ANALYZING THE LONG MEMORY AND CONTAGION EFFECT WITH THE PRESENCE OF STRUCTURAL BREAKS

A THESIS SUBMITTED FOR THE DEGREE OF DOCTOR OF PHILOSOPH

Anwar Yimam Wasia

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Department of Business Administration
Finance Program

Supervisor: Prof. Dr. Güven Sevil

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Graduate School of Social Sciences
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FINAL APPROVAL FOR THESIS

This thesis titled **"Analyzing The Long Memory and Contagion Effect With The Presence of Structural Breaks"** which has been prepared and submitted by **Anwar Yımam WASIA** in partial fullfillment of the requirements in **"Anadolu University Directive on Graduate Education and Examination"** for the PhD. in **Department of Business Administration Finance** has been examined and approved on 27/12/2021.

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ABSTRACT

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This thesis presents two essays on long memory and shift-contagion effect. The first chapter investigates long memory properties for German, France, Turkey, the Netherlands, England, Italy, and US stock market returns within the framework of weak-form efficient market hypothesis and asset allocation. Weekly data are used for the period January 1998- December 2019 in both chapters of the thesis. The study uses the ARFIMA-FIEGARCH model to examine the long memory in seven stock indices returns. In addition, change points are detected by employing of Bai-Perron structural test. The findings suggest that the stock returns are highly persistent in almost all European and US stock indices except for Turkey. These markets are interdependent which violates the weak efficiency of the market hypothesis. This would mean that historical returns can contribute to predicting future returns in those markets. Then, the study compares the persistence of volatility with and without structural breaks. Due to its structural breaks, the results are mixed. The finding of the study shows that structural break effectively reduces the persistence of volatility in the countries of Germany, France, England, and the Netherlands. Whereas the long memory value for each index of FTSEMIB, BIST100, and S&P500 does not reduce the persistence of volatility or long memory. The findings offer valuable insights and create an opportunity for skilled investors to make speculative profits consistently.

The second chapter examines the shift-contagion effect of stock markets with the presence of structural breaks for asset allocation and risk management. I propose the bivariate DCC-GARCH model to test shift contagion between European countries of Germany, France, Italy, Netherlands, England, and Turkey indices with the US index. Our results suggest that the dynamic conditional correlations do not show a positive

increase between European and US markets as well as a weak in market co-movements. The weak values of correlations suggest that they enable investors to get long-term benefits by diversifying over across markets. The relationship of the US stock market with each European market is not contagious but the markets are only interdependence. We conclude that investors would achieve a greater advantage of diversification in European and US stock markets. However, the study found shift contagion between US and Turkey stock markets co-movement. So, a higher degree of relationship between markets would reduce the diversification benefits in the period of crisis.
Keywords: DCC-GARCH Model, FIEGARCH, Contagion Effect, Long memory

ÖZET

Doktora Tezi

UZUN HAFIZA VE BULAŞMA ETKİSİNİN YAPISAL KIRILMALARIN VARLIĞIYLA ANALİZ EDİLMESİ

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Tez çalısması uzun hafıza ve bulaşıcılık etkisi konularyla ilgili iki araştırmayı içermektedir. Birinci bölümde, menkul kıymetlerin fiyatlarının zayıf etkinlikteki piyasalar hipotezi ve varlık dağılımı çerçevesinde Almanya, Fransa, Türkiye, Hollanda, İngiltere, İtalya ve ABD hisse senedi getirileri için uzun hafıza özelliklerini incelemektedir. Çalışmada Ocak 1998- Aralık 2019 dönemine ait haftalık veriler kullanılmıştır. Çalışmada yedi hisse senedi endeksi getirisindeki uzun hafıza özelliğini incelemek için ARFIMA-FIEGARCH modeli kullanılmıştır. Ayrıca, Bai-Perron yapısal testi kullanılarak değişim noktaları tespit edilmiştir. Bulgular, hisse senedi getirilerinin Türkiye hariç hemen hemen tüm Avrupa ve ABD hisse senedi endekslerinde oldukça kalıcı olduğunu göstermektedir. Bu piyasalar, piyasa hipotezinin zayıf etkinliğini ihlal edici şekilde birbirine bağımlıdırlar. Bu durum, tarihsel getirilerin, bu piyasalarda gelecekteki getirilerin tahmin edilmesine katkıda bulunabileceği anlamına gelmektedir. Çalışmada, yapısal kırılmaları olan ve olmayan oynaklığın kalıcılığı karşılaştırılmıştır. Yapısal kırılmalar nedeniyle elde edilen sonuçlar karmaşıktır. Çalışmanın bulgusu, yapısal kırılmanın Almanya, Fransa, İngiltere ve Hollanda ülkelerinde oynaklığın kalıcılığını etkin bir şekilde azalttığını göstermektedir. Oysa, FTSEMİB, BIST100 ve S&P500'ün her bir endeksi için uzun hafıza özelliği değeri, oynaklığın kalıcılığını veya uzun hafıza özelliğini azaltmamaktadır. Bulgular değerli öngörüler sunmaktadır ve yetenekli yatırımcıların tutarlı bir şekilde spekülatif karlar elde etmeleri için bir fırsat yaratmaktadır.

