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### **Paper:**

Choudhry, T., Hassan, S. & Shabi, S. (in press). Relationship between gold and stock markets during the global financial crisis: Evidence from nonlinear causality tests. *International Review of Financial Analysis*

<http://dx.doi.org/10.1016/j.irfa.2015.03.011>

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# **Relationship between gold and stock markets during the global financial crisis: Evidence from Nonlinear Causality Tests**

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## **Abstract**

This paper investigates the nonlinear dynamic co-movements between gold returns, stock market returns and stock market volatility during the recent global financial crisis for the UK (FTSE 100), the US (S&P 500) and Japan (NIKKEI 225). Initially, the bivariate dynamic relationships between i) gold returns and stock market returns and ii) gold returns and stock market volatility are tested; both of these relationships are further investigated in the multivariate nonlinear settings by including changes in the three-month LIBOR rates. Current evidence in this research area is limited because of the assumption of a unidirectional relationship between the gold returns, and stock market returns/volatility. In this paper correlation integrals based on the bivariate model show significant evidence of nonlinear feedback effect among the variables during the financial crisis period for all the countries under study. Very limited evidence of significant feedback is found during the pre-crisis period. Results from the multivariate tests including changes in the LIBOR rates provide results similar to the bivariate results. These results imply that gold may not perform well as a safe haven during the financial crisis period due to the bidirectional interdependence between gold returns and, stock returns as well as stock market volatility. However, gold may be used as a hedge against stock market returns and volatility in stable financial conditions.

### *Keywords:*

Gold returns

Stock returns

Stock volatility

LIBOR

Nonlinear causality

JEL Classification: C5, C22, G01, G1, G15

## 1. Introduction

According to Coudert and Raymond (2011) and Tuysuz (2013), during periods of financial crisis, the price of risky financial assets falls almost simultaneously as the losses in one market cause contagion in other markets, and there is ‘flight to quality’ resulting in increase in prices of safer assets (particularly gold compared to other assets). Baur and McDermott (2010), Chan et al. (2011), Coudert and Raymond (2011), Miyazaki et al. (2012), Miyazaki and Hamori (2013), Chen and Lin (2014), Emmrich and McGroarty (2013), and Tuysuz (2013) provided empirical evidence in support for the property of gold as a safe haven during the financial crash, and confirmed that there was a ‘flight to quality’ towards gold during the financial crisis.<sup>1</sup> However, most of the studies adopt a unidirectional approach, ignoring the possibility of mutual dependence among various asset classes. We contribute to the substantial and ever-growing literature in this field by studying nonlinear dynamic co-movements among various assets. This paper empirically investigates the nonlinear Granger causality between the gold market and three major stock markets, the US, the UK and Japan during the recent global financial crisis. The Granger causality test applied in this paper is based on correlation integrals, which test the dynamic relationship between the underlying variables in nonlinear settings (Baek & Brock, 1992; Hiemstra & Jones, 1994). This implies that in the presence of nonlinear causality, variables exhibit dynamic association and can be used to test the hedging and safe haven properties of the gold with respect to the stock market returns and volatility.

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<sup>1</sup>A safe haven asset is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil (Baur & Lucey, 2010). In the recent times of uncertainty and financial crisis, gold has gained importance as a safe haven against inflation for US and European investors (Ciner et al., 2013). Levin et al. (2006) provide significant evidence of gold price and inflation/price levels’ long-term relationship. Gold has not only traditionally been used for investment, particularly in developing countries but has also been considered as a viable investment commodity for portfolio diversification by fund managers and investors.

To the best of our knowledge, this is the first attempt at investigating nonlinear causality between the gold market and the three major stock markets of the US, the UK and Japan. We employ these markets because of their large size stock markets and gold markets. The three stock indices employed are FTSE100 (UK), S&P500 (US) and Nikkei 225 (Japan). These markets represent three of the largest equity markets in the world with combined market capitalization standing at around US\$19.93 trillion on December 2013 (DATASTREAM) and, combined, these three markets account for almost 31% of the global equity market. According to the World Gold Council (2010) in 2009 daily trading volumes in gold for the UK, the US and Japan markets are 67, 20.8 and 1.8 billion dollars, respectively.

Besides stock markets, the relationship between interest rates and gold has also been explored by a number of papers, such as Koutsoyiannis (1983), Diba and Grossman (1984), Fortune (1987), and Cai et al. (2001), among others. These studies highlight the fluctuations in interest rates as one of the major determinants of gold price changes (returns), and increases in the interest rates induce a negative adjustment in the gold prices.<sup>2</sup> Interest rates play a dynamic role, as changes in interest rates have major implications for leveraged investors and corporations, and macroeconomic policy. Further, changes in the expectations of future interest rates directly affect investment and portfolio strategies, and corporate expansion plans, resulting in decisions by proactive managers to exploit/counter the expected future financial impact. Given the importance of the interest rate we also extend our analysis by including changes in the short-term interest rate (LIBOR) in the causality tests as a control variable. Multivariate nonlinear causality tests between stock returns or stock volatility, gold returns and changes in the rates in the LIBOR markets are employed as well.

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<sup>2</sup> Barsky and Kilian (2002, 2004) and Frankel (2014) show that the commodity prices, e.g. gold, oil and minerals etc., are inversely related to interest rate movements. However, Tully and Lucy (2007) report no significant relationship between interest rate and gold (returns and volatility).

While exploring the hedging, safe haven and diversification properties of gold, most of the contemporary literature resorts only to linear frameworks (Baur, 2012, 2014; Baur & Lucy, 2010; Baur & McDermott, 2010; Tully & Lucy 2007; Tuysuz, 2013). On the other hand, many researchers have indicated nonlinear attributes of economic and financial time series (e.g., Choudhry et al., 2014; Keynes, 1936; Hiemstra & Jones, 1994; Shiller, 1993, 2005; Shin et al., 2014). Any investment strategy which combines both stocks and gold may not yield the desired results, as a result of ignoring the underlying nonlinear dynamics. Therefore, this paper is motivated to explore the nonlinear causality between the two asset classes, and such causality will have significant implications for portfolio investment strategies. The application of the nonlinear bivariate and multivariate causality tests makes this paper unique in the literature.

We first apply the bivariate nonlinear causality test to investigate the causality between stock returns and gold returns. In the second test we replace the stock returns with stock volatility, thus investigating causality between stock volatility and gold returns. According to the consumption-based asset-pricing literature (e.g. Barsky 1989; Bekaert et al., 2009 and Baele et al., 2013) a flight to safety (quality) is typically defined as the joint occurrence of higher economic uncertainty with lower equity prices (through a cash flow or risk premium effect) and low real rates (through a precautionary savings effect). This paper investigates this effect by testing the nonlinear causal relationship between stock market volatility as a measure of uncertainty in the equity markets and gold returns. To the best of our knowledge this is the first such empirical study. It is expected that an increase in stock market volatility would be followed by an increase in gold returns due to an increase in the gold demand from the risk-averse portfolio investors to insulate their returns against volatility in the stock markets thereby indicating flight to safety.

The paper is set out in the following manner. Section 2 provides a discussion of the relationship between gold and stock markets during the recent financial crisis. The data and the methodology applied are described and discussed in section 3. Section 4 presents the results and section 5 concludes the study and states the implications.

## **2. Gold and stock markets, and global financial crises**

This recent global financial crisis investigated in this paper is considered to be as the worst financial crisis since the Great Depression of 1929-33 (Guidolin & Tam, 2013). The crisis started with the burst of the price bubble in the US real estate market in mid-2007, and reached its peak by October 2008 when the Lehman Brothers defaulted. During the recent financial crisis, the interbank markets across advanced economies became dysfunctional in August 2007, and there was clear evidence of a run for “quality” by investors. For example, the price of gold, regarded as a storage of value in times of financial turbulence, rose from US\$660 per ounce in August 2007 to US\$1,000 around the Bear Stearns rescue by JP Morgan and the Federal Reserve’s announcement of the Primary Credit Dealer Facility on 16 March 2008, after which the gold spot price dropped by 10% in a short period of time. The gold price hit its (then) record high of over US\$1000 per ounce in March 2008 (Chan et al., 2011). The global financial crisis also had a massive impact on the stock markets around the globe. In October 2007, the global equity market capitalization which was at an all-time high at US\$59 trillion was wiped away to a little above US\$29 trillion by November 2008 (World Federation of Exchanges, 2014). The share prices started to fall from early 2008 in various countries, but the real equity disaster took place over 31 trading days (September - October 2008) as almost all indices collapsed by 30-40%<sup>3</sup>. The FTSE 100, S&P 500 and Nikkei 225 indices dropped by 48%, 57% and 60% respectively between October 2007 and March 2009.

