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Do Volatility and Regime Switching Affect Sustainable Indices Evidence from Global Stock Markets based on Inductive Approach of GARCH Family

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ABSTRACT

Efficient financial markets comprised substantial information about the financial and economic situations domestically and globally. For an investor, it is very important to consider the international factors that affect the performance and volatility of an index, which arise as a result of the switch in volatility in the international market. This paper is determining sustainable indices are affected by regime-switching. Major sustainable indices worldwide are gathered to examine the best fit volatility model from 2009 to 2017. The study relies on several GARCH family models in efforts to identify the best fit of sustainable stock indices and subsequently to determine the volatility regime-switching behaviour of the sustainable indices. The result confirms that asymmetric behavior exists in volatility, indicating that positive shocks affect volatility differently than negative ones. The findings conclude that there is a significant impact of the regime switch on the price volatility of the sustainability indices with asymmetric behavior that exists in volatility, and positive shocks affect volatility differently than the negative ones. This study shed light on how investors can strategize by making better investment decisions based on the past volatility trends through better understanding the impact of regime-switching of one index on other sustainable indices.

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INTRODUCTION

Portfolio diversification strategy is one of the utmost important decisions for investors, especially those who wished to have an international portfolio comprises of investments in the advanced financial markets. According to Glezakos et al. (2007), developed countries have trade linkages in their capital markets which responded to certain factors, to maintain an optimal international portfolio diversification, an investor has to consider all of the factors affecting the investments in different capital markets across the globe. Through trade and capital flow and linkages, all the stock markets are practically connected and development in one market would have spillover effects to another the market.

Regime switching in volatility is one of the causes that lead to the belief that volatility is fairly consistent. In several cases of market crash globally, mild and occasionally, very high volatility is often quoted as the reasons leading to market crash. There are different models used for different regimes to allow the simultaneous change of parameters under different regimes, then switching between regimes, to capture accurately model behavior. On the other hand, regime switching is described structural changes in a data series. It enables powerful dynamic regression analysis of time series by incorporating prolong period of high price and prolong period of low price.

Sustainable stock exchange is an initiative for exploring how the capital market promotes sustainable development through initiation of responsible investment among investors, regulators and companies. Sustainable stock exchanges promote environmental, improve social and governance disclosure, and enhance performance of listed companies.

"Sustainability indexes are designed and built with the goal of providing information to institutional and retail investors that value the importance of the companies' environmental and social responsibility and corporate governance in their everyday management, in addition to economic results, in their decisions to purchase shares," notes Beatriz Fernández, environmentalist and professor at the Instituto Superior de Medioambiente (Higher Institute of the Environment). Its also focused on the transforming the world, sustainable development agenda 2030.

This study aims to assess the influence of regime switching on the structural change in the time series data of major sustainable indices in the global stock markets. It attempts to identify the regime switching behavior in the sustainable indices and explain the reasons for structural changes. Thus, the specific objectives of this study are to:

1. To identify the best fit GARCH family model of sustainable stock indices.
2. To determine the volatility of regime switching of sustainable indices.

Following hypothesizes are summaries the objectives.

H_1: GARCH family does not fit the model for the sustainable stock indices
H_2: The regime switching does not volatile the sustainability of the index.

The above objectives have analyses by the help of given hypothesis. In addition, this analysis is conducted to explore on the focused regime switch on the sustainable indices. Another way to explore the regime switching is to find out whether positive shocks affect more the volatility of the data in comparison to the negative shocks. More importantly, investors should be able diagnose the best-fit GARCH model to know the regime switch volatility in sustainable indices.

REVIEW OF LITERATURE

Regime switching behavior of stock markets can be identified via several methods. Makridakis (1974) are used the method of principal component to analyze the inter-relationship among the major stock exchanges. The major finding is that the relation among is unstable or not certain over time. That proves that any ex-ante prediction is impossible regarding price indices. Suggestion of that is the indices of world equity markets can move in a random walk fashion. The consequences to international portfolio diversification should be obvious

