Research Paper

Testing the Efficiency of the Sovereign Debt Market using an Asymmetrical Volatility Test

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About the author

Bachar Fakhry is currently an independent researcher of financial economics based in the United Kingdom. He received his PhD in Economics from the University of Bedfordshire in 2015; however, he has two master degrees in Distributed Information Systems (1996) and Financial Management (2005), both from the University of East London. His research is mainly in the areas of financial economics and econometrics with a special focus on bounded rationality. He won the prize in the Scientific Research Area of Economics and Management Sciences for his paper at IV Postgraduate Conference ESGHT 2013. He is a member of the Royal Economic Society and International Network for Economic Research.

Christian Richter is currently a professor of economics at the German University in Cairo, Egypt. He received his PhD in economics from University of Strathclyde in 2001. His main research areas are behavioural economics and finance, convergence of business cycles, Eurozone crisis, financial economics, time frequency analysis and climate change. In 2015, he won the Ernst Wagemann prize for best paper in economics in 2013-2014 in Applied Economics Quarterly. He is also Honorary Chair of the International Network for Economic Research (INFER) where he is active for many years.
Abstract

We test the efficiency of the financial market using the daily prices of the US and German sovereign debts between July 1, 2002 and December 31, 2011. This allowed us to test the efficiency during the pre-crisis, financial and sovereign debt crises periods. We extend the variance bound test of Fakhry & Richter (2015) using a GJR-GARCH model. This hints at our contribution, i.e., the inclusion of the asymmetrical effect in the variance bound test.

Our tests produced mixed results, pointing at the markets being too volatile to be efficient. Interestingly, the addition of the asymmetrical effect led to a reduction in the EMH test statistics based on the results from Fakhry & Richter (2015) and hence may have had an impact on the efficiency of the market. Conversely, this is more appropriate to speak of bounded rationality than irrationality.

A key conclusion of the paper is it hints at the use of a switching GARCH model as an alternative to the GJR-GARCH. Therefore, a prospective future research could be the use of a switching GARCH model to analyse the different impact of high and low volatility regimes on market. Given our key conclusions, another prospective is the use of sovereign debt indices instead of the issued sovereign debts.

JEL Classification: B13, B16, B21, B23, C12, C13, C58, G01, G02, G14, G15, H63

Keywords: Efficient Market Hypothesis, Volatility Tests, Asymmetrical Effect, GJR-GARCH, Sovereign Debt Market, Crises

Introduction

The efficient market hypothesis has been the cornerstone of asset pricing since the early 1960s, developed through prominence articles such as Malkiel (1962) and Fama (1965, 1970). However as suggested by Fakhry and Richter (2015), the efficient market hypothesis relies on some untestable assumptions and models like perfectly competitive markets and rational risk averse profit maximizing market participants. Hence as suggested by Ball (2009), there have been many criticisms from policy makers and academics, especially in the aftermath of the financial crisis. Yet as hinted by Fakhry and Richter (2015), it is possible to test the efficiency of the market through the use of the Shiller volatility test as derived by Shiller (1981a). Conversely, the momentum of behavioral finance in the 1990s also highlighted the issues surrounding the efficient market hypothesis.

As hinted by Black (1976), a key observation made primarily in stock markets is that there is a negative correlation between returns and volatility, meaning that a negative movement has a greater impact than a positive movement of similar magnitude on the volatility. Therefore, it suggests that market participants react differently to negative and positive shocks. The importance of this is it may have an impact on the efficiency of the market. Fakhry and Richter (2015) hint at a different effect on the efficiency of the market due to the environment. This would suggest that efficiency of the market is based on the reaction of market participants. Hence, we proposed to extend Fakhry and Richter (2015) by using the GJR-GARCH model of
volatility as the basis of the variance bound test.

A key issue with the use of issued bonds is that it does lead to accusations of a mismatch between the US and German markets. A better comparison would have been the Eurozone market. However, as of writing the article, there was no issued sovereign debt for the Eurozone. Conversely, many banking and investment firms provide indices for the Eurozone and US sovereign debt markets which could be used instead of the issued sovereign debts. Although the indices do have several major advantages, i.e., a better comparison between the US and Eurozone markets, longer observational period and overcoming issues such as the on-the-run and maturity effects. Yet the use of these indices in any research would require approval of the issuing firm and we did not have access to the indices during the research.