İkinci bölümde, varlık tahsisi ve risk yönetimi için yapısal kırılmaların varlığı ile hisse senedi piyasalarının değişim bulaşıcılığı etkisi incelenmiştir. Avrupa ülkeleri Almanya, Fransa, İtalya, Hollanda, İngiltere ve Türkiye endeksleri arasındaki bulaşıcıklığı ABD endeksi ile test etmek için iki değişkenli DCC-GARCH modeli kullanılmıştır. Sonuçlar, dinamik koşullu korelasyonların Avrupa ve ABD piyasaları arasında pozitif bir artış göstermediğini ve piyasa ortak hareketlerinde zayıf olduğunu

göstermektedir. Korelasyonların zayıf değerleri, yatırımcıların piyasalar arasında çeşitlendirme yaparak uzun vadeli faydalar sağladıklarını göstermektedir. ABD borsasının her bir Avrupa piyasasıyla ilişkisi bulaşıcı değildir. Ancak, piyasalar yalnızca birbirlerine bağımlıdır. Yatırımcıların Avrupa ve ABD hisse senedi piyasalarında çeşitlendirmeden daha büyük bir avantaj elde edecekleri sonucuna ulaşılmıştır. Bununla birlikte, çalışmada ABD ve Türkiye borsalarının ortak hareketi arasında değişim bulaşması olduğu tespit edilmiştir. Dolayısıyla, piyasalar arasında daha yüksek düzeyde bir ilişki, kriz döneminde çeşitlendirme faydalarını azaltacaktır.

Anahtar Kelimeler: DCC-GARCH Modeli, FIEGARCH, Bulaşma Etkisi, Uzun Hafıza

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STATEMENT OF COMPLIANCE WITH ETHICAL PRINCIPLES AND RULES

I hereby truthfully declare that this thesis is an original work prepared by me; that I have behaved following the scientific ethical principles and rules throughout the stages of preparation, data collection, analysis, and presentation of my work; that I have cited the sources of all the data and information that could be obtained within the scope of this study, and included these sources in the references section; and that this study has been scanned for plagiarism with "scientific plagiarism detection program" used by Anadolu University, and that "it does not have any plagiarism" whatsoever. I also declare that, if a case contrary to my declaration is detected in my work at any time, I hereby express my consent to all the ethical and legal consequences that are involved.

(Signature)

Anwar Wasia

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ABBREVIATIONS

ADF :Augmented Dickey-Fuller

AEX :Amsterdam Exchange Index

ARMA :Auto-Regressive Moving Average

BIS :Bank for International Settlements

BIST100 :Borsa Istanbul stock exchange

CAC40 :Paris Stock Exchange

DAX30 :Deutsche Aktien Index

EMH :Efficient Market Hypothesis

ECB :European Central Bank

EU :European Union

ICSS :Iterative Cumulative Sum of Squares

FIEGARCH :Fractional Integrated Exponential Generalized Autoregressive Conditional Heteroscedastic.

FTSE100 :Financial Times Stock Exchange 100 (at London Stock Exchange)

FTSEMIB :Financial Times Stock Exchange for the Milano Index Borsa

HYGARCH :Hyperbolic Generalized Autoregressive Conditional Heteroscedasticity

NPCPM :Nonparametric Change Point Model

PP :Phillips- Perron

S&P 500 :Standard and Poor's 500

SV :Stochastics Volatility

US :United State

GENERAL INTRODUCTION

In the past two decades, several financial crises have occurred and have brought devastating losses in capital markets. Kolb (2011), Shomali & Giblin (2010), and Qureshi, Uddin, & Jienwatcharamongkhol (2019) recall some of the major ones. These crises are the Asian crisis of 1997, the Russian crisis of 1998, the Brazilian crisis of 1999, the Turkish crisis of 2000/2001, the global economic crisis of 2007–2009, and the European public debt crisis of 2010. Next from the Great Depression of the 1930s, 2007-2009 global financial crisis was widely regarded as one of the most severe crises. The US mortgage crisis is claimed as the cause for the devastating shocks of the global financial crisis (GFC), and eventually the Euro-Zone Crisis (EZC) in 2010. European economies collapsed into debt crises to various levels by the end of 2009. The global financial crisis caused asset prices to decline across various markets (Terazi & Senel, 2011). It created speculative risks and capital outflows, which contributed to the subsequent significant market volatilities. Furthermore, it triggered the failure of investors' confidence, which in turn adversely affected economic developments worldwide.

There have been varied explanations offered by academics and experts in discussing the financial crises in the past two decades. Often these varied explanations emanate from some initial philosophical flows exhibited both in theoretical perspectives and in methodological approaches. As such, various assumptions, at times recession ones, have been suggested by scholars about factors that caused the past financial crises. Some of the factors may not be exclusively the causes but are presumably the factors that fomented the financial crises in the past two decades. Hence, the degrees of the factors affecting the crises are different and at times of recession.

For instance, the subprime mortgage crisis has been the widely held assumption as the cause for the 2008 global financial crisis. Like many works of literature show, the subprime mortgage crisis had a greater impact on European and US financial markets. As a result, the existence of a real estate bubble in the US economy and the subsequent mortgage crisis was primarily proposed as the cause of the global financial crisis (GFC). Yet the real crisis narrative is much more complex than this reason. Aliber & Zoega (2019) indicate some contested claims about major causal factors to the 2008 global financial crisis. Emphatically, Buckley & Arner (2011) denies the claim pointing to the subprime mortgage as the prime cause for the devastating global financial crisis. Instead, Buckley and Amer associate the failure with bankers, elites in the government, and monetary regulators. Buckley and Amer have a strong suspicion of the widely held assumption of blaming subprime mortgages for all the failures as if they all are emanated from the financial crisis then back. This implies scholarly approach towards long memory and contagion effects about the transfer of shocks to capital markets is indispensable. This would have several significances. Contagion could have profound implications for determining the process of international asset allocations, for investigating the movement towards global integration of financial markets, and for having a broader understanding of processes and implementations of strategies in international capital markets.