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<sup>3</sup> From 15 September 2008, the day Lehman Brothers filed for bankruptcy, to the end of 27 October 2008, during which the AIG was bailed out.

Given the dramatic effect of the crisis on the world gold markets and the stock markets, it is of empirical interest to study the effect of the crisis on the relationship between gold and major stock markets.

Figure 1 shows contrasting trends for both gold prices and stock market indices for Japan, the UK and the US over the financial crisis period (shaded part of the graph). The gold prices during the crisis period show an upward rise, whereas stock indices for all three countries show a massive decline for the same period. This may be attributed to investors' response to rising uncertainty in financial markets and increase in demand for gold across these countries.

### **3. The data and the methodology**

#### *3.1 The data*

As indicated above, the three stock indices used are FTSE100 (UK), S&P 500 (US) and Nikkei 225 (Japan). Three gold returns based on the UK pound, the US dollar and the Japanese yen are applied in the tests. Changes in the LIBOR rates are applied in the multivariate tests between gold returns and stock returns or volatility. The LIBOR rates based on the pound, the dollar and the yen are used in the paper. Daily data obtained from Thompson Financial Datastream for January 2000 to March 2014 are applied. In order to analyze the impact of financial crisis on the relationship between the variables, the data are split into two samples, the pre-financial crisis (January 2000 to June 2007) and the financial crisis period (July 2007 to March 2014)<sup>4</sup>. We test both periods for all three stock markets and provide a comparison of the results. Figures 2, 3 and 4 present the returns in the three gold markets, the stock markets and the LIBOR, respectively.<sup>5</sup> It can be seen clearly that returns

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<sup>4</sup>The start of the collapse of the US sub-prime mortgage market during July/August 2007 is applied as the start of the crisis period in this paper.

<sup>5</sup>Returns are estimated as the first difference of the log of the index.

are more volatile during the crisis period (shaded region); this is true for all assets for all three markets

Stock market volatility is estimated using the GARCH (1,1) model for all three stock indices.<sup>6</sup> Table 1 describes the GARCH results. The ARCH effects ( $\alpha_1$ ) are significant and positive in all three tests, implying significant volatility clustering. The ARCH effect is smaller than unity in all tests; thus implying volatility is not explosive. The GARCH effect ( $\beta_1$ ) is also significant and positive in all tests, implying persistent volatility. Moreover, the Ljung-Box statistic fails to indicate any serial correlation in the standardized residuals and the standardized squared residuals at the 5% level using 10 lags. As suggested by Giannopoulos (1995), the high-order ARCH process is not warranted in the absence of serial correlation in the standardized squared residuals. Figure 5 shows the three stock market volatilities applied in the paper. Comparison between the pre-crisis and the crisis periods (shaded region) clearly shows higher stock volatility during the crisis period, particularly during the period when Lehman Brothers defaulted during 2008. This result is expected as stock market volatility across the globe has increased during the crisis (Schwert, 2011).

The basic statistics of all three gold returns, stock returns, stock volatility and changes in the LIBOR rates show almost all series are found to follow a non-normal distribution based on the Bera-Jarque test with most of the series having negative skewness and positive kurtosis. All series are tested for unit roots by means of the augmented Dickey and Fuller (1979) and the Kwiatkowski et al. (1992) (KPSS) tests; both tests indicate that most series are level non-stationary, whereas all first-differenced series are stationary during both periods.<sup>7</sup> Only the three stock market volatilities are found to be stationary in levels during both periods. The

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<sup>6</sup> We do not provide a description of the GARCH model as it is available at many other sources.

<sup>7</sup> Description of the ADF and KPSS tests are available in many sources. Thus we do not provide a description.

causality test applied requires stationary first difference of all series involved. These results are available from the authors on request.

### 3.2 Methodology

#### 3.2.1 Nonlinear Granger causality

In this paper, nonlinear dynamic co-movements between the gold returns, stock market returns, stock volatility and changes in the interest rate have been investigated in bivariate and multivariate settings using Hiemstra and Jones (1994) and Bai et al. (2010), respectively.<sup>8</sup> Both of these models are based on the correlation integrals, defined as probability of dynamic or lagged co-movement between the two stationary time series. The ‘Granger Causality’ proposed by Granger (1969) involves dynamic co-movement in the presence of linearity assumption. Baek and Brock (1992) indicate that the parametric linear Granger test has low power against certain nonlinear alternatives or higher moments. As a result, nonparametric causality tests directly emphasizing on prediction without imposing a linear functional form have been proposed in the literature.

##### 3.2.2.1 Hiemstra and Jones (1994)

Hiemstra and Jones (1994) propose a nonparametric nonlinear Granger causality test. Given  $\theta_{t-1}$  denotes an information set comprising of an  $L_x$ -length lagged vector of  $x_t$  and an  $L_y$ -length lagged vector of  $y_t$  for a strictly stationary variable  $x_t$  and its conditional distribution is represented by  $F(x_t|\theta_{t-1})$ , Hiemstra and Jones (1994) test the following null hypothesis of  $y_t$  does not Granger cause  $x_t$  for given lags of  $L_x$  and  $L_y$ :

$$H_0: F(x_t|\theta_{t-1} - Y_{t-L_y}^{L_y}). \quad (4)$$

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<sup>8</sup> We also apply the Diks and Panchenko (2005) nonlinear bivariate method but do not provide the results as they are very similar to those of Hiemstra and Jones (1994). They are available from the authors on request.

The test statistic proposed by Hiemstra and Jones (1994) describes the above generic null hypothesis in terms of joint probabilities in the following manner:

$$\begin{aligned}
& P(\|X_t^m - X_s^m\| < \varepsilon \mid \|X_{t-Lx}^{lx} - X_{s-Lx}^{lx}\| < \varepsilon, \|Y_{t-Ly}^{ly} - Y_{s-Ly}^{ly}\| < \varepsilon) \\
& = P(\|X_t^m - X_s^m\| < \varepsilon \mid \|X_{t-Lx}^{lx} - X_{s-Lx}^{lx}\| < \varepsilon).
\end{aligned} \tag{5}$$

For given  $m$ -length lead vector of  $x_t$  and for all  $\varepsilon > 0$ , equation (5) implies that the null hypothesis cannot be rejected in case the above equation holds. In other words, lag vector of  $y_t$  and lead vector of  $x_t$  are dynamically independent of each other as the lagged values of  $y$  do not hold any new information to explain changes in the current values of variable  $x$ . Further,  $\varepsilon$  represents a threshold for validating the variations in terms of standard deviation multiplier, to rule out the outlier movements exceeding this limit. This threshold is typically set between 0.5 and 1.5. Following Baek and Brock (1992), Hiemstra and Jones (1994) have proposed the following test statistics based on joint ratios of correlation integrals. For given values of  $m$ ,  $Lx$ , and  $Ly \geq 1$  and  $e > 0$  under the assumption that  $X_t$  and  $Y_t$  are strictly stationary and weakly dependent, if  $Y_t$  does not strictly Granger cause  $X_t$  then,

$$\sqrt{n} \left( \frac{C1(m+Lx, Ly, e, n)}{C2(Lx, Ly, e, n)} - \frac{C3(m+Lx, e, n)}{C4(Lx, e, n)} \right) \rightarrow N(0, \sigma^2(m, Lx, Ly, e)), \tag{6}$$

where correlation integrals C1, C2, C3 and C4 are defined as the

$$C1(m+Lx, Ly, e, n) \equiv \frac{2}{n(n-1)} \sum_{t < s} I(x_{t-Lx}^{m+Lx}, x_{s-Lx}^{m+Lx}, e) \cdot I(y_{t-Ly}^{Ly}, y_{s-Ly}^{Ly}, e),$$

$$C2(Lx, Ly, e, n) \equiv \frac{2}{n(n-1)} \sum_{t < s} I(x_{t-Lx}^{Lx}, x_{s-Lx}^{Lx}, e) \cdot I(y_{t-Ly}^{Ly}, y_{s-Ly}^{Ly}, e),$$

following:  $C3(m+Lx, e, n) \equiv \frac{2}{n(n-1)} \sum_{t < s} I(x_{t-Lx}^{m+Lx}, x_{s-Lx}^{m+Lx}, e),$

$$C4(Lx, e, n) \equiv \frac{2}{n(n-1)} \sum_{t < s} I(x_{t-Lx}^{Lx}, x_{s-Lx}^{Lx}, e),$$