The Recent Empirical Evidence on 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 and MacKinlay (1988) allow the testing of the random walk model, the influencing assumption in 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 and 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.

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

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 that the likelihood test and the volatility test have more power under certain parameters. Nevertheless, as pointed by Bollerslev and Hodrick (1992) the use of ARCH/GARCH models in the estimation process can overcome seasonality in fundamentals and volatility clustering issues.

In general, there is a large body of empirical literature on the efficiency of the financial market. A large percentage of these are based on the stock market, and the recent evidence on the efficiency of the stock market is mixed. Some found the stock market to be inefficient; an example is Cajueiro et al. (2009) who
found that the liberalization of the Greek stock market made it significantly less efficient. However, the evidence from Cuthbertson and Hyde (2002) seem to suggest the acceptance of the EMH for the French stock market and slightly less so for the German.

In comparison, the body of empirical literature on the efficiency of the sovereign debt market is limited despite the first model of international efficient market being based on the French sovereign debt market as stated by Zunino et al. (2012). As Zunino et al. (2012) suggest that the main reasons are the size of trading on the stock market and the type of trading for the sovereign debt market, mainly traded “over-the-counter”. Like the stock market, the recent empirical evidence on efficiency in the sovereign debt market is mixed. Zunino et al. (2012) using sovereign debt indices found that developed markets tend to be more efficient than emerging markets.

In a study of the impact of the recent financial and sovereign debt crises on the US and German sovereign debt markets, Fakhry and Richter (2015) found that in general both markets were too volatile to be efficient. Although the US datasets do suggest that the market is efficient, yet the subsamples suggest a mixed results pointing to both crises having an impact on the efficiency of the US and German markets. This leads to a possible explanation of the efficiency of the US datasets using the behavioral finance theory. Since market participants were overreacting/underreacting to information during different periods, one possible conclusion is that the overreaction/underreaction cancel each other out, leading to a stable state in the datasets and thus giving the impression of market efficiency. Fakhry et. al. (2016) found similar evidence using the GIPS markets.

The Empirical Evidence on the Asymmetrical Effect in the Sovereign Debt Market

A key observation made primarily in stock markets and also to a lesser extent in the sovereign debt market, there is a negative correlation between returns and volatility as hinted by Black (1976). This means that 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 generalizing 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 means 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 difference is that unlike many other GARCH models where the need arises to constrain 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.

The leverage or asymmetrical effect is well documented in the stock markets but little empirical evidence has 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) analyze 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 found 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.

Recently much of the empirical evidence has 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 Metui (2011), Tamakoshi (2011) and Mohl and Sondermann (2013).

In a paper researching contagion among the Eurozone sovereign debt markets, Metui (2011) employ the GJR-GARCH model to analyze 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 1 April 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 seems to correspond with the periods of high financial distress during the recent financial and following sovereign debt crises. They find statistical evidence 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 that 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. They use daily 10-year yield data from seven Eurozone members (i.e. GIIPS plus Germany and France) observed over the period between 1st January 2007 and 31st March 2011. They conclude 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 came from Portugal and Italy. Although Germany remains the strongest economy and has the best credit rating driven by strong sound fiscal policies, yet the evidence seems 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 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, Mohl and Sondermann (2013) 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 May 1, 2010 and June 30, 2011 from Haver and a number of news agencies (i.e. Bloomberg, Dow Jones Newswire, Market News International and Reuters). These 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 improved communication discipline.

Model Specification for the Asymmetrical Variance Bound Test

The main aim of this paper is to extend the test for the efficient market hypothesis (EMH) used in Fakhry and Richter (2015) to account for the asymmetrical effect. We proposed an asymmetrical variance bound test by extending Fakhry and Richter (2015) using a GJR-GARCH variant of the variance bound test proposed by Shiller (1979, 1981a). We use the 5% critical value F-statistics to test the efficient market hypothesis. Although Shiller does advocate the use of such methodology, yet he does not specify a specific econometric model. There are a number of pre-requisite steps in the model specification of the test:

1. As illustrated by Shiller (1981a), the key factor underlying any 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 (1). We used the 20 lagged system advocated by Fakhry and Richter (2015).