Analysis of long-term memory and contagion effects between stock markets has gained significant attention. Because it has implications for portfolio diversification and risk evaluation. In many kinds of literature of finance and economics, there is no agreed single definition of contagion. Kao, Zhao, Ku & Nieh (2019) have reviewed World Bank working papers and have identified the definitions of contagion as broad, restrictive, and extremely restrictive. Contagion is broadly defined as the cross-country transmission of shocks or cross-country spillover effects, whether during a crisis or a calm period. Contagion is defined as the transmission of shocks to other countries or the cross-country correlation, irrespective of any fundamental link between the countries, in the restrictive definition. Contagion is defined as an increase in cross-country correlations during crisis times compared to correlations during stable times in the most restrictive definition. On other hand, Forbes & Rigobon (2002), the definition of contagion is a significant positive increase of co-movement of cross-markets after a crisis occurs.

In the monetary economy, Claessens & Forbes (2001a) describe that contagion can propagate through different channels. By this, different theories explain cross-country linkage channels, contagion effects, and interdependence of financial markets. In fact, the three key linkage channels; namely, financial connections, real linkage or macro-economic linkage, and political linkage are the commonly used ones in the discourse of contagion effect's linkage channels. Forbes & Rigobon (2002) point that the countries are the cross-market links within the international financial capital markets. Forbes & Rigobon classify the channels of contagion into real and financial linkages. Peiwan, Wang & Zong (2020) identified the strongest linkages in a highly integrated financial system. Among various financial markets, along with currency, housing, stock, and interest rate markets. Housing and stock markets are significantly the highest roles in the spreading of shocks.

In the monetary intermediation of any global economy, capital markets have key roles by stabilizing financial sectors and facilitating essential investment channels. BIS (2019), such stabilized financial sectors and facilitated investment channels are opportunities to attract both domestic and external capital flows. In addition, developed and structured capital markets are important roles in financing economic growth and influencing financial stability. They contribute to risk sharing, and support for asset allocation. Ahmad, Abdullah, Sulong, and Abdullahi (2015) claim that stock markets are also valuable tools to mobilize and allocate assets among investors. From the fact that stock markets are vital aspects of asset markets, which have the potential to strengthen the financial system of a country by offering various sources of financial instruments and advantageous for a country, for they open financing sources of investments.

As many financial works of literature state, stock markets are the sensitive markets that drastically influence a country's economic condition and financial system. Attesting this, Barakat, Elgazzar, and Hanafy (2016) underscore the need for cautious decisions in stock markets, for any aggressive shift in the stock markets could have major effects on the entire economy of the country. Hence, the stock market is one of the fragile economic assets; thereby, a significant change in stock prices could have adverse effects on the economy. For this reason, the causal relationships between macroeconomic variables and stock prices have stimulated the interest of theoreticians and practitioners. As such, the various kinds of literature on the behavior of stock prices have attempted to show new insights for increasing the integration of international financial markets. Rui, Rasiah, Yuen, Ramasamy & Shalini, (2018) emphasize capital markets. Hedgers, speculators, and arbitrageurs would understand the time-series properties of stock returns and risks.

Stavarek, Repkova & Gajdosova (2011) describe the growth of the economic market integration because a country's financial system is inextricably linked to another country's financial system; at times, the systems are inseparable. For instance, Terzi (2011) indicates, financial integration has intensified in the European financial markets after the adoption of the common currency in 1999. Financial integration provides opportunities for investors by doing risk sharing, better allocation of assets, and diversification among asset investments. In contrast, Fidrmuc & Schardax (2000) suggest, financial integration can increase the vulnerability of financial markets. Increasing capital flows aggravate economic pressure and reveal the economic system's vulnerability.

The stock markets in Europe and the US have been an alternative for attracting foreign investors. In addition, Sooreea & Wheeler (2011) illustrates, these stock markets are strongly interdependent particularly UK, Germany, and Italy with the US. These markets are sources of external funds. Belcaid & El Ghini (2019) emphasizes, with globalization and many financial crises, a better understanding of long memory and contagion effects on financial markets has a myriad of advantages. Particularly, issues of long memory and contagion effects examined along the lines of structural breaks are strongly related to stock market returns. Scholarly approaches to these issues are very much important for evaluating investments and a country’s selection decisions in globally and regionally diversified portfolios. As Roll & Brealey (1970) indicate, diversification alone does not guarantee losses in a declining economy. Obviously, investments in stocks are susceptible to systematic and unsystematic risks like interest rate risks, inflation risks, currency volatility, financial risk, and political instability. As result, international investments have brought huge risks. The risks of the investment in portfolio stocks can reduce to some extent because changes in market conditions affect the prices of all stocks and other assets.

This study has two parts. The first part deals with long memory in structural breaks at stock indices volatilities in Europe and the US. The subject of persistence in stock return has practical contributions. Persistence in stock returns has an impact on the market's efficiency of securities. The study found that the existence of persistence in return volatility of stocks in the United States and Europe. The market will not respond instantly to new information. They have long-term dependence characterization of asset returns; however, investors will react to market information gradually. International investors can do asset allocation throughout the persistence of stock indices returns due to the predictability of markets. The empirical investigations of the first part are carried out as follows: First, stock index change points are detected using (Bai & Perron, 2003) method, while episodes of long memory are examined using the FIEGARCH model.

The second part of this study investigates the contagion effects among stock indices returns in Europe and the US. The conditional correlation has proved, it is a key issue for successful international asset allocations and effective asset management.

