THREE ESSAYS ON IDENTIFYING SAFE HAVENS FOR EQUITY INVESTORS

By

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A thesis submitted in the fulfilment of the requirements for the degree of

Doctor of Philosophy (PhD)

In the Department of Economics, Finance & Accounting

National University of Ireland Maynooth (NUIM),
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October 2013

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SUMMARY

Chapter 2 examines conditional mean and volatility spillover between equity and gold to ascertain if gold is a safe haven for investors. This is achieved using a VAR-GARCH model allowing for simultaneous transmission of shocks between series. This also provides the time-varying inputs for portfolio construction to aid investors' understanding of the interactions between gold and equity. Results reveal that statistically significant return and volatility spillover from equity to gold is nonexistent over a thirty-one year period. On the strength of these results gold is recommended as a safe haven for a well diversified portfolio.

Chapter 3 determines how potential safe havens are affected by the arrival of negative shocks in the stock market. A test for mean and variance spillover from equity to potential safe haven assets is achieved using Cheung and Ng's (1996) two-stage Cross-Correlation Function procedure. Next, information transmission is analysed between equity - gold and equity - 10-year bond based on Volatility Impulse Response Functions developed by Hafner and Herwartz (2006). Results indicate that both assets have the potential to be used as safe havens. However, gold proves slightly more attractive and as such should be chosen over a long-term U.S. Treasury bond.

Chapter 4 presents the uniformed Markov-switching framework of Flavin and Panopoulou (2010) for a more in depth analysis of the relationship between the stock market and potential safe havens. The first test for shift-contagion identifies changes in the normal relationship between assets during periods of high-volatility, while the second test for pure-contagion provides insight into how a high-volatility equity idiosyncratic shock affects other assets. Results suggest that investors should proceed cautiously if simultaneously investing in equity and a 1-year bond.

ACKNOWLEDGEMENTS

I would like to take the time to sincerely thank the people whose support and guidance made the completion of my PhD a reality.

First and foremost, I will forever be thankful to my mentor and supervisor Dr. Thomas Flavin whose encouragement, patience and thoughtful guidance kept me going through the most challenging and difficult times. When I, and others, doubted my ability he remained steadfast in his support - for which I will always be grateful.

I am also indebted to my PhD committee, Prof. Rowena Pecchenino and Dr. Fabrice Rousseau for all the support they gave me. Their guidance and suggestions in the final stages served me well and I owe them both my heartfelt appreciation. I wish to acknowledge each and every lecturer in the Department for their comments during the many internal presentations. Each of them has provided me with the invaluable experience of defending my work which I hope will stand to me into the future. In particular, special thanks must be given to Margaret Hurley and Dr. Fabrice Rousseau for their advice and suggestions in the weeks leading up to the Viva Voce. A much deserved thank you must also be given to Máire Adderley and Sandra Doherty who were always there with a kind word of encouragement when I was feeling most anxious. I am also indebted to Ekaterini Panopoulou, without whom Chapter 4 would not have been possible. I am grateful for the time she dedicated to this project and her advice throughout.

I must also give a heartfelt thanks to everyone in the Records Office and the Access Office for providing me with the means to support myself through the last four years. To Ann, Enda, Gretta, Michael, Catherine and Marina - every summer I looked forward to the tea-time chats that never failed to provide a welcome distraction from the stress and worry of research. A special thanks to Adrienne for all her help and encouragement in recent months and to Gráinne for our monthly catch-ups and all her support. I am also grateful to Bridget Gormley, Simon Ahern and Gemma Lynch who allowed me to be part of the Student+ family for the past three years.

On a personal level, I would like to thank my PhD class and friends. Anita, Adele, Lena and Mick have each helped with many helpful comments and suggestions for my work. Scone dates with Kate and Paul kept me going through the writing-up stages in the final months and I thank them both for all the laughs over the past few years. I thank two of my best friends, Shelly and Jen, for never letting me get too bogged down in PhD worries. Their friendship and support helped me maintain some semblance of sanity through this whole process. In particular, I thank my dearest friend, Lisa. Having met all those years ago in JH5, we have shared tears together and panicked together but most importantly we have always laughed together... and at each other! I will forever be grateful for the motivation derived from the fact that we are the exact same - if Lisa can do it, maybe I can too.

I reserve special thanks for my Family. I owe an enormous debt to my Mother, Eileen, and Father, Michael who have taught me more than any lecturer or teacher ever could. They have raised me to be hard-working and persistent and to be open to and accepting of everything life offers me. I thank them both for these precious gifts. To my three beautiful sisters, I thank you for your love and encouragement. Lorraine, thank you for our GAA dates and the distraction they provided over the past few summers. Ursula, thank you for never failing to make me laugh even when I felt most stressed. Sinéad, thank you for helping me keep things in perspective by never really understanding how it takes four years to write just three chapters. I must also thank my wonderful Aunt and Godmother, Brigid. I know none of this would have been possible without her prayers.

Finally, I will forever be grateful to Brian and all that he has sacrificed for me. He has had to endure more than most and it is through his love and unwavering patience and support that I am able to complete this journey. When I felt most lost and on the verge of giving up, he kept the light burning at the end of the tunnel and has always helped me find my way.

CONFERENCES & PUBLICATIONS

Chapter 2, "*Is gold a safe haven for equity investors? A VAR-GARCH analysis*" was presented at the *Irish Economic Association* at its 26th Annual Conference in Dublin (April, 2012); The 9th annual *Irish Society of New Economists Conference* in UCC (Aug, 2012); The 44th annual *Money, Macro and Finance Conference* in TCD (Sept, 2012). Earlier versions of this chapter were also presented at *NUIM PhD internal seminars* (2011) and *NUIM Department of Economics, Finance and Accounting internal seminars* (2011).

Chapter 3, "*Utilising Cross-Correlation and Volatility Impulse Response Functions to Identify Safe Haven Assets*" was presented at the *Irish Economic Association* at its 27th Annual Conference in Co. Kildare (May, 2013) and at the 10th annual *Irish Society of New Economists Conference* in NUIM (Sept, 2013). Earlier versions of this chapter were also presented at *NUIM Department of Economics, Finance and Accounting internal seminars* (2012).

Chapter 4, "*Detecting Shift- and Pure-Contagion between Equities and Potential Safe Haven Assets*" was presented at *NUIM Department of Economics, Finance and Accounting internal seminars* (2013).

Chapter 1: Introduction

This PhD dissertation consists of three essays on the identification of safe haven assets for equity investors. The increased uncertainty of global stock markets in recent years has reignited interest in safe haven assets and has fundamentally motivated this study. Historically, havens have been associated with places of protection or refuge and this concept has been adopted by financial markets to explain investors' preference for currencies, treasuries and commodities in periods of extreme stock market and economic uncertainty. Given that equity investors in particular have experienced substantial losses in the past five years, comparable only to the Wall Street Crash of 1929, it is vital that they are aware of the strengths and weaknesses of these potential safe havens.

Two such asset classes have maintained and even increased in value despite the uncertainty that has prevailed in global stocks markets. The first of these is U.S. Treasuries which investors have turned to time and time again. The latest recession was exceptional in that both stock and bond markets worldwide were affected simultaneously. In spite of this global effect, treasuries associated with some of the strongest economies, like the United States and Germany, for example, have realised a substantial fall in yields indicating that investors' sentiment regarding this asset has remained robust. Gold has also proven resilient in light of the losses experienced in U.S. stock markets, recently entering its thirteenth year of a bull market. Investors may consider this asset a safe haven based on the fact that an investment in it does not carry the risk that a coupon payment might not be made (bonds) or a company may go out of business (equities). Neither is the value affected by the economic policies of the issuing

country or undermined by inflation (currencies). It is also possible that this commodity's historic role as a standard of exchange has afforded it the title, by some investors, of the ultimate safe haven.

Regardless of investors' perception, anecdotally or otherwise, it is crucial that we understand the true relationship between the risky stock market and these specific assets. Each chapter assesses this relationship with a unique empirical examination including an investigation of the conditional mean and variance spillover between equity and gold; an analysis of causality-in-mean and causality-in-variance and volatility impulse responses between the asset pairings of equity - gold and equity - 10-year bond; and finally an investigation of shift- and pure-contagion between equity and three potential safe havens: gold, a 10-year bond and a 1-year bond.

A common theme runs through this dissertation with the primary aim of establishing if gold and U.S. Treasuries can be used as safe havens and, if so, how they compare. Throughout, modern time-series econometric techniques are used to analyse the time-varying relationship between equity and potential safe havens. Chapters follow one from another with each addressing an issue arising from the previous. Chapters 2 and 3 focus on the time-varying relationship based on univariate GARCH (Chapter 3) and multivariate asymmetric GARCH (Chapter 2) models, the latter of which determines how "bad news" specifically affects volatility spillover which can prove vital in an investor's choice of a safe haven. Chapter 4 offers a more comprehensive analysis with the use of a unified Markov-switching framework providing a detailed assessment of the various relationships through tests for both shift- and pure-contagion.

The dissertation is structured as follows:

Chapter 2 looks exclusively at gold and assesses its characteristics as a potential safe haven. A novel approach is taken in this assessment of gold by redefining what a safe haven is. Unlike previous literature which tends to concentrate on the changes in correlation between the risky asset and the safe haven, this paper focuses specifically on the time-varying mean and variance relationship. A safe haven is only considered "safe" if there is no statistically significant conditional mean or conditional volatility spillover from equity to gold. Based on this definition when a shock occurs in the stock market, it should not "spill over" to affect the return and/or volatility of gold, the presumed safe haven. This paper therefore simultaneously tests the interactions between series in both the conditional first- and second-order moments through a Vector Autoregression – Generalised Autoregressive Conditional Heteroskedasticity (VAR-GARCH) model. Similar to the study of El Hedi Arouri, Jouini and Nguyen (2011) this VAR-GARCH model allows exploration of both the conditional volatility dynamics of gold and equity and also the volatility spillover between the two series. The approach shows gold to be a credible safe haven insulated from the stock market inferred from the lack of significant spillover between the two series. Based on results from the VAR-GARCH analysis it is also possible to conduct a portfolio analysis, calculating the optimal equity - gold portfolio for an investor. It is important that investors are informed when allocating wealth within a risky portfolio and the results prove that investors utilize their knowledge of conditional variance and covariance by investing the majority of their wealth in equity. This suggests that gold may be held as a safe haven in a predominantly equity based portfolio.

Chapter 3 expands on this analysis by introducing a second potential safe haven, a 10-year U.S. Treasury bond to determine which of gold or a U.S. Treasury is most suitable to hedge against negative shocks in the stock market. The decision to focus on gold and U.S. Treasury bonds as potential safe havens is motivated by a number of economic factors. For example, despite one of the most turbulent financial periods in recent history the value of gold has increased substantially over the past ten years while investors also appear to be attracted to the guaranteed return associated with U.S. Treasuries in a market where yields are steadily decreasing. This chapter proposes two methodologies to examine mean and variance transmissions between the asset pairings which overcome the dimensionality problem of the M-GARCH models. The first of these is the two-stage Cross-Correlation-Function procedure of Cheung and Ng (1996) which tests for causality-in-mean and causality-in-variance and can be interpreted as a check for mean and variance spillover. Results indicate that of the two assets available, gold appears to be the most insulated from negative information arriving in the stock market. Volatility Impulse Response Functions developed by Hafner and Herwartz (2006) are employed in a second stage to analyse information transmission between equity - gold and equity - 10-year bond. This technique allows for an in-depth analysis of the persistence of negative shocks as well as determining the effect of such shocks on covariance. The results from both methodologies substantiate the finding that gold appears to be the most appropriate choice for equity investors.

In Chapter 4 a more comprehensive approach is taken to specifically determine the contagious effects between the stock market and three potential safe havens. This method is used to resolve which of gold, a 10-year U.S. T-bond or 1-year U.S. T-bond is the most important when an investor wishes to hedge against high-volatility in the

stock market. Flavin and Panopoulou (2010) note the importance of analysing contagious effects between different asset types within the same country in order to give equity investors a complete understanding of the evolution of adverse shocks. The appeal of this model is derived from the fact that it allows us to test for both shift- and pure-contagion within one unified Markov-switching framework to determine the true links between equity, gold and U.S. Treasury bonds. It also allows us to distinguish between common and purely idiosyncratic shocks. It is important that investors are aware of the type of contagion that may operate between assets as market linkages have the potential to become unstable in the presence of increased volatility. Therefore the test for shift-contagion reveals changes in the normal relationship between pairs of assets during periods of high-volatility while the test for pure-contagion distinguishes the effect of a high-volatility idiosyncratic shock on other assets. The results suggest that of the three potential safe havens gold emerges as the most appropriate while the 1-year bond appears the most inappropriate safe haven asset exhibiting evidence of both shift and pure contagion.

To finish, Chapter 5 offers an overview of results and concludes with some suggestions of future research which this thesis identifies as potentially important.

Chapter 2: Is gold a safe haven for equity investors? A VAR-GARCH analysis

2.1 Introduction

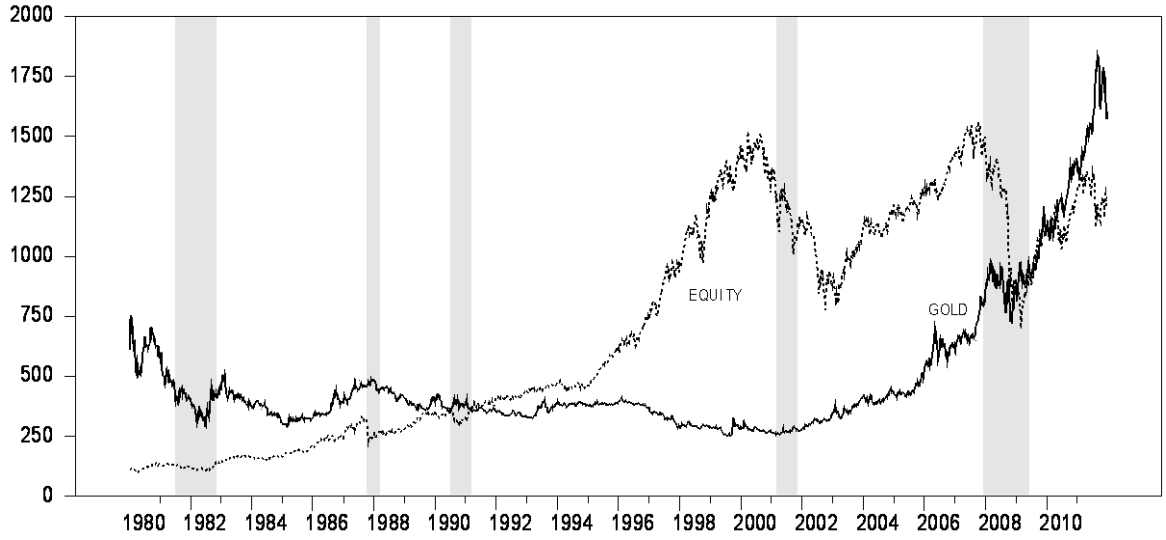
With the onset of the financial crisis of 2007-2009, stock markets world-wide plummeted as a crisis rippled through the world's financial system. Stock markets in the United States, Europe and other major economies fell simultaneously, leading investors to reallocate their portfolio wealth away from equities to what they perceived to be safer alternatives. To ensure that these portfolio reallocations reduce portfolio risk, it is important that investors understand the manner through which shocks in the stock market can potentially be transmitted to and increase the risk associated with other assets.

In recent years, equity investors have sought safe havens in which to invest their wealth during stock market turmoil. One such perceived safe haven is gold. Figure 2.1 shows that in the aftermath of the initial crisis, the S&P500 Index fell from a high of 1,504.66 index points in 2007 to a low in June 2009 of 683.38, a 54 per cent decrease. Over the same period gold prices were increasing steadily and on the 31st August 2011, gold bullion broke through the U.S.$1,800 per troy ounce barrier, reaching an all time high of $1,826 in its eleventh year of a bull market. Such price movements have reignited both media and investor interest in gold with headlines in the Telegraph[1] ("Is gold a safe haven for investors?", 2008), CNBC[2] ("Is gold the only safe haven investment left?", 2011) and Financial Times[3] ("Gold set to cement safe haven status", 2008) highlighting the desperate search for a safe haven by investors as well as the

[1] Available at: http://www.telegraph.co.uk/finance/personalfinance/investing/3047311/Is-gold-a-safe-haven-for-investors.html
[2] Available at: http://www.cnbc.com/id/44193266
[3] Available at: http://www.ft.com/intl/cms/s/0/9d002228-8eb9-11dd-946c-0000779fd18c.html

emerging attractiveness of gold. This paper therefore focuses on the channels through which shocks can "spill over" or be transmitted from the equity market to gold, thereby reducing the safe haven status of gold.

Figure 2.1: *Gold: Gold Bullion U.S.$/Troy Ounce;*
Equity: S&P Composite 500 U.S.$ Price Index



Several definitions of safe haven have been proposed in the existing literature and whichever definition is used affects the interpretation of the results derived. Baur and McDermott (2010) and Baur and Lucey (2010) base their analysis on the assumption that a safe haven is an asset that has a zero or negative correlation with the risky portfolio. Under this definition they conclude that while gold acts as a strong safe haven for most developed world stock markets, in periods of extreme global uncertainty gold fails to act as a safe haven. It is for this reason that this paper proceeds with what is considered to be a more comprehensive definition of a safe haven.

If an equity investor uses gold as a diversifier, then their primary concern is how a shock to the equity portion of the portfolio affects the return on gold. For a safe haven to be considered safe there must therefore be no statistically significant conditional mean or volatility spillover from equity to gold. This means that if a shock occurs in the stock market, it should not "spill over" to affect the return and/or volatility of gold, the safe haven asset. This definition should allow for a more thorough analysis of safe haven assets in that it encompasses both the first- and second- moments of the return distribution, the key inputs into an investor's portfolio selection model.

Unlike other studies on the relationship between gold and equities, this paper simultaneously tests interactions in both the conditional first- and second-order moments through a Vector Autoregression – Generalised Autoregressive Conditional Heteroskedasticity (VAR-GARCH) model. This multivariate model, by allowing for time-varying variance, determines if shocks are transmitted from the stock market to gold by a spillover in conditional mean and the conditional variance rather than the univariate approach taken, for example, by Baur (2012) and Baur and Lucey (2010).

Similar to the methodology of El Hedi Arouri, Jouini and Nguyen (2011) who focuses on oil prices and stock returns, this VAR-GARCH model allows analysis of both the conditional volatility dynamics of gold and equity and also the volatility spillover between the two series. If there is no volatility spillover between the two series then a shock will have no impact on gold return volatility. This being the case, gold will be a suitable safe haven available to investors who can be confident in the knowledge that the turbulence of the stock market will not negatively affect their investment in gold.

The methodology is based on the Glosten, Jagannathan and Runkle (1993) specification, GJR-GARCH, in which asymmetry is included to ascertain whether or not gold responds differently to positive and negative shocks in the stock market. This follows the results of Schwert (1990) who reports stock market volatility increases during recessions and crises. Thus, if gold is indeed a safe haven, then investors would like its returns to respond positively to positive shocks and more importantly there should be no response to negative shocks.

While the extant literature has explored the relationship between equities and gold, few to date have explored it in terms of identifying conditional mean and volatility spillover in a multivariate setting. It is also possible to conduct portfolio analysis, calculating the optimal portfolio for an investor based on the results from the VAR-GARCH analysis. Portfolio theory establishes that an investor is better placed when a portfolio is diversified across numerous assets. Ideally these assets will not be perfectly positively correlated and it is crucial that certain safe havens are insulated from shocks that are likely to affect other assets in the portfolio. In this way the investor reduces the portfolio losses associated with equity crashes. This portfolio analysis, along with the VAR-GARCH model will provide investors with the critical insight needed when choosing safe haven assets as a component of their portfolio.

The paper is structured as follows: Section 2.2 reviews the literature on the relationship between gold and the stock market. Attention, in particular, is given to literature of volatility spillover from equities to other assets and the literature on safe havens. Section 2.3 details the data while section 2.4 covers the VAR-GARCH methodology; results are presented in section 2.5. Portfolio analysis is provided in section 2.6. Conclusions are drawn in the final section.

2.2: Literature Review

The aim of this paper is to analyse the spillover effects between gold and the stock market in an effort to resolve gold's position as a safe haven for investors. The primary role of a safe haven is to provide a safety net for investors during periods when there is increased uncertainty in the stock market. There is some debate within the literature over what a safe haven is and several studies have provided definitions.

McCauley and McGuire (2009) compile a number of definitions in their analysis of dollar appreciation following the 2008 crisis. One such definition states that investors, nervous of market losses, seek out an asset with low market risk and high liquidity. This definition is similar to one used by Kaul and Sapp (2006) where a safe haven is any asset that investors are drawn to in uncertain times. This implies that the safe havens that investors choose can change from one crisis period to the next depending on investor sentiment at the time.

Others, such as Baur and Lucey (2010) and Baur and McDermott (2010), have defined a safe haven as being a type of hedge asset where the return is unrelated or negatively related to that of the reference portfolio. The safe haven asset should therefore exhibit negative or zero correlation in periods of market stress. The correlation between the safe haven and the asset or portfolio may be positive or negative on average but must exhibit negative correlation in specific periods of uncertainty.

Historically gold has exhibited highly volatile returns so investors tend not to hold a portfolio composed largely of gold. However, the attractiveness of gold appears when it is held with other assets in a portfolio and, in particular, when it is held with equities. Coudert and Raymond (2010) outline the properties of gold that lead it to being a potential safe haven even though volatility is characteristically high. They note gold's

historical role as a medium of exchange in international monetary exchange, hinting that it may still be the ultimate safe haven. Jaffe (1989) shows that the inclusion of gold bullion in a portfolio not only reduces the risk but also increases the return which will make gold very attractive to investors over the alternative of holding cash, for example, which will reduce the risk but may also reduce return.

Until Baur and Mc Dermott (2010), no previous literature had examined the explicit role of gold as a safe haven. They focus on the changing relationship between major emerging and developed countries and gold over three crisis periods. Focusing on the stock market crash of 1987, the Asian crisis of 1997 and the most recent recession of 2007, they conclude that gold does not appear to exhibit safe haven qualities in periods of extreme market uncertainty. The rising uncertainty in the stock market forces worried investors to seek out a safe alternative. Under extreme global uncertainty, however, the authors conclude that gold begins to move with the stock market, establishing a situation where all assets move in the same direction. Coudert and Raymond (2010) agree with the findings of Baur and Mc Dermott (2010) concluding that gold is a weak safe haven in periods of stock market uncertainty and acts only as a strong safe haven for a relatively short period of time.

Lawrence (2003) also provides insight into the evolving relationship between gold and the stock market. He takes it a step further by taking into account consumption commodities such as oil, copper and zinc to determine the strength of gold as a diversifier. The paper concludes that gold appears to be insulated from the business cycle in contrast to other commodities which may make it more attractive as a diversifier and indeed as a safe haven.

The use of volatility spillover models was first introduced by Engle, Ito and Lin (1990) with the analysis of Yen/USD exchange rates. Since then volatility spillover has been used by Bekaert and Harvey (1997), Baele (2002) and Ng (2000) to analyse the relationships between markets and assets, while Johnson, Soenen and Summer (2010) document the interdependence between stocks, bonds and gold using a similar spillover index model. When choosing a safe haven equity investors are concerned with how that safe haven is insulated from the equity portion of a portfolio. This can be measured using such spillover models. Focusing on the stock market and gold they find extremely low levels of spillover from the stock market to gold. They conclude that gold, while remaining an important safe haven asset for investors, displays a life of its own.

Most similar to the approach taken by this paper is the analysis of Morales (2008) who investigates the existence of volatility effects on precious metals' returns using a GARCH and EGARCH approach. She concludes that there is clear volatility persistence between precious metals' return but there is little evidence that these precious metals influence the gold market.[4] Similar results are found by Morales and Andreosso-O'Callaghan (2011) who, using the same GARCH and EGARCH approach, analyse the effects of the Asian and global financial crises on precious metals markets. Over the period 1995-2010 they find little evidence of palladium or silver generating any kind of influence on the gold market.

Using information derived from the VAR-GARCH analysis this analysis is concluded by developing the optimal portfolio for an equity investor to determine how or if gold is used to hedge against equity risk. Existing literature has found gold to be an extremely useful hedge in portfolios but little attention has been given to the use of gold

[4] Morales (2008) and Morales and Andreosso-O'Callaghan (2011) both use precious metals of gold, palladium and silver in their analysis.

as a safe haven. Hillier, Draper and Faff (2006) find that any financial portfolio containing a moderate weighting of gold tends to perform better than portfolios comprised only of financial assets. Baur and Lucey (2010) find similar results in that gold acts as a hedge - a security that is uncorrelated with stocks or bonds on average - for stocks in both the United States and the United Kingdom. Faff and Chan (1998) make similar conclusions in their empirical analysis of the Australian equity market. Coudert and Raymond (2010), differentiating between high and low market volatility, find that gold, platinum and silver exhibit some hedging capability, especially over periods of abnormal stock market volatility.