(Makridakis and Wheelwright, 1974). Focusing on the period 2000-2006 with monthly data and investigates periodic relationships among major financial markets attention to the Greek stock exchange, Glezakos et al. (2007) documented a strong impact of the American financial market on DAX and FTSE (Glezakos et al., 2007). Meanwhile Sharkasi et al. (2005) examined the price interdependence of seven stock markets, namely *viz.*, Irish, UK, Portuguese, US, Brazilian, Japanese and Hong Kong. Using a new testing method, Wavelet transform, and reconstructs the data series, and confirm the evidence for intra-continental relationships and spillover effects. Liew (2020) the study examined the spillover effects of Covid-19 on the Shenzen stock market especially on the tourism shares companies. It observed that 20% of shape down after continuously tree days the announcement of Coronavirus fever in the country. It has a negatively significant impact on the tourism share companies in the Chinese stock market. The spillover effects of the announcement of coronavirus in the country, investors are not buying the share of tourism share in Shenzen stock market. Sharma and Bodla (2010) summarizes results of studies on the integration and dynamic linkages between stock markets, and found that Indian stock market is the place where FDI is ready to invest in it. It also witnessed that other than SAARC nations, are interested to make trade relation with India. Ayub et al. (2020) stated that the regime durability of FDI flow on the 67 countries from 1984-2016. The finding interpreted those countries have benefited from the FDI inflows during the study period. The result concluded that the growing view of the FDI has spill-over effects on the host countries, to observe the new technologies along with the FDI inflows. A number of studies suggested that market integration becomes an integral part of economies over the years. Hamilton and Gang (1996) focused on the periodic behavior of stock returns and growth of industrial production. The stock returns are characterized by high volatility, separated by longer given periods. The causes of economic recessions are high volatility of stock returns. French et al. (1987) evaluated the relationship between stock returns and stock market volatility. In addition, it found the evidence that the expected market risk premium positively related to the volatility of stock returns. They also observe that unexpected stock market returns negatively related to the unexpected change in the volatility of stock returns. The negative relation provides indirect evidence of a positive relation between expected risk premiums and volatility. Gagnon and Karolyi (2006) examined the literature on the dynamics of co-movements in asset prices and volatility across world stock market. It observed that the literature began in the 1970s, in conjunction with early theoretical developments on international asset pricing models. However, it blossomed in the late 1980s and early 1990s. With due availability of comprehensive international stock market databases, the development of econometric model is to measure the price and volatility transmission across several countries. Brooks and Persand (2003) evaluated the volatility forecasting literature in the context of a relatively new use of volatility forecasts for financial markets. Using various linear and GARCH-type models of volatility to compare outputs of multivariate approach. In addition, found that that the relative accuracies of the various methods are highly sensitive to the measured them. Such results have implications for any econometric time series forecasts, which are subsequently employed in financial decision-making. The outcome of Hamilton and Raul (1994) study shows that U.S. weekly stock returns are allowing the parameters of an ARCH effects model. ARCH model is come to know that the several different regimes with transitions between regimes governed by an unobserved Markov chain. Extreme large shocks like market crash arise from different causes and have different consequences for volatility than the small shocks. Moreover, other observation that high-volatility regime is to some degree associated with economic recessions. In addition, the findings of early research that stock price decreases lead to a bigger increase in volatility than would a stock price increase of the same magnitude. Mishra (2010) examined the efficient market hypothesis in its weak form in the framework of random walk model for NSE India. Using ADF, DF-GLS and PP tests to examine stock market efficiency. It also found that the Indian stock market does not follow a random walk model. It have rejected the weak form of efficient market hypothesis. Marcucci (2005) used different GARCH models in terms of their ability to describe forecast volatility in financial time series from one-day to one-month horizon. Markov Regime-Switching GARCH (MRS-GARCH) model used for the analysis. The parameter allowed to switch between low and high volatility regime were analyzed. It found that no model seems to outperform, all the others in forecasting volatility according to the different out-of-sample evaluation criteria adopted. The most common non-linear technique has given good in-sample fit. They usually outperformed in out of-sample forecasting by simpler models using an economic loss function. Nelson et al. (2001) examined the size performance of unit-root tests when the data undergo Markov regime switching. It is considered both process that are $I(0)$ and $I(1)$ in the periods between the regime switch. It also found that previously

documented size, distorted in Dickey-Fuller-type tests caused by a single break in trend growth rate. In addition, variance do not generalize to most parameterizations of Markov switching in trend. ADF test does a poor job of distinguishing an *I*(0) process from an *I*(1) process with Markov-switching breaks in trend growth. (Cavaliere and Eorgiev, 2008) examined the new asymptotic results for the case of Markov regime switches that are infrequent in the sense that their number bounded in probability. The study relates probability of regime switching to the sample size. Moreover, found that the infrequent regime switches invalidate the consistency of the DF test against alternatives such as the stochastic UR model. Chu et al. (1996) examined variations in stock market volatility to regime shifts in stock market returns, by applying Markov switching model to market returns. It measured the variation in volatility in different return regimes. They found that stock returns are best characterized by this model. King and Wadhwani (1990) investigated the reasons for all stocks worldwide falling together in October 1987 despite widely different economic circumstances. They develop a method through which the volatility in one market can be transmitted to another market. They found that the volatility can be self-sustaining. Caporale et al. (2006) studied the transmission of volatility in the 1997 financial crisis by estimating a bivariate GARCH model and carried out LR tests for causality in variation for US, European, Japanese and south east Asian markets. They found the evidence of volatility spillover and the precipitation of the crisis represents a regime switch. Sentana et al. (1994) attempted to examine the time-variation in covariance between international markets. Using data of sixteen stock markets by applying a multivariate factor model in which the volatility of returns is induced by changing volatility in the factors. They found that only a small proportion of the covariance between national stock markets and their time-variation can be accounted for by observable economic variables. Lee et al. (2019) observed that corporate diversification can predict the future stock price of crash risk. The sample has been used in the study from 2010-2015, mitigate the risk from the market based on the coinsurance effect. The result interpreted the dominant effects on the existence of a crash market risk of diversified corporate decisions. Basically, Bad news is hoarding the model of the study. Outcome supports the diversification promoted by the corporate governance of the firm. Diversification is more useful for the management of the firm to handle the risk.