Similarly, asset pricing and arbitrage pricing theories suggest that the correlation trend of risk and return determine asset allocation and diversification strategies. Among stock markets, cross-market linkages and associations are especially important for designing speculation and optimal dynamic hedging strategies. Concerning stock markets, international investors can allocate assets to the European and US equity markets. The investors are enhancing the risk-return potentials of investment and encouraging effective risk management. Hence, the second part employs the time-varying (Engle, 2002) dynamic conditional correlation (DCC) multivariate GARCH model and Stochastic Volatility (Nakajima, 2011). Correlation parameters of European and the US stock indices are determined by the model. Furthermore, the breakpoints at the time of crisis are also identified by employing the Bai & Perron (2003) method. Thus, the study compares the correlation coefficients in the crisis period, which differ from the pre-crisis, and post-crisis periods.

Cognizant of the above, investigation of structural breaks in line with economic time series analysis of long memory and with an exploration of contagion effects using latent correlation analysis is found vitally important. Latent factor analysis is an umbrella term implying there are versions of analytical tools within. Hence, to emphasize the unobserved (i.e., the latent) correlation, latent correlation analysis is used particularly in investigating contagion effects in the existence of structural changes. The analytical tools applied for investigating long memory and for exploring contagion effects are different since the grand objectives of studying the two aspects of risks, namely long memory and contagion effects are different. However, as stipulated in the final section of this study, studying long memory and contagion effects in the existence of structural changes is indissolubly.

I. ANALYSIS OF LONG MEMORY: STRUCTURAL BREAKS IN VIEW

1.1 INTRODUCTION

Academicians and practitioners suggest different, yet closely related causal factors for explaining the successive financial crises that the world has experienced in the last two decades. Many scholars agree what means the international economic crisis of 2007\2009 has triggered the attention of many monetary analysts to look deep into long memory. For instance, Ural & Küçüközmen (2011) indicates the importance of investigating long memory between the European and US stock indices. According to Gil-Alana, Gupta & Roubaud (2019), the results of the time-series analyses of long memory and the assumed structural breaks are closely interconnected.

Ferreira, Menezes, & Oliveira (2013) point out structural changes or breaks observed at times of crisis would have affected the stock returns and econometric models in the financial time series. Similarly, Lakshman & Dayaratne (2012) analyze the possible relationship between volatility and financial crises. They claim that the main cause for the volatility in the stock markets is linked with the highly competitive nature of the business world. They associate the social, political, and economic events as the major contributing factors for the growing phenomenon in the volatility of economic systems and the ensuing financial crises. However, an important aspect of studying long memory along the lines of a time series analysis has gotten less scholarly attention. Nor considerations of the intermittent structural breaks affecting the stock markets and returns between the major European countries and the United States have been done. No appropriate analytical models have been employed in many previous studies to verify the interfaces between volatility in financial systems and the ensuing economic crises. The complexity of studying long memory along with investigating the sophisticated properties of structural breaks has not been seriously studied to the extent it deserves. Understanding long memory as manifested either in regime or in occasional structural breaks would have myriad implications and relevance. Nonetheless, the prevailing knowledge gaps in this regard have opened loopholes for mistaken financial decisions made by monetary regulators, authorities in central banks, investors, and so forth. Hence, investigation of the consequential patterns of long memory in structural changes, and examination of stock markets and returns employing appropriate methodological tools would have been of optimal capabilities of estimations and predictions.

Basically, the long memory is described in line with the analysis of the observed level of strong persistence to autocorrelations. Hassler (2019) illustrates how long memory in financial time series works to realize financial behavior. In addition, Hassler explains long memory in volatility especially applicable to assess stochastic volatility processes. By this, the effects of long memory can be realized in situations of volatility on stock market returns. Hassler indicates the pattern of long memory as it is a long-range dependence. On other hand, financial behavior in a country's temporality analysis of long memory indicates the long-range dependence of episodic economic and financial occurrences. Often, temporality analysis of financial activities does not show instantaneous effects of long memory rather shows slowly decaying correlations. In line with this, Briere, Burgues & Signori (2010) illustrate how aspects of volatility persistence of stock market return and related to long-term options price and optimal portfolio allocations. This in turn points to the vulnerability of stock market returns to investment horizons. As such, investments in optimal hedging strategies, which must consider long-range dependencies of volatility, are pursued to manage the risk of stock indices. Similarly, French, Schwert, & Stambaugh (1987) indicate how the persistence of stock prices in volatility has profound repercussions for stock market predictabilities and premiums of risk.

Consequently, investigating the persistence of stock index return has been an important issue and research focus both in theoretical and empirical research. If stock returns show persistence in volatility, they implicitly inform that the statistical results are dependent on overtime and values of stock returns. For instance, Fama, Fisher, Jensen, and Roll (2005) explain how the Efficient Market Hypothesis (EMH) of persistence in volatility has been proved. By this, stock market prices reflect all available and relevant information, so they must follow a random walk process. As a result, market efficiency implies that no pure arbitrage opportunities exist. Historical data does not support asset returns. Similarly, Baillie, Han, Myers & Song (2007) have studied how market efficiency and persistence of asset returns. They show that the long-range dependence has shown a hyperbolic decreasing tendency to autocorrelation functions of returns and volatility. They also imply what is meant by gradual mean reversion and asset price decay. They conclude, in a situation where the price movements have a long-range dependence, the asset prices can be predictable; thereby, plausible forecasting of the financial behavior would be by using historical data of return prices.

