or positive asymmetrical effect on the efficiency tests, hence we proposed a GJR-GARCH variant of the variance bound test

2. The second objective: to identify the changing behaviour of volatility in the sovereign debt market using the GARCH family of volatility models as described above

In essence the key objectives to research the impact of the crises on the efficient market hypothesis and behaviour of volatility remained. However, focussing the research on the efficiency of the sovereign debt market during the crisesmakes the impact of the crises on the efficiency of the market the focal point of the thesis.

5.2. A Summary ofthe Findings

We find theoretical and empirical evidence to support both the efficient market hypothesis and behavioural finance theory.

Although there are many tests of market efficiency like the cointegration test, variance ratio test and variance bound test; we opted to base our empirical evidence on the variance bound test as a more modern version of an EHM test. Simply put the variance bound test, as argued by Shiller (1992), dictates that if the information does not explain the markets then the prices exhibit persistent excess volatility. Therefore, the markets are deemed too volatile to be efficient. This is the key to our empirical evidence section.

We initially use a GARCH based variance bound test to test the efficiency of the market. However, since theory dictates that volatility behaves differently to negative than to positive news, we extend ourvariance bound test to account for the asymmetrical effect by using the GJR-GARCH. Our empirical evidence is suggesting in general, the six sovereign debt markets are inefficient because they are too volatile to fulfil the efficient market hypothesis. However, the key to our thesis is that the market environment does affect the efficiency of the sovereign debt market as indicated by the changing market environment during the financial and sovereign debt crises, which have influenced the efficiency of the market.

In general, the GJR-GARCH variant of our variance bound test did hint at the inclusion of the asymmetrical effect making the test more susceptible to accepting the efficient market hypothesis. Although the test of the models using the information criterions methods showed that, the GARCH model is able to explain the information contained in the dependent variable better. In the end as previously argued the acceptance of the efficient market hypothesis could depend on various factors and not just on whether the market is too volatile to be efficient. However, we accept the null hypothesis of the market being too volatile to be efficient because the market has to efficient throughout the sample and not just for a few numbers of observational periods.

Since the markets were in general accepting the null hypothesis of the market being too volatile to be efficient. The alternative theory is the behavioural finance theory, which dictates that movement in asset prices is mainly due to the reaction of market participants to the information or events. Interestingly, this leads to the underreaction or overreaction hypotheses, which indicate that market participants sometimes underreact or overreact to information or events. Perhaps the biggest issues in the efficient market hypothesis are the lack of a plausible explanation for an assetprice bubble like the US asset bubble of the mid-2000s. The behavioural finance theory provides an elegant explanation as to the mechanics of any asset bubble in the overreaction/ underreaction hypotheses. The hypotheses also seem to provide an explanation for the behaviour of price volatility in the sovereign debt market during the pre-crisis period as well as the financial and sovereign debt crises. This was the key for our empirical study into the behaviour of price volatility in the sovereign debt market.

Since as argued by Mandelbrot (1963), a key observation made frequently in the field of financial economics is the existence of volatility clustering in asset pricing. Another observation often made is the existence of feedback and asymmetrical effects as indicated by Engle *et al.,* (1987) and Black (1976) respectively. This leads tothe GARCH family to model the volatility in the market and there is certainly a large and growing literature base on the use of the GARCH family to explain the behaviour of volatility during the financial and sovereign debt crises over the past few years.

Using the GARCH and EGARCH-m to model the clustering and asymmetrical/feedback effects, we certainly found evidence of volatility clustering in the market. This seems to be backing our earlier observation that the changing market environment affected the efficiency of the market. The results of our empirical evidence seem to be pointing at the existence of changing feedback and asymmetrical effects in the markets. These factors seem to be hinting at the changing reaction of market participants to the events and information during the three periods: pre-crisis, financial crisis and sovereign debt crisis. The evidence certainly seems to be hinting at the existence of the over or under reaction hypotheses.

Perhaps the key finding is that the overreaction/underreaction may cancel each other out so that the market seems to be efficient. This means where there are periods of overreaction and other periods of underreaction by the market participant, this leads to the overreaction/underreaction cancelation state. However, a market deemed too volatile to be efficient, is a market where there is still over- or under-reactionremaining after the cancellation state.

An interesting finding for policy makers such as the central banks and governments is that supply side factors such as quantitative easing or fiscal stimulus policies could affect the behaviour of price volatility and hence the market efficiency, where quantitative easing policies seem to reduce and fiscal stimulus policies tend to increase, the supply of sovereign debts. Interestingly, this seems to be providing an explanation to the behaviour of price volatility and market efficiency in the US sovereign debt market in particular during the financial and sovereign debt crises.