RESEARCH METHODOLOGY

This study adopts the logic-based multi-quantitative study along with the daily closing prices of ten major sustainable indices from across the globe (Greenfield and Greener, 2016). Which is namely, *viz.*, NSE, BSE, CAC40 index, FTSE100, DJIA, Heng Seng, S&P500, KOSPI, Madex and Nikkei225. Ten years closing price data have been collected from 1st January 2009 to 31st December 2017. The data of Sensex and Nifty50 were collected from the official website of BSE and NSE India respectively and other major sustainable indices is collected from the website of (investing.com).

Sustainability index is unique feature, which is focused on the responsibility on social and environment of individual company which listed in the index. Every business accountable for the sustainable business. It also deals with high score of sustainable accountabilities. This is the way these indices are difference from conventional indices of the world.

Table 1 below lists the sustainable indices which exist in different stock markets throughout the globe.

Table 1 Sustainable Indices in the World

S.N.	World Indices	Country	Listed Companies	Exchange
1	NSE	India	Top 50 Companies Weighted	NSE
2	BSE	India	Top 30 Companies Weighted	BSE
3	The CAC 40 index	Paris	Top 40 Companies Weighted	Euronext
4	DJIA	US	Top 30/40 Companies Weighted	DJIA
5	FTSE 100	London-UK	Top 100 Companies Weighted	FTSE
6	The Hangseng index	China	Top 50 Companies Weighted	Hangseng
7	S&P500	US	Top 500 Companies Weighted	S&P500
8	KOSPI	South Korea	Top 200 Companies Weighted	KOSPI
9	The MADEX	Morocco	Most Active Shares Weighted	MADEX
10	The Nikkei 225 Index	Japan	Top 225 Companies Weighted	Nikkei

Source: Sustainable Stock Exchange Initiative (2017)

Various tools have been applied for the empirical analysis i.e, ADF Test, GARCH, EGARCH, PARCH, AIC and SIC criteria, Diagnostic test like Least Square Residuals, Q-statistics and Normality test with the help of E-views software.

QUALITATIVE AND QUNTITATIVE DATA ANALYSIS AND INTERPRETATION

Table 2 Commentary Analysis of Country-wise Regime Switch

S.N.	World Indices	Country	Country-wise Regime Switch
1	NSE	India	07-Jan-09
			18-May-09
			24-Aug-15
2	BSE	India	16-Aug-13
			10-Sep-13
			24-Aug-15
3	The CAC 40 index	Paris	24-Aug-15
			10-Aug-11
			18-Aug-11
			27-Oct-11
			24-Jun-16
4	DJIA	US	10-Feb-09
			10-Mar-09
			08-Aug-11
			30-Nov-11
5	FTSE 100	London-UK	14-Jan-09
			02-Mar-09
			31-Mar-09
			05-Aug-11
6	The Hangseng index	China	06-Oct-11
			08-Jul-15
7	S&P500	US	20-Jan-09
			10-Feb-09
			23-Mar-09
			10-May-10
			04-Aug-11
			08-Aug-11
			09-Aug-11
			11-Aug-11
8	KOSPI	South Korea	16-Aug-11
			19-Aug-11
9	The MADEX	Morocco	21-Feb-11
10	The Nikkei 225 Index	Japan	13-Mar-09
			14-Mar-09
			15-Mar-09
			23-May-13
			13-June-13
			09-Sep-15
			15-Feb-16
			24-Jun-16
			24-Jun-16

Sources: estimated by authors

Regime Switch of Nifty50: 7 January2009 - “The Satyam computers scam was unfolded on January 7, 2009 and as a result, the stock fell 80 percent was the trading was not suspended for the stock. This was a serious blow to the accountability and monitoring mechanism of the Indian financial system. The demand to reverse all the trades that happened in the Satyam share on January 7 has thus gained ground and in reaction to this uncertainty, the Nifty50 saw a correction of 6.18%” (Rediff-Business, 2009). 18 May 2009 – “As a reaction to the United Progressive Alliance's impressive victory in the general elections, trading was halted at the upper circuit as the market rose to 4203 (Higher 14.48 percent) and after the market resumed trading the Nifty50 Ended the day at 4308, higher 17.78%” (Rediff-Business, 2009). 24 August 2015 – “The Indian markets saw a fall due to sharp sell off by foreign investors, rupee fall, Wall Street fall over 3% and a sharp plunge in the Shanghai market of 8% due to the rising concerns of the Chinese stalling economy” (Business Today, 2015).

Regime Switch of Sensex: 16 August 2013 - “Due to fresh concerns about US stimulus withdrawal and rupee plunging to record low of 62; the Sensex saw a fall, which was biggest in last four years. The Sensex ended 3.97% lower at 1859” (Business Today, 2013). 10 September 2013 - “The fact that rupee has been strong has renewed the hopes of foreign funds inflow and as the apprehensions for a US attack on Syria has been averted, the Sensex gained highest since 2009. It ended 3.77% higher at 1997” (Maps of India, 2013). 24 August 2015 – “The Indian markets saw a fall due to sharp sell off by foreign investors, rupee fall, Wall Street fall over 3% and a sharp plunge in the Shanghai market of 8% due to the rising concerns of the Chinese stalling economy” (Business Today, 2015).