The long-term dependence characterization of asset prices shows that the market would not respond instantly towards the information, then investors will react to market information gradually. Gil-Alana & Caporale (2008) indicate occurrences of persistence in asset prices often refute the theory of an efficient market. These occurrences of persistence can be solid grounds for predictions of prices. Furthermore, the use of long-range historical data of asset prices would enable investors to have informed knowledge of forecasting future returns and of making consistent speculative decisions. Bentes, Menezes & Mendes (2008) explain the benefits of studying long memory that reflect long-run dependencies among equity returns and prices. By this, Price movements clusters explain the natural inclination. For large changes in asset prices are followed by large changes in stock market returns, and also for small changes in asset prices are followed by small changes in stock market returns. As such, these concepts of returns and prices are strongly interrelated, and they are often viewed as complementary.

In financial economics, several studies have addressed structural changes, which have been particularly developed for the case of single changes. This attests to how multiple structural breaks have gotten that much less consideration. In other words, in many of the previous research, investigations about investigations into the presence of breakpoints in the long memory of stock prices have noticeable methodological flaws as revealed in the results of this research. For instance, Andreou & Ghysels's (2002) study is not supported with empirical evidence of the possibly existing structural breaks. Stock market prices can lead to a forecasting degree of persistence. It is undervalued or overvalued volatility on average for prolonged periods when researchers use fixed or standard GARCH models to generate volatility forecasts. Attesting this, Beran, Feng, Ghosh, & Kulik (2013, 55) explain the methodological limitations of using the already existing GARCH models in a nutshell. They state that "GARCH (p, q) models cannot explain the empirical observation that often dependence in volatility is rather strong and long-lasting while the process still seems to be stationary." For this reason, Beran et al. propose extended versions of GARCH models to capture empirical observation of dependence patterns in volatility and to investigate long-range dependence.

In some other cases, the empirical studies to generate volatility forecasts have particularly employed the uses of the univariate GARCH model, fixed GARCH model, and cointegration test model. As such, these empirical studies have not offered appropriate and plausible results in the persistence of volatility. For instance, Kasman & Torun (2007) have evaluated the long-term dependence of the Turkish equity markets, but they have neglected the possible structural breaks. Similarly, Kasman, Turgutlu & Ayhan (2009) describe the persistence of volatility of central Europe stock markets without inclusive structural breaks. Furthermore, many other empirical studies in the persistence of crisis are more focused on the exchange rate markets, commodity markets, and debt markets in developed countries than on the possible structural breaks. Moreover, Wang & Moore (2009) have investigated the persistence of Central Europe equity markets with structural breaks. They have conducted their research without the use of an appropriate fractionally integrated persistence variance model. Hence, their study provided biased results possibly due to an inappropriate specification model.

Currently, statistics and econometrics have developed multiple structural change models. Among them, Bai & Perron (2003) test multiple structural changes and treat them in the context of a model. They provide consistent estimates of breakpoints due to efficient algorithms and procedures to detect the number of breakpoints. Beran, Feng, Ghosh & Kulik (2013) and Hassler (2019) state, Mandelbrot & Walles, (1969) work is the precursor for proposing the R/S analysis to test long memory properties. This statistical tool of the R/S analysis has been widely employed for the study of the long memory of volatility in equity markets. Following Mandelbrot’s seminal work, which does many scholars regard as the vigorous quality of R/S analysis; several other methodologies that are applicable for studying long memory in financial markets have been introduced.

Giraitis, Leipus, & Surgail (2007) compare several models under the ARCH general heading. Among these models, as examples of non-linearity, the FIEGARCH model, the LARCH model, stochastic volatility, and related exponential volatility models are mentioned. Giraitis et al. (2007) seem they are more in favor of the FIEGARCH model thinking that it is more robust than other models especially the FIGARCH and LM-ARCH models. They state, “the long memory property (and even the existence of stationary regime) of some other models (FIGARCH, LM-ARCH) has not been theoretically established” (p.4). Furthermore, Giraitis et al. (2007) indicate how some regime-switching SV models have shown their successful application for analysis of covariance long memory. Hence, they underscore the possible compatibility or differentiation between long memory and short memory.

On the other hand, Palma (2007) states that this inherent characteristic of long memory’s time series analysis could potentially alter ‘the statistical behavior of estimates and predictions. As such, Palma differentiates between short memory and long memory's time-series analyses of dependent processes claiming that they are not interoperable in their theoretical results and methodological applications. In contrast to what is claimed by (Palma, 2007) implying short memory models are incompatible for analyzing long memory processes, Giraitis et al. (2007, 4) point how "the observed long memory in sample autocorrelations can be explained by short memory GARCH models with structural breaks and/or slowly changing trends." Furthermore, Giraitis et al. (2007, 13) indicate that the FIGARCH model often used as the fractional differencing operator has been used extensively by Baillie (1996). Giraitis et al. (2007, 13) cited Baillie indicating the main purpose of FIGARCH as "to capture long memory effect in volatility, allows a hyperbolic decay of the coefficients which are positive, summable, and satisfy the unit root condition." Additionally, Giraitis et al. (2007) argue that the FIGARCH model is problematic in the sense that it cannot show "the existence stationary solution to FIGARCH equation" (p.13). By this, Giraitis et al. (2007) conclude that the FIGARCH model is still controversial and is very difficult to prove its applicability in the analysis of long memory. Concerning the HYGARCH model, Giraitis et al. (2007, 9) explain the uses of the HYGARCH model in time series analysis. Accordingly, they claim that its best applications are for studying the properties of 'moderate memory' and 'near epoch dependence'. Hence, the FIEGARCH model has been used to address and investigate long memory in the presence of structural changes.