In general, our findings seem to be hinting atmany factors during a crisis, which determine the market efficiency and the behaviour of price volatility. However, the key factor is the market environment, which is backed by the results from the SWARCH models, since as hinted by Cai (1994) and Hamilton & Susmel (1994) financial markets go through alternate periods characterized by high and low volatility. Certainly, the past empirical evidence seems to hint at a link between the general market environment and the regime switches in high and low volatility. Our results are pointing at is these volatility switches being linked with the changes in the general market environment with respect to each market.

5.3. A Review of the Limitations

Hindsight is a lovely tool; unfortunately, there are some limitations, which became glaringly obvious by the end of the research. Although we tried to accommodate these issues by changing some of the objectives as already illustrated in section 5.1, we still believe there are a few limiting issues. Below we list these issues.

Perhaps the biggest limitation is the data used to test the efficient market hypothesis and model the volatility in the sovereign debt market. The problem is by using the prices we were restricted with the issue and maturity dates. Therefore, we had to use two bonds to cover the period we wanted to observe. This was partly because we know how the prices behave in the benchmark bonds, which were the 10 years government bonds. However, the other problem was the non-existence of a longer duration bond across all the observed markets. As an example, the US had a 20-year bond but the Eurozone markets do not extend to this duration.

Part of the reason why we limited the number of markets we observed was due to the use of a second bond to overcome the maturity effect during the sovereign debt crisis. Although the thesis would have benefited from the inclusion ofother markets, especially the Japanese, British and French market, the reason being that each would have added a different angle to the research. Certainly, the inclusion of the Japanese market would have been interesting because of the similar problems the Japanese financial sector and economy went through in the 1990s and early part of the 2000s, which would only have extended the volume of this thesis, but would not have added to the crises' countries.

A key limitation is the omission of a section to define the characteristic of the market. This section is important because it provides some background information on the market and the type of market participants. However, we could not obtain the data required for this.

While our choice of data limited our ability to research the true extent of the crisis effect on the market efficiency and behaviour of market volatility, a key problem was the interpretation the SWARCH model. This was the restriction of the regime switching to the intercepts only. This meant that that we could not distinguish between the sensitivity levels to market shocks of high and low volatility regimes. An associated issue with the SWARCH model in general is that they do not account for the persistent levels. It would have been nice to know, how the regime changes in the volatility, affected the sensitivity and persistent levels in markets, during a period of changing market environment.

5.4. A Review of Recent Developments

There were a number of developments during the later stages of the thesis, which had an effect onthe sovereign debt market. These developments could have implications on our research, especially on the efficiency and behaviour of volatility in our observed markets. Therefore, it will be interesting to widen our research to the impact of these developments:

- The shutdown and near default of the US governmentsee Nippani & Smith (2014): we previously discussed the debt-ceilingcrisis in section 2.3.2. The problem here was that both sides of the US federal government could not agree to a compromise plan to raise the debtceiling before the next payment was due which could have resulted in them defaulting. Hence, the US federal government effectively ran out of money and had to shut down from 1st October 2013 to 13th October 2013. The crisis saw the credit rating and hence price of US sovereign debt fall sharply to below 100 at one point. Importantly the price has since recovered. Wesuspect that mainly due to the overreaction/ underreaction steady state the market could be efficient at present. However, in the immediate aftermath of the crisis we suspect that the market is likely to have suffered from overreaction making the market inefficient.

- The continuation of the Eurozone sovereign debt crisissee De Grauwe & Yi (2015) and Cornett *et al.,* (2015), the central issue here is the Greek sovereign debt crisis. As of 26 June 2015, there was no agreementto prevent the Greekgovernment from defaulting on its debt. The fear is that if Greece was to default then it could lead to an exit from the Eurozone. This could lead to added pressures on the Eurozone markets in general but more specifically the sovereign debt market. The market participants are already overreacting to the news as is evident in markets across Europe. This could have the impact of pushing the markets away from efficiency. However, given that these crises do have a tendency for last minute agreement, I would not rule out a deal that would "save" the euro. I think the markets are grossly overreacting towards the euro given the small size of the Greek market in relation to the global financial market. The main problem is the impact on the other sovereign debt markets especially the other members of the GIPS nations.
- The influencing factor from the German high court ruling (see Winkler, 2014) on the bank bailouts by the Second Senate of the Federal Constitutional Court in Karlsruhe on 7 February 2014 was the endorsement of the efficient market hypothesis. The results from our tests seem to suggest that although there are periods where the German sovereign debt market is efficient, however in general the market seems to be accepting the null hypothesis of the market being too volatile to be efficient. However, this does not rule out the possibility that using an index of the German sovereign debt or the stock market could result in the market accepting the efficient market hypothesis.