\[
\lim_{t \to T} \text{var}(Price_t) = \frac{\sum_{q=1}^{Q} (Price - \mu)^2}{Q}
\]

(1)

2. The first order autoregressive model estimates the residuals in the econometric model underpinning the test as illustrated by equation (2) and (3).

\[
\text{var}(Price_t) = a + b_t \text{var}(Price_{t-1}) + \mu_t
\]

(2)

\[
\mu_t = \rho \mu_{t-1} + \varepsilon_t
\]

(3)

We opt to use the GJR-GARCH model in our tests. An influencing factor in the GJR-GAARCH model is the asymmetrical order, which we set to one. Hence, we estimate a GJR-GARCH (1, 1) using equation (2)
and (3).

\[ h_{jt} = \omega + \alpha_1 K_{t-1} + \beta_1 h_{t-1} + \gamma_1 k_{t-1} I \]  

(4)

Where \( I = \begin{cases} 0, & \varepsilon_t \geq 0 \\ 1, & \varepsilon_t < 0 \end{cases} \)

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 \( \gamma \) coefficient in equation (4) 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.

As noted by Alexander (2008: 137) and Engle and 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 that the reaction and mean reversion of the market shocks to volatility can be naturally interpreted by the two remaining coefficients in equation (4). 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 that the use of the price variance had the impact of hiking the \( \alpha \) coefficient leading to a massive increase in the volatility’s sensitivity to market shocks. In contrast, the \( \beta \) coefficient decreased significantly leading to massive downgrade in the persistence of the volatility in the aftermath of a crisis in the market.

The coefficients of the GJR-GARCH model of volatility are also key to our asymmetrical variance bound test. 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 (5):

\[ EMH \text{ Test} = \frac{(\alpha + \beta + \gamma) - 1}{\text{standard deviation}(\text{var}(x))} \leq \text{F statistics} \]  

(5)

By definition, the market is efficient when the condition as set in equation (5) is true. Theoretically, the market is only truly 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 (5) is true but accept the null hypothesis of the market being too volatile to be efficient for anything else.

Data Description

As stated earlier, the data used in the empirical section is the US and German 10-year notes observed from July 1, 2002 to December 31, 2011, meaning a uniformed 2,480 daily observations for each sovereign debt market.

In order to analyze the efficiency of the sovereign debt market under different global market conditions, we subdivide our observed markets into the following periods: pre-crisis period, financial crisis of the late 2000s and sovereign debt crisis of the 2010s.

As illustrated in Table 1, we use the daily 10-year sovereign debt, maturing in 2012, end of day bid prices for US and Germany obtained from Bloomberg. We follow the norm by defining our week as Monday to
Friday. In order to make the observed data uniformed across all observed datasets, we substitute all missing observations with the last known price.

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<th>Download Date</th>
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An Asymmetrical Volatility Test

This section aims to provide empirical evidence of the impact of the crises on the efficiency of the financial market. 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 use of the GJR-GARCH is the use of the asymmetrical effect to analyze whether our EMH test responses differently to negative and positive shocks.

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.

Pre-Crisis Period (07/01/2002-06/29/2007)

The evidence seems to suggest that 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 9/11 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 difference between these two impacts on the sovereign debt market is that 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 in Table 2, the asymmetrical coefficients for the entire observed markets hint at a negative asymmetrical or leverage effect, meaning that 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
Table 2  EMH Test Statistics

<table>
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<td></td>
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<td>Financial Crisis Period&lt;sup&gt;(2)&lt;/sup&gt;</td>
<td>Sovereign Debt Crisis Period&lt;sup&gt;(3)&lt;/sup&gt;</td>
<td>Pre-Crisis Period&lt;sup&gt;(1)&lt;/sup&gt;</td>
<td>Financial Crisis Period&lt;sup&gt;(2)&lt;/sup&gt;</td>
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<tr>
<td>Mean Eq. a</td>
<td>0.002250 (0.000434)</td>
<td>0.004796 (0.000204)</td>
<td>0.001098 (0.000327)</td>
<td>0.001767 (0.000190)</td>
<td>0.002075 (5.62E-05)</td>
</tr>
<tr>
<td>Mean Eq. b</td>
<td>1.002679 (0.001199)</td>
<td>0.974958 (0.001581)</td>
<td>1.010343 (0.002140)</td>
<td>0.987780 (0.001897)</td>
<td>0.993822 (0.001896)</td>
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<td>Mean Eq. u</td>
<td>0.749415 (0.007641)</td>
<td>0.699719 (0.011537)</td>
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<td>0.682694 (0.015221)</td>
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</table>