Cont (2007, 295) offers the possible reasons for choosing the FIGARCH model as shown in Baillie (1996). Thus, Cont put the rationale for choosing the FIGARCH model that this model is appropriate to analyze long-range dependence in amplitudes rather than to analyze asset returns that have no autocorrelation to signs of increments. Furthermore, from the fact that the alternative models in the GARCH family models are the FIGARCH and HYGARCH models, which are not applicable in the analysis of long memory in observed structural breaks, this study has dropped out the FIGARCH and HYGARCH models. As Cont (2007, 296) indicates, GARCH and FIGARCH offer "statistical constructions which propose volatility clustering in financial time series, they do not provide any economic explanation for it." This implies the origin of volatility in long memory such as structural breaks would not be explained. Implicitly, Cont (2007, 290) states the relevance of empirically supported financial time series analysis of long memory. Attesting this, Cont (2007, 290) points "statistical analysis alone is not likely to provide a definite answer for the presence or absence of long-range dependence phenomenon in stock returns or volatility unless economic mechanisms are proposed to understand the origin of such phenomena.”

Based on the aforementioned comparative reviews between the three major GARCH models, we have an informed ground to choose the FIEGARCH model. In comparison to the HYGARCH and FIGARCH models, we assumed that the FIEGARCH model is identified as the best model with fitting distribution, for it would enable us to obtain valid and reliable results. More importantly, using the FIEGARCH model and the Bai & Perron structural breaks test, this study attempted to address long memory in the presence of structural breaks. We compare with and without structural breaks in each stock market index in proposing sample. For this reason, it is hoped that this study would contribute to optimal portfolio allocations and portfolio risk management. Investors are expected to pay due to considerations on dependencies of volatility to follow and invest on portfolio allocations. Hence, the analysis of long memory among stock markets is found important.

This type of analysis could have an impact on international portfolio allocation and risk management decisions. First, it is assumed to fill the research gaps of the few existing academic papers of persistence and structural changes. This study has investigated persistence and structural breaks in key aspects of economic turmoil and stable periods from the financial data obtained from Thomson Reuters DataStream. Using the FIEGARCH model in these markets, analysis of long memory in structural breaks is addressed. It is assumed that the FIEGARCH model is a more flexible class for analyzing processes of long-range dependence against other models. This model is applicable for the variance's time dependence and enables a slow hyperbolic rate of decay for lagged squared innovations in the conditional volatility function. Addressing long-memory components in volatility would give some insights into how optimal portfolio allocations are affected. As investors follow and invest optimal portfolio allocations, they can consider long-range dependencies of volatility. Thus, the empirical results of this study would help investors, financial regulators, and academicians, whose success is unsteadily connected to the ability to predict stock price movements.

Cognizant of the above points, this study has the general objective of investigating long-term dependence in major European countries and the US stock markets in the existence of structural changes. The purpose of this research is to determine the evidential persistence volatility in the presence of multiple breaks. In addition, the research paper explored the effect of intermittent regime changes in the long memory of sample indices. We compared long-range dependence with and without existing structural breaks. It is believed that having a clear picture of persistence in the volatility of stock markets, which is helpful for investors, risk managers, and monetary regulators to make rational decisions. To meet these objectives, this study has the following research questions: -

- Does long memory exist in major European and US stock indices returns in the existence of multiple structural breaks?
- Do intermittent structural breaks affect the long-term dependence on the volatility of stock indices returns in the major European countries and the US?

Analytical models are employed to offer a vivid picture of the interfaces which reveals the dimension of persistence volatility in the existence of structural changes. This study has attempted to answer the above research questions and developed the following hypothesis.

H1: There exists long-term dependence in major European and US stock index returns in the presence of structural changes.

H2: Intermittent structural breaks affect the long-term dependence of stock index returns in the major European countries and the US.

1.2 LITERATURE REVIEW

In this section, critical readings on previous research and working papers of long memory in equity index return volatility and structural changes in the financial crises are done. In so doing, some of the underlying conceptual frames in the research and the assumed structural changes are reviewed. Hence, the dynamic relationship between long-term dependence and volatility, concepts of structural breaks, long-term dependence in structural breaks, long-term dependence in market efficiency, the significance of long memory for investors, a brief historical review of major financial crises in Europe, and finally assumed causes for the financial crises and forecasts of future challenges are presented in the same order.

1.2.1 Volatility and Long Memory

Understanding an aspect of volatility revolves around an investigation of fluctuations of asset prices or returns from mean values. Ederington & Guan (2005) state the parallel pattern of higher stock indices and consequently generate higher volatility that suggests the possibility of significant risks. Rajput & Kakkar (2012) Rajput, Kakkar, Batra & Gupta (2012, 4) illustrate “the volatility is a measure of the difference between an asset's current prices and its average past prices. it is the standard deviation of returns, which measures the distribution of returns from the average." Many asset pricing models employ volatility to determine the risk of an asset. Commonly, volatility is characterized in association with risk management and is categorized into historical volatility (realized volatility), and implied volatility (Padhi & Shaikh, 2014).

Andersen & Benzoni (2008) have evaluated different volatility methods for forecasting. They underscore that it is essential to come up with a good quality measure of implied volatility to value forecasts. The implied volatility, which is often figured based on the daily closing prices, would have huge data of financial information. For this reason, analysts usually prefer realized volatility to compute the ex-post volatility pattern for estimation. According to Ghosh and Gregoriou (2008) indicates, implied prices or less-frequent data are frequently used while estimating realized volatility, intraday data are used. The standard method for estimating realized volatility is to take the square root of the sum of the squared intraday returns to obtain the daily fluctuation.