(7)

$$I(x, y, e) = \begin{cases} 0, & \text{if } \|x - y\| > e \\ 1, & \text{if } \|x - y\| \leq e \end{cases}$$

and where  $t, s = \max(Lx, Ly) + 1, \dots, T - m + 1$ ,  $n = T + 1 - m - \max(Lx, Ly)$ .

Here, equation (6) estimates the nonlinear dynamic relationship between the underlying variables i.e. i) stock market returns and gold returns; and ii) stock market volatility and gold returns. It is important to highlight that the above test statistic in equation (6), if significant, shows dynamic association between the variables while controlling for their contemporaneous dependence. In other words, such evidence may have significant implications for hedging and safe haven properties of gold against stock markets.

### 3.2.2.2 Multivariate nonlinear causality

Bai et al. (2010) extended the bivariate nonlinear Granger causality model of Hiemstra and Jones (1994) to multivariate settings for analyzing the causal relationships between more than two variables. Lead vector of size  $m_{xi}$  for  $X_{i,t}$  can be defined as

$X_{i,t}^{m_{xi}} = (X_{i,t}, X_{i,t+1}, \dots, X_{i,t+m_{xi}-1})$ . Lag vector of length  $L_{xi}$  for  $X_{i,t}$  can be defined as:

$X_{i,t-L_{xi}}^{L_{xi}} = (X_{i,t-L_{xi}}, X_{i,t-L_{xi}+1}, \dots, X_{i,t-1})$ . Similarly  $m_{yi}$ -length lead vector  $Y_{i,t}^{m_{yi}}$ , and lag

vector  $Y_{i,t-L_{yi}}^{L_{yi}}$  based on vector  $Y_{i,t}$  can be defined.

The test statistic proposed by Bai et al. (2010) to test multivariate causality is based on correlation integrals

$$\sqrt{n} \left( \frac{C1 (Mx + Lx, Ly, e, n)}{C2 (Lx, Ly, e, n)} - \frac{C3 (Mx + Lx, e, n)}{C4 (Lx, e, n)} \right) \quad (9)$$

where ‘e’ is a threshold value that defines a band within which we allow values of  $X_t$  and  $Y_t$  to deviate in different formations of lead and lag of variables, and ‘n’ is the number of observations.<sup>9</sup> C1, C2, C3 and C4 are correlational integrals, and defined in the following manner:

$$\begin{aligned} C1 (Mx + Lx, Ly, e, n) &\equiv \frac{2}{n(n-1)} \sum_{t < s} \sum_{i=1}^{n1} I(x_{i,t-L_{xi}}^{m_{xi}+L_{xi}}, x_{i,s-L_{xi}}^{m_{xi}+L_{xi}}, e) \cdot \prod_{i=1}^{n2} I(y_{i,t-L_{yi}}^{L_{yi}}, y_{i,s-L_{yi}}^{L_{yi}}, e) \\ C2 (Lx, Ly, e, n) &\equiv \frac{2}{n(n-1)} \sum_{t < s} \sum_{i=1}^{n1} I(x_{i,t-L_{xi}}^{L_{xi}}, x_{i,s-L_{xi}}^{L_{xi}}, e) \cdot \prod_{i=1}^{n2} I(y_{i,t-L_{yi}}^{L_{yi}}, y_{i,s-L_{yi}}^{L_{yi}}, e) \\ C3 (Mx + Lx, e, n) &\equiv \frac{2}{n(n-1)} \sum_{t < s} \sum_{i=1}^{n1} I(x_{i,t-L_{xi}}^{m_{xi}+L_{xi}}, x_{i,s-L_{xi}}^{m_{xi}+L_{xi}}, e) \\ C4 (Lx, e, n) &\equiv \frac{2}{n(n-1)} \sum_{t < s} \sum_{i=1}^{n1} I(x_{i,t-L_{xi}}^{L_{xi}}, x_{i,s-L_{xi}}^{L_{xi}}, e) \end{aligned} \quad (10)$$

$$I(x, y, e) = \begin{cases} 0, & \text{if } \|x - y\| > e \\ 1, & \text{if } \|x - y\| \leq e \end{cases}$$

Bai et. al (2010) further show that the test statistic in equation (9) above is distributed as  $N(0, \sigma^2(Mx, Lx, Ly, e))$ . They have also proposed a consistent estimator for  $\sigma^2$  for hypotheses testing, details of which can be found in Bai et. al (2010).

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<sup>9</sup> The test statistic given in equation (9) above is the difference of correlation integral ratios between C1/C2 and C3/C4, standardized by the square root of the number of observations. The first ratio explains the changes in dependent variable  $X_t$  with respect to changes in independent variable  $Y_t$  and lags of  $X_t$ . Whereas the second ratio gives the extent of changes in  $X_t$  with respect to its own lags. If the difference of the two ratios is zero, it means the independent variable  $Y_t$  does not contain any significant information to explain changes in  $X_t$ . In other words, zero difference between ratios implies acceptance of the null hypothesis that  $Y_t$  does not Granger cause  $X_t$ .

## 4. Nonlinear causality tests results

### 4.1 Gold returns and stock market returns

Nonlinear Granger causality results between gold and stock market returns are presented in Table 2 (Panel-I). During the pre-crisis period, significant causality is only found in the case of Japan and the US, from gold returns to stock returns and for the UK, from stock returns to gold returns. Thus we find limited evidence of unidirectional causality for Japan, the US and the UK but no evidence of bidirectional causality for any of the markets.

During the financial crisis period a strong feedback effect is reported for all three countries (Table 2, Panel-I). At 1% level of significance, results indicate bidirectional causality for all three countries.<sup>10</sup> This is a substantial change in the results from the pre-crisis period and those from the crisis period. The nonlinear causality result confirms the inability of gold to serve as a safe haven during the global financial crisis, although it could have been used as a hedge during the pre-crisis period. These results are bit similar those expounded by Chen et al. (2011) but are in contrast to those of Baur and McDermott (2010), Tuysuz (2013), and Miyazaki et al. (2012). Our results may be in contrast to studies cited above due to three main reasons. First, we apply the nonlinear procedure to investigate the relationships. Second, we investigate bidirectional (and multidirectional) causality between the variables. Most of the studies showing gold as a safe haven during the financial crisis period assume the underlying relationship to be unidirectional only; however our results show that this assumption cannot hold empirically as the underlying variables are mutually interdependent. Third, investors' beliefs are often cited as one of the key sources of nonlinearities in the financial time series. These contrasting results for periods of relative

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<sup>10</sup> An almost identical result is obtained via Diks and Panchenko (2006). These results are available on request.

calm and then high volatility might be indicative of fading heterogeneity in investors' beliefs. In other words, investors' outlook might be heterogeneous in stable financial markets, whereas, in turbulent financial conditions, investors in these markets would have less uniformity in their future expectations.