Regime Switch of CAC40: 10 May 2010 – “European Central Bank embraces quantitative easing and €750bn Eurozone rescue package is agreed. The pound strengthens against the dollar, the stock markets across Europe plunge. The CAC40 ends 9.66% higher at 3720” (The Guardian, 2010). 10 Aug 2011 - “As the fears in the investors increased of mounting fears about Europe's ongoing debt crisis, the U.S stock markets plunged sharply. Standard & Poor's stripped the U.S. of its AAA credit rating leading to the fear that rating agencies may also downgrade AAA-rated nations in Europe, since they are also struggling with massive debt problems. The CAC40 ended weaker 5.45% at 3,002” (Telegraph, 2011). 18 August 2011 - “In the middle of new funding crisis fragile banks struggle to raise funds in financial markets, investors bolted for cover on fears that the US and the Eurozone were dangerously close to recession and it lead to the weakness of CAC40 5.48%” (Telegraph, 2011). 27 Oct 2011 – “The Eurozone heads proclaim that they had a comprehensive debt plan and that banks would take 50% loss on Greek debt. The deal would reduce the debt to 120% of GDP and the banks would be given eight months to raise Euro 106bn and this was a turning point in the crisis and investors were optimistic on the deal. The CAC gained 6.28% to end at 3368” (Telegraph UK, 2011). 24 Jun 2016 - “British retailers were hit due to fears of the effect the vote of U.K leaving the EU could have on consumer confidence and spending. In addition, House builders were under pressure due to uncertainty over investment in the U.K. post-Brexit and the news that U.K had voted to leave the European Union led to consolidation globally. The CAC40 saw a correction of 8.04% to end at 4106” (Reuters, 2016).

Regime Switch of Dow Jones Industrial Average: 10 February 2009 – “The market is concerned about the higher interest rates and about the inflation rates going higher. The rise in yields and sharp moves in obscure volatility funds that use advantage are the reasons for the market's recent pullback and volatility spike” (Money CNN, 2009). 10 March 2009 - “The Citigroup cooled some worries about its future and the regulators said they might reinstate a key trading rule. The Citigroup was profitable in the first 2 months of the year and they were very positive about its capital position in the future. The DJIA ended higher 5.80% at 6926” (Money CNN, 2009). 08 August 2011 – “The United States lost its coveted AAA rating while gave in the feared reaction of the investors. With the European debt crisis and the rising fears of the U.S recession, The Dow Jones saw a correction of 5.55%” (Money CNN, 2011). 30 November 2011 – “The Federal Reserve offered to work with other central banks to support the global economy. The central banks coordinated market intervention gave investors hope that world leaders could take necessary steps to avoid a credit crunch stemming from Europe’s debt crisis” (Money CNN, 2011).

Regime Switch of FTSE100: 14 January 2009 – “A loss of confidence in the banking sector dragged the FTSE down by 5%. It was a grim day for all the stock markets worldwide” (The Guardian, 2009). 02 March 2009 - “UK banks teetered on the edge of collapse and were bailed out by the Government. HSBC's rights issue was priced at an almost 50pc discount to the closing price and it had previously avoided any form of capital raising. Stock market falls in Asia lead to negative sentiments and FTSE saw a fall of 5.33%” (Money CNN, 2009). 31 March 2009 – “Treasury's plan to buy up bad bank assets was significant and also the government was removing some of the uncertainty around the future of GM and Chrysler, lead to a positive sentiment in the market and the FTSE100 ended 4.34% higher at 3926” (Money CNN, 2009). 05 August 2011 - “The United States lost its coveted AAA rating while gave in the fearful reaction of the investors. With the European debt crisis and the rising fears of the U.S recession, The FTSE saw a correction of 6.01%” (Money CNN, 2011).

Regime Switch of Hang Seng: 06 October 2011 – “Hong Kong shares ended the four day losing streak. The Hang Seng Index out of technically oversold territory but the turnover declined. Gains were supported by a short squeeze, particularly in stocks that had been most battered recently” (Reuters, 2011). 08 July 2015 – “Hong Kong’s benchmark stock gauge plunged the most since the global financial crisis as an equity rout in

mainland China rippled across Asia. Investors were disappointed and afraid that the Chinese policy makers lost control of the market. The Hang Seng ended 5.84% lower at 23,516.6" (Bloomberg, 2015).