However, Martens & van Dijk (2007) have shown that it is also possible to detect intraday movements using the daily range of high and low prices. Concerning implied volatility, Black & Scholes's (1973) earlier work explains it as 'option-pricing, which is a method for traders to illustrate how to hedge and determine price derivatives. Implied volatility is calculated by rearranging the Black-Scholes pricing formula to extract the volatility from the observed option prices. Thimmaraya & Masuna (2017,2) state, "implied volatility is a forward-looking variable. It tells about the realized market volatility based on market participants' expectations. However, most of the times this implied volatility is overestimated compared to the realized volatility due to the speculative behavior of the market participants.". Hull (2012) remarks the implied volatility is to examine the current market to imply the future volatility trend of asset prices. Thus, historical volatility in a sense of its retrospective moves to past asset prices is diametrically opposite to implied volatility, which forecasts the future, defined by the current market prices.

Volatility clustering is a trend that explains the constantly changing tendency of large (low) absolute pries to be followed by large (low) prices. This implies volatility as it is empirically observable is not constant over time, rather it varies in a temporal dimension. As indicated in one of the seminal works of Mandelbrott (1963), this pattern of volatility is seen in most speculative prices and financial returns series. Brooks

(2008) attests, information about financial returns and asset prices are not readily obtainable, and they are not appearing on evenly spaced intervals. Rather, these things occur and appear in clusters. Similarly, Granger and Poon (2003), volatility appears to be very persistent, and price changes tend to maintain their overall impact on volatility.

The long memory concept exists a popular issue in studies and working papers, for its ubiquitous applicability in the discipline of financial economics. Baillie's (1996) detailed account indicates long memory processes operational in fractional integration and defines long memory in a data series. Often, the correlation and/or autocorrelation of long memory processes decay hyperbolically. In addition, they explain long memory processes in terms of decay rates of autocorrelations. This entails there are variations in measuring long memory. At times, the measurement of long memory is illustrated in a hyperbolically decaying autocovariance function which is time-domain, and a spectral density function. On the other hand, McLeod & Hipel (1978) explain the property of long memory by categorizing time-domain and frequency domain. By this, they explain long memory in consideration of an equal number of notes in which the rate domain and the spectral density of a series are unbounded at low frequencies.

Granger (1980) and Hosking (1981) introduce and describe the fractional integration model and state what statistical figures are the norms. In addition, they point that the order of integration in fractional parameters would not be of integers (i.e., 0 or 1). Rather, it should display fractional values. They claim that such fractional integration parameters would potentially reflect persistence in time series. In addition, fractionally integrated values would be different from unit-roots. As such, the persistence estimation values would be non-zeros. According to Granger (1980) and Hosking (1981) explain, the fractional integration model has secured much scholarly attention, Hassler (2019) seriously comments against the widely acclaimed benefits of the fractional integration model., Tang & Shieh (2006)

In fact, this kind of determining fractional integration parameter agrees with what is mentioned in Tang & Shieh (2006) and Box-Steffensmeier, Freeman, Hitt & Pevehouse (2014) that imply long memory processes in time series are likely to occur between distant observations. Hence, in fractionally integrated parameter (d), the persistence estimation is greater than zero but is less than one. In a diametrically opposite sense, Beran et al. (2013) briefly touch upon the problems related to the cointegration model wherein is explicit of non-integer values. Nonetheless, the original assumption of cointegration was of integer values. By this, Beran et al. (2013, 581) indicate their doubt "in some situations, this can lead to the lack of consistency of the LSE." Moreover, Beran et al. recount the altered original assumption of cointegration of integer value into non-integer value of the degree of integration in the treatment of fractionally integrated processes. As a result, Beran et al. (2013, 604) indicate how fractional cointegration appears as "somewhat controversial among economists."

1.2.2 Concepts of Structural Breaks

Detection of a structural break in volatility is important to understand volatility dynamics and stock returns. Structural breaks in stock markets could have an impact on models related to key financial markets, such as economic growth and stock returns. Many works of literature on finance and economics discuss issues of structural changes, Zivot & Andrews (1992); Perron (1997); and Lumsdaine & Papell (1997) studies are among the many pieces of literature emphatically addressing issues related to multiple structural breaks. Nonetheless, other scholars such as Lee & Strazicich (2003) criticize the applications of multiple structural breaks. Instead, they recommend uses of structural breaks aimed at testing structural breaks and presenting evidence of stationarity with breaks. The cumulative sum (CUSUM) of the squared series is one of the most widely used tests for structural change in volatility.

In testing structural breaks, researchers often investigate both endogenous and exogenous phenomena. In dealing with the endogenous phenomena, which is often dependent on the previous asset prices and economic activities, Zivot & Andrews (1992) employ a full range of endogenous structural break tests and use a separate dummy variable for each break. According to Banerjee, Lumsdaine & Stock (1992) endogenous break dates also utilize sequentially, rolling, and recursive tests. Perron (1989) has modified Dickey-Fuller unit root tests with accompanying dummy variables. By this, Perron has introduced how a single exogenous (known) fixed breakpoint works by underlying asymptotic distribution theory. Similarly, Wang & Moore (2009) identify breakpoints. The research also explored the stock indices volatility of European Union (EU) members using the GARCH model and the iterated cumulative sums of squares (ICSS) algorithm. The results of the study illustrate breakpoints and volatility of shifts.