#### *4.2 Gold returns and stock market volatility*

This section describes nonlinear Granger causality results between stock market volatility (uncertainty) and gold returns (Table 2, Panel II). The results from the pre-crisis period show no significant causality. Thus there is no evidence of unidirectional or bidirectional causality among the variables for any of the three countries. This highlights the significance of gold in reducing portfolio risk when combined with equity securities during relatively stable economic periods. Again, results from the crisis provide very strong bidirectional causality (at the 1% level) for all three countries included in the study. Similar to the returns results in section 4.1, the crisis period indicates strong feedback between the stock volatility and the gold returns. The same reasons may also apply here in explaining the results involving stock volatility.

#### *4.3 Gold returns, stock market returns and interest rate (multivariate)*

As stated earlier, we further investigate the above relationships in the presence of changes in the short-term interest rates (three-month LIBOR). The changes in short term interest rate are introduced as control variable which is considered to be a key driver for fixed-income securities markets. Further, Fortune (1987) reports that any changes in the expected interest rate triggers negative adjustment in gold prices and vice versa as the investors switch between the different assets classes according to future expectations of

interest rates. This provides the theoretical bases to include changes in three-month LIBOR rates for respective markets to test nonlinear dynamic co-movements in multivariate settings.

Table 3 presents the results from the nonlinear causal tests between three variables for both periods. During the pre-crisis period, causality from stock returns and interest rate returns to gold returns is only significant for the UK (at the 5% level). There is no evidence of feedback in the case of Japan and the US. For all three countries, causality from interest rate returns and gold returns to stock returns is significant. In the case of the US, this evidence is weak at the 10% level only.

The results from the financial crisis period show strong feedback among the variables for all three countries in most of the cases. The only exception is in the case of Japan, where gold returns and changes in the interest rate jointly cause stock returns in addition to stock returns and interest rates jointly causing gold returns. For the UK and the US, feedback is reported among all variables. These results are in line with the bivariate results above, where nonlinear dependence among the variables is much stronger during the financial crisis period, as compared to the pre-crisis period. Once again we find evidence that gold lost some of its safe haven characteristics during the crisis period.

#### *4.4 Gold returns, stock market volatility and interest rate (multivariate)*

In this section, multivariate dynamic relationships are analyzed between gold returns and stock market volatility in the presence of the short-term interest rates (three-month LIBOR). Table 4 presents results from the nonlinear causal tests between among the underlying three variables for both periods. In the pre-crisis period, stock market volatility and change in LIBOR cause gold returns (at 10% significance level) only in the case of the UK. In the case of the US, changes in LIBOR and gold returns lead to stock market volatility

at 10% significance and at the 1% level for the UK. Stock volatility and gold returns cause changes in LIBOR in all three markets.

Results from the financial crisis period show strong feedback among the variables for all three countries except in the case of Japan in one instance where stock market volatility shows nonlinear independence of changes in LIBOR and gold returns. For the UK and the US, feedback is reported among all three variables. These results are in line with the bivariate results above, where nonlinear dependence among the variables is much stronger during the financial crisis period, as compared to the pre-crisis period.

## **5. Conclusion and implications**

In recent years there has been an increase in the number of research papers investigating the hedge and safe haven characteristics of gold during the financial crisis. However, most of the studies adopt a unidirectional approach, ignoring the possibility of mutual dependence among various asset classes. We contribute to the substantial and ever-growing literature in this field by studying nonlinear dynamic co-movements allowing for feedback effect among gold returns, stock returns and stock volatility in the US, the UK and Japan during the pre-crisis and crisis periods. Daily data from January 2000 to March 2014 are applied. In order to analyze the impact of the financial crisis on the relationship between the variables, the data are split into two samples, the pre-financial crisis (January 2000 to June 2007) and the financial crisis period (July 2007 to March 2014).

The bivariate nonlinear test is conducted by means of Hiemstra and Jones (1994) and the multivariate test is conducted by means of Bai et al. (2010). Stock returns from FTSE100 (UK), S&P500 (US) and Nikkei 225 (Japan) are used in the paper. These three stock markets represent three of the largest markets in the world. Three gold returns based on the UK pound, the US dollar and the Japanese yen are applied in the tests. Changes in the LIBOR rates are applied in the multivariate tests between gold returns, stock returns or volatility and

the interest rates. The LIBOR rates based on the pound, the dollar and the yen are used in the paper. Short-term interest rate is introduced as a control variable which is considered to be a key driver for fixed-income securities markets. Frankel (2014) and Barsky and Kilian (2002, 2004) show that the commodity prices- e.g., gold, oil and minerals, etc. - are inversely related to interest rate movements.

Bivariate nonlinear results show very little evidence of causality between the gold returns and stock returns during the pre-crisis period. This is true in the case of all three countries studied. Thus we find evidence of gold having been a safe haven during the pre-crisis period; however the results are the opposite during the crisis period. We find ample evidence of significant causality between the two variables during the crisis period. These results provide evidence against the ability of gold to act as a safe haven during the recent global financial crisis; similar results are obtained when testing between stock volatility and gold returns, implying the same conclusion. Thus, this paper provides evidence of reduction of gold as a safe haven in the UK, the US and Japan from the pre-crisis period to the crisis period. This result is in complete contrast to most of what has been reported in the literature.

Results from the multivariate nonlinear tests provide the same conclusion as the bivariate tests. Pre-crisis results show limited evidence of causality and feedback between the stock returns, gold returns and changes in the LIBOR rates. During the pre-crisis period, causality from stock returns and interest rate returns to gold returns is only significant for the UK. Results from the financial crisis period show strong feedback among the variables for all three countries in most of the cases. The exception is in the case of Japan; there is no evidence of feedback from the stock and gold returns to interest rate returns. Replacing the stock returns with stock volatility in the multivariate tests, the results are similar to the stock returns results. Results from the financial crisis period show stronger feedback (compared to the pre-crisis period) among the variables for all three countries except in the case of Japan in

one instance where stock market volatility shows nonlinear independence of changes in interest rate and gold returns. For the UK and the US, feedback is reported among all three variables.

Both bivariate and multivariate tests show that the gold lost its ability to as a safe haven in the UK, the US and Japan during the global financial crisis. Thus, according to our results from the recent crisis, the use of gold to reduce portfolio risk may not be very feasible. These results are the same whether we apply stock returns or stock volatility. Significantly, our results contradict the majority of the results presented in the literature; and we believe there are three main reasons for this. First, in contrast to the majority of the previous studies, we study bidirectional and multi-directional relationship between stock returns/volatility and gold returns. Most studies to date only investigate a unidirectional relationship. Second, many researchers have indicated nonlinear attributes of economic and financial time series and these attributes advocated the use of nonlinear causality methods and other nonlinear tests. This is the first paper to apply the nonlinear methods. Third, investors' outlook might be heterogeneous in stable financial markets, whereas, in turbulent financial conditions, investors in these markets would have less uniformity in their future expectations. These beliefs may impose more nonlinearity in any investment strategy involving stock and gold. Our results have significant implications for the investors and portfolio managers, as gold may be used to hedge equity portfolio exposures in the three markets both in terms of returns and as well as volatility. The implications are more relevant during the pre-crisis period than the current global financial crisis period. Our results also advocate further research in this field to back or dispute our results using different methods, markets, sample periods, and variables.

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**Table 1**

Stock Market Volatility – GARCH (1,1)

<b>Parameters</b>	<b>S&amp;P 500</b>	<b>FTSE 100</b>	<b>NIKKEI 225</b>
M	0.000455***	0.00038**	0.000381
$\alpha_0$	0.000001***	0.000001***	0.000004***
$\alpha_1$	0.081260***	0.09857***	0.091345***
$\beta_1$	0.908270***	0.89260***	0.893906***
L	11756.20	11824.9	10706.31
Std. Resids (Q-Stat,10)	9.09	14.63	12.87
Sq.Std.Resids (Q-Stat,10)	13.56	4.15	5.9

**Note:**

1. \*\*\*, \*\*, \* denote significance levels at 1%, 5%, and 10% respectively.
2. M: Mean Stock Market Return;  $\alpha_0$ : Contemporaneous Conditional Variance;  $\alpha_1$ : ARCH effect;  $\beta_1$ : GARCH effect; L: Log Likelihood; Std. Resids: Standardised Residuals; Sq.Std.Resids: Squared Standardised Residuals; (Q-Stat, 12): Ljung-Box Autocorrelation Test up to 10 lags.