To date, no paper has attempted to explain the relationship between these two series using a multivariate VAR-GARCH model and as such focus is given to several crises affecting the S&P500 over the period 1980-2011 in an attempt to determine the strength of gold as a potential safe haven for equity investors.

2.3: Data

This paper uses thirty-one years of weekly data from 9th January 1980 to 28th December 2011, 1,669 observations in total. The Standard & Poor's Composite 500 – U.S.$ Price Index is the chosen stock market, while the London Bullion Market (LBM) U.S.$/per troy ounce is chosen to represent the gold market. All data is sourced from Datastream. The excess log return is taken of both series using the U.S. 3-month Treasury bill as the risk-free rate.

In addition to the full sample analysis, the data is divided exogenously into four, approximately similar sized, sub-samples 1980 - 1988, 1988 - 1996, 1997 - 2004 and

2004 - 2011 containing 443, 443, 392 and 391 weekly observations respectively. Dividing the data into sub-samples allows for a more in-depth analysis of the potentially time-varying relationship that may exist between the series and ensures that each sub-sample contains at least one crisis period.

Table 2.1 provides summary statistics and shows that gold, on average, exhibits negative weekly excess returns which occur when the return on the asset is less than the return on the risk free asset. The standard deviation for gold in the full sample, as well as each of the four sub-samples reinforces the findings of Coudert and Raymond (2010) that gold is the riskier of the two assets available.

Table 2.1: *Summary Statistics*

	Excess Log Return S&P500	**Excess Log Return Gold**
Mean	-0.0004	0.0004
Standard Deviation	0.02	0.03
Skewness	-0.69	0.30
Excess Kurtosis	4.90	6.17
Jarque-Bera	1807.79	2672.44
Observations	1,669	1,669

Notes: Skewness is defined as m_3/s^3 where $m_3$is the centred third moment of the data and s is the sample standard deviation. Kurtosis is defined as (m_4/s^4)-3 where m_4 is the centred fourth moment of the data.

Across the full sample as well as the sub-samples the Jarque-Bera test rejects the hypothesis that returns are normally distributed. Skewness and kurtosis are also included and reinforce the rejection of normality. According to Chiang (2007) investors

are drawn towards positively skewed distributions and over the thirty-one years, gold weekly excess returns are positively skewed while equity weekly excess returns are negatively skewed, which implies that gold (equity) has the propensity to generate positive (negative) returns with greater probability than suggested by a normal distribution.

Table 2.2: *Sub-Sample Summary Statistics*

	Sub Sample 1 1980 -1988	**Sub Sample 2 1988 - 1996**	**Sub Sample 3 1997 - 2004**	**Sub Sample 4 2004 - 2011**
S&P500				
Mean	0.0004	0.001	0.0003	-0.0001
Standard Deviation	0.02	0.02	0.02	0.02
Skewness	-0.93	-0.38	-0.03	-1.11
Excess Kurtosis	6.09	1.49	1.09	6.61
Jarque-Bera	750.54	51.92	19.73	793.49
Observations	443	443	392	391
Gold				
Mean	-0.002	-0.001	-0.0005	0.003
Standard Deviation	0.03	0.01	0.02	0.02
Skewness	0.63	-0.40	1.04	-0.05
Excess Kurtosis	5.02	2.97	6.88	1.89
Jarque-Bera	494.53	175.59	846.32	79.08
Observations	443	443	392	391

Notes: Skewness is defined as m_3/s^3 where $m_3$is the centred third moment of the data and s is the sample standard deviation. Kurtosis is defined as (m_4/s^4)-3 where m_4 is the centred fourth moment of the data.

Summary statistics were also computed for each of the four sub-samples provided in Table 2.2. Focusing on the weekly mean and standard deviation, equity has remained quite stable over the thirty-one years with negative weekly mean occurring

only in sub-sample 4, possibly attributable to the 2008 recession. Gold weekly excess returns and standard deviations vary across each of the four sub-samples. The highest volatility appears in the first subsample, a period notoriously volatile in gold's history. Trück and Liang (2012) note that since 1971 the price of gold proved to be very volatile reaching an historic high of U.S.$850 on January 21, 1980 before experiencing a 40 per cent decline in March 1980 on entering a twenty-year bear market. They hypothesise that, unlike other commodities, gold can be hoarded resulting in large discrepancies between the amount of gold stored and the quantity produced. Therefore, the price of gold is largely driven by investor sentiment rather than actual changes in annual production resulting in high volatility.

Table 2.3: *National Bureau of Economic Research Business Cycles*

NBER Crisis Period	Duration
December 2007 – June 2009	18 months
March 2001 – November 2001	8 months
July 1990 – March 1991	8 months
October 1987 – March 1988	5 months
July 1981 – November 1982	16 months

The National Bureau of Economic Research (NBER) determines the last four recession periods, reported in Table 2.3. The most recent recession began in December 2007 and lasted eighteen months to June 2009. While these dates may not coincide directly with stock market crises, the recession dates from the NBER provide guidance as to when stock market returns may be more volatile than usual.[5] This also allows focus to be drawn to particular periods over the thirty-one year sample and distinguishes

[5] Schwert (1990) reports stock market volatility increases during recessions and crises from 1834 to 1987.

if or how the relationship between the two series varies across tranquil and crisis periods. It is also worth noting that each sub-sample contains at least one of these recessionary periods.

2.4: Methodology

When dealing with financial data constant error variance, which is a basic assumption of most econometric models, is usually violated. This is because the standard deviation of financial series, such as equity, is likely to vary substantially from one period to the next, or to be heteroskedastic. As noted by Roach and Rossi (2009) when asset return volatilities exhibit time-variation and clustering, evident in stock market returns in particular, a VAR-GARCH specification which jointly models price returns and volatility is often appropriate.[6] In the past two decades variants of the (G)ARCH model have become increasingly widely used in empirical finance studies, see Bollerslev, Chou and Kroner (1992) for a survey.

The GJR-GARCH specification employed here allows for potential asymmetries caused by negative shocks on return volatility. This asymmetric extension of the standard BEKK model, developed by Baba, Engle, Kraft and Kroner (1987) and finalized by Engle and Kroner (1995), insures positive definiteness of the conditional covariance by formulating the model in a way that this property is implied by the model structure as in equation (2.3) below. The model is estimated simultaneously, computing the conditional mean and variance,

[6]Mandlebrot (1963): "large changes tend to be followed by large changes, of either sign, and small changes tend to be followed by small changes."

$$R_t = \Omega + \Phi R_{t-1} + \varepsilon_t + \theta \eta_{t-1}, \quad (2.1)$$

$$\varepsilon_t \mid \varphi_{t-1} \sim N(0, H_t); \quad (2.2)$$

$$H_t = C'C + A\varepsilon_{t-1}\varepsilon_{t-1}'A' + BH_{t-1}B' + D\eta_{t-1}\eta_{t-1}'D', \quad (2.3)$$

where, in equation (2.1), R_t is a vector of returns at time t; Ω is a 2x1 vector of constants; Φ is a 2x2 coefficient matrix and ε_t is a 2x1 vector of error terms. This model anticipates asymmetries where θ is a 2x2 diagonal coefficient matrix and η is equal to ε_t when ε_t is negative and zero otherwise. Essentially, the excess log return of gold, for example, is conditional both on its own and equity's previous periods return, identified through Φ, as well as its own and equity's previous periods negative shocks which is picked up in the θ term. The statistical significance of these parameters indicates a causal relationship between the previous periods return and next periods return. The equation permits differentiation between the effects of negative and positive shocks in both equity and gold which is consistent with a natural assumption of financial data whereby negative shocks have a greater impact on the series than positive shocks.

Bollerslev's (1986) GARCH model allows us to establish gold as a potential safe haven by testing the existence of conditional volatility spillover between series. The importance of such a specification in financial analysis is highlighted by Chen and Liow (2006) who stress the importance of investors' understanding the return volatility and shock persistence of different markets when creating and diversifying a portfolio. The GJR-GARCH model is an appropriate extension of Bollerslev's (1986) model given its ability to deal with conditional cross effects as well as volatility transmission

between series. This particular GARCH model predicts the period's variance by taking into account the weighted average of the long-term historical variance, the previous variance for the period and the previous period's squared residuals.

In equation (2.2), $\varepsilon_t|\varphi_{t-1}$ is the real-value discrete-time stochastic process conditional on all information, φ through to time t, which is normally distributed with mean of 0 and conditional variance H_t. In equation (2.3) volatility spillovers are identified through the ARCH parameter, A, which represents the spillover between series. The GARCH parameter, B, represents the persistence of the previous period's volatility on current volatility. Each of these are 2x2 coefficient matrices while C is a 2x2 symmetric matrix of constants from which the long-run relationship between the two series is inferred.

This asymmetric extension includes an additional quadratic form D with η_t, defined as above, equal to $\min(0,\varepsilon_t)$. The inclusion of an asymmetric term provides vital information for investors seeking safe havens. Koutmas and Booth (1995) amongst others have found that volatility spillover in one market is increased when the news arriving from another market is bad. Findings in the international finance literature, for instance Hamao, Masulis and Ng (1990) and Ng (2000) suggest that volatility spillover between markets are much more pronounced when bad news is received in one market.

This specification will determine if bad news in equity creates greater conditional volatility spillover to gold than good news does. Good news, $\varepsilon_{t-1}>0$, has an impact of A while bad news ($\varepsilon_{t-1}<0$), through the inclusion of the asymmetric term, has an impact of A + D. If $D \neq 0$ then an asymmetric effect exists. It is vital when choosing a safe haven in a well diversified portfolio that investors understand the risks

associated with the stock market and how negative shocks, in particular, are likely to affect returns of other assets.

The statistical significance of the off-diagonal terms in each of the matrices, A, B and D indicates volatility spillover between assets. In determining gold as a safe haven asset, interest lies with the statistical significance of A_{12}, B_{12} and D_{12} which indicates spillover from equity to the gold market. Equations (2.1) through (2.3) are estimated by a Quasi Maximum Likelihood estimator using the Broyden–Fletcher–Goldfarb–Shanno algorithm (BFGS).[7]

2.5: Results

The aim of this paper is to infer if gold is indeed a potential safe haven for equity investors. If no significant conditional mean or volatility spillovers exist between the stock market and gold, gold can be presumed to be a credible safe haven.

Conditional mean results are provided in Table 2.4 below and show that any disturbance in equity returns is not transmitted to gold returns. What is observed is a statistically significant transmission of disturbances from the last period's stock market return to its current return. This implies that equity slowly mean reverts to its long run average following its own negative shock but gold returns appear to be insulated from both positive and negative stock market return shocks.

[7] BFGS is a method for solving nonlinear optimization problems.

Table 2.4: *Conditional Mean Results*

Full Sample 1980 – 2011	**Excess Log Return S&P500$_t$**	**Excess Log Return Gold$_t$**
Constant	-0.0007	-0.0004
	(-1.83)	(-0.57)
Excess Log Return Gold$_{t-1}$	0.01	0.005
	(0.20)	(0.16)
Excess Log Return S&P500$_{t-1}$	0.005	-0.002
	(0.20)	(-0.07)
Asymmetric Shock Gold$_{t-1}$	-0.05	-0.01
	(-1.95)	(-0.17)
Asymmetric Shock S&P500$_{t-1}$	**-0.12**	0.06
	(-3.18)	(1.17)

Notes: T-statistic reported in parentheses. Bold numbers indicate statistical significant values. "Excess Log Return" and "Asymmetric Shock" correspond to Φ and θ respectively.

Table 2.4 shows no conditional mean spillover between the two series which means that there is no significant causality in returns between equity and gold. A natural progression in the analysis is to determine whether conditional volatility spillover between gold and equity exists through the GARCH component of the model.

As previously mentioned, volatility spillovers are identified through the ARCH parameter. For example, A_{12} represents the spillover from any shock to the stock market to gold and the reverse is true for A_{21}. The GARCH parameter B_{12} represents the persistence in volatility from the stock market to gold and again the reverse is true for B_{21}. The long-run relationship between the two series is inferred through C_{12} and vice versa. Focusing on these parameters in Table 2.5 there is no evidence of statistically significant spillover.

Table 2.5: *Bivariate GARCH Results*

C_{11} C_{12}		A_{11} A_{12}		B_{11} B_{12}		D_{11} D_{12}	
C_{21} C_{22}		A_{21} A_{22}		B_{21} B_{22}		D_{21} D_{22}	
0.002	**-0.005**	**0.11**	-0.01	**0.89**	0.02	**0.49**	–0.06
(3.51)	**(-3.24)**	**(3.99)**	(-0.29)	**(19.72)**	(0.71)	**(4.87)**	(–1.21)
0.001	**0.002**	0.01	**0.32**	0.01	**0.93**	–0.01	0.04
(2.84)	**(2.75)**	(0.37)	**(10.65)**	(1.09)	**(77.10)**	(–0.39)	(1.42)

Notes: T-statistics are reported in parentheses. Bold numbers indicate statistical significant values. A_{ij}, B_{ij} and D_{ij} represent ARCH, GARCH and asymmetric spillover from market i to market j.

Across the thirty-one year sample none of the off-diagonal elements of A, B or D are statistically significantly different from zero, implying no volatility spillover to either market. At first glance this is good news for investors as it suggests that gold may be an attractive safe haven asset. There are no significant spillovers in the ARCH or GARCH components and also there is no spillover in the asymmetric term which implies that gold is affected in the same way by negative and positive shocks in the stock market. There does appear to be a significant long-run relationship suggesting that there is interdependence between the two series in the long-run which cannot be diversified away. One can infer from these results that any shocks in the equity market have no significant effect on gold, making gold an attractive alternative for investors when uncertainty is high in the stock market. If one defines a safe haven as being an asset insulated from conditional mean and volatility spillover then investors choosing gold can be assured that it is completely insulated from equity shocks, negative or otherwise. The results reported in Tables 2.4 and 2.5 are wholly in line with the expectations of a safe haven.

Possible reasons for the lack of significance in the full sample may be because of the large number of recessionary periods and crises in the past thirty-one years and possible time-varying preferences among investors so the model (2.1) to (2.3) is re-estimated over each of the shorter time periods.

Table 2.6 details the results of the conditional mean for each of the four sub-samples. The results echo those found for the full sample in Table 2.4 in that there is no statistically significant conditional mean spillover from equity to the gold market. Considering that each of these sub-samples contains at least one recession the results are encouraging for investors. Separating the asymmetric effects into two components allows identification of the true impact of negative returns in both markets on the dependent variable. In the case of gold, across each of the four sub-samples, negative shocks in the stock market return do not have a significant effect on current gold returns. This is a principle characteristic for a safe haven.

Table 2.6: *Conditional Mean Results: Sub-Samples 1 - 4*

	Excess Log Return S&P500	**Excess Log Return Gold**
Panel A: Sub-Sample 1 (*1980 – 1988*)		
Constant	-0.0007	**-0.0005**
	(-0.71)	**(-6.26)**
Excess Log Return	0.01	-0.01
$Gold_{t-1}$	(0.32)	(-1.77)
Excess Log Return	-0.0007	-0.03
$S\&P500_{t-1}$	(1.07)	(-1.36)
Asymmetric Shock	-0.04	0.04
$Gold_{t-1}$	(-0.71)	(1.70)
Asymmetric Shock	-0.09	0.11
$S\&P500_{t-1}$	(-0.91)	(1.95)
Panel B: Sub-Sample 2 (*1988 – 1996*)		
Constant	-0.00005	**-0.0004**
	(-0.05)	**(-2.14)**
Excess Log Return	-0.04	**-0.13**
$Gold_{t-1}$	(-0.51)	**(-152.63)**
Excess Log Return	-0.02	0.02
$S\&P500_{t-1}$	(-0.39)	(1.56)
Asymmetric Shock	-0.05	**0.24**
$Gold_{t-1}$	(-0.50)	**(3.45)**
Asymmetric Shock	**-0.18**	0.08
$S\&P500_{t-1}$	**(-2.41)**	(1.13)
Panel C: Sub-Sample 3 (*1997 – 2004*)		
Constant	-0.004	0.001
	(-1.54)	(0.59)
Excess Log Return	0.13	-0.005
$Gold_{t-1}$	(1.36)	(-0.05)
Excess Log Return	0.10	-0.06
$S\&P500_{t-1}$	(0.81)	(-1.22)
Asymmetric Shock	-0.19	0.12
$Gold_{t-1}$	(-1.15)	(0.49)
Asymmetric Shock	-0.38	0.15
$S\&P500_{t-1}$	(-1.91)	(1.54)
Panel D: Sub-Sample 4 (*2004 – 2011*)		
Constant	-0.0006	0.001
	(-0.45)	(1.05)
Excess Log Return	-0.04	-0.04
$Gold_{t-1}$	(-0.72)	(-0.67)
Excess Log Return	-0.03	0.08
$S\&P500_{t-1}$	(-0.37)	(1.76)
Asymmetric Shock	-0.05	-0.04
$Gold_{t-1}$	(-0.68)	(-0.53)
Asymmetric Shock	-0.03	-0.13
$S\&P500_{t-1}$	(-0.23)	(-1.66)

Notes: T-statistic reported in parentheses. Bold numbers indicate statistical significant values. "Excess Log Return" and "Asymmetric Shock" correspond to Φ and θ respectively.

As mentioned earlier, to satisfy the definition of a safe haven there must be no conditional mean or volatility spillover from equity to the potential haven. Our results suggest that gold adheres to this definition for any investors wishing to diversify an equity portfolio.

The GARCH sub-sample results, reported in Table 2.7, determine the strength of gold as a safe haven in terms of conditional volatility. The results are similar to those drawn from Table 2.5. The only significant spillover that occurs from the stock market to gold occurs in sub-sample 1 in terms of persistence and asymmetric spillover, B_{12} and D_{12} respectively. This implies that a shock in the stock market has a persistent effect on gold in terms of increasing the correlation between the two assets. This is not ideal for investors, but the negative significance of the asymmetric term provides consolation as it indicates that negative shocks to the stock market will actually reduce the correlation between the two series, an attractive trait for investors in search for a safe haven.

The results offer strong empirical support for the suitability of gold as a safe haven. The results are broadly in line with the initial assessment of what an investor requires from a safe haven – an asset which, in crisis periods especially, acts independently of the stock market and is not at risk of increased volatility as a result of spillover from equity.

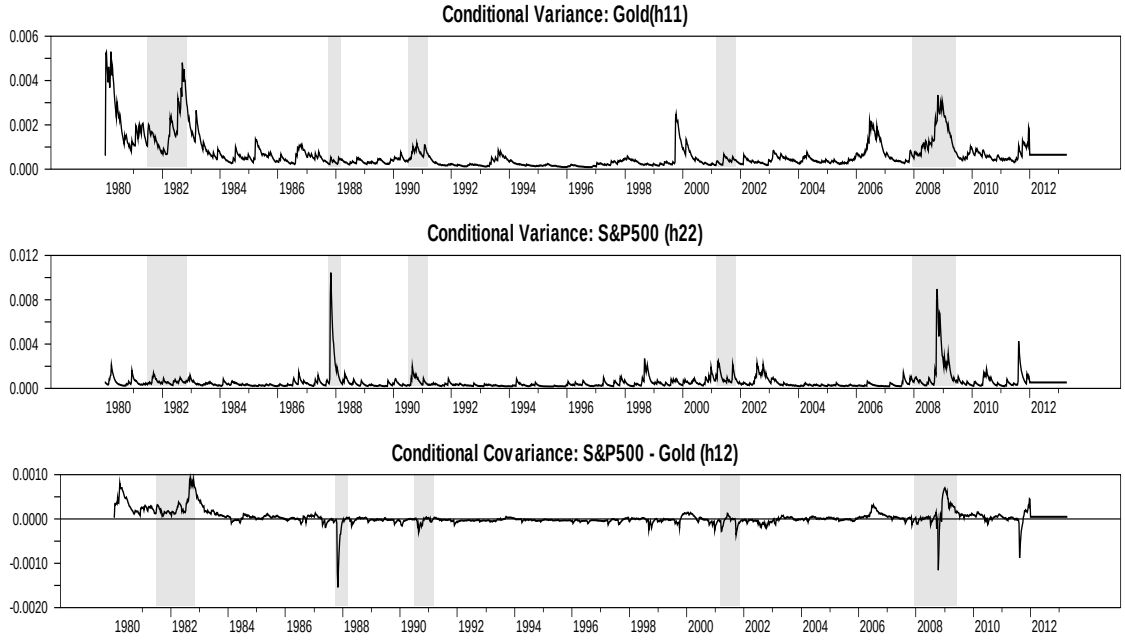
Table 2.7: *GARCH Results: Sub-Samples 1 - 4*

$\begin{bmatrix} C_{11} & C_{12} \\ C_{21} & C_{22} \end{bmatrix}$		$\begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix}$		$\begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix}$		$\begin{bmatrix} D_{11} & D_{12} \\ D_{21} & D_{22} \end{bmatrix}$	
Panel A: Sub-Sample 1 *(1980 – 1988)*							
0.005	**-0.01**	0.26	0.04	0.23	**0.12**	**0.69**	**-0.10**
(2.04)	**(-10.98)**	(1.45)	(1.72)	(0.60)	**(6.19)**	**(4.10)**	**(-3.15)**
0.002	**0.005**	–0.05	**0.24**	0.18	**0.91**	–0.02	0.14
(3.66)	**(5.47)**	(–0.85)	**(4.79)**	(1.74)	**(50.30)**	(–0.21)	(1.56)
Panel B: Sub-Sample 2 *(1988 – 1996)*							
–0.0004	**0.001**	–0.06	–0.007	**0.97**	–0.02	**0.20**	–0.03
(–0.37)	**(2.21)**	(–0.60)	(–0.25)	**(50.07)**	(–0.89)	**(2.45)**	(–0.12)
–0.0005	**0.001**	**-0.13**	**0.38**	**0.04**	**0.91**	–0.02	–0.0008
(–0.58)	**(3.38)**	**(-4.67)**	**(21.53)**	**(4.19)**	**(195.34)**	(–0.59)	(–0.01)
Panel C: Sub-Sample 3 *(1997 – 2004)*							
0.0005	0.0001	0.02	–0.0007	**0.92**	–0.05	**0.42**	–0.05
(27.22)	(0.14)	(0.72)	(–0.01)	**(62.51)**	(–0.43)	**(7.95)**	(–0.70)
0.0009	0.01	–0.02	0.37	0.07	0.45	0.01	0.005
(0.09)	(1.98)	(–0.19)	(1.08)	(0.71)	(0.51)	(0.17)	(0.07)
Panel D: Sub-Sample 4 *(2004 – 2011)*							
0.004	**-0.002**	0.20	–0.09	**0.86**	0.03	**0.60**	0.02
(2.85)	**(-2.27)**	(1.74)	(–0.97)	**(10.89)**	(0.95)	**(4.03)**	(0.21)
0.003	**0.003**	0.06	**0.34**	–0.03	**0.91**	–0.06	–0.02
(3.37)	**(4.36)**	(0.93)	**(10.55)**	(–1.19)	**(146.64)**	(–1.54)	(–0.33)

Notes: T-statistic reported in parentheses. Bold numbers indicate statistical significant values. A_{ij}, B_{ij} and D_{ij} represent ARCH, GARCH and asymmetric spillover from market i to market j.

The methodology also allows the conditional variance of both series and the conditional covariance between series to be computed. These series are graphed in Figure 2.2 and aim to shed further light on the extent to which volatility spillovers occur between the two series. NBER recession dates are shaded in grey for identification.

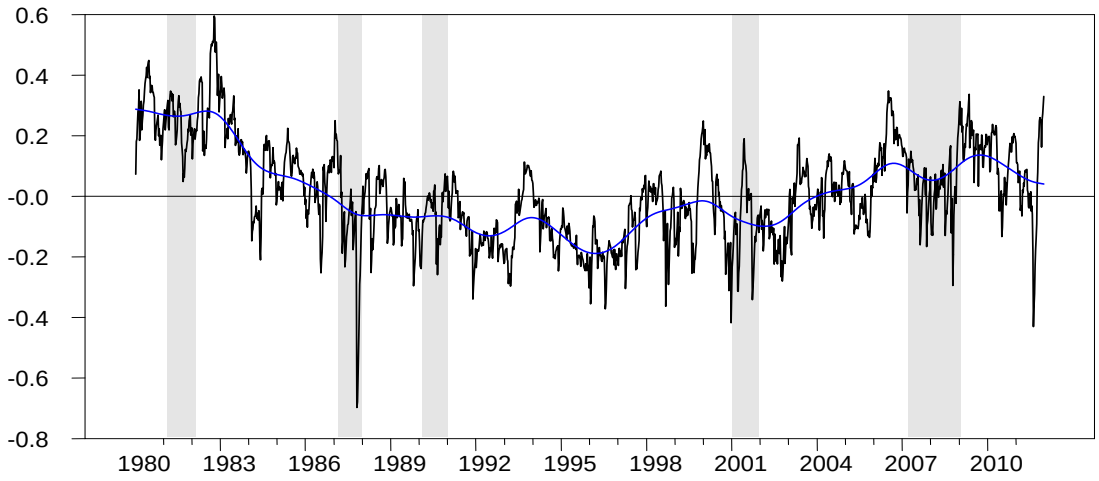
Figure 2.2: *Conditional Variances and Covariance: S&P500 and Gold*



Over the sample period, gold and equity display varied degrees of conditional variance coinciding with periods of market uncertainty. Also note that for much of the period gold and equity exhibit negative conditional covariance and these periods become more pronounced with the NBER crisis periods of 1987, 1990 and 2007 suggesting that the two series operate independently of each other especially in crisis periods which is consistent with results.