5.5. A Review of Possible Future Research

In looking at future research possibilities based on the findings and limitations of the research, two possible routes standout. The key findingin our research seemsto point at the further analysis of the overreaction/underreactionsteady state, which seems to hint at a possible explanation of the efficient market hypothesis within the behavioural finance theory. Another possible research route based on a key limitation; is to analyse the impact on the efficiency of the equity and euro/dollar FX market from a volatility spillover effect in the sovereign debt market. Since evidence during both the financial and sovereign debt crises, seem to suggest that the sovereign debt market did make the equity, especially the financial sector and the euro/dollar FX marketsincreasingly volatile. Similarly, the equity market had a spillover effect on the sovereign debt market especially during the financial crisis.

One possible future research stems from one of the key conclusions in our research. Since our findings suggest that, the efficient market hypothesis is in reality the steady state of the over- and under-reactionduring an observed period, this implies a possible rewriting of the model for the efficient markets, as the cancellation or balancing effect of the reaction of market participants. If this is the case then thebehavioural finance theory can explain the efficient market hypothesis. In its simplest form the model could be represented by the equation $SS = O - U = 0$ where SS is the steady state, O is the overreaction and U is the underreaction. If the steady state is positive than there is an overreaction during the observed period and if the steady state is negative then there is an underreaction.

Having said that a difficult question then arises: how do we get the variables O and U? A possible approach seems to be in the models of switching regimes. Using a Markov-Switching Model could allow us to distinguish between an over- and under-reaction. Hamilton & Susmel (1994) use the arch coefficients to switch between regimes. As illustrated by our results, this throws another issue in that volatility seems to be sometimes reactive and on other times persistent. In essence, the basis of the SWARCH models is the reaction to shocks in the markets. Therefore, there is a need to use a switching GARCH model like the one proposed by Gary (1996) or Dueker (1997). This would give us the required coefficients to calculate the variance bound test for both the high and low volatility states. The variance bound tests for the over- and under-reaction status can calculate from the coefficients of the two states. This approach would not only help in understanding the efficiency of the market but also the reasons why the market is efficient or inefficient.

Another possible future research is to understand the impact of the spillover effect from the sovereign debt market to the stock market during the crisis. While we could use a multivariate

GARCH model such as the BEKK, however as the results seem to suggest there is a difference between negative and positive shocks in the efficiency of the market. Hence, the model must account for the asymmetrical effect on both markets and therefore it must be an asymmetrical based multivariate GARCH model such as the DAM GARCH model proposed by Caporin & McAleer (2011). A key factor would be to understand the spillover effect impact on the steady state of the markets; in reality, the spillover effects should make the market inefficient because the market participants are not only pricing the information of the market. Therefore, an underreaction at some point in the observed period could cancel out an overreaction to the spillovereffect. It would be interesting to see if the efficiency in one market could influence the efficiency in another market, mainly due to the efficient market hypothesis stating that prices should reflect only information about the market.

A big problem with our results is that the on-the-run and maturity effect affectsthe data. A possible way around this is to use an index of sovereign debts, this would complement the use of an index such as the Dow Jones average or DAX in the stock market. Another key benefit of using a sovereign debt index is that it is a mixture of different maturities, and in the case of the Eurozone index, it is also a mixture of different markets. However, the influencing factor is that the use of an index would allow for the use of longer duration in the observed sovereign debt markets. Going back with some indices until 1994, this would allow for the research of the impact of the euro on the efficiency of the stock and sovereign debt markets.

Since the prices gave some out of bound coefficients. Another possible future research is to use the returns instead of the prices to test the efficiency and analyse the behaviour of volatility. On initial tests, we found that using the returns to test the efficiency resulted in better coefficients and meant we could combine the variance bound test with the analysis of the behaviour of volatility. This would be interesting, since it would tell us exactly why the markets are efficient or inefficient without using a different dataset to estimate the models.

5.6. Reflective Statement

When I started this research, I was an avid supporter of the fundamental principles of neoclassical economics. Although in general, the research did not change my views on the fundamental principles of neoclassical economics. Yet I do not think the efficient market hypothesis explains the pricing of assets. Throughout this research, I have highlighted the main arguments for and against the efficient market hypothesis; however, my concerns are two folds in that the basis of some of the simplifying assumptions are the unrealistic theories made in neoclassical economics. The second and more important of my concerns is in the end it is not the information that is vital; it is the reaction of market participants to the information. The efficient market hypothesis seems to dictate that no matter what the information is, the price of the asset must immediately reflect it. In essence, this means that market participants always react in the right way to the information. In this research, we have proven that this is not the case and it is essential to take the reaction of the market participants into account when pricing the asset. This is at the heart of my concerns with respect to the efficient market hypothesis.