Regime Switch of S&P500: 20 January 2009 – "Investors looked beyond President Barack Obama's historic inauguration to the battered economy he inherits. Although Obama is a positive for the markets, his inauguration does not change the underlying issues. Stocks slumped to two-month lows and S&P was a correction of 5.28%".10 February 2009 – "The U.S government's bank rescue plan failed to reassure investors burned by the 14-month-old recession. Treasury prices rallied, lowering the corresponding yields, and the dollar slipped versus other major currencies. The S&P ended lower 4.91% at 827.16" (Money CNN, 2009). 23 March 2009 – "The U.S Treasury's plan to buy billions in bad bank assets and a better existing home sales report lead to the hope that the U.S economy is stabilizing. This lead to a positive sentiment in the market and S&P500 jumped 7% to 822.92" (Money CNN, 2009). 10 May 2010 - "S&P ended 5.16% higher at 5387" (The Guardian, 2010). 04 August 2011 – "U.S. markets were lower due to job worries and Japanese and European policymakers stepped in with dramatic measures to shore up their financial markets. As a result, all the major indices tumbled and erased their gains of the year. The S&P500 ended 4.78% lower" (Money CNN, 2011). 08 August 2011 – "The United States lost its coveted AAA rating while gave in the feared reaction of the investors. With the European debt crisis and the rising fears of the U.S recession, the S&P ended by 6.66%" (Money CNN, 2011). 09 August 2011 – "As the fears in the investors increased of mounting fears about Europe's ongoing debt crisis, the U.S stock markets plunged sharply. Standard & Poor's stripped the U.S. of its AAA credit rating leading to the fear that rating agencies may also downgrade AAA-rated nations in Europe, since they are also struggling with massive debt problems, The S&P ended at 1172" (Telegraph, 2009). 11 August 2011 – "As the fears in the investors increased of mounting fears about Europe's ongoing debt crisis, the U.S stock markets plunged sharply. Standard & Poor's stripped the U.S. of its AAA credit rating leading to the fear that rating agencies may also downgrade AAA-rated nations in Europe, since they are also struggling with massive debt problems" (Telegraph, 2011).

Regime Switch of KOSPI: 16 August 2011 - "the eurozone and US come under increasing pressure to deal with high levels of debt and stave off another recession. UK inflation rates goes higher at 4.4%. The FTSE ended 0.7% higher while KOSPI ended at 1880 higher 4.83%" (Telegraph, 2011). 19 August 2011 – "The Pope criticized economic structures that put profits ahead of people. Bank shares crash amongst the fears of fund crisis. The FTSE and US markets slip as US and Europe move dangerously close to recession. The KOSPI ended 6.22% lower at 1744.9" (Telegraph UK, 2011).

Regime Switch of MADEX: 21 February 2011 – "Libya's escalating political crisis sparked a sharp sell-off, with major indexes posting their biggest one-day drops of the year, as oil prices continued to skyrocket" (Money CNN, 2011).

Regime Switch of Nikkei225: 13 March 2009 – "Japan's big banks may soon need to raise more capital and could go cap in hand to the companies whose weak shares triggered the problem in the first place. Japan's banks held 25.6 trillion-yen ($263 billion) worth of shares as of End of March 2008, according to data from the Japanese Bankers Association. Since then, the Nikkei has dropped nearly 42 percent, implying a loss of nearly 11 trillion yen for the nation's banks" (US-Japan-Bank, 2009). 14 March 2011 – "Despite efforts by the Bank of Japan to shore up confidence, Shares in Japan's major companies fell sharply because of the devastating earthquake and tsunami and the second reactor building at the Diiachi atomic power station had exploded. The Nikkei ended lower 6.18% at 9620" (The Guardian, 2011). 15 March 2011 – "Owing to the earthquake last week, the nuclear crisis of Japan deepened. World markets finished generally lower Monday, as investors assessed the impact of the Japanese disaster on the global economy" (Money CNN, 2011). 23 May 2013 – "After data showing an unexpected contraction in Chinese manufacturing activity added to worries the Federal Reserve could downscale its bond purchases, The Japanese market plunged 7%. There was a fall in the Japanese government Bond yields and it left a negative sentiment among the investors. The nikkei225 ended lower 7.32% at 14483" (Market Watch, 2013). 13 June 2013 – "Uncertainty over central banks rolling back stimulus saw dollar/yen drop below the key 95-handle, rising nearly 2 percent to plumb a new 10-week low. The Bank of Japan launched its stimulus program and ever since, it saw correction. The Nikkei ended at 12445 lower 6.35%" (CNBC, 2013). 09 September 2015 – "Japan's Prime Minister Shinzo Abe proposed a mild corporate tax cut but investors were expecting that move from quite some time. There were no major economic data releases or policy actions. Investors were optimistic that central banks and governments would soon roll out more stimulus measures in a bid to support growth" (Money CNN, 2015). 15

February 2016 – "Tokyo recorded its biggest weekly fall for more than seven years after Business Today years over a slowdown in the global economy and there was an overnight sell off in the banking shares. This was mainly due to the fears about global banks, a rising yen and limitations of government intervention" (California Inc, 2016). 24 June 2016 – "Global markets had generally been trending up in recent sessions on hopes that Britons would choose to stay in the EU, though most polls had indicated it was too close to call. Britain voted to leave the European Union, roiling financial markets and raising fears of a shock to the already fragile global economy. The Nikkei plunged 7.92%" (Reuter, 2016). 10 November 2016 – "Markets reassessed the economic implications of Republican Donald Trump's shock U.S. presidential election victory. Expectations of higher inflation and economic growth under Trump, whose key policy priorities include generous tax cuts and higher infrastructure and defense spending, spurred the sudden reversal in market sentiment" (Independent UK, 2016).