There is a considerable increase in the conditional variance of equity in the recent recession period which corresponds to the increased investor and market uncertainty surrounding the collapse of Lehman Brothers and other turmoil in the U.S. around this time. Over this period there is a large negative spike in the conditional covariance which suggests that a combination of both series in an investor's portfolio would provide investors with some certainty that the increase in gold returns will offset the increased risk in the stock market.

Figure 2.3: *Time-Varying Correlation: S&P500 - Gold*



A similar story emerges in Figure 2.3, for the time-varying correlation. Again, focusing on the four NBER recession periods, the relationship can be tracked over tranquil and crisis periods. Following Baur and Lucey's (2010) definition of a safe haven, the correlation between a safe haven and risky alternative is much more important during recession periods than over relatively calmer periods. As noted in Table 2.8, the average time-varying correlation over the entire sample is negative and although the average time-varying correlation is positive in sub-sample 4 it turns negative over the critical 2007 – 2009 recession period. This supports the definition of a safe haven outlined above and provides evidence that gold appears to be a suitable diversifier for equity investors in periods of stock market turmoil.

One can infer from Figure 2.3 and Table 2.8 that the two series exhibit negative or zero conditional correlation and covariance over critical periods, which is echoed in our empirical analysis with few periods of statistically significant conditional mean or volatility spillover from stock market returns to gold returns.

Table 2.8: *Time-Varying Correlations*

	Average Time-Varying Correlation
Full Sample (*1980 - 2011*)	-0.02
Sub-Sample 1 (*1980 - 1988*)	0.09
Sub-Sample 2 (*1988 - 1996*)	-0.09
Sub-Sample 3 (*1997 - 2004*)	-0.09
Sub-Sample 4 (*2004 - 2011*)	0.02
NBER Crisis Periods	
July 1981 – November 1982	0.25
October 1987 – March 1998	-0.24
July 1990 – March 1991	-0.17
March 2001 – November 2001	-0.03
December 2007 – June 2009	-0.07

2.6: Portfolio Analysis

Having found that there is very little significant spillover from the stock market returns in the conditional mean or variance, we proceed to analyse investment portfolios that contain only gold and equity stocks. The optimal weighting of gold and equity is analysed following the assumptions of Markowitz (1952) mean-variance framework paying particular attention to the investor's allocation of wealth over recessionary periods. This analysis is crucial for portfolio design and identification of the optimal distribution of wealth between equity and a safe haven.

One advantage of this approach is that investors utilise information on the conditional covariance matrix of returns derived from the GARCH analysis in deciding the allocation of wealth within a portfolio. Flavin and Wickens (2000) note that since the conditional covariance is sufficiently serially correlated the aim of short term asset allocation is to exploit these regularities with the aim of reducing risk and return

maximization can be left to the second stage of the stock selection. This is an improvement over alternative methods which rely on standard deviations alone in determining hedging options. For example, Cotter and Hanley (2006) note that standard deviations cannot distinguish between positive and negative returns and thus are an inadequate measure of risk for hedgers when return distributions are not normal as with the data employed in this chapter.

The optimal portfolio weightings of gold and equity are constantly re-balanced in line with the time-varying mean-variance frontier. In generating this frontier the conditional distribution of $\mathbf{R}_{t+1}$ is assumed to have mean $E_t\mathbf{R}_{t+1}$ which is considered constant and variance-covariance $\mathbf{H}_t$ which is n x n matrix extracted from the VAR-GARCH model.[8] It is the objective of the investor to exploit knowledge of the conditional variance and covariance to adopt optimal weightings $\mathbf{w}_{it}$ that will maximize the return in a gold-equity portfolio. Since it is assumed that all funds are invested in the portfolio, $\sum_i w_{it}=1$. The conditional distribution of the return on the portfolio has an expected return and variance of

$$E_tR_{p,t+1}=\sum_i w_{it}E_tR_{i,t+1}=\mathbf{w}_t^{'}E_t\mathbf{R}_{t+1} \tag{2.4}$$

$$\sigma_{p,t}^2=\sum_i\sum_j w_{it}w_{jt}\sigma_{ij,t}=\mathbf{w}_t^{'}\mathbf{H}_t\mathbf{w}_t \tag{2.5}$$

Flavin and Wickens (2000) follow the standard Markowitz (1952) framework where investors allocate the sum of their wealth to minimize the conditional variance of the portfolio return,

[8] This assumption follows analysis of the data in Table 2.4 which indicates no predictability in the return. There would be no advantage to letting the mean vary over time. Flavin and Wickens (2000) generate portfolios under a similar assumption.

$$\text{minimise } \mathbf{w}_t'\mathbf{H}_t\mathbf{w}_t$$

$$\text{subject to } w_t'E_tR_{t+1}=\mu_t \ , \ \sum_i w_{it}=1.$$

Using Lagrange multipliers for the two constraints, the solution is

$$\mathbf{w}_t=\mathbf{H}_t\begin{bmatrix}\mu_t\\1\end{bmatrix}\mathbf{A}_t^{-1}\ E_t\mathbf{R}_{t+1}\quad \mathbf{i}\ , \tag{2.6}$$

$$\sigma_{pt}^2=\mathbf{w}_t'\mathbf{H}_t\mathbf{w}_t=\ \mu_t\quad 1\ \mathbf{A}_t^{-1}\ E_t\mathbf{R}_{t+1}\quad \mathbf{i}\ '\mathbf{H}_t^{-1}\mathbf{H}_t\mathbf{H}_t^{-1}\ E_t\mathbf{R}_{t+1}\quad \mathbf{i}\ \mathbf{A}_t^{-1}\begin{bmatrix}\mu_t\\1\end{bmatrix},$$

$$=\ \mu_t\quad 1\ \mathbf{A}_t^{-1}\begin{bmatrix}\mu_t\\1\end{bmatrix}=\ \mu_t\quad 1\ \frac{1}{\Delta_t}\begin{bmatrix}c_t & -b_t\\-b_t & a_t\end{bmatrix}\begin{bmatrix}\mu_t\\1\end{bmatrix},$$

$$=\frac{1}{\Delta_t}(a_t-2b_t\mu_t+c_t\mu_t^2)\,, \tag{2.7}$$

where,

$$\mathbf{A}_t=\begin{bmatrix}a_t & b_t\\b_t & c_t\end{bmatrix}=\begin{bmatrix}E_t\mathbf{R}_{t+1}'\mathbf{H}_t^{-1}E_t\mathbf{R}_{t+1} & E_t\mathbf{R}_{t+1}'\mathbf{H}_t^{-1}\mathbf{i}\\E_t\mathbf{R}_{t+1}'\mathbf{H}_t^{-1}\mathbf{i} & \mathbf{i}'\mathbf{H}_t^{-1}\mathbf{i}\end{bmatrix}, \tag{2.8}$$

$$\mu_t=\begin{bmatrix}a_1\\b_1\end{bmatrix}\ \text{and}\ \ \Delta_t=(a_tc_t-b_t^2)>0\ ,$$

with standard deviation of the optimal portfolio as

$$\sqrt{\frac{a-2b\mu_t+c\mu_t^2}{ac-b^2}}\,. \tag{2.9}$$

With 1,669 observations Table 2.9 shows that an investor with just gold and S&P500 stock in their portfolio will hold on average 40 per cent of his wealth in gold

and 60 per cent of his wealth in equity. The investor will take advantage of any "up-turns" in the market and thus, in general will hold a greater proportion of his wealth in this asset. Following the results from the VAR-GARCH model a weighting of 40 per cent wealth in gold suggests that gold is used as a haven from potential "down-turns" in the stock market.

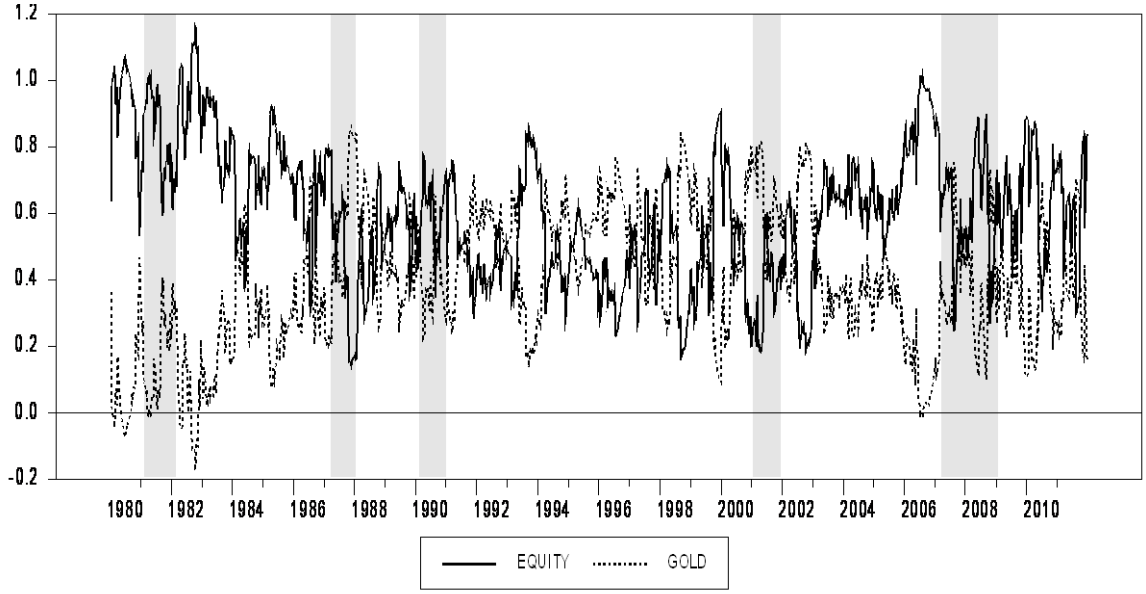
Results also indicate that in certain periods investors take part in the practice of short-selling gold in order to invest over 100 per cent of their wealth in the stock market. This investment decision becomes much clearer when Table 2.8 and Figure 2.4 are viewed together. It is interesting to note that short-selling only occurs in two brief periods at the beginning of the 1980's when gold was extremely volatile. Beyond this, investors appear to recognise the importance of holding a positive proportion of their wealth in gold. There is an understanding, which is consistent with the aforementioned literature, that gold does provide some protection for investors against the volatility of the stock market and thus it is of paramount importance that investors continue to invest a positive fraction of wealth in the safe haven.

Table 2.9: *Weighting of Optimum Portfolio*

Series	Observations	Average Weight	Minimum Weight	Maximum Weight
S&P500 (W1)	1,669	60%	13%	116%
Gold (W2)	1,669	40%	-16%	86%
Portfolio Return	1,669	0.001	0.001	0.001
Portfolio Std. Deviation	1,669	0.01	0.006	0.04

There are a number of periods that should be focused on in particular. The first of these is during the 1987 stock market crash when investors invest the majority of their wealth in gold rather than the stock market. This, of course, is due to the extreme turbulence experienced in the stock market in October 1987. This is also echoed in the 2001 "dot-com" stock market crash when investors again reduce their holding in the stock market in favour of the perceived safe haven of gold. It is interesting to note that this occurs in two of the most extreme stock market crashes while over longer recessionary periods investors tend to reweight their portfolio in favour of an almost fifty-fifty composition. This is the case with each of the 1981, 1990 and 2008 recessions.

Figure 2.4: *Allocation of Funds to Assets*



The use of portfolio analysis along with the VAR-GARCH model emphasizes the importance for investors to understand the risks associated with the stock market

and highlights the role of gold as a possible safe haven. The results suggest that gold may be utilised as a safe alternative for investors' wealth when they cannot be certain of stock market returns. Primarily, the portfolio analysis shows how investor sentiment changes as the proportion of wealth invested in equity varies over time. It also shows that when investors lose confidence in the stock market they quickly move to a more evenly weighted portfolio between the volatility of the stock market and the safety of gold.

As noted by Flavin and Wickens (2000), the strategy of rebalancing this equity - gold portfolio may prove costly as our analysis does not account for transaction costs which may act as a deterrent for investors in re-balancing their portfolio over certain periods. As such, these allocations may not always be viable for investors.

2.7: Conclusion

In the current literature little attention has been paid to conditional mean and volatility spillover between the stock market and gold returns in determining the role of gold as a safe haven. This paper differs in that it is motivated with an alternative definition of a safe haven. It is assumed that a safe haven is any asset that is insulated from potential conditional mean and volatility spillover from the stock market.

The results of this paper show that over a thirty-one year period from 1980 – 2011 there is indeed no significant spillover in either the first- or second-order moments of the series. Our VAR-GARCH approach has shown gold to be a credible safe haven as it is insulated from the stock market, an inference drawn from the lack of significant spillover between the two series. These results echo those of Wolfe (2006) and Morales

and Andreosso-O'Callaghan (2011) as they also find little evidence of significant relationship between the two series.

These results also prove essential in optimal portfolio diversification with investors utilizing knowledge of conditional variance and covariance to invest on average 40 per cent of their wealth in gold, a weighting which suggests that gold is held as a safe haven in a predominantly equity based portfolio.

To improve on this understanding it would be interesting to include government debt as a third variable in our analysis. From the previous research of Connolly, Stivers and Sun (2005) and McCauley and McGuire (2009) government bonds have been shown to be safe havens. Our results from the 2008 recession in sub-sample four indicate that investors may have moved toward gold in the immediate aftermath of the crisis. With the recent downgrading of several economies such as the United States, Ireland and Greece, these government bonds may no longer be the attractive safe haven that they once were for investors.

It is for this reason that the introduction of a government bond into the analysis would firstly determine the level of conditional mean and volatility spillover from the stock market to bonds and secondly it would allow for the analysis of how the use of a government bond as a safe haven has changed over time, especially over the 2008 recession. It will then be possible to compare the strength of gold and the strength of a government bond as potential safe havens so that investors can make informed decisions when diversifying their equity portfolios.

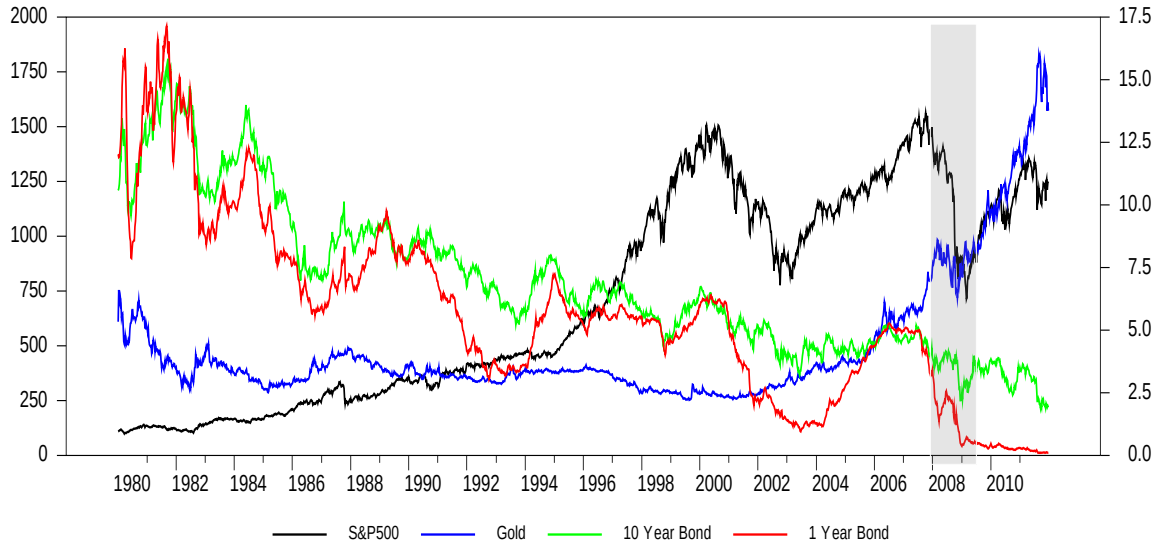
Chapter 3: Utilising Cross-Correlation and Volatility Impulse Response Functions to Identify Safe Haven Assets

3.1: Introduction

The aim of this paper is to analyse and compare potential safe haven assets. Chapter 2 looked exclusively at gold but here a long-term bond is also included. Long-term government bonds are often considered as a substitute for stocks given their similar investment horizons and previous analyses of safe havens have identified them as assets that investors can turn to in times of stock market uncertainty. Recent financial crises have reignited interest in the conditional mean and conditional volatility linkages between these assets and equity.

Figure 3.1 shows that in light of the most recent crisis, not only did the price of gold increase but yields on both short- and long-term government bonds have decreased substantially. This indicates that equity investors may also have been using government bonds to hedge against the substantial losses experienced in the stock market. With this in mind, the primary question to be answered in this paper is which, if either, gold or a U.S. Treasury bond is a suitable safe haven with which to hedge against increased volatility in the stock market.

Figure 3.1: *Gold: Gold Bullion U.S.$/Troy Ounce;*
Equity: S&P Composite 500 U.S.$ Price Inde;
LongBond: U.S. Benchmark 10- year Total Return Index;
Short Bond: 1-year U.S. Constant Maturity Treasury.



During periods of financial and economic uncertainty, investors tend to reweight their equity portfolio in favour of safer alternatives. The investor's desire for either a safe or high return will dictate which of gold or government bond he turns to. The choice between the two assets should ideally reduce the risk of the portfolio with, at the very least, an equivalent reduction in the return. For example, Jaffe (1989) and Coudert and Raymond (2010) both note that while gold is volatile in its own right it does have the tendency to provide diversification when added to an equity portfolio as it not only reduces the risk but also increases the return.

The decision to focus on gold and U.S. Treasury bonds as potential safe havens in this paper is motivated by a number of economic factors. In the case of gold, prices have increased substantially over the past decade during one of the most turbulent financial periods in recent history. Gold entered the eleventh year of a bull market in

2011 realising a high of U.S.$1,826, an increase of over 500 per cent from 2001. The fact that gold prices have increased despite the global crisis warrants a more in-depth analysis of how exactly gold and equity interact with each other. The increase in price suggests that demand has increased substantially over this period and it may be argued that this is due to investors reallocating their wealth from the volatile stock market to gold, perceiving it to be a possible safe haven.

Similarly, the holdings of U.S. marketable Treasury securities increased from U.S$4.9 trillion in August, 2008 to U.S.$7.4 trillion by February 2010. As with all government bonds, investors are attracted by the fact that investments are guaranteed by the U.S. government making portfolio reallocations from stocks to bonds during volatile periods potentially rewarding. One drawback of an investment in U.S. Treasury bonds is the correlation between bonds and macroeconomic variables such as gross domestic product, a leading indicator of productivity. Lawrence (2003) examines the behaviour of returns on U.S. stocks, bonds and gold and establishes a lack of correlation between returns on gold and other financial assets which he links to the lack of correlation between gold and macroeconomic variables, such as GDP and inflation. On the other hand, both the stock market and government bonds are known to be highly correlated with GDP and this may have a negative impact on the investor's choice of government bonds as a possible safe haven.

Ideally an extension of the bivariate VAR-GARCH model introduced in the previous chapter would have been used here, however increasing the number of assets in the model leads to unstable results. While variations of the VAR-GARCH methodology exist that accommodate a trivariate setting, alternative methods for assessing the relationships between equity and the potential safe havens are explored in

this chapter based on the same criteria outlined in Chapter 2, where a safe haven is considered safe if there is no statistically significant mean or volatility spillover between assets. This approach will also determine the strength of the results derived in Chapter 2.

This chapter examines the issue of mean and variance transmission between the stock market and two possible safe haven assets using two methodologies. The first of these is the two-stage Cross-Correlation Function (CCF) procedure of Cheung and Ng (1996) to test for both mean and volatility spillover. The second methodology of Volatility Impulse Response Function (VIRF) developed by Hafner and Herwartz (2006) is used to analyse information transmission between equity - gold and equity - 10-year bond. This technique will establish how a shock affects the dynamic adjustment of volatility in each of the possible safe haven assets.

To my knowledge no previous literature has utilised the combination of Cheung and Ng's (1996) CCF and Hafner and Herwartz (2006) VIRF to explicitly establish firstly how appropriate gold and government bonds are as a hedging investment for the stock market and secondly which, if either, gold or 10-year U.S. T-bond is the most appropriate safe haven for U.S. equity investors. This combination should also establish if or how the relationships in the pairings of stocks and gold and stocks and bonds have changed throughout tranquil and volatile periods.

The remainder of this paper is organised as follows. In the next section a review of previous literature is presented. Section 3.3 details the data used for this analysis. In section 3.4 a brief outline of the CCF and VIRF methodology is presented with results reported in section 3.5. The paper concludes with section 3.6.

3.2: Literature Review

The academic research on gold as a safe haven is relatively sparse compared to the literature which exists for U.S. Treasury bonds. Prior to Baur and Mc Dermott (2010), no literature had examined the explicit role of gold as a safe haven. They define a safe haven as being a type of hedge asset the return of which is unrelated or negatively related to that of the reference portfolio. The correlation between the stock market and the chosen safe haven will therefore matter much more in volatile periods. They conclude that under extreme uncertainty gold begins to move with the stock market, establishing a situation where all assets move in the same direction which reduces the attractiveness of gold as a safe haven.

Although the volatility of gold is characteristically high, Coudert and Raymond (2010) outline the properties that lead to it being an attractive safe haven for equity investors. They note gold's historical role as a medium of exchange in international monetary exchange, hinting that it may still be the ultimate safe haven. It is also a highly liquid asset, continuously quoted on the spot and futures markets. This literature is covered in greater detail in Chapter 2, section 2.2.

In comparison, the literature analysing the relationship between equity and bonds is vast. Steeley's (2005) two-factor no-arbitrage analysis of the time-varying correlation between volatility of the equity and bond markets indicates a reversal in the sign of this correlation, from positive to strongly significantly negative in the past twenty years. Kim, Moshirian and Wu (2006) also find obvious downward trends in time-varying correlations between stock and bond market returns in Europe, Japan and the U.S. which will have important implications for portfolio selection. Connolly, Stivers and Sun (2005) note in their regime-switching analysis that there are two sharply

defined regimes. The first of these is a relatively normal, low uncertainty regime where the stock - bond return relation is substantially positive and the second is a relatively abnormal, high uncertainty regime in which the stock - bond return relation is modestly negative.

Andersson, Krylova and Vähämaa (2008) examine the impact of perceived stock market uncertainty on the time-varying correlation between U.S. T-bonds and stock markets and German bond and stock markets between 1994 and 2004. They conclude that sustained periods of negative correlation are observed and that the time-varying correlation has a tendency to change substantially and turn negative in a very short period of time. The reportedly frequent changes in the relationship have great potential to affect an investor's choice of government bonds as a potential safe haven where negative correlation is desired.

Based on the aforementioned literature, Kim, Moshirian and Wu (2006) note that there is general agreement on how equity and bond returns co-move over time, however the reasons for this comovement is not as clear. The extant literature has focused on this phenomenon in an attempt to explain the apparent decoupling of equity and bond returns. Explanations have focused primarily on macroeconomic factors. For example, Li (2002) also finds that the sign of the stock - bond correlation can be explained by their common exposure to macroeconomic factors and in particular the major trends in stock - bond correlation are determined primarily by uncertainty in expected inflation. Knowledge of the exposure of the stock - bond relation to macroeconomic variables such as inflation and the real interest rate undoubtedly helps to improves investors' portfolio decisions, as shown by Barberis (2000) and Brennan and Xia (2002).

Generally, the literature which examines the relationship between gold, government bonds and the stock market utilizes volatility spillover models. The use of such models was first introduced by Engle, Ito and Lin (1990) with the analysis of Yen/USD exchange rates. Since then volatility spillover models have been used by Bekaert and Harvey (1997), Baele (2002) and Ng (2000) for example, to analyse the relationships between markets and assets. As mentioned previously equity investors, when choosing a safe haven, are concerned with how much that safe haven is insulated from equity. This can be measured using such models.

GARCH methodology has proven very important in the analysis of stock - bond relationships and as a consequence the associated literature is immense. The existing literature has found that there appears to be very little volatility spillover from equity to bond markets and more frequently the spillover occurs from the bond to the equity market. For example, Fleming, Kirby and Ostdiek (1998) focus on the nature of volatility linkages in stock, bond and money markets and note that if volatility changes across these three markets are highly correlated, then bonds may not provide the safe haven that investors require. They conclude that the volatility linkages between the three markets are strong especially since the 1987 stock market crash.