| Mean Eq. ω           | 2.61E-05 (5.13E-06)     | 1.63E-06 (7.11E-07)  | 3.43E-08 (8.72E-09)     | 9.53E-06 (1.65E-06)  | 1.30E-06 (4.37E-07)  | 4.39E-08 (9.20E-09)  |
| Mean Eq. α           | 1.617939 (0.207861)     | 3.361139 (0.941532)  | 1.104164 (0.198694)     | 1.508946 (0.188876)  | 1.681302 (0.305273)  | 1.547679 (0.270323)  |
| Mean Eq. β           | 0.171466 (0.022344)     | 0.205077 (0.033263)  | 0.256096 (0.048658)     | 0.180951 (0.025875)  | 0.208881 (0.034594)  | 0.121111 (0.029265)  |
| Mean Eq. γ           | -0.189597 (0.243610)    | -1.334381 (0.712667) | -0.25853 (0.223850)     | -0.301401 (0.223691) | -0.324167 (0.358069) | -0.345743 (0.328016) |

<table>
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<td>0.257360</td>
<td>0.133095</td>
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</tbody>
</table>

| EMH Test             | 0.857795                | 5.503145             | 5.734724                | 1.509543             | 4.252722             | 24.484387            |
| Efficiency Accept    | Reject                  | Reject               | Accept                  | Reject               | Reject               | Reject               |

<sup>(1)</sup>Pre-Crisis Period: 07/01/2002-06/29/2007

<sup>(2)</sup>Financial Crisis Period: 07/02/2007-10/30/2009

<sup>(3)</sup>Sovereign Debt Crisis Period: 11/02/2009-12/30/2011

Remembering that high volatility blighted the early part of this period and although there were many highly volatile factors influencing the early parts of this period, 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.

Unlike the US market, the $\alpha$ coefficient of the German market is hinting at relatively low levels of sensitivity to market shocks. In essence, the German market seems to be illustrating the stability of the euro effect on the market. In truth, the US market does not hint at a high level of sensitivity to market shocks. 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 $\alpha$ 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. Although, on the face of it, the asymmetrical effect does not seem to have had an impact on the $\alpha$ coefficient, yet on closer inspection as illustrated by Fakhry and Richter (2015), the asymmetrical effect seems to have had a decreasing impact on the sensitivity levels of all the markets.

The $\beta$ coefficients seem to be hinting at relatively low volatility persistence in the aftermath of a crisis in the market, especially the US market. 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”. As pointed by Fakhry and Richter (2015), 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 both 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 Fakhry and Richter (2015). Conversely, this reduction led to the acceptance of the efficient market hypothesis by German market. Interestingly the German market is closer to the key f-statistics. Although the US market is further away from the key statistic, yet it is efficient. A key explanation for this is the standard deviation, which is higher than all the other markets. This is essential because 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, which means that the US market had satisfied one of the key assumptions. In essence, the difference between being efficient and not was maybe the reaction to a certain event or events.

**Financial Crisis Period (07/02/2007-10/30/2009)**

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, and 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.

During the financial crisis period, the asymmetrical coefficients were hinting at a leverage effect for all the observed markets as illustrated in Table 2. The effect seems to be significant in both markets. 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 September 15, 2008, an example is the Dow Jones Average index, which fell from 13,950 on July 16, 2007 to 6,547 on March 9, 2009. This partly explains the high leverage effect in the US market and to a lesser extent the German market which is the risk free market in the Eurozone.

The $\alpha$ coefficients are interesting because they truly reflect the different impact of the financial crisis on the observed sovereign debt markets, and whereas the $\alpha$ coefficient seems 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 $\alpha$ 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. The German market seems to be hinting at a limited impact from the financial crisis. However, as illustrated by Fakhry and Richter (2015), certainly the asymmetrical effect had the impact of raising the levels of sensitivity to shocks in both observed markets.