Table 3 Descriptive Statistics of Sustainable Indices

Properties	**Nifty**	**Sensex**	**DJIA**	**CAC**	**FTSE**	**MADEX**	**NIKKEI25**	**S&P50**	**HANGSENG**	**KOPSI.**
Mean	6622.378	21846.7	14861.49	4081.39	6117.651	8589.847	13886.6	1656.304	22138.05	1926.444
Median	6011.9	20031.56	15151.93	4041.035	6162.06	8433.82	14214.73	1650.405	22326.43	1967.88
Maximum	10531.5	34056.83	24837.51	5517.97	7687.77	10965.49	22939.18	2690.16	30003.49	2557.97
Minimum	2573.15	8160.4	6547.05	2519.29	3512.1	6782.18	7054.98	676.53	11344.58	1018.81
Std dev.	1779.312	5628.883	3913.564	664.7493	841.9276	989.7797	4335.658	485.7548	2910.112	249.0094
Skewness	0.2422	0.1474	0.1757	0.1364	-0.5423	0.2251	0.2275	0.0961	-0.3836	-0.7815
Kurtosis	2.238547	2.252534	2.329378	2.25936	3.0164	1.884971	1.624978	1.860026	4.693249	5.046131
Jarque-Bera	78.26741	62.03614	55.0884	59.86725	113.0545	138.9355	201.5263	128.418	332.0545	637.0265
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Sum	15271203	50378493	34270585	9411686	14107304	19808186	32022497	3819437	51050335	4442380
Observations	2306	2306	2306	2306	2306	2306	2306	2306	2306	2306

Source: Author's estimates by Eviews.

Table 3 summarized the data of the daily close prices of the sustainable indices. The volatility of variables in terms of the standard deviation as percentage of means is high in all the indices. It is suggesting that high volatility in the longer time frame supported by small frames of low (Irfan and Hooda, 2017). Skewness of the indices Nifty50, Sensex, DJIA, CAC, MADEX, Nikkei225 and S&P500 are negatively skewed which suggest that numbers of high values are higher than the low values in the time series data. On other hand FTSE100, HangSeng and KOPSI are negatively skewed implying that the low values are higher than the high values (Sharma and Bodla, 2010).

Table 4 Unit Root test of Sustainable Indices in World

Test Critical Value	Nifty	Sensex	CAC	DJIA	FTSE	Hangseng	S&P500	Kopsi	Madex	Nikkei25
1% level	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330	-3.4330
5% level	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626	-2.8626
10% level	-2.5674	-2.5674	-2.8626	-2.5674	-2.5674	-2.5674	-2.5674	-2.5674	-2.5674	-2.5674
Dickey-fuller test	-44.684	-44.726	-47.930	-50.709	-46.993	-46.890	-50.204	-47.566	-40.024	-49.483
Probability	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000	0.0001

Source: Author's estimates by Eviews.

As mentioned, the Augmented Dicky-Fuller (ADF) test has been used to examine the stationarity of the ten time series, namely, NSE, BSE, CAC40 index, FTSE100, DJIA, Hengseng, S&P500, KOSPI, Madex and Nikkei225, Stated the same interpretation of Irfan (2021). All the series appear to be stationary in the on first difference. However, we decided to further carry out a rigorous test of ADF to these series by estimating the following one models i.e. equation (1), same as follow in Irfan (2020).

Intercept and trend model

$$\Delta y_t=\alpha_0 + \alpha_1 t + \gamma y_{t-1} + \sum_{i=1}^{u} \beta_i \Delta y_{t-i} + \varepsilon_t \quad (1)$$

where y is the time indices series of different country.

The outcome of Table 4, the unit root test on the variable ADF of the sustainable indices. The assumptions of ADF test were fulfilled at 1st level Difference this ADF test has been checked on the variable - intercept. The ADF test is used to check the stationarity of data and as the data becomes unit root at 1st difference, the data is stationary (Irfan, 2016).

Table 5 GARCH model results on Sustainable Indices

Mean Equation				
Variable	Coefficient	Std. Error	z-Statistc	prob.
C	-576.9254	42.13999	-13.69069	0.000
Variance Equation				
C	6978.385	541.590	12.885	0.000
RESID(-1)^2	0.781	0.065	12.103	0.000
GARCH(-1) ^2	-0.021	0.030	-0.693	0.488

Source: Author's estimates by E-views.

$$\sigma_t^{\delta} = \alpha_0 + \sum_{i=1}^{n} \alpha_1 \varepsilon_{t-1}^{\delta} + \sum_{i=1}^{n} \alpha_2 \, \sigma_{t-1}^{\delta} + \sum_{k=1}^{n} \gamma_k \varepsilon_{t-1}^{\delta} \, I_{t-k} \tag{2}$$

where I_t =1 if $\varepsilon_t < 0$ and 0 otherwise

If , $\varepsilon_{t-1} < 0$ is not the sign of good result, and $\varepsilon_{t-1} > 0$ is good sign to conditional variance.γ_k >0 it shows the volatility. It can be a leverage effect for order. If γ_k not equal to 0 the news impact is asymmetric.