Using daily return on a long- and short-term bond, S&P500 and NASDAQ, De Goeij and Marquering (2004) continue in a similar vein and conclude that there is strong evidence of conditional heteroskedasticity in the covariance between stock and bond market returns and not only variances but also covariances respond asymmetrically to return shocks. They also find that the covariance between stocks and bonds tends to be relatively low after bad news in the stock market and good news in the bond market. Scruggs and Glabadanidis (2003) allow for asymmetry in a GARCH-

in-mean model and conclude similar results to Dean, Faff and Loudon (2010) and Fleming, Kirby and Ostdiek (1998) that bond market variance responds symmetrically to bond return shocks but is relatively unresponsive to stock return shocks. In a similar study using the asymmetric version of the Dynamic Conditional Correlation model, Cappiello, Engle and Sheppard (2006) find evidence that national equity index return series show strong asymmetries in conditional volatility, with little evidence that bond index returns exhibit the same behaviour.

The evidence provided in the aforementioned literature suggests that a long-term government bond may potentially be used by investors seeking a hedging asset.

3.3: Methodology

There are a number of potential drawbacks in using GARCH models to evaluate conditional mean and volatility spillover between assets. Pedersen and Rahbek (2012) assert that despite the BEKK-GARCH model being a simple extension of the popular univariate GARCH models, it contains a large number of parameters, even for a small number of series. Such models can become difficult to implement as the number of series under investigation increases making the use of a multivariate GARCH to model the relation between the stock market, gold and bonds not always estimable.

In their seminal paper Cheung and Ng (1996) develop an alternative test for volatility spillover focusing on the sample cross-correlation function between two series. The series of squared standardized residuals is used to test the null hypothesis of no causality-in-variance. They also discuss the effect of causality-in-mean, an important component of this paper, finding that it can exist with or without the presence of

causality-in-variance and vice versa. Much of the literature employing CCF methodology focuses on the spillover or causation which occurs across stock markets with very few using the approach to examine spillover between stock markets and potential safe havens.

One paper applies this CCF approach to identify volatility spillover between the stock market and gold. Miyazaki and Hamori (2013) investigate the causal relationships between gold and stock market performance with the aim of clarifying the characteristics of gold as an investment asset. Applying this approach to data from the last ten years they detect a unidirectional causality-in-mean from the stock market to gold but find no causality-in-variance between the two series.

The second methodology employed is Volatility Impulse Response Function developed by Hafner and Herwartz (2006). It is my understanding that no previous literature has taken advantage of this innovative technique to establish the causal relationship and interdependencies between stock market and possible safe haven assets. There are certain advantages in applying this methodology over the traditional impulse response function. Sims (1980) introduced impulse response analysis for VAR models and Hafner and Herwartz (2006) note that with the similarities between GARCH and VAR-type models it should be possible to generalise the initial model to provide information on the effect of an independent shock on volatility.

Panopoulou and Pantelidis (2009) use this approach in a study of second-order interdependencies between national stock markets. Among their results is evidence of bidirectional volatility spillover between the U.S. and Japan, as well as the U.S. and the UK. In terms of their VIRF analysis they find evidence in favour of increased amplitude

and duration of volatility spillover stemming from the increased interdependence and persistence of equity market volatility in recent years.

This paper first uses the CCF test of Cheung and Ng (1996) to establish mean and volatility spillover from the stock market to two assets, gold and 10-year U.S. T-bond, with the intention of indentifying which of the two assets is most appropriate as a safe haven based on the aforementioned definition. In a second step, the VIRF of Hafner and Herwartz (2006) is used to further establish the persistence of independent shocks to each of the assets.

3.3.1 Cross-Correlation Function

Consider two stationary time series X_t and Y_t and two information sets I_t and J_t. These information sets are defined by $I_t=(X_{t-j}, j \geq 0)$ and $J_t=(X_{t-j}, j \geq 0)$. Y_t is said to cause X_{t+1} in variance if

$$E\left[X_{t+1}-\mu_{x,t+1}\right]^2 | I_t \neq E\left[X_{t+1}-\mu_{x,t+1}\right]^2 | J_t \quad , \tag{3.1}$$

where $\mu_{x,t+1}$ is the mean of X_{t+1} conditioned on I_t. Feedback in variance only occurs if X causes Y and Y causes X in the case of

$$E\left[X_{t+1}-\mu_{x,t+1}\right]^2 | I_t \neq E\left[X_{t+1}-\mu_{x,t+1}\right]^2 | J_t + Y_{t+1} \quad . \tag{3.2}$$

Likewise, Y_t is said to cause X_{t+1} in mean if

$$E\left[X_{t+1} | I_t\right] \neq E\left[X_{t+1} | J_t\right] \quad . \tag{3.3}$$

Additional restrictions on (3.1) and (3.2) are required in order to empirically test for causality-in-mean and -variance. Assume X_t and Y_t can be written as

$$X_t = \mu_{x,t} + \sqrt{h_{x,t}}\varepsilon_t \quad \text{and} \quad Y_t = \mu_{y,t} + \sqrt{h_{y,t}}\zeta_t \ ,$$

where ε_t and ζ_t are two independent white noise processes with zero mean and unit variance. The conditional mean and variance equations are then given by

$$\mu_{z,t} = \sum_{i=0}^{\infty} \Phi_{z,i}(\theta_{z,\mu}) Z_{t-i} \ , \tag{3.4}$$

$$h_{z,t} = \varphi_{z,0} + \sum_{i=0}^{\infty} \varphi_{z,i}(\theta_{z,h}) \quad Z_{t-i} - \mu_{z,t-1}^{\ 2} - \varphi_{z,0} \ , \tag{3.5}$$

where $\theta_{z,w}$ is a $p_{z,w} \times 1$ parameter vector; $W = \mu, h$; $\omega_{z,i}(\theta_{z,\mu})$ and $\omega_{z,i}(\theta_{z,h})$ are uniquely defined functions of $\theta_{z,\mu}$ and $\theta_{z,h}$; and $Z = X, Y$. Specifications (3.4) and (3.5) include times series models such as the commonly used ARMA models for the mean and the GARCH models for the variance.

Next let U_t and V_t be the squared residuals for the series X_t and Y_t ,

$$U_t = \quad X_t - \mu_{x,t}^{\ 2} / h_{x,t} \ = \varepsilon_t^2 , \tag{3.6}$$

$$V_t = \quad Y_t - \mu_{x,t}^{\ 2} / h_{y,t} \ = \zeta_t^2 , \tag{3.7}$$

and the standardized residuals ε_t and ζ_t . Let $r_{\varepsilon\zeta}(k)$ be the sample cross-correlation of the standardized residual series and $r_{uv}(k)$ be the sample cross-correlation of the squared standardized residual series at lag k.

$$r_{uv}(k) = c_{uv}(k)(c_{uu}(0)c_{vv}(0))^{-1/2}, \tag{3.8}$$

where $c_{uv}(k)$ is the k^{th} lag length sample cross covariance given by

$$c_{uv}(k) = T^{-1}\sum(U_t - \bar{U})(V_{t-k} - \bar{V}), \; k = 0, \pm1, \pm2, ... \tag{3.9}$$

and $c_{uu}(0)$ and $c_{vv}(0)$ are the sample variances of U and V, respectively. Since U_t and V_t are independent, the existence of their second moments implies

$$\begin{pmatrix} \sqrt{T}r_{uv}(k) \\ \sqrt{T}r_{uv}(k') \end{pmatrix} \rightarrow AN\left(\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}\right), k \neq k'. \tag{3.10}$$

Expression (3.10) suggests that the CCF of the squared standardized residuals can be used to identify causal relations in the second moment.

For empirical implementation the sample cross correlation coefficient $\hat{r}_{uv}(k)$ computed from consistent estimates of conditional means and variances of X_t and Y_t is used in place of $r_{uv}(k)$. Let $\hat{\theta}_z \equiv \{\hat{\theta}_{z,\mu}, \hat{\theta}_{z,h}, \hat{\varphi}_{z,0}\}$ be a consistent estimator of the parameter vector; $\theta_z^0 \equiv \{\theta_{z,\mu}^0, \theta_{z,h}^0, \varphi_{z,0}^0\}$; Z=X,Y ; $\theta^0=(\theta_x^0, \theta_y^0)$; and $\hat{\theta}=(\hat{\theta}_x^0, \hat{\theta}_y^0)$. And $\hat{r}_{uv}(k)$ is defined as

$$\hat{r}_{uv}(k) = r_{uv}(k)|_{\theta=\hat{\theta}}. \tag{3.11}$$

Similar definitions apply for the sample cross-covariance $\hat{c}_{uv}(k)$ and the sample variances $\hat{c}_{uu}(k)$ and $\hat{c}_{vv}(k)$.

Following Hu, Chen, Fok and Huang (1997) causality-in-variance between two series is evaluated with $S=T\sum_{i=j}^{k}\hat{r}_{uv}(i)^2$ which tests the hypothesis of no causality from lag j to k comparing to the chi-square distribution with (k-j+1) degrees of freedom. In the case where T is small $S_m=T\sum_{i=j}^{k}\omega_i\hat{r}_{uv}(i)^2$ can be used, where $\omega_i=T/(T|i|)$ or (T+2)/(T-|i|). If one wishes to test the causal relationship at a specific lag k the test statistic $t_k=\sqrt{T}r_{uv}(k)$ can be compared to the standard normal distribution.

The CCF test is applied in two stages. In the first stage the widely used GARCH(1,1) process is used to model the series returns allowing for time variation in both conditional means and variances. The GARCH(1,1) model, predicts the period's variance by taking into account the weighted average of the long-term historical variance, the previous variance for the period and the previous period's squared residuals.

$$\varepsilon_t \mid \varphi_{t-1} \sim N(0, h_t), \tag{3.12}$$

$$h_t = \alpha_0 + \alpha_1\varepsilon_{t-1}^2 + \alpha_2 h_{t-1}, \tag{3.13}$$

where $\varepsilon_t \mid \varphi_{t-1}$ is the real-value discrete-time stochastic process conditional on all information, φ, through to time t, normally distributed with mean of 0 and conditional variance h_t. To ensure the non negativity of the conditional variance the following must hold - $\alpha_0>0$, $\alpha_1 \geq 0$, $\alpha_2 \geq 0$ and $\alpha_1+\alpha_2 \leq 1$.

The second stage of the procedure involves the construction of the resulting series of squared residuals standardized by the conditional variances. The CCF of the

standardized residuals and the squared standardized residuals are then used to test the null hypothesis of no causality-in-mean and no causality-in-variance respectively.

3.3.2 Volatility Impulse Response Functions

Following the methodology of Hafner and Herwartz (2006) and Panopoulou and Pantelidis (2009), VIRFs are calculated based on a bivariate vec-GARCH representation. It is shown that for every BEKK model (see Engle and Kroner (1995)) there exists a unique vec specification.

$$\varepsilon_t = H_t^{1/2} Z_t \ ,$$

$$H_t = C'C + A\varepsilon_{t-1}\varepsilon_{t-1}'A' + BH_{t-1}B' \ , \qquad (3.14)$$

where,

$$Z_t = (z_{1t}, z_{2,t})' \sim \text{i.i.d}\left(\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}\right) ,$$

$$\text{vech}(H_t) = Q + R * \text{vech}(\varepsilon_{t-1}\varepsilon_{t-1}') + P * \text{vech}(H_{t-1}) . \qquad (3.15)$$

Q is a 3×1 matrix of constants, both R and P are 3×3 coefficient matrices and vech is the operator that stacks the lower triangular part of the square matrix to a vector. Following Panopoulou and Pantelidis (2009) Q, R and P matrices of the vec-model are linked to the parameters of the BEKK model as follows:

$$Q=\begin{bmatrix} c_{11}^2 \\ c_{11}c_{21} \\ c_{21}^2+c_{22}^2 \end{bmatrix},$$

$$R=\begin{bmatrix} a_{11}^2 & 2a_{11}a_{12} & a_{12}^2 \\ a_{11}a_{21} & a_{11}a_{22}+a_{12}a_{21} & a_{22}a_{12} \\ a_{21}^2 & 2a_{21}a_{22} & a_{22}^2 \end{bmatrix}, \text{ and}$$

$$P=\begin{bmatrix} b_{11}^2 & 2b_{11}b_{12} & b_{12}^2 \\ b_{11}b_{21} & b_{11}b_{22}+b_{12}b_{21} & b_{22}b_{12} \\ b_{21}^2 & 2b_{21}b_{22} & b_{22}^2 \end{bmatrix}.$$

Modelling volatility dynamics through the BEKK model and calculating VIRFs through its equivalent vec-representation is advantageous as it reduces the number of parameters to be estimated by imposing some specific restrictions on the vec-model.

At time $t=0$ the conditional variance is assumed to be the steady state H_0 and some specific shock hitting the system is reflected by $Z_0=(z_{1,0},z_{2,0})'$. One can then define the VIRF, $V_t(Z_0)$ as

$$V_t(Z_0) = E\ \text{vech}(H_t) \mid F_{t-1}, Z_0\ - E\ \text{vech}(H_t) \mid F_{t-1}\ , \qquad (3.16)$$

where F_{t-1} is the observed history through to time t - 1. $V_t(Z_0)$ is an N^*-dimensional vector. If N = 2 then $N^*=3$ and the first and third elements of equation (4.16), $\upsilon_{1,t}$ and $\upsilon_{3,t}$, represent the impulse response of the conditional variances of the two variables in the analysis. The second element of the equation, $\upsilon_{2,t}$, is the impulse response of the conditional covariance to the shock Z_0 that occurred t periods ago. The VIRF can be computed recursively based on

$$V_1(Z_0) = R * \ \text{vech}(H_0^{1/2} Z_0 Z_0' H_0^{1/2} - \text{vech}(H_0)\ , t = 1$$

$$V_1(Z_0) = (R + P)V_{t-1}(Z_0), t > 1\ . \qquad (3.17)$$

The expressions above show that the VIRF has three properties:

(i) The VIRF is an even function i.e. $V_t(Z_0)=V_t(-Z_0)$ since it is based on the squares of the innovations.

(ii) The VIRF is not homogenous to any degree.

(iii) The VIRF depends on history through the volatility state H_t at the time the shock occurs.

In this study of safe havens we are only concerned with the impulse response caused by a shock to the stock market as this will give us the most information on how insulated each potential safe haven is. Following Panopoulou and Pantelidis (2009) we assume the 3 x 1 matrix $\psi=\left[\varphi_{i,1}\right]:=\text{vech}(H_0^{*1/2}Z_0Z_0'H_0^{*1/2})-\text{vech}(H_0^*)$ where i =1,2,3. The elements of ψ are functions of the elements of the shock Z_0 as well as the elements of the baseline state H_0^*.

In the case of a unidirectional spillover we assume that $a_{12}=b_{12}=0$ while $a_{21}\neq 0$ and/or $b_{21}\neq 0$ and as a consequence both R and P are lower triangular matrices. Therefore, the following must hold

$$\upsilon_{1,1}=a_{11}^2\psi_{1,1} \text{ and } \upsilon_{1,t}=(a_{11}^2+b_{11}^2)^{t-1}\upsilon_{1,1} \text{ for } t>1,$$

$$\upsilon_{2,1}=a_{11}a_{21}\psi_{1,1}+a_{11}a_{22}\psi_{2,1} \text{ and } \upsilon_{2,t}=f(\upsilon_{1,1},\upsilon_{2,1}) \text{ for } t>1,$$

$$\upsilon_{3,1}=a_{21}^2\psi_{1,1}+2a_{21}a_{22}\psi_{2,1}+a_{22}^2\psi_{3,1} \text{ and } \upsilon_{3,t}=g(\upsilon_{1,1},\upsilon_{2,1},\upsilon_{3,1}) \text{ for } t>1,$$

here f is a function of $\upsilon_{1,1},\upsilon_{2,1},a_{ij}$ and b_{ij}, i,j=1,2, and g is a function of $\upsilon_{1,1},\upsilon_{2,1},\upsilon_{3,1},a_{ij}$ and b_{ij}, i,j=1,2. In this case there is unidirectional spillover from the first series to the second and the effect of the shock on the conditional variance of the first series does not depend on the response of the second.

3.4: Data

This paper uses thirty-one years of weekly data from 9th January 1980 to 28th December 2011. This allows for a thorough analysis of the evolving relationship between the stock market, gold and bond market. The Standard & Poor's Composite 500 – U.S.$ Price Index is the chosen representative of the U.S. stock market while the London Bullion Market (LBM) U.S.$/per ounce is chosen to represent the gold market, the first of the two potential safe haven assets.

To represent the U.S. Treasury bond market a choice is made between the 1-year U.S. T-bond (short-term bond) and the 10-year U.S. T-bond (long-term bond). It is well documented that there are many shortfalls associated with applying (G)ARCH methodology to short-term rates. Gray (1996) notes that estimates of GARCH models have a tendency to imply explosive conditional variance caused by the fact that the model assumes a single-regime where the long-run mean and speed of reversion is the same throughout the entire sample. It is for this reason that Hamilton (1988), Gray (1996) and others propose the use of regime-switching models to account for the possibility that the economic mechanism that generates the short-term rate undergoes a finite number of regime changes over the sample period. Lamoureux and Lastrapes (1990) document the importance of allowing for these shifts in regime based on the fact

that if a single-regime is implemented then any shifts that do occur will tend to be mistaken for periods of volatility clustering which lead to untenable results. Indeed, these exact problems are encountered when applying the methodologies to the 1-year T-bond return and so this chapter proceeds without it in the analysis. It is investigated in a more appropriate regime-switching framework in Chapter 4.

It is because of these problems that the U.S. Benchmark 10 Year Total Return Index represents the long-term U.S. T-bond market in an attempt to avoid complications that may arise in the VIRF analysis which utilises GARCH methodology. Kim, Moshirian and Wu (2006) also note that government bonds with more than ten years to maturity are used to match their duration with stocks, which are generally viewed as long-term investments. All data are sourced from Datastream and excess log returns are calculated for all series using the 3-month U.S. Treasury Bill as a proxy for the risk free rate of return.

Table 3.1 provides summary statistics for the weekly excess log returns of the S&P500, Gold and the 10-year bond. In terms of the weekly mean return, we see that gold exhibits negative excess returns which occur when the return on the asset is less than the return on the risk free asset. Reinforcing the findings of Coudert and Raymond (2010), gold is also the riskiest of the three assets based on the standard deviation. It is also interesting to note the skewness and excess kurtosis associated with the 10-year bond. As well as the distribution of the long-term bond being platykurtic meaning that it is relatively flat peaked compared to a normal distribution, it also reports positive skewness. Chiang (2007) highlights that safer bonds like Treasuries and investment grade corporate bonds exhibit positive skewness, while “junk” bonds have substantial

negative skewness. Across the full sample the Jarque-Bera test rejects the hypothesis that weekly excess returns are normally distributed.

Table 3.1: *Summary Statistics*

	Excess Log Return S&P500	**Excess Log Return Gold**	**Excess Log Return 10-Year Bond**
Mean	0.0004	-0.0004	0.0006
Standard Deviation	0.02	0.03	0.01
Skewness	-0.69	0.30	0.25
Excess Kurtosis	4.90	6.17	2.65
Jarque-Bera	1807.79	2672.44	508.61
Observations	1,669	1,669	1,669

Notes: Skewness is defined as m_3/s^3 where $m_3$is the centred third moment of the data and s is the sample standard deviation. Kurtosis is defined as (m_4/s^4)-3 where m_4 is the centred fourth moment of the data.

Skewness over the sample indicates that equity has the propensity to generate negative returns with greater probability than suggested by a normal distribution as opposed to gold and the 10-year bond. This is potentially a very important characteristic in identifying possible safe haven assets to hedge against uncertainty in the stock market. It is also important to note the excess kurtosis, especially in the case of gold which is particularly high. This justifies the use within Hafner and Herwartz (2006) VIRF model of GARCH methodology which is sufficiently heavy-tailed to deal with this excess kurtosis.

3.5: Results

3.5.1 Cross-Correlation Function Results

The first step in implementing the CCF test is to run univariate GARCH models for each of the series under analysis. Table 3.2 reports the maximum likelihood estimates of the three univariate GARCH(1,1) models. The coefficients of the conditional equations are all significantly different from zero, revealing significant GARCH(1,1) effects. Volatility persistence is reported in the final column. For each of the three series, the measure of persistence is close to unity which implies the response of volatility to shocks decays relatively slowly.

Table 3.2: *Maximum Likelihood Estimates of Univariate GARCH(1,1) Model*

	α_0	α_1	α_2	$\alpha_1 + \alpha_2$
S&P500	**0.00**	**0.15**	**0.82**	0.97
	(2.97)	**(5.83)**	**(25.38)**	
Gold	**0.00**	**0.12**	**0.86**	0.98
	(3.23)	**(6.99)**	**(54.77)**	
10-Year Bond	**0.00**	**0.10**	**0.86**	0.96
	(3.24)	**(6.67)**	**(40.19)**	

Notes: T-statistic reported in parentheses. Bold numbers indicate statistical significant values. ARCH and GARCH effects are measured through α_1 and α_2 respectively. $\alpha_1 + \alpha_2$ measures the persistence of shocks.

Results from the univariate GARCH(1,1) models are then used to estimate the standard innovations of U_t and V_t as in (3.6) and (3.7) and cross correlation functions at k lags are then determined following equation (3.8). The χ^2 test statistics for these tests are reported in Tables 3.3 and 3.4. The choice of lag length is found not to qualitatively affect results and so the χ^2 test statistics for a lag length of k=10 are

reported below. As in Chapter 2, the data is arbitrarily divided into four sub-samples 1980 - 1988, 1988 – 1996, 1997 – 2004 and 2004 – 2011 containing 443, 443, 392 and 391 weekly observations respectively. Dividing the data into sub-samples allows for a more in-depth analysis of the potentially time-varying relationship that may exist between the series and ensures that each quarter contains at least one crisis period.

Causality-in-mean from the stock market to the 10-year bond market is identified in the full sample and in the period 1980-1988, reported in Table 3.3. These results indicate that the return on equity causes the return on the long bond over these periods. Sub-sample 1 is a period which contains both the 1980 recession and 1987 stock market crash as defined by National Bureau of Economic Research. Baur (2012) notes that it is possible for investors to transmit the volatility and uncertainty of the stock market to the bond market by purchasing 10-year bonds en-masse. It is also a period, Ireland (2000) notes, during which the Federal Reserve followed a policy of maintaining the short-term nominal interest rate in order to control inflation. It is possible, therefore, that these crises and Federal Reserve policies may be driving the results of sub-sample 1, which in turn is driving the significance of the full sample.

Table 3.4 reports the χ^2 test statistics for the causality-in-variance test. The results indicate that there is no statistically significant volatility spillover from equity to either gold or the 10-year bond.

Table 3.3: χ^2 *Test Statistic for the Causality-in-Mean Test*

A:	B:	**Gold**	**10-Year Bond**
Full Sample S&P500	A → B	9.84	24.53***
Sub Sample 1 1980-1988	A → B	5.56	19.13**
Sub Sample 2 1988-1996	A → B	2.29	12.64
Sub Sample 3 1997-2004	A → B	4.88	0.24
Sub Sample 4 2004-2011	A → B	14.11	2.96

Notes: Test statistic reported is for null hypothesis of no causality-in-mean from market A to B at k=10. *** indicates statistical significance at 1% level. ** indicates statistical significance at 5% level. * indicates statistical significance at 10% level.

Comparing the two assets, gold appears to be a marginally stronger safe haven. Investors capitalize on the highly liquid characteristic of gold and use it as a haven, sheltered from any spillover in mean and volatility from the stock market. However, given that we do identify statistical significance in the 10-year bond in the full sample and sub-sample 1 it may prove informative to take a more in-depth look at the relationship between the stock market and these two assets. This in-depth analysis of volatility persistence can be achieved with Hafner and Herwartz (2006) VIRF model as discussed in section 3.4. In particular, we want to focus on negative shocks as opposed to the current (CCF) methodology which looks at the size of all shocks when computing causality-in-variance.

Table 3.4: χ^2 *Test Statistics for the Causality-in-Variance Test*

A:	B:	**Gold**	**10-Year Bond**
Full Sample S&P500	A → B	11.34	7.51
Sub Sample 1 1980-1988	A → B	9.59	11.49
Sub Sample 2 1988-1996	A → B	7.82	13.17
Sub Sample 3 1997-2004	A → B	6.88	4.30
Sub Sample 4 2004-2011	A → B	4.13	8.19

Notes: Test statistic reported is for null hypothesis of no causality-in-variance from market A to B at k=10. *** indicates statistical significance at 1% level. ** indicates statistical significance at 5% level. * indicates statistical significance at 10% level.