The $\beta$ coefficients of the US and German markets hint at a high level of volatility persistence during the financial crisis. This is 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. Not surprisingly during the financial crisis as illustrated by Fakhry and Richter (2015), the asymmetrical effect had the impact of rising the $\beta$ 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 the observed markets. The EMH test statistics imply 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 means 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 previously, the continued upwards trend meant that in essence the markets were predictable to a certain extent. As Fakhry and Richter (2015) 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 seems to be going against the norm for this period in deviating further from the efficient market.
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Sovereign Debt Crisis Period (11/02/2009-12/30/2011)

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, an influencing factor to bear in mind is the maturity effect. Another influencing factor is that 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 both markets especially the US.

The asymmetrical coefficients in Table 2 are indicating a leverage effect during the period accounting for the sovereign debt crisis. The evidence seems to be pointing at a significant leverage effect.

Not surprisingly, the $\alpha$ coefficients of the US and German markets hint at relative low levels of sensitivity to market shocks during the sovereign debt crisis. 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. It is worth remembering that both markets were seen as safe havens from the crisis. However, the asymmetrical effect did have an impact on the $\alpha$ coefficients for both markets raising the levels of sensitivity to market shocks.

The $\beta$ coefficients for both markets seem to be painting a rather mixed picture. While the US market seems to be suggesting a high level of persistence in the market, the German market seems to be hinting at a lesser level of persistence. A possible explanation for the mixed picture is the different policies adopted by the Federal Reserve and the ECB. Another factor is the beginning of the fiscal cliff crisis in the US which meant that the US market experienced a longer period of volatility. However, this does not explain the relatively low persistence in the German market. A possible explanation is the strength of the German economy. As illustrated by Fakhry and Richter (2015), the inclusion of 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. 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, especially the German market. During the early stages of the sovereign debt crisis, both markets were seen as risk free and liquid markets, hence the upwards trend continued making them more predictable. Conversely, the EMH test statistic for the German market is significantly higher than the US market, with the inclusion of the asymmetrical effect hinting at a large deviation from the efficient market as pointed by Fakhry and Richter (2015).
Conclusion

In this paper, we use the Shiller volatility test to analyze the efficiency of the market during different periods. In order to analyze the impact of the asymmetrical effect on the efficiency of the market, we extended Fakhry and Richter (2015) in using a GJR-GARCH. We estimate the excess volatility in two of the biggest financial asset markets, the US Treasuries and German Bunds, in a fast changing environment encompassing fixed periods of high and low volatility. By using daily data, we have enough degrees of freedom to create subsamples where we could test each subsample individually. The aim is to find out how the financial crisis of 2008 and the sovereign debt crisis of 2009 may or may not have changed the efficiency of the financial markets.

Our results show asymmetrical effects on the EMH. In comparison to the results in Fakhry and Richter (2015), the EMH test statistics appear to have increased in general. This meant that the German market accepted the efficient market hypothesis during the pre-crisis period whereas under the GARCH-based test the German market (narrowly) rejected the EMH. However, both the financial and sovereign debt crisis periods did reflect the efficiency status of Fakhry and Richter (2015) in the sense that in “normal times” the EMH holds, whilst in crises times it does not.

A relevant factor raised by our empirical evidence regarding the efficient market hypothesis is that during some highly volatile periods some markets rejects the null hypothesis of the market efficiency due to too volatile behavior. According to Kirchler (2009), underreaction and/or overreaction occurs 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 when it actually is not. This is what seems to have happened during these periods as market participants overreacted to new information, which reflects a regime switching model.

From here are at least two lines of prospective research: the first is to use a switching GARCH model to analyze the impact of high and low volatility on the efficiency of the market. The second is as proposed in the introduction to use an index of the sovereign debt market to better analyze and compare the markets. A major benefit of the use of an index is that it allows us to do a better comparison with the use of the Eurozone sovereign debt index as opposed to the issued German sovereign debt. Another advantage with the use of an index is that it has a longer period of observation, this means we analyze the impact of the Euro on the efficiency of the sovereign debt market.

Overall, our results show that market participants were acting under uncertainty and lack of full information. Therefore, the results are backing the conclusions of Fakhry and Richter (2015) in that it is more appropriate to speak of bounded rational behavior than irrationality. This further confirms that financial markets are not as efficient as assumed, especially in the neoclassical theory.
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References