Here σ_t^2 shows the GARCH at t time, α_0 is the constant C, α_1 is the coefficient for residual with lag period, α_1 is the coefficient for GARCH lag period, γ is leverage effect by residual's lag as well as constants lag effect from time t to k. The estimated result is given in Table 5 (Irfan, et al., 2021) interpreted in the same manner.

Table 5 shows the output of the GARCH model. The constant C is not significant in the mean equation while it is significant in the variance equation. The variance equation describes that the RESID(-1)^2 term is statistically significant at the close price of sustainable indices which implies that the volatility of the risk is influenced by past squared residual terms. The GARCH(-1) term is not statistically significant in the sustainable indices, which implies that the past volatility of the sustainable indices does not significantly influence the current volatility of the sustainable indices, Tsen et al. (2018) stated on the same results on the Malaysian stock market.

Table 6 EGARCH model results on Selected Sustainable Indices

Mean Equation				
Variable	Coefficient	Std. Error	z-Statistc	prob.
C	-631.968	31.558	-20.026	0.000
Variance Equation				
C(11)	2.799	0.368	7.599	0.000
C(12)	1.171	0.076	15.395	0.000
C(13)	0.025	0.043	0.598	0.550
C(14)	0.615	0.039	15.606	0.000

Source: Author's estimates by Eviews.

$$\sigma_t^{\delta} = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \sigma_{t-1}^{\delta} + \alpha_2 \sum_{j=1}^{n} (\varepsilon_{t-1} | \sigma_{t-1}) + \cdots + \alpha_2 \sum_{j=1}^{n} (\varepsilon_{t-4} | \sigma_{t-4}) + \gamma_k \sum_{k=1}^{n} (\varepsilon_{t-k} | \sigma_{t-k}) \tag{3}$$

If , $\varepsilon_{t-1} < 0$ is not the sign of good result, and $\varepsilon_{t-1} > 0$ is good sign to conditional variance.γ_k >0 it shows the volatility. It can be a leverage effect for order. If γ_k not equal to 0 the news impact is asymmetric.

Here σ_t^2 shows the EGARCH at t time to generalized error distribution by ε_t, α_0 is the constant C, α_1 is the coefficient for residual with lag period, α_1 is the coefficient for EGARCH lag period, γ is leverage effect by residual's lag as well as constants lag effect from time t to k . The estimated result is given in Table 6.

Table 6 shows the results of equation 3 of the EGARCH model which demonstrates that the term, C, is not statistically significant in the mean. The variance equation describes that the C(11), C(12) and C(14) terms are statistically significant except C(13), which imply that the past volatility of sustainable indices are significant and influence current volatility. The EGARCH variance equation also signifies that there exists the asymmetric behavior in volatility, which means that positive shocks are affecting differently than the negative impact on volatility.

Table 7 PARCH model results on selected Sustainable Indices

Mean Equation				
Variable	Coefficient	Std. Error	z-Statistc	prob.
C	-565.765	43.394	-13.038	0.000
Variance Equation				
C(11)	189376.500	521497.200	0.363	0.717
C(12)	0.823	0.114	7.237	0.000
C(13)	0.024	0.037	0.653	0.514
C(14)	-0.008	0.017	-0.440	0.660
C(15)	2.718	0.609	4.462	0.000

Source: Author's estimates by Eviews.

$$\sigma_t^{\delta} = \alpha_0 + \alpha_1 \sum_{i=1}^{n} \sigma_{t-1}^{\delta} + \alpha_2 \sum_{j=1}^{n} ((\varepsilon_{t-1}) - \gamma_i(\varepsilon_{t-1})) \quad (4)$$

Table 7 shows that the output of the PARCH model which is simply a standard GARCH specification, highlights the value of the constant C which is not significant in the mean but is significant in the variance equation. The variance equation coefficient of PARCH describes the C(12) and C(15) are statistically significant, meaning that the past volatility of the close prices of the sustainable indices which is significant in influencing the current volatility. Coefficient GARCH does not significant, and negative and less than 0 indicating the impact is symmetric. The analysis shows that the close price of the sustainable indices is associated with stock market volatility.

Table 8 AIC and SIC criteria for Best Fitted Model

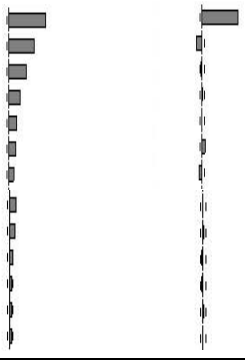
Criteria	GARCH	EGARCH	PARCH
Akaike info criterion	12.70525	12.7213	12.706
Schwarz info criterion	12.73762	12.75617	12.743

Source: Author's Estimatesby eviews.