3.5.2 Volatility Impulse Response Function Results

Bivariate GARCH(1,1) BEKK models are estimated for each pair of S&P500 - gold and S&P500 - 10-year bond based on the specifications of equations (3.15) and (3.16). These results are reported in Table 3.5 below. It must be noted that the GARCH(1,1) is estimated using Gaussian likelihood, better known as quasi maximum likelihood (QML). Hafner and Herwartz (2008) note that certain drawbacks exist when using the alternative Student-t distribution, such as inconsistent maximum likelihood estimates whereas QML retains consistency under misspecification.

Primarily, we are concerned with the spillover reported from the stock market to each of the two safe haven assets. This spillover is identified through A_{12} and B_{12}

which can be interpreted as a shock spillover and the level of persistence, respectively. There is no statistically significant volatility spillover at the 5 per cent level from the stock market to either of the two alternative assets.

Table 3.5: *Bivariate GARCH(1,1) BEKK Results*

C_{11}		A_{11}	A_{12}	B_{11}	B_{12}
C_{21}	C_{22}	A_{21}	A_{22}	B_{21}	B_{22}
S&P500 – Gold					
0.0043		**0.3317**	0.0002	**0.9277**	0.0005
(5.58)		**(10.48)**	(0.00)	**(59.09)**	(0.03)
-0.0001	**0.0029**	0.0102	**0.3148**	–0.0033	**0.9449**
(-0.11)	**(6.78)**	(0.43)	**(12.83)**	(–0.38)	**(123.37)**
S&P500 – 10-Year Bond					
0.0038		**0.3755**	–0.0160	**0.9185**	0.0032
(6.14)		**(11.19)**	(–1.41)	**(63.69)**	(0.91)
0.0002	**0.0008**	0.0223	**0.1893**	–0.0011	**0.9782**
(0.78)	**(3.02)**	(0.61)	**(9.83)**	(–0.08)	**(217.27)**

Notes: Gaussian t-statistics are reported in parentheses. Bold numbers indicate statistical significant values. A_{ij} and B_{ij} represent ARCH and GARCH spillover from market i to market j.

The second stage of the methodology allows for the graphing of the VIRF to identify exactly the persistence of volatility shocks to the three assets and the effect of negative shocks on the expectation of covariance between equity and gold and equity and the 10-year bond. These results are represented in Figures 3.2, 3.3 and 3.4. Essentially, these results show us the relative effect of negative shocks compared to the expectation of the conditional variances and covariance had the shock not occurred.

Shocks to the stock market have been chosen on the basis that a "large" negative shock to the stock market is defined as excess log return greater than or equal to -10 per cent. Based on this definition three independent shocks to the stock market have been chosen. Following Panopoulou and Pantelidis (2009) we adopt the half-life of a volatility shock as a measure of the decay of persistence. It is defined as the time required for the volatility impact of the shock to reduce to half of its maximum value.

The first of these shocks occurs on the 21st October 1987 which corresponds to the Stock Market Crash of 1987. As this is weekly data, the dates chosen may not represent the exact date of the shock but instead represent the week in which the shock occurred. The S&P500 lost over 20 per cent of its value in this particular week. Figures 3.1(a) and 3.1(b) show the effect that this shock had on the expectation of variance for the stock market, gold, 10-year bond and the expected covariance between S&P500 and gold and S&P500 and the 10-year bond.

Figure 3.2(a): *VIRF S&P500 - Gold*

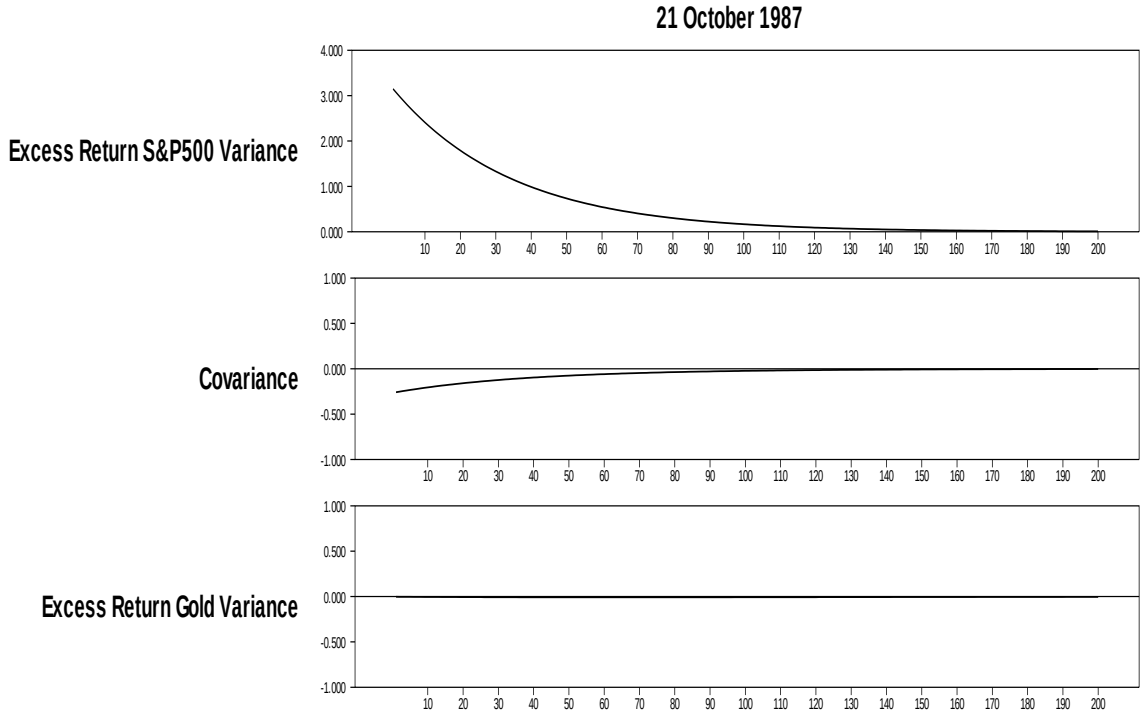
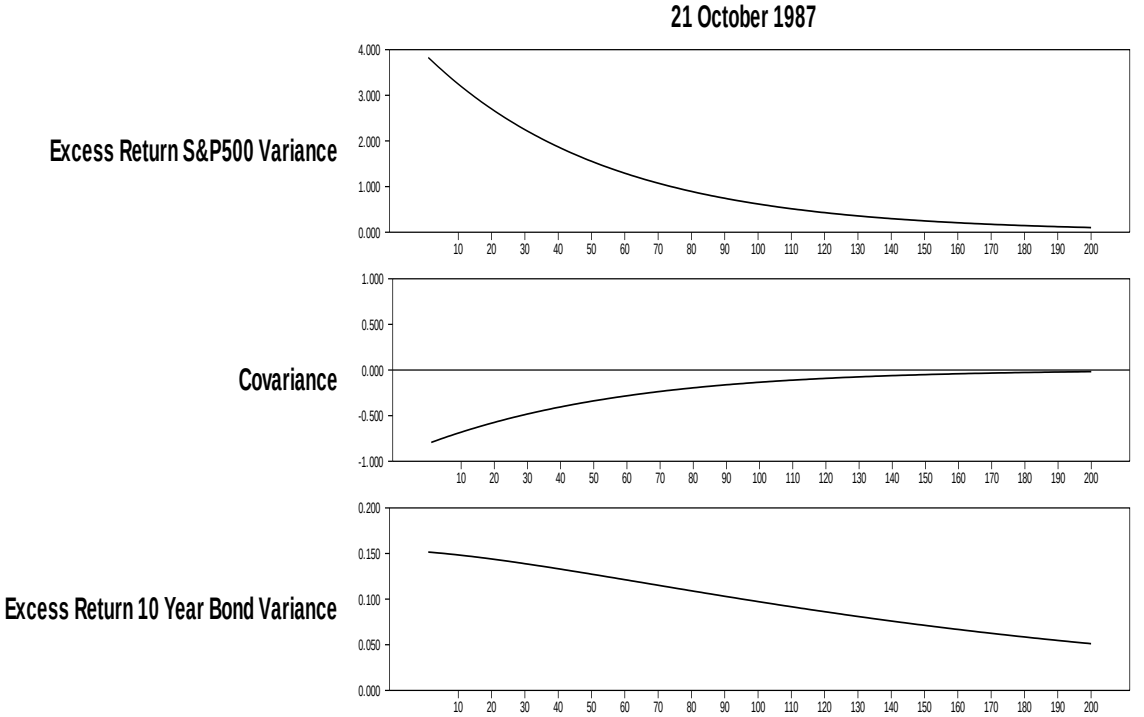


Figure 3.2(b): *VIRF S&P500 – 10-Year Bond*



As anticipated, the shock had a large positive effect on the volatility of the S&P500 which dies out relatively slowly over time, absorbing half of the shock after 27 weeks, measured along the x-axis. The effect on the 10-year bond volatility is positive and large when compared to the effect of the shock on gold, which is negligible. Persistence is also large for the 10-year bond with half of the shock being absorbed only after 140 weeks. However it must be noted that compared to equity, the effect on bonds is only half the size. The expectations for the covariances in Figures 3.2(a) and 3.2(b) are very similar for both potential safe havens. The expectation of the covariance between equity and gold, in light of this large negative shock, returns to its baseline or predictable level almost 100 weeks before the covariance between equity and 10-year bond does.

On the second shock date, the 10th October 2008, stock markets crashed across Europe and Asia with the S&P500 experiencing one of its worst weeks since the Wall Street Crash of 1929. It is interesting to note that this substantial shock has a similar effect on the expectations of the variance for both the 10-year bond and gold as identified in the previous figure. Similar to Figure 3.2(b) the volatility of the 10-year bond is initially positively affected, the persistence of which increases over a number of weeks before starting to die out. It is interesting to note that, despite the increase in volatility in S&P500, the volatility of gold is only marginally affected and appears to actually reduce the volatility of gold. The impact of the shock on the expected covariance is similar across both assets and comparable to Figures 3.2(a) and 3.2(b).

Figure 3.3(a): *VIRF S&P500 - Gold*

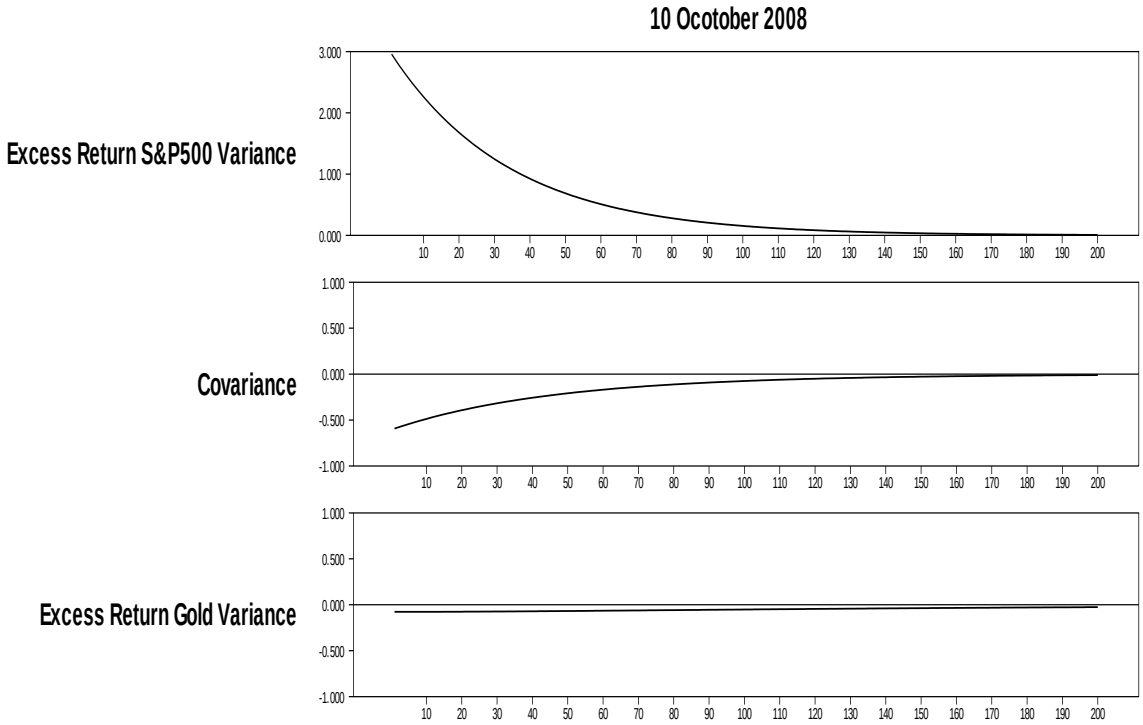
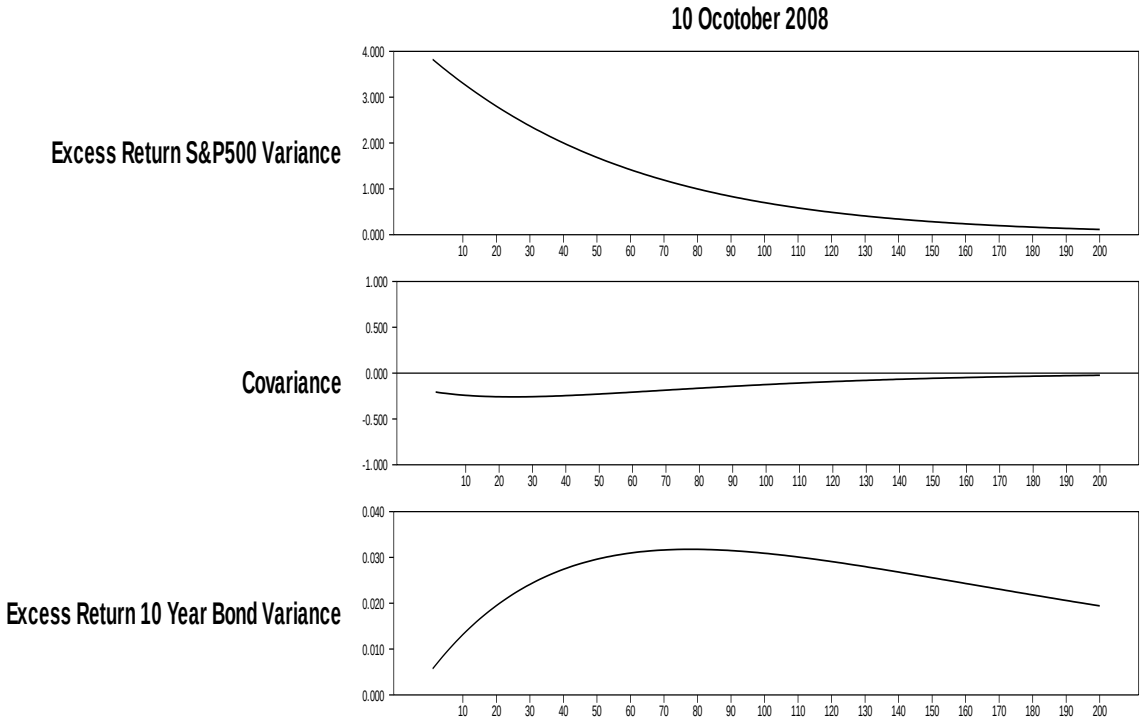


Figure 3.3(b): *VIRF S&P500 – 10-Year Bond*



The final shock is identified as the 10th August, 2011 which corresponds to the week in which Standard and Poor's rating agency downgraded the United States credit rating from AAA to AA+. Figure 3.4(b) corresponds quite closely to the results reported in Figure 3.2(b) and 3.3(b). Surprisingly, there is a relatively large positive response from the volatility of gold which is unique when compared to the previous shocks analysed. The persistence of this shock is also substantial as it takes eighty weeks for half of the shock to be absorbed. However this volatility response dies out relatively quickly when compared to the volatility persistence of the three shocks on the 10-year bond. It must also be noted that, despite this positive effect on the volatility of gold, there is a substantial reduction in the expected covariance between equity and gold, similar to results in Figures 3.2(a) and 3.3(a)

In all Figures presented above, a shock in the stock market causes the covariance to be reduced for both gold and the U.S. Treasury bond. This indicates that both assets have the potential to be suitable safe havens, characterised by negative covariance in periods of stock market uncertainty. However, when the results of the CCF and VIRF analyses are viewed in conjunction they suggest that of the two viable safe haven assets available to investors, gold appears, marginally, to be the most suitable.

Figure 3.4(a): *VIRF S&P500 - Gold*

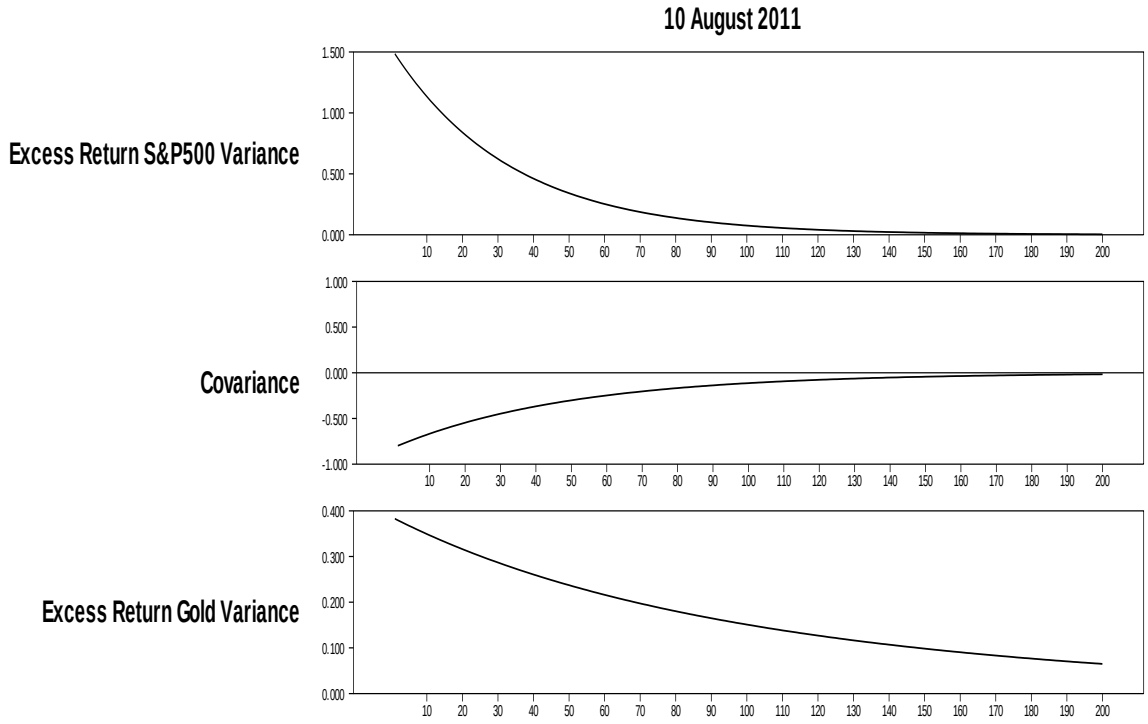
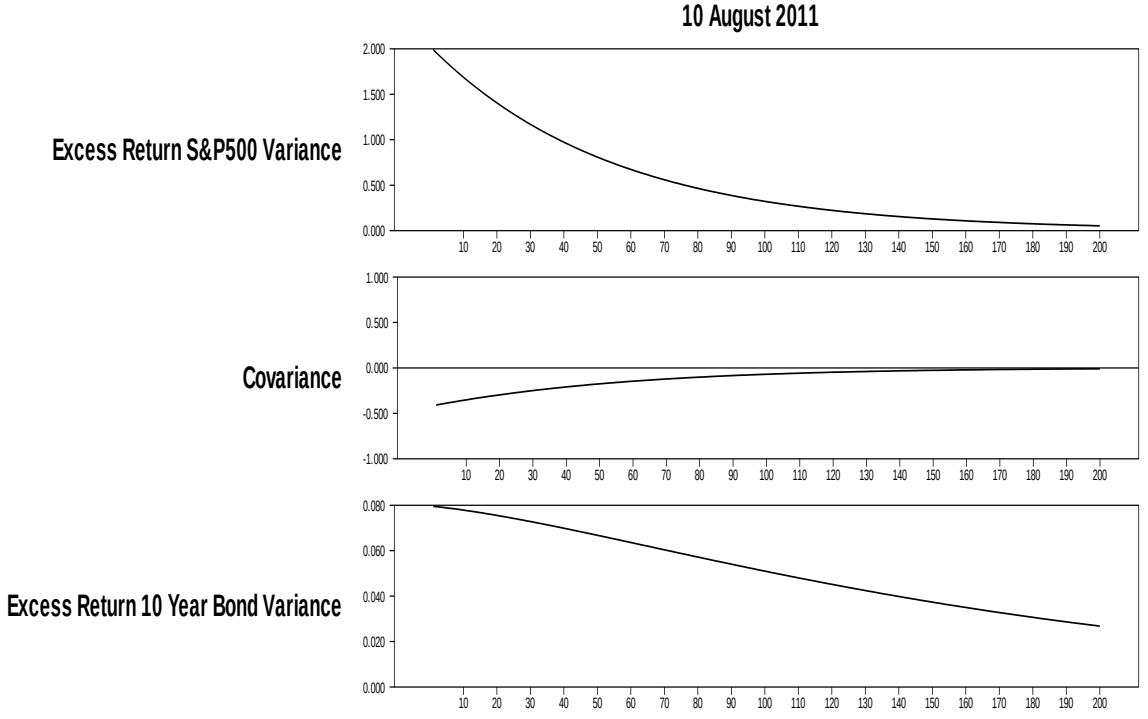


Figure 3.4(b): *VIRF S&P500 – 10-Year Bond*



The CCF results suggest that gold is insulated from both mean and variance spillover from the stock market and this is supported by the VIRF's which shows that both the variance and covariance of gold are relatively unaffected by considerable shocks to the stock market, especially when compared to the VIRF's for the 10-year bond.

3.6: Conclusion

This paper utilises CCF and VIRF methodologies with the aim of identifying whether gold or a 10-year U.S. T-bond is the most appropriate asset for investors to turn to when negative news is received in the stock market.

The CCF model allows us to identify causality-in-mean and causality-in-variance between equity and the two safe haven assets. Results indicate that of the two assets available, gold appears to be the most insulated from negative news in the stock market. The VIRF allows for more in-depth analysis of how persistent negative shocks are as well as determining the effect of such shocks on covariance. Again these results corroborate the finding that gold is the most suitable for equity investors as impulse responses of gold to shocks are not as persistent when compared to the impulse response of the 10-year bond.

Chapter 2 presented little evidence of any relationship between equity and gold and a similar story emerges here with the CCF results indicating that there is no statistically significant causality-in-mean or -variance. Results obtained from the VIRF stage of the analysis are also broadly in line with those derived from the VAR-GARCH model in the previous chapter. While the results of Chapter 2 revealed that gold

responds symmetrically to equity shocks, the VIRF employed in this chapter illustrates a modest reduction in the covariance between the two assets when “large” negative equity shocks occur.

Undoubtedly there are some limitations to this analysis. Most notably, and worth further investigation, is the inclusion of a 1-year, or short-term bond in both the CCF and VIRF methodologies. This could be achieved with an asymmetric term which may lead to a reduction in the persistence of shocks in the 1-year bond which previous literature has noted as a significant problem. An alternative way of improving the analysis is through the introduction of a regime switching model which will also have the ability to deal with the problem of high persistence in the 1-year bond.

Chapter 4: Detecting Shift and Pure Contagion between Equities and Potential Safe Havens

4.1 Introduction

The aim of this paper is to determine the contagious effects from the stock market to three potential safe havens in order to determine whether gold, a 10- or a 1-year U.S. T-bond is the most effective safe haven when an investor wishes to avoid high volatility in the stock market. In the past five years investors have witnessed one of the most turbulent periods in global equity markets since the 1987 stock market crash. The uncertainty associated with this period has ignited the necessity for investors to understand the underlying relationships between different asset classes and whether contagion is an issue.

A number of economic factors motivate the choice of these three potential safe havens in this particular analysis, with Lawrence (2003) and Steeley (2005) among others highlighting the appeal of gold and U.S. Treasuries respectively. Firstly, despite one of the most volatile periods in the recent history of equity markets, gold prices have experienced a substantial increase over the past decade which suggests that demand has increased considerably.

A similar story emerges with U.S. Treasury bonds. While there are obvious advantages associated with an investment in government bonds, such as guaranteed return, there are also some notable disadvantages. One of the primary disadvantages arises with the positive correlation between the bond market and key macroeconomic variables. Lawrence (2003) explores this issue in-depth and notes the high correlation between gross domestic product (GDP), for example, and both the equity and bond

markets. This relationship may potentially impact investors' decisions to choose a U.S. Treasury bond as a potential safe haven.

In this paper we employ a regime-switching model to facilitate the identification of potential safe havens. One advantage of this approach is that it allows us to identify contagious affects in a more in-depth manor compared to previous chapters. Also, in Chapters 2 and 3 crisis periods were chosen a priori, however an obvious shortcoming of this method is that it is notoriously difficult to accurately identify when crisis periods begin and end. Utilising a regime-switching model in this chapter removes the uncertainty associated with this technique and allows for a more comprehensive study.