**Table 2**

Bivariate nonlinear Granger Causality (Hiemstra &amp; Jones, 1994)

Panel – I: Stock market returns vs. gold returns

Countries	Nonlinear Causality			
	Pre-Crisis		Financial Crisis	
	SR ---> GR	GR -- > SR	SR ---> GR	GR -- > SR
Japan	1.095	2.546 <sup>***</sup>	4.137 <sup>***</sup>	4.66 <sup>***</sup>
United Kingdom	2.029 <sup>**</sup>	1.015	5.37 <sup>***</sup>	3.38 <sup>***</sup>
United States	0.06	3.724 <sup>***</sup>	4.39 <sup>***</sup>	3.803 <sup>***</sup>

Panel – II: Stock market volatility vs. gold returns

Countries	Nonlinear Causality			
	Pre-Crisis		Financial Crisis	
	SV ---> GR	SV ---> GR	SV ---> GR	SV ---> GR
Japan	0.97	0.571	4.489 <sup>***</sup>	3.973 <sup>***</sup>
United Kingdom	1.13	1.009	3.991 <sup>***</sup>	3.662 <sup>***</sup>
United States	0.791	0.683	5.091 <sup>***</sup>	4.325 <sup>***</sup>

Notes:

Table-2 (Panels I and II) present the results of the bivariate nonlinear Granger causality tests based on Hiemstra and Jones' (1994) method (Section 3.2.2.1) between stock market returns and gold returns (Panel-I) and stock market volatility and gold returns (Panel-II). Each panel above provides results for both pre-crisis period (01:2000-06:2007) and during/including global financial crisis period (07:2007-03:2014).

- 1) SR: Daily changes in Sock Returns; GR: Daily Changes in Gold Prices (Returns);  
SV: Daily changes in Stock Market Volatility.
- 2) \*\*\*, \*\*, & \* imply causality at the 1%, 5%, & 10% level, respectively

**Table 3**

Multivariate nonlinear causality

Countries	Nonlinear Causality					
	Pre-Crisis			Financial Crisis		
	SR,IR --> GR	IR,GR--> SR	SR,GR--> IR	SR,IR --> GR	IR,GR--> SR	SR,GR--> IR
Japan	1.05	3.16***	1.33*	3.90***	5.057***	0.865
UK	1.67**	2.301**	2.32**	5.32***	4.13***	3.22***
US	0.293	1.54*	2.36***	4.92***	5.26***	4.34***

Notes:

Table-3 presents the results of the multivariate nonlinear Granger causality test proposed by Bai et. *al.*(2010) as described in section 4.3 between gold returns (GR), daily changes in three-month LIBOR (IR), and daily stock market returns (SR) for Japan, the UK and the US. Each panel above provides results for both pre-crisis period (01:2000-06:2007) and during/including global financial crisis period (07:2007-03:2014). Each pair of independent variables followed by the “→” causality sign shows test statistic for lag vectors of the respective variables jointly causing another variable and providing evidence for/against possible Granger causality in each case.

- 1) SR: Daily changes in Sock Returns; GR: Daily Changes in Gold Prices (Returns);  
SV: Daily changes in Stock Market Volatility.
- 2) \*\*\*, \*\*, & \* imply causality at the 1%, 5%, & 10% levels, respectively.

**Table 4**

Multivariate nonlinear causality

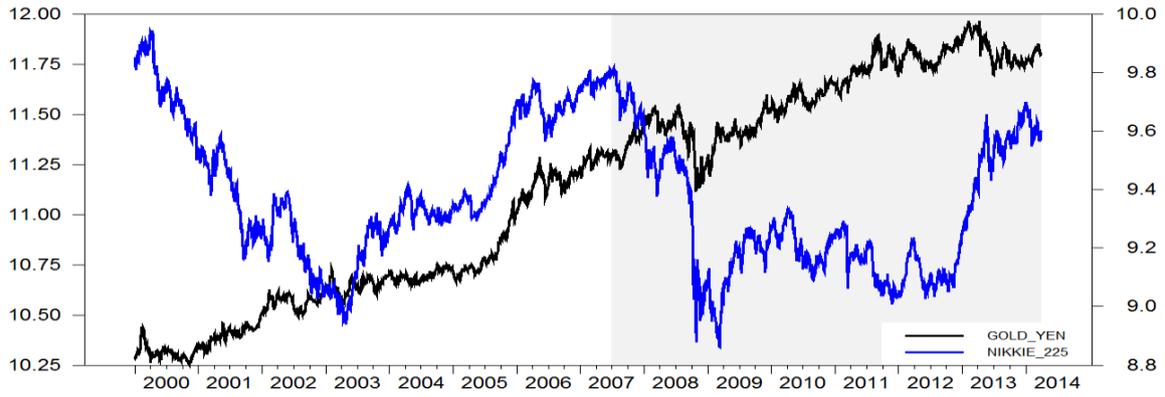
Countries	Nonlinear Causality					
	Pre-Crisis			Financial Crisis		
	SV,IR --> GR	IR,GR-->SV	SV,GR-- >IR	SV,IR --> GR	IR,GR-->SV	SV,GR-- >IR
Japan	0.926	1.10	3.136 <sup>***</sup>	3.805 <sup>***</sup>	0.714	4.979 <sup>***</sup>
UK	1.604 <sup>*</sup>	2.37 <sup>***</sup>	2.31 <sup>**</sup>	5.633 <sup>***</sup>	1.92 <sup>**</sup>	3.55 <sup>***</sup>
US	0.43	1.58 <sup>*</sup>	2.28 <sup>**</sup>	4.89 <sup>***</sup>	5.227 <sup>***</sup>	4.315 <sup>***</sup>

Notes:

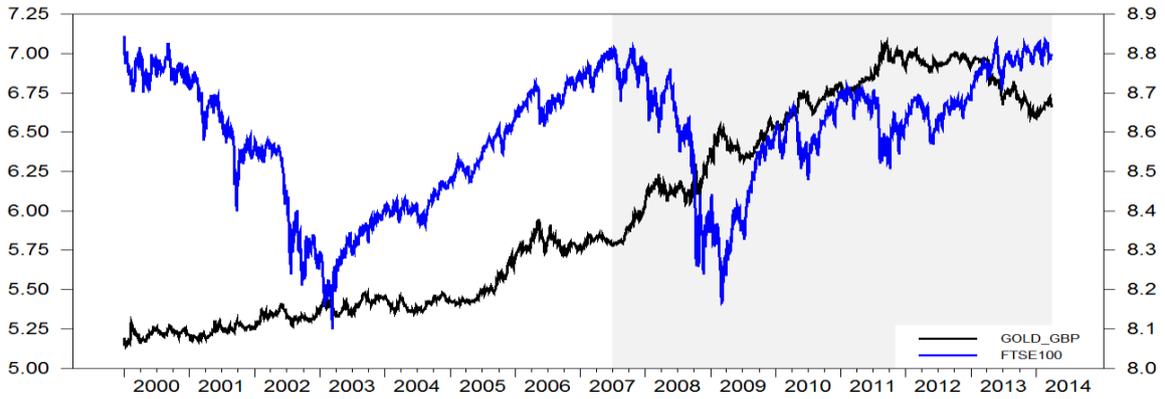
Table-4 presents the results of the multivariate nonlinear Granger causality test proposed by Bai et., al.(2010) as described in section 4.4 between gold returns (GR), daily changes in three-month LIBOR (IR), and daily changes in stock market volatility (SV) for Japan, the UK and the US. Each panel above provides results for both pre-crisis period (01:2000-06:2007) and during/including global financial crisis period (07:2007-03:2014). Each pair of independent variables followed by the “→” causality sign shows test statistic for lag vectors of the respective variables jointly causing another variable and providing evidence for/against possible Granger causality in each case.