Therefore, I agree in order to understand the pricing of any asset, there is a need to incorporate the behavioural finance theory. The research has highlighted a number of areas, only explained by the inclusion of the behavioural finance theory. However, a key but understated factor is that within the overreaction/underreaction hypotheses there is an elegant explanation for efficient markets. This means that the behavioural finance theory not only explains anomalies but also efficiency, this is the key for me. However, a key issue is the non-existence of models of asset pricing and tests of the behavioural finance theory. It seems that the academics are more concerned with how the efficient market hypothesis fails than testing the fundamental principles underpinning the behavioural finance theory. Moreover, unless there is a tesTable hypothesis and a model of pricing assets, I am afraid the behavioural finance theory will never be as widely accepted as the efficient market hypothesis even though my opinion is, in theory, it is a better model of the real world of asset pricing.

In concluding, the research did find that on some occasions the financial markets could be efficient, therein lays the fundamental issue: could a market be partly efficient. Another factor is that it seems that the behavioural finance theory could explain the efficiency in the market using the reaction of the market participants. However, this is missing the point, the efficient market hypothesis is a model of where the price has to be given the information and this leads to it being ideally suited to be used as a benchmark, used in this way it can be a powerful tool to regulate the market.

Appendix

The Timeline of the Financial and Sovereign Debt Crises

Table A1.1. *Financial and Sovereign Debt Crises Timeline*

Event	*Date*	*Source*	*Notes*
Bear Stearns Funds problems	07/06/2007	Federal Reserve Bank of St Louis as of 5/4/2013	Acknowledged as the start of the Financial Crisis
BNP Paribas	09/08/2007	Federal Reserve Bank of St Louis as of 5/4/2013	Financial Crisis spread to Eurozone
Financial Market Pressure Intensify	01/11/2007	Federal Reserve Bank of St Louis as of 5/4/2013	Diminishing liquidity in interbank market
US Recession	01/01/2008 to 31/05/2009	NBER as of 5/4/2013	
Eurozone First Recession	01/01/2008 to 31/03/2009	CEPR as of 5/4/2013	
Bear Stearns Collapse	14/03/2008	Federal Reserve Bank of St Louis as of 5/4/2013	
Lehman Brothers Bankruptcy	15/09/2008	Federal Reserve Bank of St Louis as of 5/4/2013	
US Economic Stimulus Package	17/02/2009		Initially the package was $787 billion, however it was later revised to $831 billion
Greece Revised Annual Budget Deficit	05/11/2009	CFA Institute as of 5/4/2013	Annual deficit will be more than twice previously announced at 12.7%
First Downgrade of Greek Debt	08/12/2009	CFA Institute as of 5/4/2013	S&P downgrade from A- to BBB+
First Downgrade of Portuguese Debt	27/04/2010	CFA Institute as of 5/4/2013	S&P 2 notch downgrade
First Downgrade of Spanish Debt	28/04/2010	CFA Institute as of 5/4/2013	S&P downgrade from AAA to AA-
Greece First Bailout Agreed	02/05/2010	CFA Institute as of 5/4/2013	IMF and EMU grant €110billion bailout
EFSF & EFSM created	09/05/2010	CFA Institute as of 5/4/2013	€750billion total funds from IMF & EMU
Greece Debt Junk Rated	14/01/2011	CFA Institute as of 5/4/2013	Fitch downgrade to

			BB+ / Junk
Japanese Earthquake	11/03/2011		
Portugal Bailout Agreed	17/05/2011	CFA Institute as of 5/4/2013	IMF and EMU grant €78billion bailout
Volatile Markets	09/06/2011 11/06/2011	CFA Institute as of 5/4/2013	Quotes from senior EMU politicians leads to backlash from investors
EFSF increased	21/07/2011	CFA Institute as of 5/4/2013	The EFSF is increased to €780billion
First Downgrade of Italian Debt	19/09/2011	CFA Institute as of 5/4/2013	S&P downgrade from A+ to A-
Eurozone Second Recession	1/10/2011 to present day	CEPR as of 5/4/2013	
Greek PM puts 2nd bailouts to vote	31/10/2011	CFA Institute as of 5/4/2013	Leading to volatile markets which leads to his resignation on 6/11/2011
Italian PM resigns	12/11/2011	CFA Institute as of 5/4/2013	
Spanish Election	20/11/2011	CFA Institute as of 5/4/2013	A new government, the People's Party

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