We follow very closely the methodology of Flavin, Panopoulou and Unalmis (2008) in which they identify channels of contagion between currency and equity markets during periods of high-volatility. They note the importance of analysing contagious effects between different asset types within the same country in order to develop the equity investors understanding of the source and more importantly the evolution of adverse shocks. The appealing aspect of this model is that it allows us to test for both shift- and pure-contagion within a unified framework. These two types of contagion are of particular interest to us as they allow us to determine the true linkages between equity, gold and U.S. Treasury bonds.

The test for shift-contagion determines changes in the normal relationship between pairs of assets during periods of high-volatility while the test for pure-contagion analyses the effect of a high-volatility idiosyncratic shock on other assets. While analysis provided in previous chapters allowed us to determine contagious effects, through mean and volatility spillover, neither approach was sufficient in determining if contagious effects are caused by common or asset specific shocks.

In this analysis, the test for pure-contagion may prove particularly insightful when identifying safe haven assets. In a well-diversified portfolio, investors will opt for assets that act independently of each other with zero or negative correlation. If an idiosyncratic shock occurs it should therefore not affect other assets within the same portfolio. These channels, through which the idiosyncratic shock travels, only exist in periods of high-volatility. Consequently, it is crucial that any contagion operating between assets is correctly identified in order to fully understand dependable safe havens for the stock market. Essentially, the unified framework presented here allows us to test explicitly the relationship between equity and each of the three potential safe havens, which the extant literature suggests is an approach that has not been utilised in this way before.

The results suggest that of the three potential safe havens gold and the 10-year bond are very similar in terms of their potential as a safe haven, while the 1-year bond appears to be the least appropriate given the existence of both shift- and bi-directional pure-contagion. The remainder of the paper is organised as follows. Section 4.2 presents the existing literature. Sections 4.3 and 4.4 detail the methodology and data, respectively. Section 4.5 reports the results. Concluding remarks are made in section 4.6.

4.2 Literature Review

A detailed review of the literature on the equity - gold and the equity - bond relationship is provided in Chapters 2 and 3 of this dissertation. This section will therefore focus on the literature concerning the methodology employed in this paper.

4.2.1 Regime-Switching Models

In previous chapters variants of the (G)ARCH family were used to study the relationships between several assets. However in this chapter, when conducting analysis on a 1-year bond it is important to use a model which is able to overcome some of the shortcomings which may arise for example the potential for the short-term bond to exhibit explosive behaviour in the conditional variance process. Lamoureux and Lastrapes (1990) note the importance of using regime-switching models in these situations as unstable results can sometimes be caused when shifts actually do occur and are mistakenly identified as periods of volatility clustering. It is therefore reasonable to employ a model with adequate specifications to deal with this dilemma.

Quandt (1958) first introduced a linear regression model which inherently obeys two different regimes; however it requires a priori knowledge of the exact number of regime switches. Hamilton (2005) notes that these shifts are commonly associated with events like financial crisis or sharp changes in government policies, and so it may prove difficult, based on Quandt's (1958) model, to confirm the exact number of switches within a data set especially if it spans several crises and numerous policy changes. Based on this weakness, Goldfeld and Quandt (1973) develop a more sophisticated multi-switch model which controls for regime switches as a Markov process to describe the probability of switching between regimes. It is from this base that countless variations have emerged and Guidolin (2011) provides a comprehensive evaluation of these Markov-switching (MS) models in empirical finance.

Hamilton (1988, 1989) provides seminal contributions to the literature by developing a simple two-regime model focusing on the mean behaviour of variables to deal with the affect of abrupt changes in government policy. He proposed regime-

switching models as an alternative approach to deal with the possibility that the economic mechanism that generates the short-term rate undergoes a number of regime changes in its life time. Kuan (2002) highlights the innovative features of Hamilton's (1988, 1989) regime switching models. For example, the switching mechanism was designed to be controlled by an unobservable state variable following a first order Markov chain which improved on the preceding contribution from Quandt (1958) where each regime occurred independently.

These papers motivated numerous other studies focusing on Markov-switching (MS) models of conditional means. For example, Engel and Hamilton (1990) apply Hamilton's (1989) approach to model changes in exchange rates corresponding to episodes of increasing or decreasing exchange rates and conclude that movements in the dollar persist for long periods of time. Engel (1994) and Filardo (1994) also base their analysis on Hamilton's (1989) model to investigate whether a Markov-switching model can be used to describe the behaviour of floating exchange rates during the expansionary and contractionary phases of the business cycles, respectively.

Kuan (2002) notes that given the success of the Markov-switching models of conditional mean, a natural progression is to consider including the switching mechanism into conditional variance models. Hamilton and Susmel (1994) explore a specification in which the parameters of an ARCH process can occasionally change with the overall aim of reducing spuriously high persistence associated with ARCH models. They note that most of the persistence in the stock price volatility from 1962 to 1987 is attributable to the persistence of low-, medium- and high-volatility regimes where the high-volatility regimes are largely associated with recessionary periods.

Cai (1994) takes a similar approach in combining Hamilton's (1989) model and Engle's (1982) ARCH model to develop a more realistic analysis of the variability of financial time series. Focusing on the 3-month U.S. Treasury over the period 1964 to 1991 he discovers two periods during which there was a notable regime-shift, in 1974 associated with the oil shock and the period from 1979 to 1982 associated with Federal Reserve's policy decisions.

Despite the advantages of this model combination, Cai (1994) highlights the tremendous difficulty associated with the estimations. Hamilton and Susmel (1994) also conclude that regime-switching GARCH models are impossible to estimate because of the dependence of the conditional variance on the past history of the data. Gray (1996) was first to combine GARCH and Markov-switching models and proposed a solution by developing a non-path-dependent GARCH model where conditional variances depend only on the current regime.

Chen (2009) proposes a Markov-switching multivariate GARCH model to study the stock - bond correlations, which extends Haas, Mittnik and Paolella (2004) whose approach, while flexible, only allows the covariance not the correlation to change between regimes. They conclude that a "low-to-high" switch in stock market volatility is associated with a "high-to-low" switch in the correlation with the bond market, which has potential implications for investors using U.S. Treasuries as a hedge or safe haven.

4.2.2 Contagion in Financial Markets

In this chapter we adopt the Markov-switching factor model of Flavin and Panopoulou (2010) which is an extension of Gravelle, Kichian and Morley (2006). Unlike Gravelle, Kichian and Morley (2006) whose model only analyses shift-contagion, Flavin and Panopoulou (2010) allow for both shift- and pure-contagion to be examined, which is potentially important when identifying safe haven assets. Another advantage of using this methodology is that it allows the identification of how the co-movement between the stock market and the three potential safe haven assets changes, not only over time but, more importantly, across high- and low-volatility regimes.

There are many different approaches to determining the links between financial assets. The methods that are used in the extant literature crucially depend on the definition of contagion. The approach taken in this chapter examines contagion as defined by Pericoli and Sbracia (2003) where cross-country co-movements of asset prices cannot be explained by fundamentals. Markov-switching models like the one employed here are most commonly used to analyse contagion defined in this way, specifying a number of regimes and estimating the probabilities of moving from one regime to another as described by a Markov transition matrix.

However, there is an ongoing debate within the literature regarding the exact definition of contagion with some believing that any transmission of a shock between countries or assets constitutes contagion. Moser (2003) notes that contagion should be confined to describe the situation in which a crisis in one market causes a crisis in other markets, or at least increases the possibility of a crisis. One of the more common approaches which tests this particular definition is the study of cross-market correlations.

There is also substantial research which focuses on whether increased integration between markets leads to increased contagion. Pappas, Ingham and Izzeldin (2013) note that while integration has the potential to lead to highly efficient financial systems which enhances risk-sharing, it does not necessarily increase stability. Indeed increased integration between markets allows for cross boarder transmission of shocks leading to contagion. Evidence in previous chapters presented in this dissertation suggest some level of mean and volatility spillover between assets, however these contagious effects may well be driven by normal interdependence. Forbes and Rigobon (2002) for example, define contagion as a significant increase in cross-market linkages after a shock in a particular country and models such as those based on cross-market correlation may be appropriate for testing this. However they note the inadequacy regarding this method in the presence of heteroskedasticity. They establish that when correlation coefficients are adjusted for heteroskedasticity there is no statistically significant evidence of contagion during the 1997 East Asian Crisis, the 1994 Mexican peso devaluation and the 1987 stock market crash. They conclude that the increased comovement between markets is due to interdependence. Bordo and Murshid (2001) and Gonzalo and Olmo (2005) draw similar conclusions in that cross-market correlations can lead to misleading results and very few cases of pure-contagion are identified when correlation coefficients are adjusted for heteroskedasticity.

Flavin and Panopoulou (2010) apply a unified Markov-switching factor model to test for contagion between East Asian equity markets from 1990 to 1997.[9] Defining shift-contagion as a change in the normal relationship between pairs of markets during a

[9] Dungey et al. (2005) note the use of latent factor models of asset returns, which have their origins in factor models in finance based Arbitrage Pricing Theory (APT), in modelling the interdependence of asset markets during non-crisis periods. In determining hedging possibilities amongst various assets Dee et al. (2013) derive a model based on the capital asset pricing model and APT.

crisis and pure-contagion as only occurring when a negative shock that is normally idiosyncratic spills over to other markets, they conclude that contagion has been an important feature of these markets over the past two decades. The inclusion of a test for pure-contagion is of particular interest as it determines the affect of both low- and high-volatility equity idiosyncratic shocks on the potential safe haven. This should highlight how "bad news" arriving in the stock market affects the relationships with the potential safe havens.

It is crucial that investors understand the links between assets with King and Wadhwani (1990) highlighting that when rational agents cannot distinguish between an idiosyncratic and a systematic shock there is the potential to transmit this shock from one market to another. Calvo (1999) also develops a model of constrained asymmetric information and finds that uninformed investors may wrongly infer decisions made by informed traders and exit 'crisis' markets for safer assets, creating contagion. It is therefore critical for investors to understand the source and transmission of shocks especially if they are in pursuit of a safe haven.

An alternative but equally popular approach in identifying linkages between financial assets is the use of GARCH models. This method tests for contagion based on the definition that it occurs when volatility of asset prices spills over from the crisis asset to other assets. Marcucci (2005) notes the popularity of these models is derived from their ability to capture some of the typical stylised facts of financial time series, however Pericoli and Sbracia (2003) note that a simultaneous rise in volatility in different markets might be due to normal independence between these markets which this definition fails to address.

Flavin, Panopoulou and Unalmis (2008) focus on the transmission mechanism of common shocks between emerging financial markets of East Asia across different volatility regimes. They highlight the fact that very little attention has been paid to the contagious effects between different asset types within the same country with the extant literature focusing on the transmission of a shock in a source market to the same asset class in another market. For example, Forbes and Rigobon (2002) and Chiang, Jeon and Li (2007) concentrate on equity markets while Favero and Giavazzi (2002) and Dungey, Fry, Gonzalez-Hermosillo and Martin (2006) focus on bond markets. There is therefore great promise in applying this approach to identify potential safe haven assets for equity investors.

4.3 Methodology

This paper follows the methodology of Flavin, Panopoulou and Unalmis (2008) which extends on the model developed by Gravelle, Kichian and Morley (2006), capturing the potential effects of shift- and pure-contagion. The addition of a test for pure-contagion is advantageous in this safe haven analysis as it allows us to identify how shocks specific to one asset are transmitted to other markets during episodes of high-volatility.

In the bivariate factor model, let r_{it} represent the excess log return from each of the series i. Under the assumptions of this bivariate setting the paper will analyse the pairings of gold, a 10-year U.S. T-bond and a 1-year U.S. T-bond with the S&P500. Returns are decomposed into an expected and an unexpected component, μ_i and u_{it},

respectively, which reflects the arrival of news to each of the markets. Thus r_{it} can be represented as,

$$r_{it} = \mu_i + u_{it}\,,\ E(u_{it}) = 0\,,\ i = E, SH\,, \tag{4.1}$$

where $i=E,SH$ refers to equity and the potential safe haven, respectively. The forecast errors are contemporaneously correlated, $E(u_{1t}u_{2t}) \neq 0$ which implies common structural shocks between series returns. Given this assumption, the forecast errors are decomposed into a common shock and an idiosyncratic shock,

$$u_{it} = \sigma_{cit} z_{ct} + \sigma_{it} z_{it}\,,\ i = E, SH\,, \tag{4.2}$$

where, z_{ct} and z_{it} denote the common and idiosyncratic shocks, respectively and σ_{cit} and σ_{it} determine the impact of the structural shocks on the series returns. It must also be noted at this stage that shock variances are normalised to unity, which results in the interpretation of the impact coefficients as their standard deviations.

Following both Gravelle, Kichian and Morley (2006) and Flavin, Panopoulou and Unalmis (2008), the common and idiosyncratic shocks are allowed to switch between a high volatility state and a low volatility state. The structural impact coefficients switch regimes as follows,

$$\sigma_{it} = \sigma_i (1 - S_{it}) + \sigma_i^* S_{it}\,,\ i = E, SH\,, \tag{4.3}$$

$$\sigma_{cit} = \sigma_{ci} (1 - S_{ct}) + \sigma_{ci}^* S_{ct}\,, i = E, SH\,, \tag{4.4}$$

where state variables $S_{it}=(0,1)$, $i=E,SH$ take a value of zero in normal times and a value of unity in turbulent times and σ_i^* and σ_{ci}^* denote the high-volatility regime. Since

the state variable S_{it} is unobservable probabilistic inferences of its value must be formed. Regime paths are allowed to change endogenously and are Markov-switching which allows for sudden jumps between high- and low-volatility regimes following a first order Markov chain with the following transition matrix,

$$p=\begin{bmatrix} p(S_t=0|S_{t-1}=0) & p(S_t=1|S_{t-1}=0) \\ p(S_t=0|S_{t-1}=1) & p(S_t=1|S_{t-1}=1) \end{bmatrix},$$
$$p=\begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}. \tag{4.5}$$

Following Mizrach and Watkins (1999) these transition probabilities are restricted so that $p_{11}+p_{12}=p_{21}+p_{22}=1$. In order to estimate the parameters of the MS model we must compute the probabilities associated with each regime. This is an important step since the state variable is generally unobservable and the transition probabilities determine the persistence of each regime. These probabilities are estimated using Hamilton's recursive filter which is discussed in greater detail by Mizrach and Watkins (1999) who base their discussion on a general MS(r) model. Very briefly, they use the appropriate density to find the joint probability inference of the current observation and the r + 1 most recent states, conditional on the last period's datum

$$p(y_{t+1}, s_{t+1}, s_t, ..., s_{t-r+1} \mid Y_t) = p(y_{t+1} \mid s_{t+1}, s_t, ..., s_{t-r+1}, Y_t) \cdot p(s_{t+1}, s_t, ..., s_{t-r+1} \mid Y_t) \tag{4.6}$$

They derive the density conditional only on prior data by integrating over states and end up with an r + 1 period inference conditional on current data

$$p(s_{t+1}, s_t, ..., s_{t-r+1} \mid Y_{t+1}) = \frac{p(y_{t+1}, s_{t+1}, s_t, ..., s_{t-r+1} \mid Y_t)}{p(y_{t+1} \mid Y_t)}. \tag{4.7}$$

An updated inference is then used as an input for the next iteration. The entire sample must be passed through this process and the filter is initialized with r-period unconditional probabilities

$$p(s_r, s_{t-1}, ..., s_1) = p(s_t, s_{t-1}, ..., s_{t-r+1}), \tag{4.8}$$

which are solved by computing the unconditional estimates that the process, at an arbitrary date will fall into each regime

$$\pi^{(j)} \equiv p(s_t = j), j = 0,1. \tag{4.9}$$

The unconditional estimates are derived by summing the probabilities of being in each regime

$$p^{(0j)} \cdot \pi^{(0)} + p^{(1j)} \cdot \pi^{(1)} = \pi^{(j)} \text{ for } j = 0,1,$$

under the restriction that the unconditional estimates for regimes sum to unity

$$\pi^{(0)} + \pi^{(j)} = 1. \tag{4.10}$$

The necessary r-period unconditional probabilities can then be computed by taking the appropriate transition probabilities into consideration

$$p(s_t = 0, s_{t-1} = 1, s_{t-2} = 0) = (1 - p(s_t = 1 | s_{t-1} = 1)) \cdot (1 - p(s_{t-1} = 0 | s_{t-2} = 0)) \cdot \pi^{(0)}. \tag{4.11}$$

In the case of an MS(r) system, as discussed by Mizrach and Watkins (1999), we need to compute 2^r of these probabilities to initialize the filter.

In an extension to Gravelle, Kichian and Morley (2006), Flavin, Panopoulou and Unalmis (2008) allow the idiosyncratic shock of the S&P500 to potentially influence the other series returns over and above that captured by the common shock during

episodes of high-volatility. For example, the return equation of gold is augmented with the idiosyncratic shock of the S&P500 during the crisis period which thus captures pure contagion.

Flavin and Panopoulou (2010) note that even though the factor model is estimated in one single step using maximum likelihood, similar to that of Hamilton (1989), it implies different features of the model in each of the eight possible states. Assume, for example, that returns during the tranquil periods are given as follows,

$$r_{Et} = \mu_E + \sigma_{cE} z_{ct} + \sigma_E z_{Et}, \tag{4.12}$$

$$r_{SHt} = \mu_{SH} + \sigma_{cSH} z_{ct} + \sigma_{SH} z_{SHt}. \tag{4.13}$$

The return comovements are solely determined by the common shock since the idiosyncratic shocks are assumed to be independent.

$$\sum\nolimits_1 = \begin{bmatrix} \sigma_E^2 + \sigma_{cE}^2 & \sigma_{cE}\sigma_{cSH} \\ \sigma_{cE}\sigma_{cSE} & \sigma_{SH}^2 + \sigma_{cSH}^2 \end{bmatrix}.$$

However, when an idiosyncratic shock occurs in one asset we need to allow for pure contagion in the return generating process of the other asset given by:

$$r_{Et} = \mu_E^* + \sigma_{cE}^* z_{ct} + \sigma_E^* z_{Et} + \delta_E \sigma_{SH}^* z_{SHt}, \tag{4.14}$$

$$r_{SHt} = \mu_{SH}^* + \sigma_{cSH}^* z_{ct} + \sigma_{SH}^* z_{SHt} + \delta_{SH} \sigma_E^* z_{Et}, \tag{4.15}$$

where δ_E and δ_{SH} reveal the presence of bi-directional pure contagion effects to equity and the potential safe haven. In this chapter we are concerned with the relationship between equity and the potential safe haven and, in particular, we are worried about how a negative shock in the stock market affects other assets. The test, developed by

Flavin, Panopoulou and Unalmis (2008), isolates this affect by augmenting the return equation in (4.15) with the high-volatility idiosyncratic shock from the equity market. If δ_{SH}, for example, is positive it verifies the existence of pure-contagion which means that when the equity idiosyncratic shock enters the high-volatility regime information is transmitted to the potential safe haven which will act in reducing the return on the safe haven and increasing the correlation between the assets. However, a negative δ_{SH} implies that as the equity idiosyncratic shock enters the high-volatility regime information is transmitted to the potential safe haven which increases the return on the haven but also decreases the correlation between assets. This is evidence of flight-to-quality. The corresponding variance-covariance matrix of returns is given as:

$$\sum_8 = \begin{bmatrix} \sigma_E^{*2} + \sigma_{cE}^{*2} + \delta_E^2 \sigma_{SH}^{*2} & \sigma_{cE}^{*} \sigma_{cSH}^{*} + \delta_{SH} \sigma_E^{*2} + \delta_E \sigma_{SH}^{*2} \\ \sigma_{cE}^{*} \sigma_{cSH}^{*} + \delta_{SH} \sigma_E^{*2} + \delta_E \sigma_{SH}^{*2} & \sigma_{SH}^{*2} + \sigma_{cSH}^{*2} + \delta_{SH}^2 \sigma_E^{*2} \end{bmatrix}.$$

One of the advantages of this model is that, as well as testing for pure contagion using an additional term in the return generating process, it also allows us to identify shift contagion which was proposed by Gravelle, Kichian and Morley (2006). As a test for shift contagion, a likelihood ratio test is used with the following hypotheses that the impact coefficients in both low- and hig-volatiltiy periods will move proportionately in the absence of shift contagion

$$H_0 = \frac{\sigma_{cE}^{*}}{\sigma_{cSH}^{*}} = \frac{\sigma_{cE}}{\sigma_{cSH}} \text{ versus } H_1 = \frac{\sigma_{cE}^{*}}{\sigma_{cSH}^{*}} \neq \frac{\sigma_{cE}}{\sigma_{cSH}}.$$

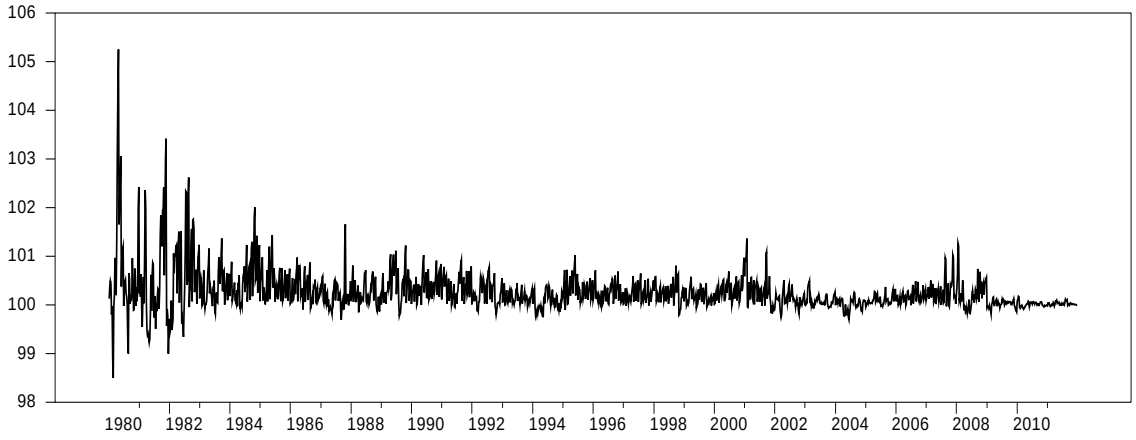
Essentially this test reveals if the normal relationship between a pair of assets changes when the common shock enters a high-volatility regime. There are two ways of identifying a safe haven based on this test. In the first instance, statistically

insignificance proves stable shock transmission across regimes. In the second instance, instability is found but the potential safe haven shows much less of a reaction to the high-volatility shock than equity does. If the latter is the case then the potential safe haven asset can be used to hedge against high-volatility common shocks with equity.

4.4 Data

This paper uses thirty-two years of weekly data from 9th January 1980 to 26th December 2012, 1,721 observations in total. The Standard & Poor's Composite 500 – U.S.$ Price Index represents the U.S. stock market. The London Bullion Market (LBM) U.S.$/per troy ounce is chosen to represent the gold market, the first of the two potential safe haven assets, while the 1-year U.S. Constant Maturity Treasury (CMT) is used to represent a short-term U.S. T-bond and U.S. Benchmark 10-year Total Return Index represents a long-term U.S. T-bond. To ensure series are stationary, excess log returns are calculated for each series using the 3-month U.S. Treasury Bill as a proxy for the risk free rate of return. All data is sourced from Datastream.

Figure 4.1 *Price Series using 1-Year Constant Maturity Treasury (daily data)*



Assumptions must be made in order to approximate the return on the 1-year CMT for benchmark comparisons. This paper follows the assumptions outlined by a Morningstar Methodology Paper (2008):

$$p(t,y,m)=\left[\frac{100}{\left(1+\frac{y}{2}\right)^{2N_m-1+\frac{D_{t,m}}{S_m}}}\right]+\left\{100\frac{y_{p,m}}{y}\left(1+\frac{y}{2}\right)^{1-\frac{D_{t,m}}{S_m}}\left[1-\left(1+\frac{y}{2}\right)^{-2N_m}\right]\right\},$$

where y is the yield in decimal format, N_m is the maturity of the bond in years, $D_{t,m}$ is the number of days between time t and the next coupon date of the bond, S_m is the number of days in the coupon period in which time t falls, $y_{p,m}$ is the coupon rate expressed in decimal format of the bond on its purchase day, p. The price of the bond with maturity date m, yield y, at time t has two components. The first component is the discounted face value of a bond and the second component is the present value of coupon payments. The constructed price series is given in Figure 4.1.

Table 4.1 provides summary statistics for each of the four series. One expects the variance of the short-term bond to be less than that of the long-term bond as there is a shorter time to maturity. Across the full sample the short-term bond does indeed provides investors with the lowest risk and return. Both bonds provide lower risk than the alternative of the stock market.