- 1) SR: Daily changes in Sock Returns; GR: Daily Changes in Gold Prices (Returns);  
SV: Daily changes in Stock Market Volatility.
- 2) <sup>\*\*\*</sup>, <sup>\*\*</sup>, & <sup>\*</sup> imply causality at the 1%, 5%, & 10% levels, respectively.

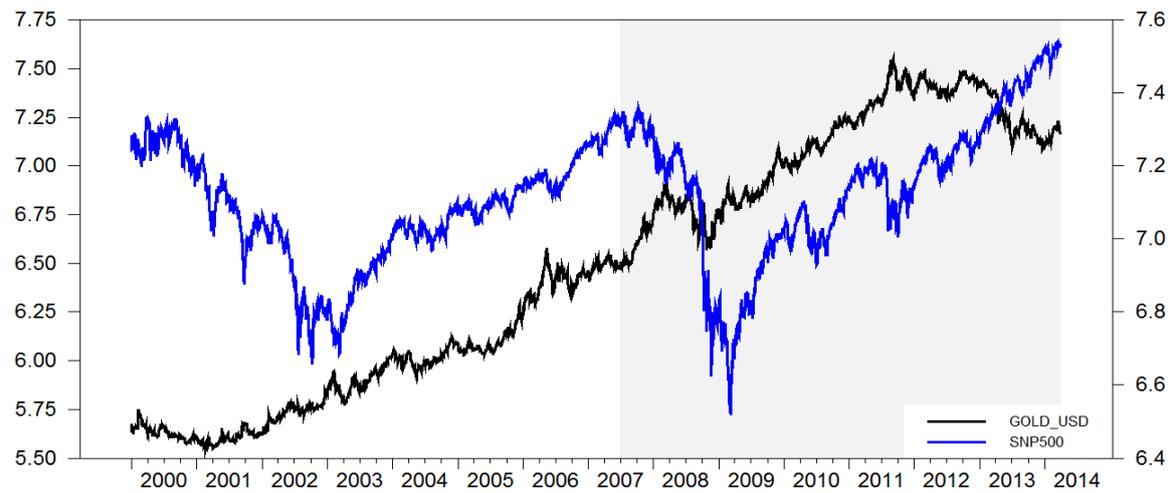
### Japan



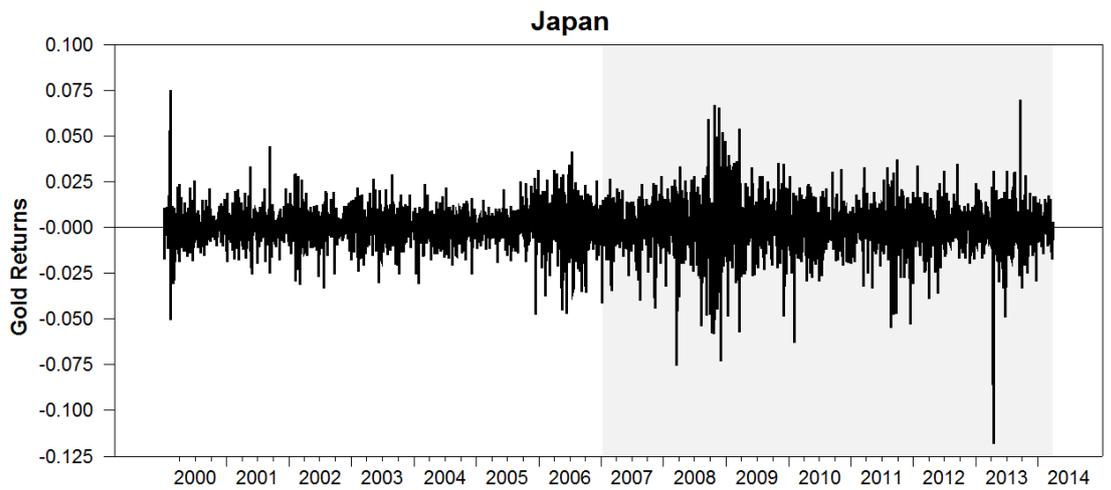
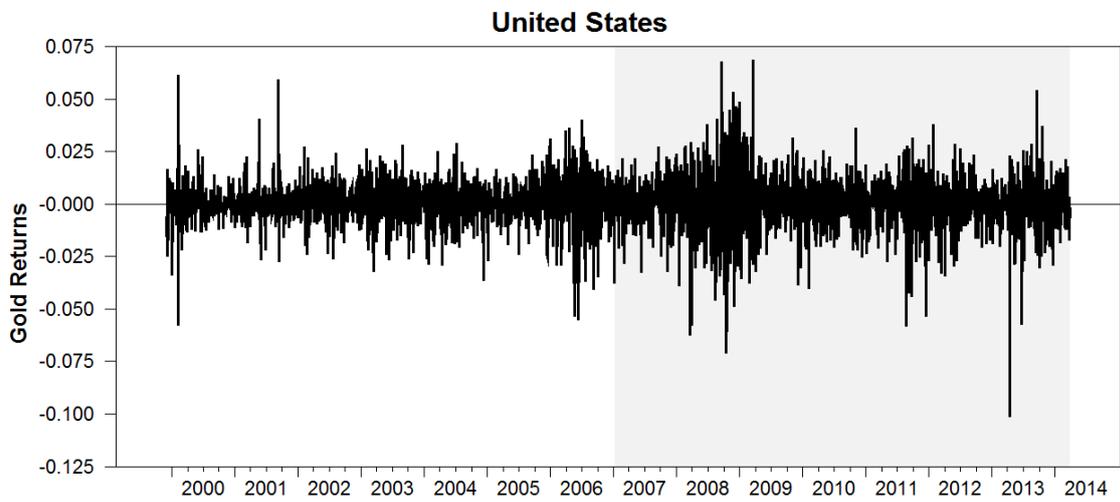
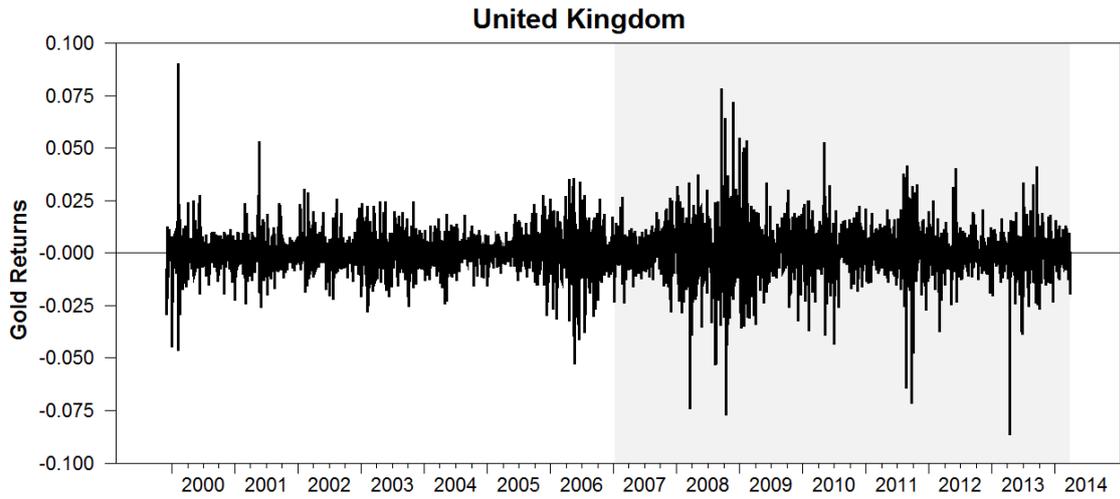
### United Kingdom