Table 8 shows that the AIC and SIC criteria of all the three models. AIC and SIC criteria indicate lower the value better the model fit. It is concluded that the GARCH model is the best fitted model as it has the lowest value of AIC and SIC (12.70525, 12.73762) respectively as compared to two models EGARCH and PARCH. Now run the diagnostic check of the GARCH model, Gooi et al. (2018) has done the same interpretation of GARCH family model.

Diagnostic Statistics In The Garch Model

Table 9 Q-statistics for Serial Correlation

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.76	0.76	1332.9	0.6
		2	0.53	-0.111	1982.2	0.5
		3	0.357	-0.014	2276.9	0.5
		4	0.243	0.012	2412.9	0.8
		5	0.166	0.002	2477	0.5
		6	0.143	0.068	2524.5	0.7
		7	0.107	-0.049	2550.8	0.8
		31	0.104	0.003	2848	0.6
		32	0.085	0.009	2865.1	0.6
		33	0.062	-0.023	2874	0.9
		34	0.037	-0.015	2877.2	0.8
		35	0.027	0.016	2878.9	0.6
		36	0.027	0.005	2880.6	0.8

Source: Author's Estimatesby eviews.

Table 9 shows that the correlogram of Standardized residual squared, there is no serial correlation in the data meaning that first condition of robustness verification with lag 36 is satisfied.

Table 10 Heteroskedasticity Test: ARCH

F-statistic	5541.953	Prob. F	(1,2303)	0.5
Obs*R-squared	1628.334	Prob. Chi-Square	(1)	0.6

Table 10 shows that there is no ARCH effect in the data because the p-value is more that 5%, here second condition is satisfied.

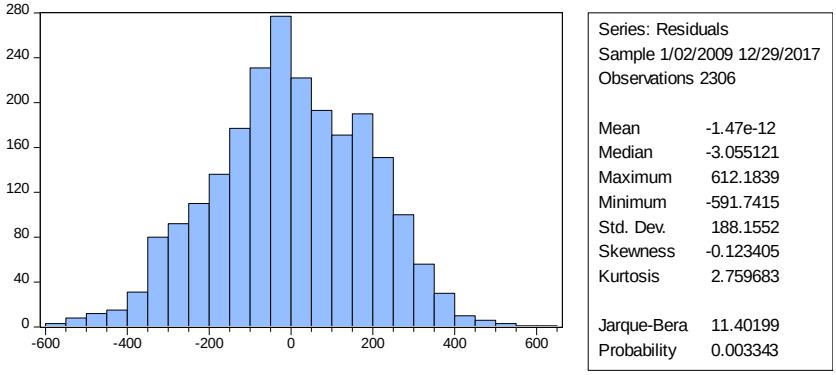


Figure 1 Normality Test

Figure 1 is the last and third condition to be verified for the robustness of best-fitted model in the GARCH model. It is important to check whether the residuals are equally distributed or not. Here, P-value is less than 5% and therefore we accept the null hypothesis, showing that the residuals are not normally distributed.

This model has no serial correlation and no ARCH effect but residuals are not normally distributed and only the first two conditions are satisfied and not the third. In this situation many of economist says that accept the model (Herper and Jin, 2012) two conditions for best fitted model and accept GARCH model as best fitted model.

CONCLUSION

The objective of this paper was to estimate the best-fitted volatility model from the ARCH family models and to investigate the cases of regime switch of the sustainable indices. Researchers have been found numerous cases of regime switches in the sustainable indices. There have been various reasons for this regime switch includes natural calamities as in the case of Japan, the financial crisis in the United States as also the United Kingdom's decision to exit from the European Union which lead to financial crunch in the United Kingdom banks. Some of these regime switches also resulted in volatility spillover in other markets.

In this study the GARCH, EGARCH and PARCH models applied as benchmark models for the study purpose. GARCH model is the best-fitted model as it has the lowest AIC and SIC values. The first hypothesis does not reject, the variance equation coefficient of square of residual with lag term is statistically significant at the close price of sustainable indices which implies that the volatility of the risk is influenced by past squared residual terms. The lag coefficient of GARCH term is not statistically significant in the sustainable indices, which implies that the past volatility of the sustainable indices does not significantly influence the current volatility of the sustainable indices. The EGARCH variance equation also signifies that there exists the asymmetric behavior in volatility, which means that positive shocks are affecting differently than the negative impact on volatility. The variance equation coefficient of PARCH describes meaning that the past volatility of the close prices of the sustainable indices which is significant and influencing the current volatility positively.

On the basis of these result discussion, the second hypothesis rejected and the volatility of regime switching determining the sustainability of indies. The results imply that there is significant impact of the regime switch on the price volatility of the sustainable indices. The outcomes of the study have shown that the past volatility of the sustainable indices significantly influences the current volatility of the sustainable indices. Therefore, it is demonstrated that the asymmetric behavior exists in volatility, indicating that the positive shocks affect volatility differently than the negative ones. The investors can take better investment decisions based on the past volatility trends and the impact of regime switch of one index on other sustainable indices.

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