Table 4.1: *Summary Statistics*

	Excess Log Return S&P500	**Excess Log Return Gold**	**Excess Log Return 10-Year Bond**	**Excess Log Return 1-Year Bond**
Mean	0.0005	-0.0003	0.0006	0.00005
St. Deviation	0.02	0.03	0.01	0.002
Skewness	-0.69	0.29	0.24	1.11
Excess Kurtosis	4.89	6.14	2.66	16.18
Jarque-Bera	1857.15	2731.11	528.13	19143.05
Observations	1,721	1,721	1,721	1,721

Notes: Skewness is defined as m_3/s^3 where $m_3$is the centred third moment of the data and s is the sample standard deviation. Kurtosis is defined as (m_4/s^4)-3 where m_4 is the centred fourth moment of the data.

Gold exhibits negative weekly excess returns which occur when the weekly return on the asset is less than the weekly return on the risk free asset. Reinforcing the findings of Coudert and Raymond (2010), gold is also the riskiest of the three assets based on the standard deviation. Across the full sample the Jarque-Bera test rejects the hypothesis that excess returns are normally distributed. Skewness and Kurtosis are also included and reinforce the rejection of normality, which may indicate the presence of more than one return distribution, i.e. a regime switch.

4.5 Results

To begin, we report estimates of mean returns across the two regimes of the common shock, presented in table 4.2 below. Columns 1 and 2 report the expected mean returns in the low-volatility regime while estimates for the high-volatility regime are reported in columns 3 and 4. In the case of the 10- and 1-year bonds the high-volatility regime is characterised by lower equity returns than experienced in the low-volatility regime. While in the case of the potential safe havens both gold and the 1-year bond experience an increase in the expected return on entering the high-volatility regime.

Table 4.2: *Estimate of Mean Returns across Regimes*

	μ_E	μ_{SH}	μ_E^*	μ_{SH}^*	LR	p-val
Gold	0.13	**-0.20**	**0.15**	0.09	8.72***	0.01
	(1.22)	**(-3.46)**	**(2.44)**	(1.13)		
10-Year Bond	**0.19**	**0.09**	0.09	-0.01	5.01*	0.08
	(3.30)	**(2.31)**	(1.15)	(-0.61)		
1-Year Bond	**0.19**	**-0.007**	-0.27	**0.01**	30.88***	0.00
	(3.87)	**(-3.21)**	(-1.85)	**(3.68)**		

Notes: t-statistics in parentheses under coefficients. Bold numbers indicate statistical significant values. μ_i and μ_i^* refer to average returns in low- and high-volatility regime respectively. Likelihood ratio statistic is for the null of equality of mean returns across the regimes. The test statistic has a chi-square (2) distribution under the null hypothesis. *** denotes significance at the 1% level. ** denotes significance at the 5% level and * denotes significance at the 10% level.

Flavin and Panopoulou (2010) and Flavin, Panopoulou and Unalmis (2008) both analyse shift- and pure-contagion in equity markets and note in their results that the low-volatility regime is characterized by positive mean returns while lower returns are associated with the high-volatility regime. Ang and Timmerman (2011) also report that

this pattern has been confirmed since the earliest studies of regime-switches on equity returns. The results reported in Table 4.2 appear somewhat inconsistent with what we expect given the existing literature. Firstly, we observe a decrease in mean return from the low- to high-volatility regime for equity when paired with U.S. Treasury bonds, however the opposite occurs in the case of gold which is likely a consequence of the frequency of high-volatility common shocks.

Secondly, in terms of the safe haven assets, theoretically we expect the returns to increase when moving from a low- to high-volatility regime, as in many cases a safe haven will be negatively correlated with equity. For example, in the case of U.S. Treasury bonds De Goeij and Marquering (2004) and Baele, Bekaert and Inghelbrecht (2010), amongst others, note the decreasing and often negative stock - bond correlation in recent years. Chapter 2 also confirmed the predominantly negative time-varying stock - gold correlation in Figure 2.3. Despite this, we find that only gold and the 1-year bond display an increase in the mean return when the common shock enters the high-volatility regime. A likelihood ratio test is therefore used to assess the null hypothesis of equality of mean returns across the regimes. This hypothesis is rejected in every case and consequently we perform the remaining analysis without the restriction of equal means across regimes.

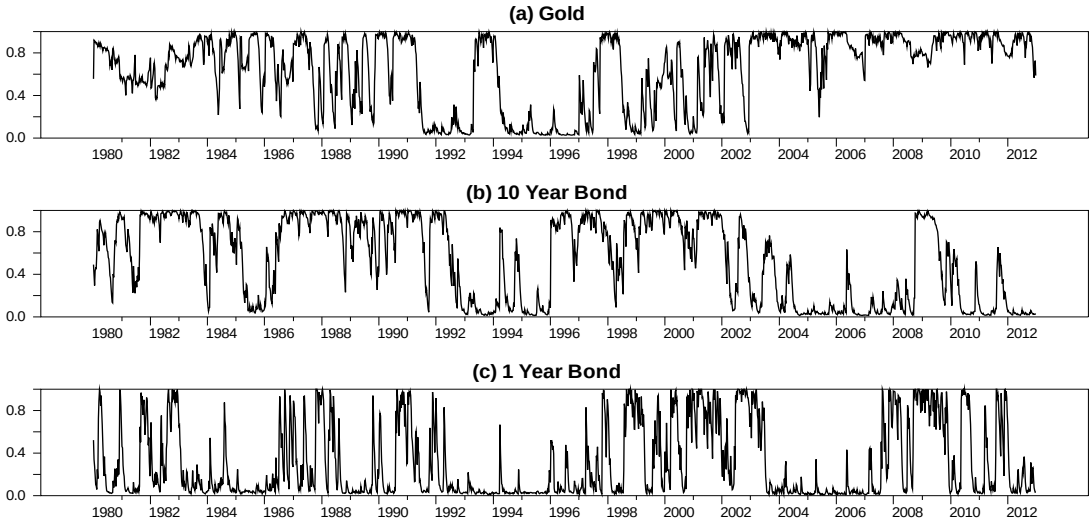
4.5.1 Test for Shift-Contagion

When analysing shift-contagion we are particularly interested in the stability of the transmission of common shocks between low- and high-volatility regimes. Figure 4.2 presents the filtered probabilities of the high-volatility regime being realized. There

are pronounced and persistent periods of high-volatility in the common shock for equity and each of the three potential safe havens. While the low- and high-volatility regimes are determined endogenously in this model it is interesting to note that the probability of the common shock being in the high-volatility regime matches crises and recessions over the past thirty years, for example, the 1987 stock market crash and more notably the most recent 2008 financial crisis.

Both the 10- and 1-year bonds exhibit increases in the probability of high-volatility common shocks over the short period of mid-2008 to mid-2009 which the NBER associates with the most recent crisis period while the probability of high-volatility common shocks for gold is slightly reduced over the same period. All three assets are quite similar in terms of persistence up until the turn of the century after which it appears that the probability of the common shock being in the high-volatility state becomes considerably more persistent compared to both Treasury bonds.

Figure 4.2: *Filter Probabilities of High-Volatility Common Shocks: (a) Gold, (b) 10-Year Bond, (c) 1-Year Bond*



We also estimate the impact coefficients of the common shock as well as the frequency and duration of the high-volatility state which are presented in Table 4.2. Of the three potential safe havens the frequency of the common shock, which measures the proportion of time that the shock is in the high volatility regime, is the highest for gold, while duration, which expresses the duration of the high volatility shock in years, is highest for the 10-year bond which implies that the persistence of the high-volatility state is highest for these assets.[10] These results, when taken in conjunction with the impact coefficients in Table 4.3 show that in the high-volatility state both gold and the 10-year bond become more sensitive to the common shock than equity. However, in the case of gold Coudert and Raymond (2010) state it is a highly volatile asset when held independently in a portfolio and only exhibits safe haven characteristics when held in an equity portfolio, this may be further evidence of this.

Table 4.3: *Estimate of Impact Coefficients of Common Shocks*

	σ_{cE}	σ_{cSH}	σ^{*}_{cE}	σ^{*}_{cSH}	γ	**Frequency (%)**	**Duration (years)**
Gold	0.0005	0.0002	0.16	**1.84**	25.45	65.24%	1.43
	(0.10)	(0.17)	(1.86)	**(19.37)**			
10-Year	0.009	0.0001	**1.74**	**0.46**	3.98	51.80%	1.97
Bond	(0.05)	(0.03)	**(16.24)**	**(7.56)**			
1-Year	**1.50**	0.00	**3.44**	0.00	2.18	30.88%	0.32
Bond	**(27.74)**	(0.03)	**(23.83)**	(0.03)			

Notes: t-statistics in parentheses under coefficients. Bold numbers indicate statistical significant values. "Duration" refers to the duration of the high volatility shock expressed in years. σ_{ci} and σ^{*}_{ci} refer to impact coefficients (standard deviations) for low- and high-volatility regimes respectively. γ is the test statistic for the null hypothesis of no shift-contagion (H_0: γ=1) against the alternative of shift contagion. 'Frequency' measures the proportion of time that the shock is in the high volatility regime and is expressed as a percentage.

[10] Frequency is computed as $(1-p_{11})/(2-p_{11}-p_{22})$, and Duration is computed as $1/(1-p_{22})$. p_{11} and p_{22} are defined in equation (4.5)

At this stage of the analysis we must construct the following statistic to test for shift-contagion,

$$\gamma=\max\left\{\left|\frac{\sigma^{*}_{cE}\sigma_{cSH}}{\sigma^{*}_{cSH}\sigma_{cE}}\right|,\left|\frac{\sigma^{*}_{cSH}\sigma_{cE}}{\sigma^{*}_{cE}\sigma_{cSH}}\right|\right\},$$

where σ_{cE} and σ_{cSH} denote the impact coefficient of the common shock for equity and the safe haven asset in the low-volatility regime while σ^{*}_{cE} and σ^{*}_{cSH} represent the impact coefficients in the high-volatility state. This statistic allows us to test if the ratio of the estimated coefficients in the high-volatility regime is proportional to the low-volatility regime. If we observe a ratio of unity this implies that the transmission mechanism governing the common shock is stable across regimes. A ratio greater than unity indicates the presence of shift contagion.

Table 4.4: *Likelihood Ratio Tests for Shift-Contagion*

	LR	**p-value**
Gold	6.8e-05	0.99
10-Year Bond	2.4e-05	0.99
1-Year Bond	20.88***	0.00

Notes: The likelihood ratio (LR) statistic is for the null of no shift contagion (H_0: $\gamma=1$) against the alternative of shift contagion between S&P500 and the indicated assets. The test statistic has a chi-square distribution under the null hypothesis. *** denotes significance at the 1% level. ** denotes significance at the 5% level and * denotes significance at the 10% level.

In order to determine the statistical significance of this ratio we perform a likelihood ratio test, the results of which are reported in Table 4.4. The results suggest that we only observe statistically significant shift-contagion for the equity - 1-year bond pair. In the case of gold, $\gamma=25.45$, which suggests market linkages become markedly

unstable when a shock moves into the high-volatility regime. However, results in Table 4.4 indicate that the ratio is not statistically different to unity. When the system moves from a low- to high-volatility regime there may be a substantial change in the size of the shock but not necessarily a change in the structural transmission of shocks between equity and gold. For both gold and the 10-year bond we fail to reject the null hypothesis of no shift-contagion, which means that market linkages are robust to changes in regime. Flavin and Panopoulou (2010) use the more general term of 'increased asset co-movement between regimes' to describe any structural changes in asset return co-movements between regimes over 'shift-contagion' to reflect the possibility that changes in co-movements may be attributable to factors other than purely contagious effects. This may be a more appropriate term when analysing and identifying safe haven assets.

In the case of the 1-year bond, while we find evidence of shift contagion, the impact coefficients in Table 4.3 suggest that the short bond does not react to the high-volatility common shock and thus may potentially be used to hedge against common shocks with equity.

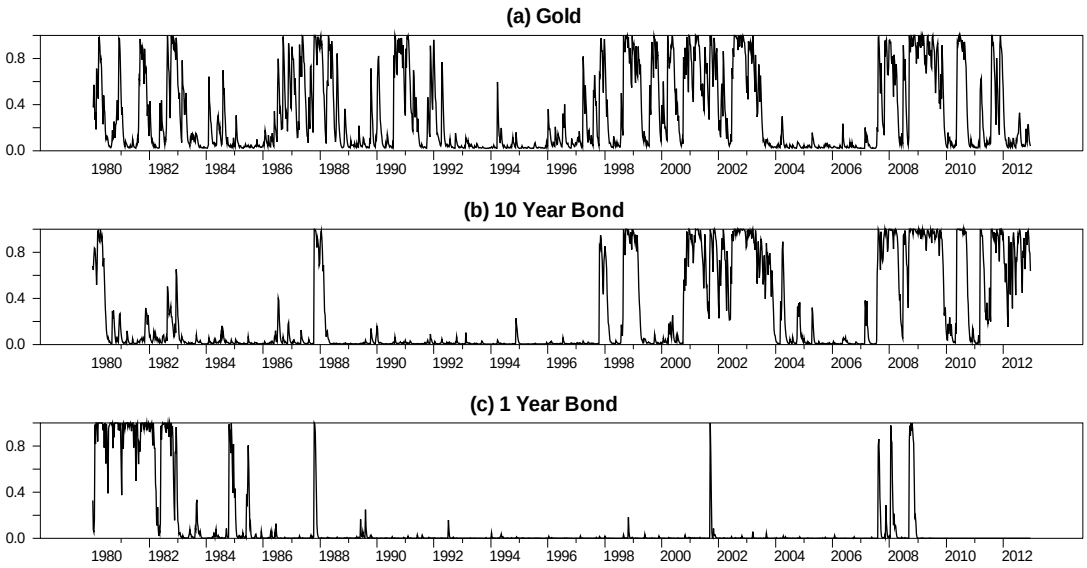
4.5.2 Test for Pure-Contagion:

Pure-contagion is the phenomenon whereby the idiosyncratic shock of one asset is transmitted to another asset through channels that only exist during periods of high-volatility. As we do not have a theoretical guide to the direction of these contagious effects we follow closely the method employed by Flavin, Panopoulou and Unalmis (2008) simultaneously evaluating the importance of bi-directional contagion. As with

the analysis of shift-contagion we first examine the filtered probabilities of the idiosyncratic shock being in the high-volatility regime for both equity and the potential safe havens, presented in Figures 4.3 and 4.4, respectively. These idiosyncratic shocks are purely equity and safe haven shocks, respectively, since, by construction, they are orthogonal to the common shocks.

In contrast to Figure 4.3, we observe persistent high-volatility idiosyncratic risk associated with equity in the pairing with gold only. In all other cases, especially for the 1-year bond the probability of the equity idiosyncratic shock being in high-volatility regime is greatly reduced with spikes only over the prominent crises of 1987, 2001 and 2007, for example. This may suggest that many of the high-volatility shocks that arrive to the stock market are also common to the 1-year bond market, diminishing its capacity as a safe haven asset. When we notice similar spikes across all three graphs this indicates that the S&P500 is the shock source of these crises.

Figure 4.3: *Filter Probabilities for Equity Idiosyncratic Shock with (a) Gold, (b) 10-Year Bond, (c) 1-Year Bond*



In Figure 4.4, gold and the 10-year bond display very similar probabilities with very few periods when there is high probability of being in the high-volatility regime while the 1-year bond idiosyncratic shock appears to be much more persistent.

Figure 4.4: *Filter Probabilities of Safe Haven Idiosyncratic Shock*

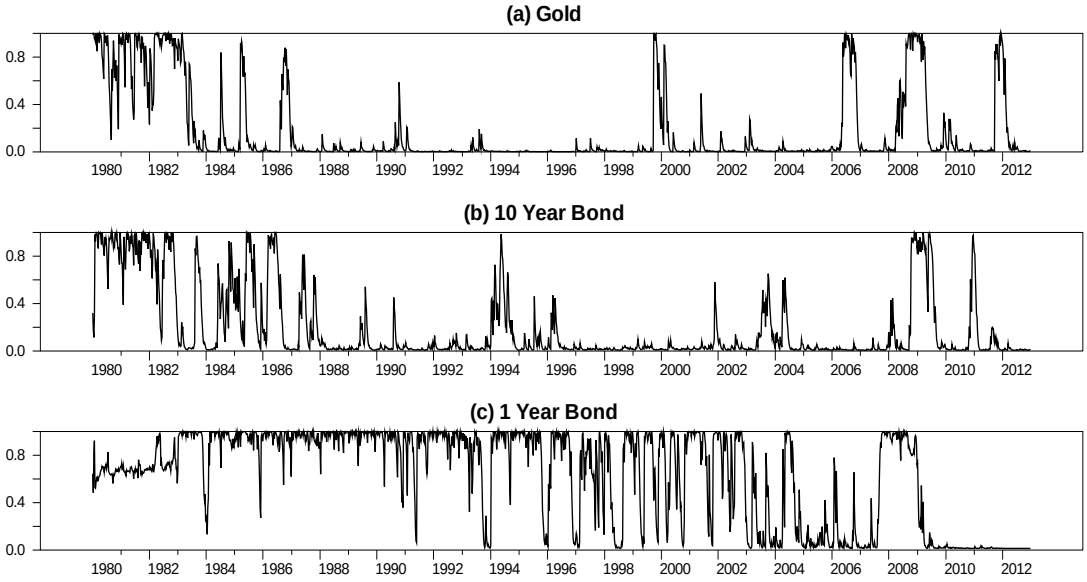


Table 4.5 presents the impact coefficients for all idiosyncratic shocks along with the frequency and duration of time spent in the high-volatility regime. The frequency of the equity shock is greatest for the gold pairing while the frequency of the safe haven shock is greatest for the 1-year bond. However, the duration of the high-volatility equity shock is greatest for the 1-year bond while the duration of the high-volatility safe haven shock is longest for gold. So, for example, while the frequency of the equity shock is greatest for gold, the duration of these shocks is relatively short lived. As with the common shock, the impact coefficients are lower in the low-volatility regimes for all asset types indicating that all assets become more risky when the idiosyncratic shock enters the high-volatility regime.

When testing for pure-contagion the key parameters of the bi-directional model are δ_E and δ_{SH} which pick up the presence of pure-contagion effects to the equity and

potential safe haven assets, respectively. In every case, we find strong evidence of pure-contagion.

Table 4.5: *Estimate of Impact Coefficients of Idiosyncratic Shocks - Bi-directional Pure Contagion*

	σ_E	σ_{SH}	σ^*_E	σ^*_{SH}	δ_E	δ_{SH}	**Frequency / Duration (E)**	**Frequency / Duration (SH)**
Gold	**1.54** **(30.39)**	**1.10** **(17.74)**	**3.32** **(23.08)**	**4.31** **(18.45)**	**0.17** **(4.51)**	**-0.10** **(-3.91)**	31.30% 0.36	15.13% 0.77
10-Year Bond	**1.24** **(26.03)**	**0.08** **(32.29)**	**2.93** **(19.21)**	**1.71** **(12.14)**	**0.40** **(4.86)**	**-0.27** **(-13.62)**	25.67% 0.90	19.63% 0.60
1-Year Bond	0.0001 (0.12)	**0.04** **(24.18)**	**0.44** **(2.50)**	**0.13** **(33.12)**	**2.66** **(5.58)**	**1.20** **(2.55)**	9.09% 0.49	63.13% 1.21

Notes: t-statistics in parentheses under coefficients. Bold numbers indicate statistical significant values. σ_i and σ^*_i refer to impact coefficients (standard deviations) for low- and high-volatility regimes respectively. δ_i refers to the pure-contagion parameter in equations (4.14) and (4.15). 'Duration' refers to the duration of the high volatility regime of the idiosyncratic shock expressed in years. 'Frequency' measures the proportion of time that the shock is in the high volatility regime and is expressed as a percentage.

The aim of this analysis is to identify safe haven assets for equity investors so we focus on δ_{SH} to determine which of the three potential safe havens is the most appropriate for equity investors. For both gold and 10-year bond we report negative coefficients for δ_{SH} which implies a flight-to-quality effect for both assets. This phenomenon occurs when investors sell what they perceive to be high-risk assets in favour for what they believe to be low-risk assets. This is in contrast to the 1-year bond whose δ_{SH} indicates that the transmission of the equity idiosyncratic shock is unstable

across regimes. In the high-volatility regime this equity shock spills over to the 1-year bond and becomes an additional common factor.

In every pairing we find evidence of pure-contagion from the potential safe haven to equity. However, in the case of both gold and the long bond the frequencies and durations indicate that their idiosyncratic shocks are very rarely in the high-volatility regime allowing little opportunity for contagion to occur. Bi-directional pure contagion only occurs in the pairing of equity – 1-year bond where the frequency and duration of the short bond high-volatility idiosyncratic shock imply it is often exposed to potentially contagious effects.

Overall, the statistical analysis indicates that investors perceive gold and the 10-year bond to be the safer options. Initially the test for shift-contagion reveals that the market linkages between equity and each of these two assets are robust to varying market conditions. Also, despite the fact that all assets become more risky in the high-volatility regime, the test for pure-contagion indicates that investors partake in the flight-to-quality phenomenon.

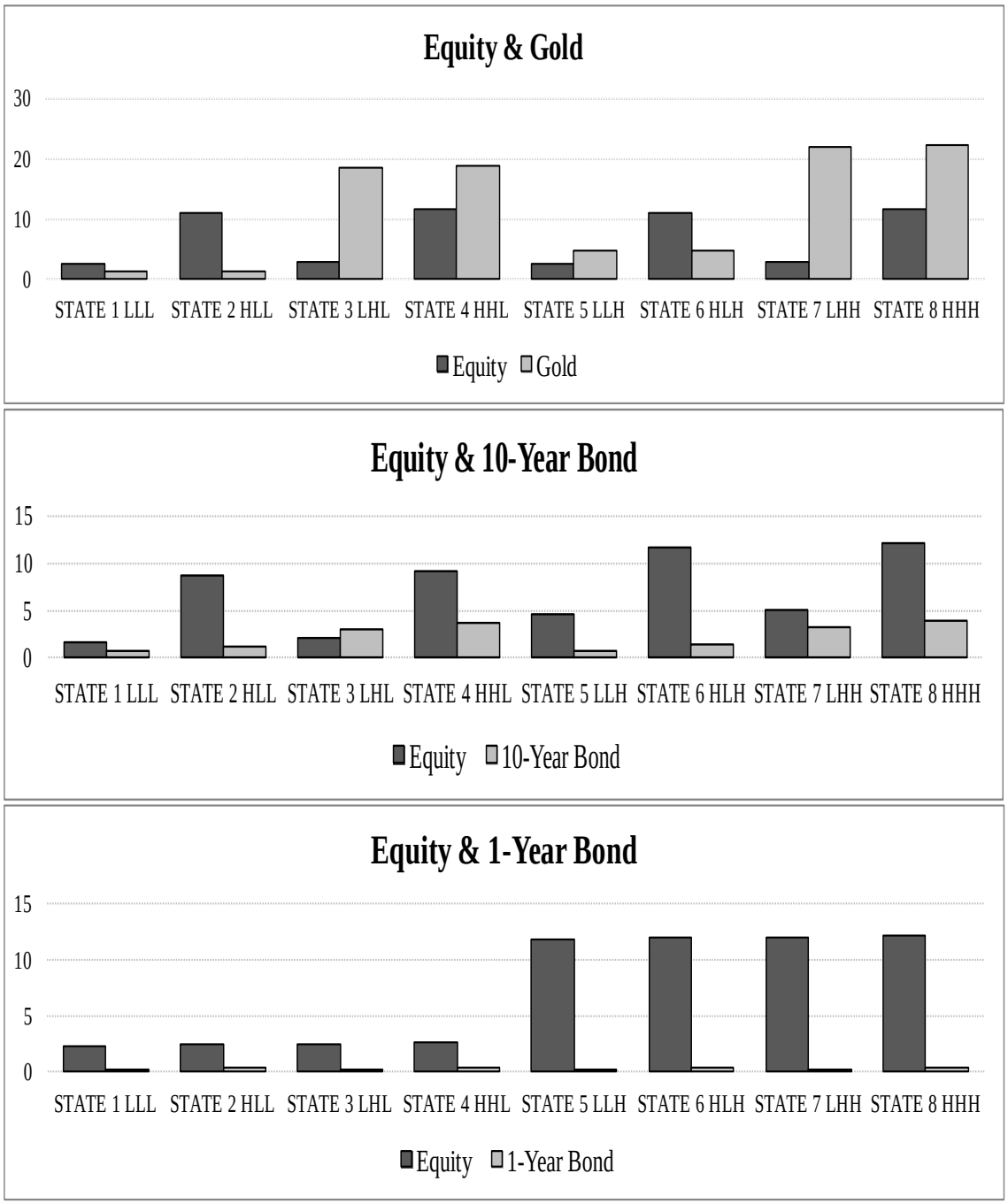
These results are in stark contrast to those for the short-term bond. While there is evidence that the short bond may potentially be used to hedge against common shocks with equity, there is statistically significant evidence of bi-directional pure-contagion which causes the 1-year bond to emerge as an unsuitable safe haven for equity investors despite the fact that the impact coefficients portray it as a relatively less risky asset compared to gold and the 10-year bond.