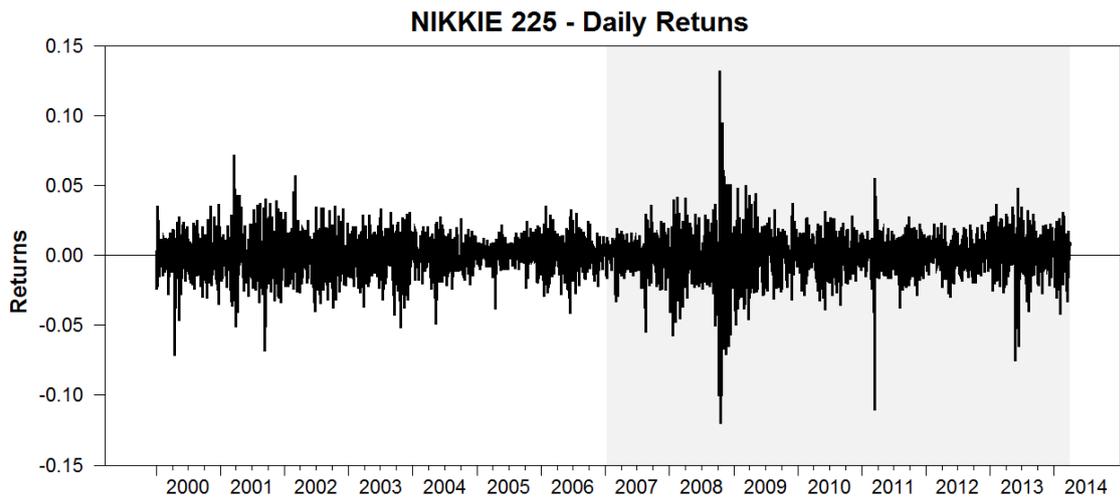
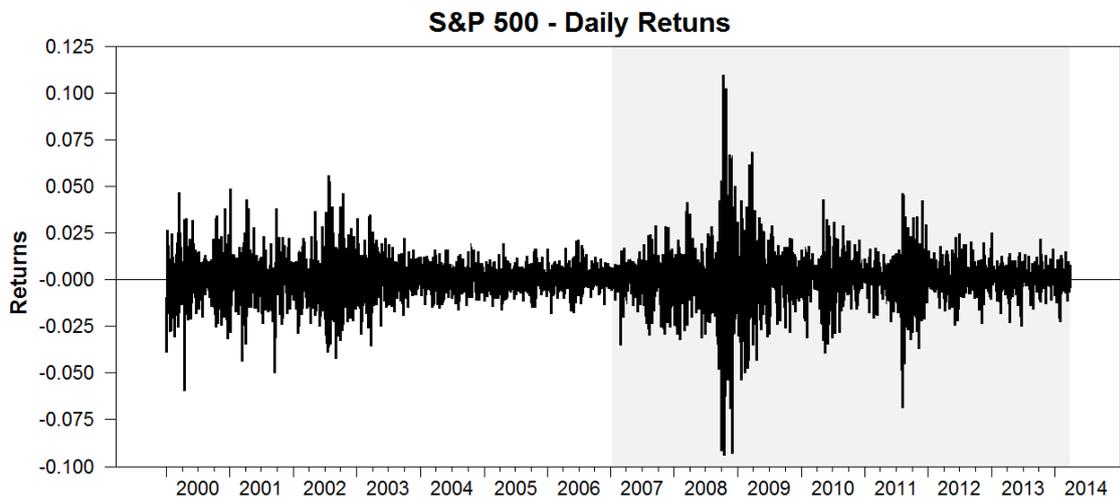
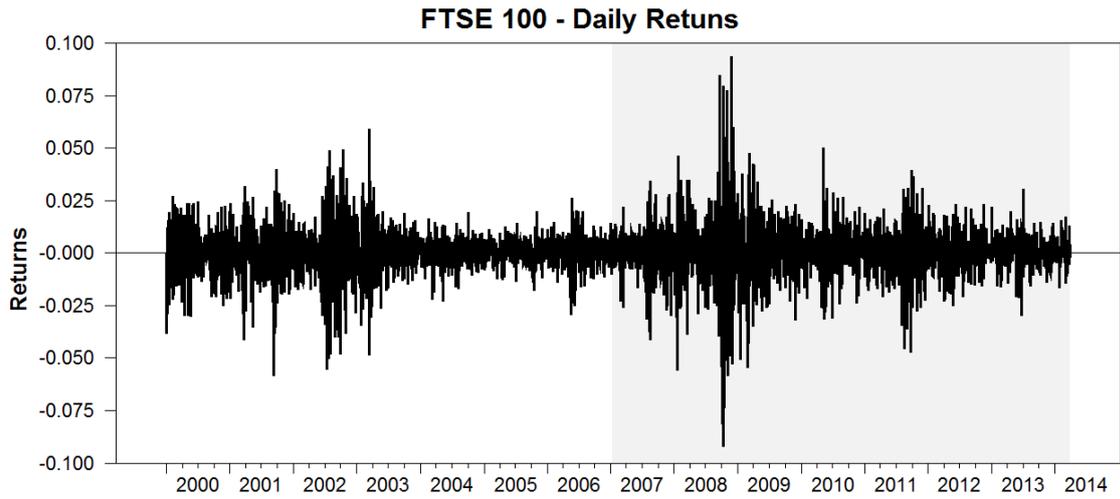
### United States



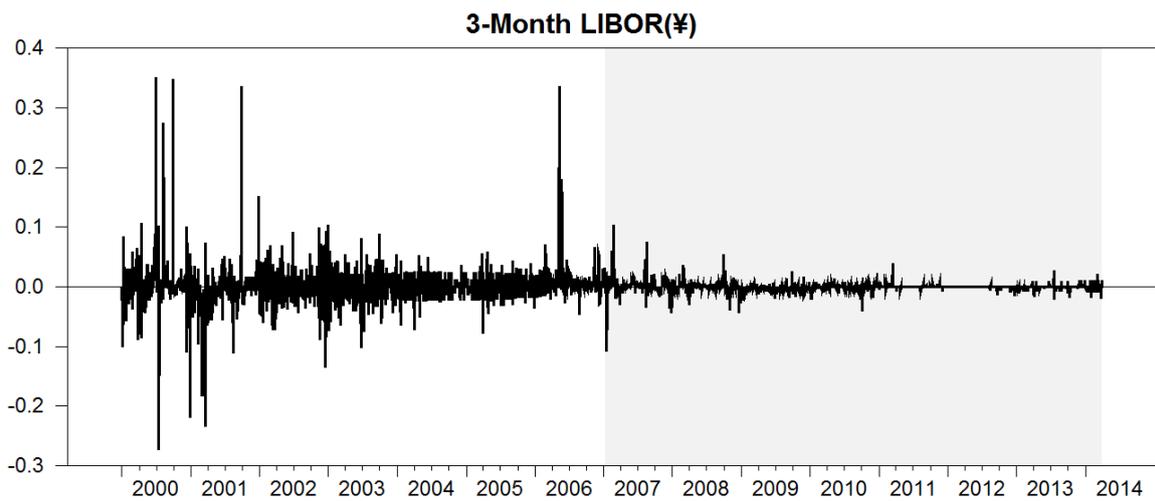
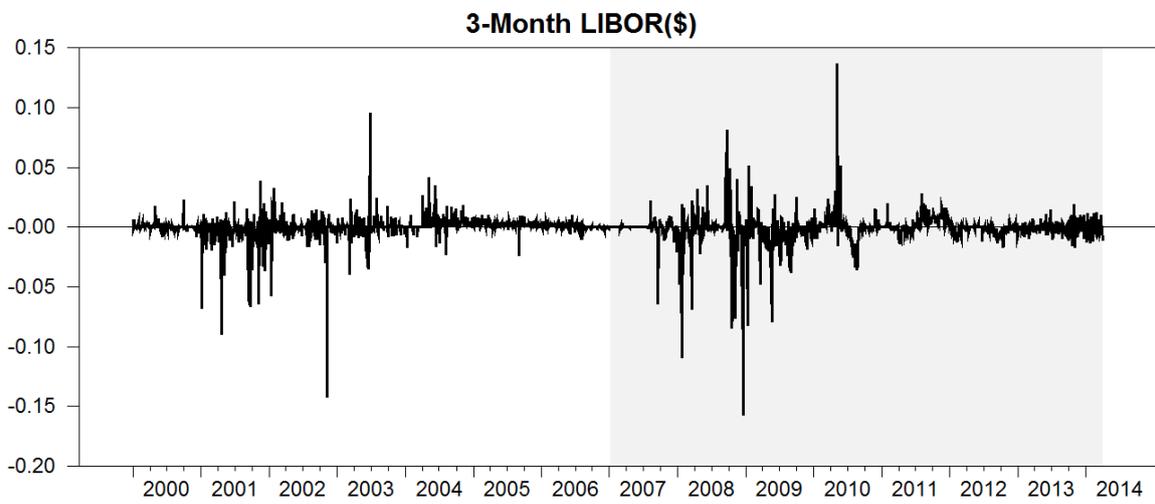
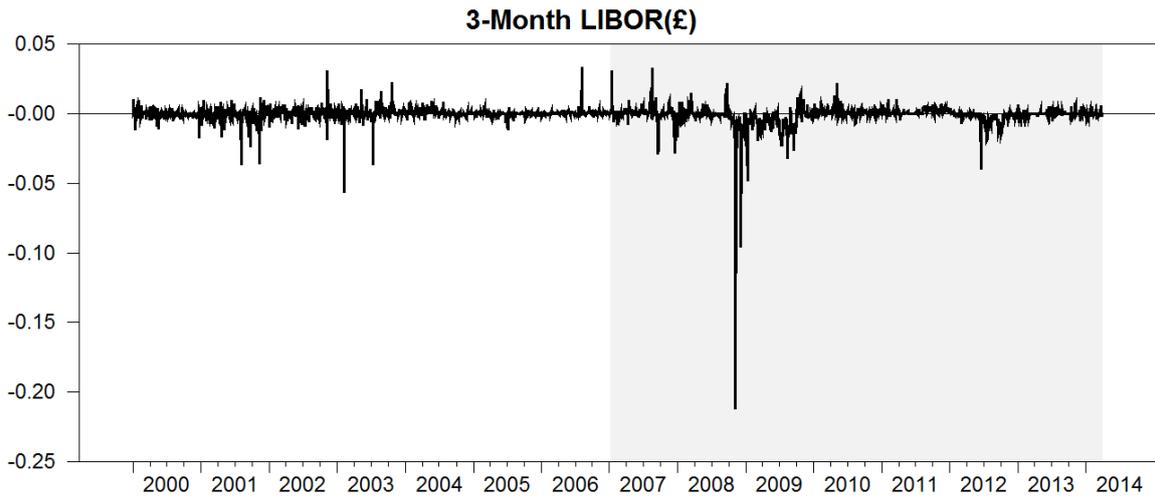
**Fig.1.** Daily gold prices and stock market indices



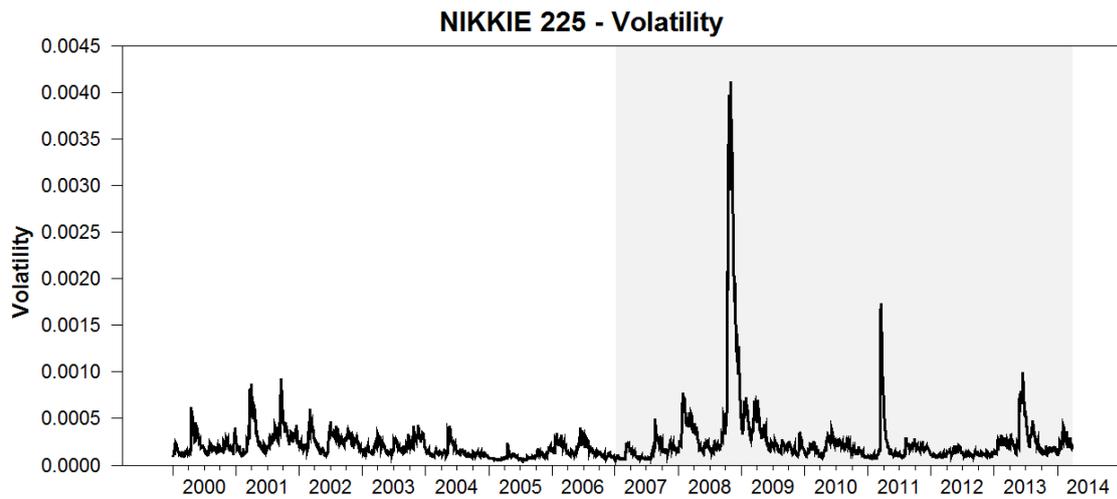
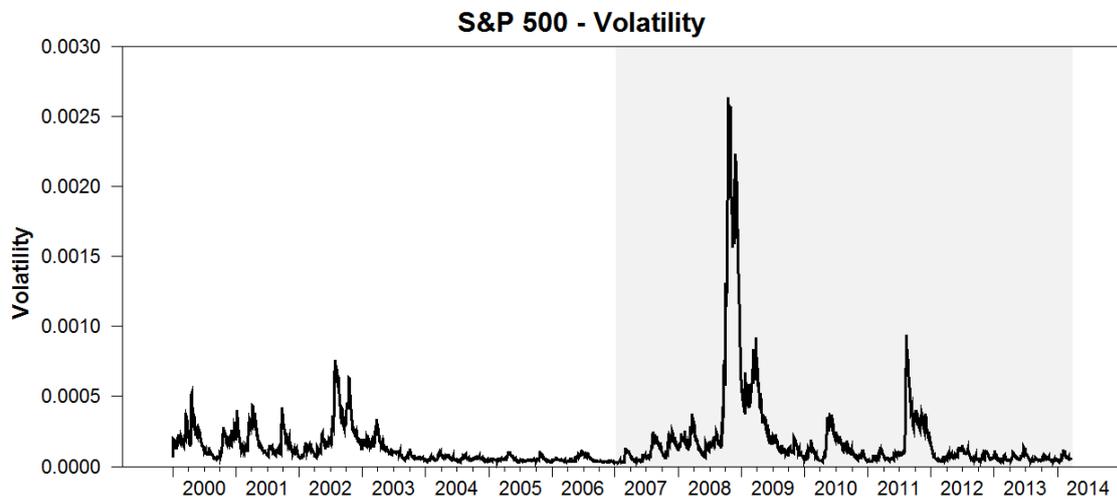
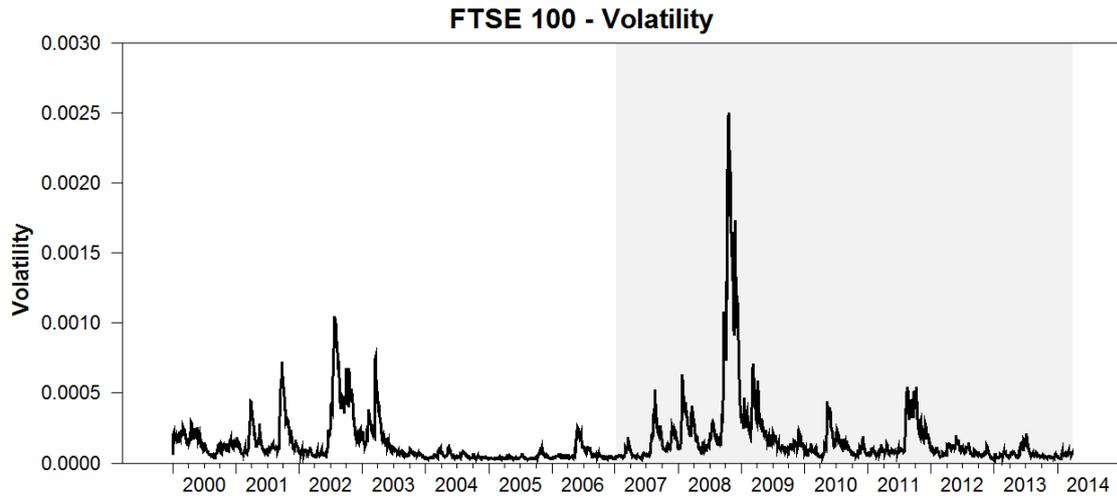
**Fig. 2.** Gold daily returns



**Fig.3.** Stock Market returns



**Fig.4.** Daily LIBOR (three-Month)



**Fig.5.** Stock market volatility