4.5.3 Conditional Variances and Correlations

Having established the statistical significance of our results, we now examine their economic significance. Also, the rejection of shift-contagion for the equity - gold pair, despite the large ratio and considering the fact that we identify bi-directional pure-contagion, the final step is to examine the asset variance by state and to decompose the conditional variance into its constituent channels to determine the importance of pure contagion.

As stated previously there are two possible regimes that each of the three shocks can be in, thus there are eight possible states of the world. In state 1 for example, all three shocks are in the low-volatility regime and in state 8 all shocks are in the high-volatility regime. Figure 4.5 presents the conditional variance for each asset type across all 8 possible states. The conditional variance for equity is greater than the conditional variance for both the 10- and 1-year bonds, which is expected given the summary statistics, while the opposite is true in the case for gold. It is recognised that gold is a highly volatile asset when held on its own and its safe haven characteristics are magnified only when held in a portfolio with other risky assets.

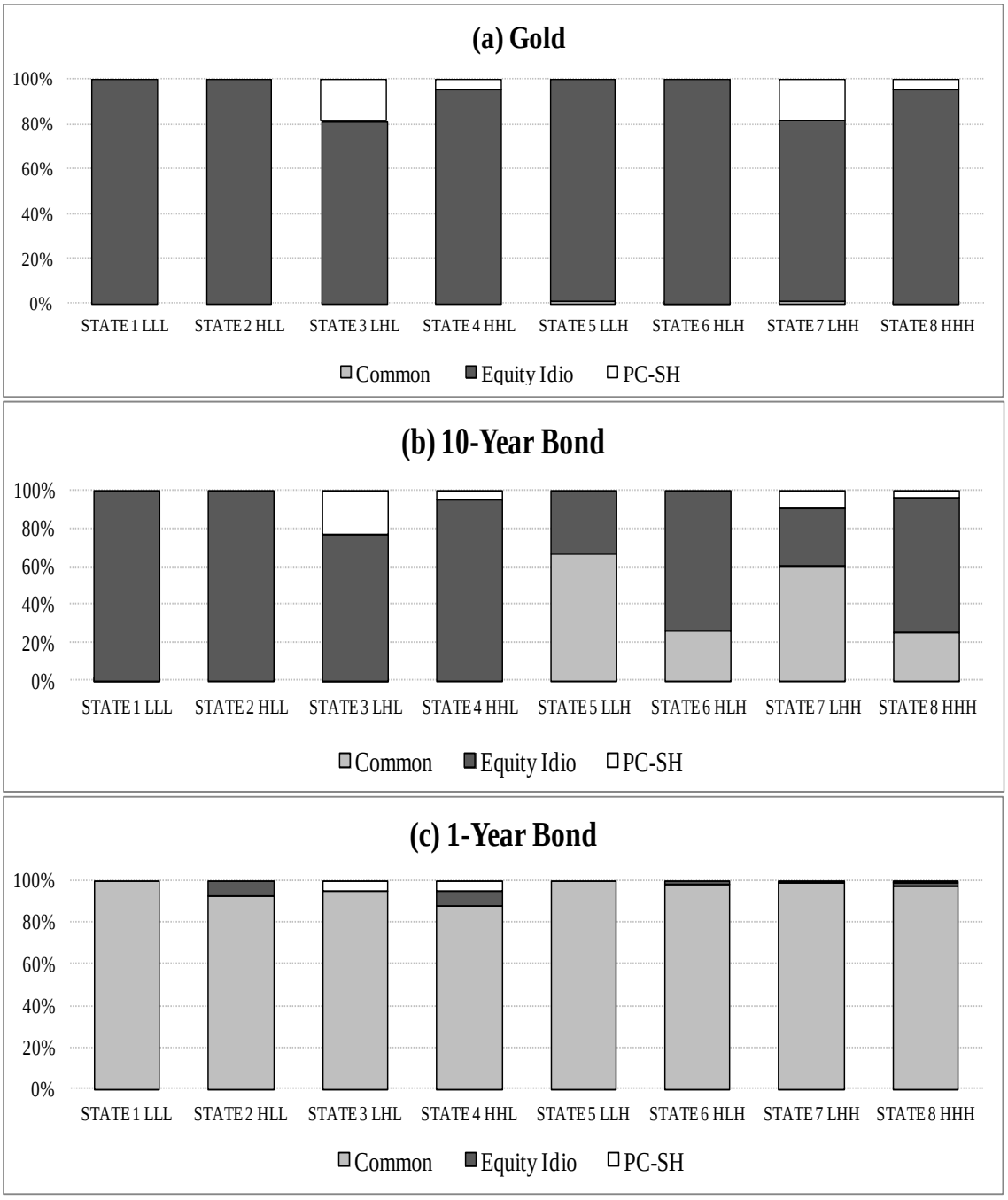
Figure 4.5: *Conditional Variances by State*



Notes: Let i, j, k represent the equity, safe haven and common shocks respectively. Then State "i, j, k" denotes each of the possible states where i, j, k can equal either L (low-volatility) or H (high-volatility).

In Figure 4.6 we decompose the variance of equity into three components. This informs us of the proportion of equity variance driven by the common shock, its own idiosyncratic shock and the pure-contagion from the potential safe haven asset. Pure-contagion effects from the possible safe havens to equity operate in states 3, 4, 7 and 8, but it is clear that this contribution to overall asset risk is relatively small. In the case of gold, the common shock plays a negligible role in determining equity risk and this proves significant in identifying potential safe haven assets as this particular shock can now be interpreted as an asset-specific shock. With the exception of the 1-year bond, the common shock is dominated by the equity idiosyncratic shock and the pure-contagion effect and thus the majority of the risk associated with equity can be attributed to its own asset-specific shock.

Figure 4.6: *Decomposition of Equity Variance by State with (a) Gold, (b) 10-Year Bond and (c) 1-Year Bond*



Notes: Let i, j, k represent the equity, safe haven and common shocks respectively. Then State "i, j, k" denotes each of the possible states where i, j, k can equal either L (low-volatility) or H (high-volatility).

We now decompose the variance of each of the potential safe havens into the three components of the common shock, their own idiosyncratic shock and the pure-contagion from equity. A similar story emerges with the common shock in the majority of cases being overwhelmed by the asset-specific shock and the pure-contagion effect. There are modest contributions from these channels to the overall variance of both the 10- and 1-year bonds while the majority of the variance of gold is attributed to its own asset-specific shock and the common shock, particularly when the common shock is in a high-volatility regime.

In addition, the extent to which pure-contagion influences the variance of the 1-year bond is apparent, comparable to the results in Table 4.5. While Table 4.5 also confirms gold and the 10-year bond as flight-to-quality assets, Figure 4.7 clearly shows that the effect of equity's idiosyncratic shock on gold's variance is modest. The largest contribution is made in state 2 when only the equity idiosyncratic shock is in the high-volatility regime. It appears that when the other two shocks are in high-volatility regimes they counteract the effect of pure-contagion. The same cannot be said for the 10-year bond where anything from 20 to 50 per cent of its variance is driven by pure-contagion in each of the periods when the equity idiosyncratic shock is in the high-volatility regime.

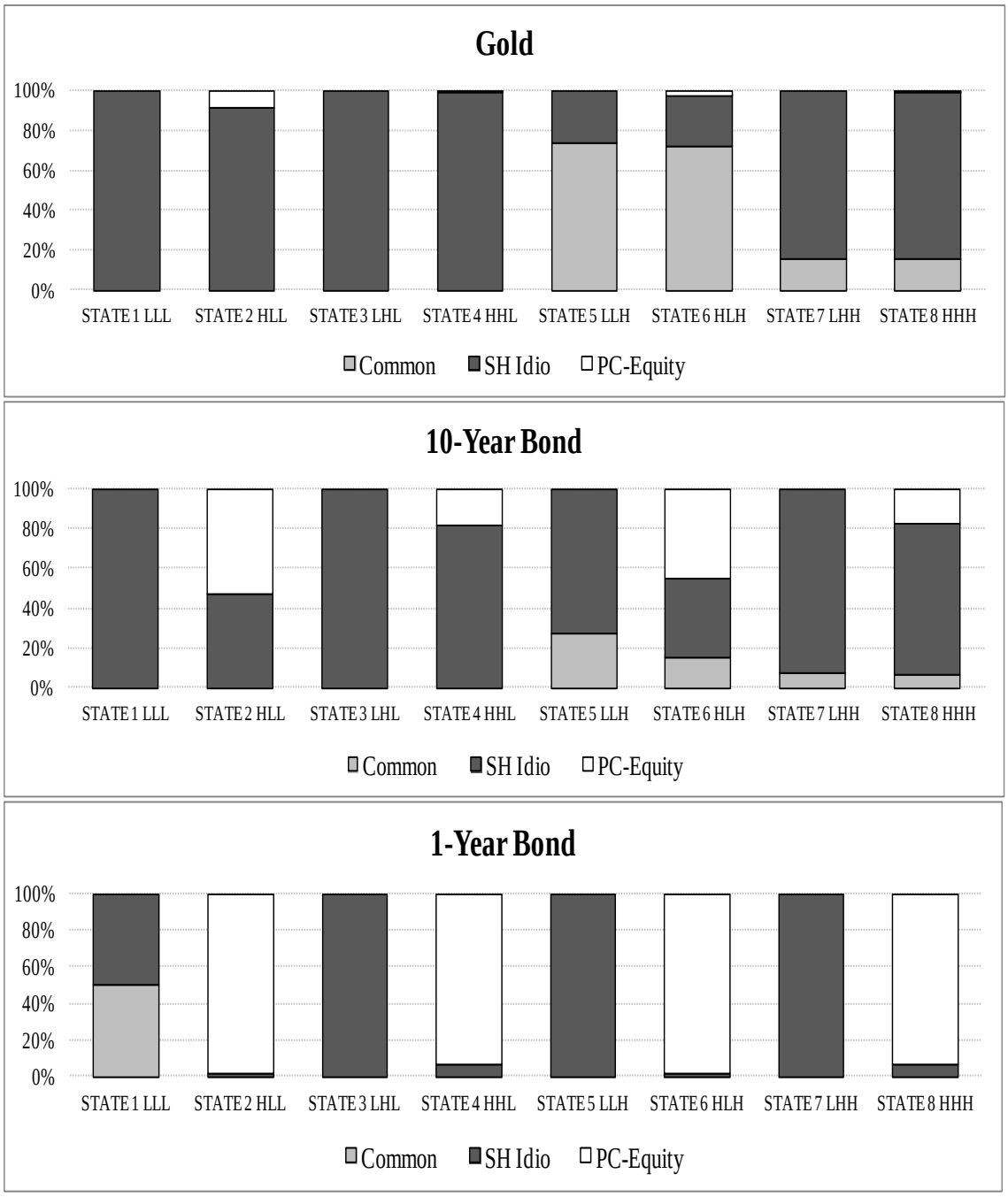
Figures 4.6 and 4.7 magnify the appeal of gold as a safe haven over its U.S. T-bond counterparts. However one of the central components used in identifying safe havens is the analysis of correlations. The majority of current research in this area focuses on this aspect when determining the strength of an asset in acting as a potential safe haven. For instance, Baur and Lucey (2010) base their analysis on the assumption

that the safe haven asset must exhibit zero or negative correlation with the risky portion of the portfolio specifically during periods of uncertainty.

There is a unique correlation in each regime and Figure 4.8 shows the decomposition of the correlation between equity and each of the three potential safe havens. The first thing to note is the similarities between the figures for gold and the 10-year bond. In every state where the equity idiosyncratic shock is in the high-volatility regime, the total correlation between equity and the 10-year bond is negative, which is consistent with the three large shocks analysed by VIRF in Chapter 3. To a lesser extent this also appears in the case of gold, however in states 4 and 8, when both equity and gold idiosyncratic shocks are in the high-volatility regime, the effect of the equity shock in turning total correlation negative is diminished.

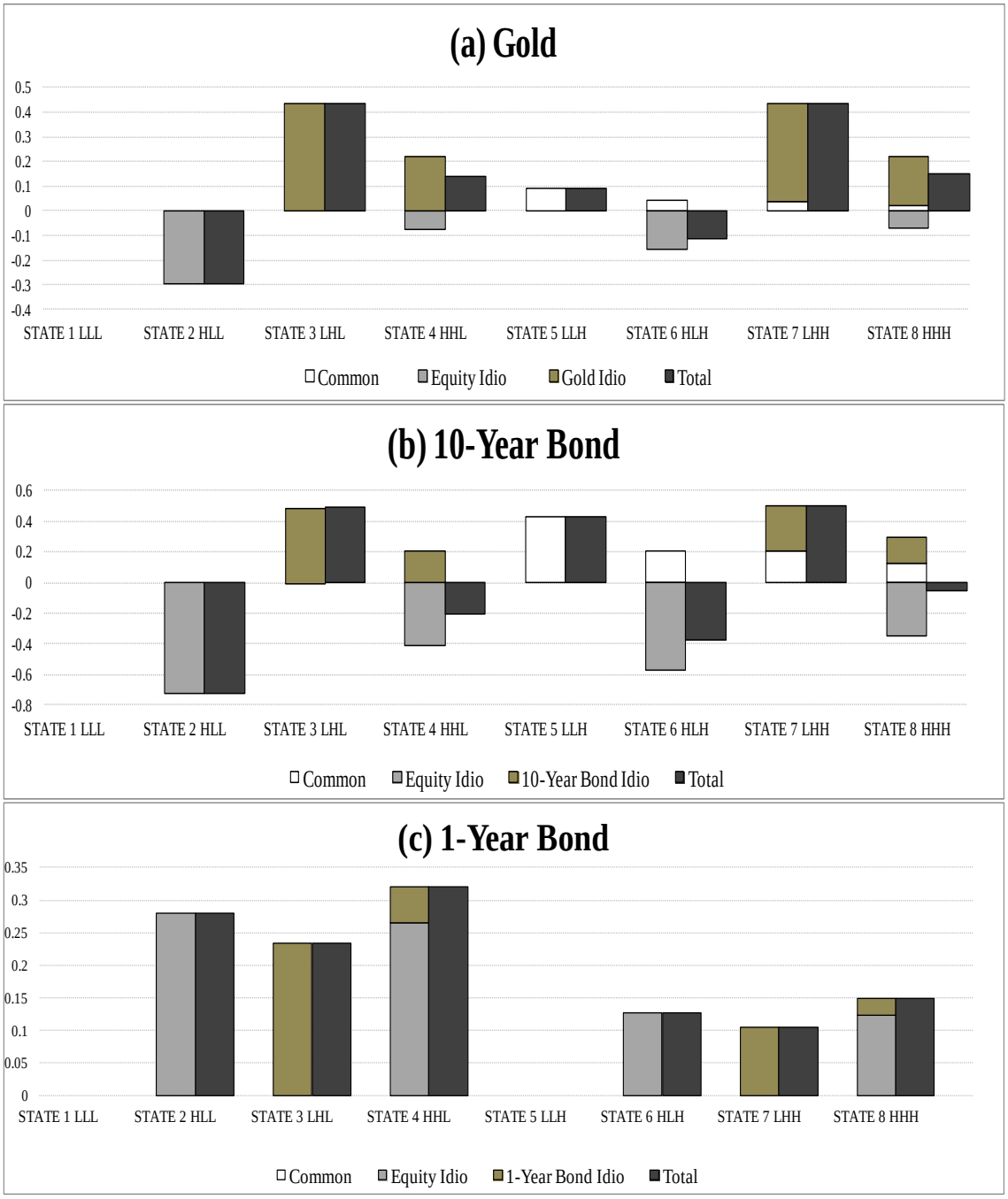
It is also interesting to note that the high-volatility common shock plays a much larger role for the 10-year bond than it does for either gold or the 1-year bond. However it acts in diminishing the overall affect of the equity idiosyncratic shock in reducing the total correlation which is not ideal.

Figure 4.7: *Decomposition of Safe Haven Variance by State*



Notes: Let i, j, k represent the equity, safe haven and common shocks respectively. Then State "i, j, k" denotes each of the possible states where i, j, k can equal either L (low-volatility) or H (high-volatility).

Figure 4.8: *Decomposition of Correlation with Equity by Shock and State for (a) Gold, (b) 10-Year Bond and (c) 1-Year Bond*



Notes: Let i, j, k represent the equity, safe haven and common shocks respectively. Then State "i, j, k" denotes each of the possible states where i, j, k can equal either L (low-volatility) or H (high-volatility).

One of the central stories emerging from this study is the statistical and economic significance highlighting the unsuitability of the 1-year bond as a safe haven with Figure 4.8 indicating that in every state of the world correlation between equity and the short bond is positive. It can therefore be definitively ruled out of consideration for many equity investors. More importantly however, is the emergence of both gold and the bong-term bond as appealing safe havens.

4.6 Conclusion

The aim of this chapter is to definitively establish which of gold, a 10-year U.S. T-bond or a 1-year U.S. T-bond is the most appropriate safe haven asset for equity investors. In determining this we apply the unified Markov-switching framework of Flavin, Panopoulou and Unalmis (2008) which allows us to test for both shift- and pure-contagion. This analysis of contagious effects is vital for equity investors wishing to make informed decisions during periods of increased volatility.

The first test for shift-contagion allows us to identify changes in the normal relationship between assets during periods of high-volatility. The impact coefficients of common shocks confirm that, of the three prospective safe haven assets available to investors, gold and the 10-year bond appear to be robust to varying market conditions however the 1-year bond may potentially be used to hedge against high-volatility common shocks with equity.

The second test for pure-contagion allows us to probe deeper into the relationship between equity and the three potential safe havens. It provides insight into how a high-volatility equity idiosyncratic shock affects other assets which is particularly

important when trying to identify safe havens. Again, the results suggest that both gold and the 10-year bond should be favoured over the 1-year bond. Results also indicate that in the presence of this high-volatility equity shock the phenomenon of flight-to-quality occurs. This suggests that investors view gold and the 10-year bond as safer options compared to the 1-year bond.

It is also very important to establish the effects of various shocks on both the asset variances and the asset covariances. Figure 4.8, in particular, sheds light on the strong similarities between gold and the long-term bond and their potential use as safe havens for high-volatility equity idiosyncratic shocks. Figures 4.6 through 4.8 also highlight the weaknesses associated with the 1-year bond, establishing it as an altogether inferior investment choice as a hedge against equity risk.

Our results have obvious implications for equity investors. Both tests for shift- and pure-contagion suggest that investors should not proceed in simultaneously investing in equity and a 1-year bond. Additional analysis of variances and covariances across each state reinforces the attractiveness of gold and the long-term bond as suitable safe havens over and above the alternative of short-term U.S. Treasuries.

Chapter 5: Concluding Remarks

5.1: Dissertation Overview

The primary aim of this dissertation is to answer the question of which of gold or U.S. Treasuries is the most appropriate safe haven asset for equity investors hedging against uncertainty in the stock market. It is important that investors are provided with a comprehensive analysis of this topic given the magnitude of crises over the past thirty years. Focusing on the United States, there have been at least four major stock market downturns over the data period alone.

This question is answered by utilizing several econometric approaches. An initial study of the underlying relationship between equity and gold is undertaken by analysing conditional mean and volatility spillover. This is followed with a more detailed examination by introducing a long-term U.S. T-bond and focusing on causality-in-mean and -variance as well as the impulse response of the three assets to large negative equity shocks. Finally a fourth asset is included, a 1-year U.S. T-bond to determine not only if gold is a safe haven but also which, if either of a short- or long-term bond, is the most appropriate safe haven in light of shift- and pure-contagion.

Chapter 2 provides a starting point for this dissertation. Attention is given solely to equity and gold which means that an asymmetric VAR-GARCH(1,1) model can be used without fear of the complications that can arise in a tri-variate setting. The extant literature proves that there is relatively little work done in this area of finance despite its importance for equity investors. The results provide a number of insights into this key relationship. Firstly, there is no evidence of conditional mean or volatility spillover.

Secondly, the lack of significance in the asymmetric terms suggests that gold responds the same to "bad news" in the equity market as it does to "good news". This is vital information for equity investors seeking a safe haven. Subsequent portfolio analysis confirms that investor sentiment has varied considerably over the past thirty years favouring an equally weighted portfolio in periods of crisis.

In Chapter 3 the study of safe havens is expanded to include a long-term U.S. T-bond. Connolly, Stivers and Sun (2005), among others, note the appeal of government bonds as safe havens thus including this third asset in the analysis allows investors to make an informed decision when choosing a safe haven. In this chapter an alternative econometric approach is introduced by identifying mean and volatility spillover through Cheung and Ng's (1996) test for causality-in-mean and causality-in-variance. Results indicate that while there is no evidence of spillover from the stock market to gold there are two periods over which statistically significant causality-in-mean is identified for the 10-year bond. The results suggest that, over the more volatile period of the 1987 stock market crash, the assumed safe haven characteristics of the long-term bond are diminished. Volatility impulse response functions further identify the relative effect of negative shocks compared to the expectation of the conditional covariance had the shock not occurred. Across three exogenously chosen equity shocks the results corroborate earlier conclusions of gold emerging as the most suitable safe haven for investors to turn to when negative shocks arrive in the stock market.

Finally, Chapter 4 concludes the investigation with a comprehensive analysis of potential safe havens concentrating specifically on shift- and pure-contagion using a unified Markov-switching framework. In this chapter a fourth asset is included, a short-term U.S. bond, with the aim of establishing which Treasury bond is the most attractive

for equity investors as well as comparing them to the potential safe haven of gold. The test for shift-contagion highlights the transmission of common shocks between low- and high-volatility regimes and is only significant for the 1-year, short-term bond. The second test for pure-contagion identifies the channels between assets that only exist during periods of high-volatility. This particular test has the potential to provide essential information for equity investors and the results suggest that investors may use gold or the 10-year bond as a flight-to-quality asset.

Each of the core chapters measures differently the effect on potential safe havens of negative news in the stock market. Firstly, Chapter 2 isolates how bad news, as opposed to good news, affects equity's relationship with gold. Chapter 3's VIRF allowed the choice of three prominent negative equity shocks to determine the level of persistence in gold and the 10-year bond while Chapter 4 isolated specifically the pure-contagion effect of idiosyncratic equity shocks in high-volatility regimes.

Regardless of the method used, gold emerges as a relevant safe haven for equity investors, which is in line with the findings of Lawerence (2003), Morales (2008) and Coudert and Raymond (2010) each of whom advocates the use of gold to hedge uncertainty in the stock market. In terms of U.S. Treasury bonds, investors are advised to choose a long-term bond over a short-term bond which verifies the conclusions of Kim, Moshirian and Wu (2006) who note that government bonds with more than ten years to maturity tend to be used by investors because they match the duration with stocks, which are generally thought of as long-term investments.

5.2: Future Research

The core of this dissertation has highlighted possible avenues for future research. From an econometric point of view, Chapter 2 and Chapter 3 identify potential safe havens by way of GARCH and VIRF methodology focusing on gold and a long-term U.S. T-bond. It may be advantageous to include a short-term bond in these two approaches by way of introducing a regime switching component. Cai (1994) claims that a MS-GARCH would be difficult to estimate for any data size greater than a sample size of fifty. However Lee and Yoder (2007) provide an important advance by constructing a regime switching multivariate GARCH. The approach derived in Chapter 2, while popular, requires that the coefficients on the conditional means and variances are fixed throughout the entire sample. As described in Chapter 3, this can lead to overwhelming problems especially when a short-term bond is introduced to the analysis.

Lee and Yoder (2007) develop a bivariate regime switching GARCH which nests within it both Grays (1996) univariate Generalised Regime Switching model and the state-independent BEKK model so that not only the conditional means and variances but also the conditional covariance are allowed to vary across two distinct regimes. This would enhance the analysis provided in Chapter 2 and allow us to determine explicitly the time-varying relationships between equity - gold and equity – U.S. T-bonds without concern of explosive results caused by a short-term bond. This approach may also allow us to return to the portfolio analysis to determine how investors may use the short- and long-term bonds to hedge uncertainty in the stock market.

Nomikos and Salvador (2011) develop a state dependent VIRF distinguishing the spillover intensities between markets in calm and crisis periods. Taking this approach means that the shock period does not need to be determined a priori, which is required in Chapter 3. Their approach is based on Lee and Yoder's (2007) regime-switching bivariate GARCH model which is transformed into its equivalent vech specification in order to determine the expected changes in conditional volatility to a one standard deviation shock occurring on one market conditional on the regime.

It would also be advantageous to extend our study further by analysing other potential safe haven assets. Emerging market debt seems to have become a popular choice for equity investors seeking a hedge in recent years. Recent articles from the Wall Street Journal and CNN have reignited interest noting that emerging market bonds and traditional safe havens have increasingly moved in the same direction.[11] Therefore it may be interesting to analyse how this option compares to U.S. Treasuries or indeed gold. Another extension could be to look at international markets and investors which would require some thought on how to overcome the foreign exchange component of gold which is commonly traded in U.S.$

[11]Available at: http://online.wsj.com/article/SB10001424053111904875404576532852868190550.html and http://money.cnn.com/2013/01/25/pf/expert/emerging-market-bonds.moneymag/index.html.

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