Mensi, Beljid, Boubaker & Managi (2013) examine the correlation between persistence and structural breaks with foreign exchange markets. In examining these correlations, Mensi et al. have employed the ARFIMA–FIGARCH model. The empirical results show spurious long memory effects in the financial data since the computing has been without the consideration of the assumed structural changes. Concerning persistence relatedness with the foreign exchange markets, the results show an overestimated persistence level. Plausibly, this overestimation has occurred due to the failure to identify the sudden structural changes. Similarly, Kang, Cheong & Yoon (2011) show the effects of structural breaks on the persistence of volatility. In their study, they tried to show variations of estimations of persistence in time series by employing the bivariate GARCH model in consideration of structural breaks and without considering them. Perhaps, the erroneously reduced estimation of the degree of persistence with structural breaks emanates from the inappropriate application of the model.

Furthermore, other studies show inappropriate methodological approaches to investigate volatility and structural breaks. Babikir, Gupta, Mwabutwa & Owusu-Sekyere (2012) have tried to show the forecasting stock returns volatility of returns of South Africa. In their study, they used to return of a stock index of South Africa. The result of their study demonstrates that the detected structural breakpoints appeared in returns of unconditional variance of the equity market. Possibly, the result that reveals strong long-term dependence came from their application of the GARCH (1,1) model. Similarly, Cheong, Isa & Mohd Nor (2008) have studied the relation between structural breaks and volatility. They examined the assumed structural breaks and used a fractionally integrated time-varying volatility model in the equity markets of Malaysian in 1996/2006. As such, the results show an excess of reductions in long memory clustering volatility by incorporating structural breaks in the volatility. Their study has ignored the impacts of structural breaks in volatility and has put aside the measurable responses of the structural breaks in volatility. Their study would have an impact on measuring persistence, which in turn, would have implications on portfolio management.

Furthermore, King & Botha (2015) have identified the conditional variance and forecasts stock returns by employing a stochastic model in selected African stock indices in the periods of 2002 up to 2012. The results have not been that much convincing to show the conditional variance and forecast stock returns. This might be because they applied a univariate model of the GARCH models, instead of the Multivariate GARCH model, which relatively performs better than the univariate model to estimate forecasting stock returns. The evidence indicated that some Markov-switching models could offer better forecasts and higher risk-adjusted returns than the multivariate GARCH model. Actually, many scholars have proved that simple Markov switching models are incapable to capture financial data fully. Bartosz (2015) identified sudden changes of volatility in Germany and the US stock indices by employing three techniques of ICSS, NPCPM, and Cheng's algorithm. This study confirms that the application of the NPCPM algorithm is better than the ICSS to detect breakpoints. In fact, using the ICSS technique has generated some erroneous structural changes. About the application of Cheng's technique, it is observed that this technique works well only when a single structural break occurs.

Therefore, what the above paragraphs attest is that a clear conceptualization of structural breaks is essential. More importantly, critical comparative views on the existing methodological approaches to investigate structural breaks in volatility are mandatory. This is because the specific methodological approaches would matter our understandings of volatility dynamics and structural changes. In the following section, the possible long-term interdependences in the view of structural breaks are addressed.

1.2.3 Long Memory in the view of Structural Breaks

In many works of literature, the volatility of long-term dependence stock markets is determined along with the existence and the non-existence of structural breaks. There are several studies in this area. Similarly, Choi, Yu & Zivot (2010) have investigated volatility persistence and have detected some structural changes between the forwarded discount and exchange rates. As the findings indicate, the structural changes have drastically reduced the persistence of the forward discount. When it has removed the breakpoints, the study illustrates the long-term dependence in the forward discount series. In addition, Malik & Hammoudeh (2007) have discussed how structural changes reduce volatility persistence and affect volatility.

Similarly, Hiremath & Kumari (2015) have studied the characteristics of long-term dependence of equity returns. By this, their study of long memory would have essential inferences by using the log periodogram test of Andrews and Guggenberger. The study has focused on the stock indices of India 2003/ 2012. The result has shown that there was a significant existence of persistence in mean returns of the medium- and small-sized indices. However, there have been weaker shreds of evidence for large-cap indices. Besides, this research has examined the link between persistence and index structure, but as the results have shown there have been incorrect inferences of structural breaks. This suggests the need for research on the property of long-term dependence applying appropriate models in the framework of the Indian equity markets.

Gil-Alana & Caporale (2008) have analyzed persistence and structural changes at Spanish Stock Market. The result indicated a break at the beginning of 1998 that strengthen the evidence of the mean-reverting behavior. It had given a higher degree of persistence. Chen & Malinda (2014) studied long memory property and multiple structures in New Zealand, London, and US Travel and Tourism Stock Exchanges by employing the FIGARCH model. It is shown in each stock market; indices have structural breaks, interconnections, and strong asymmetrical effects. Jibrin, Musa, Zubair & Saidu (2015) have studied structural breaks and persistence of crude oil prices in West Texas by using the ARFIMA model. They have shown the property of long memory in the three structural breaks in 1999, 2004, and 2008 respectively and the WTI series also have three breaks captured in 1999, 2005, and 2009 in the Brent series. Turhan, Emrah & Nesrin (2009) have used the ARFIMA-FIGARCH model to test structural breaks and persistence on Turkey's Stock market. The empirical findings do not show the persistence of equity returns. Hence, their study indicates the existence of weaker forms of inefficient markets in the Istanbul Stock Exchange than elsewhere.

Henry (2002) has assessed long memory in stock returns to forecast long-horizon stock returns by the parametric and semiparametric estimators in nine international equity indices. The German, Japanese, South Korean, and Taiwanese stock indices have an existence of persistence of volatility. Ewing & Malik (2010) show, oil prices provide persistence of volatility with structural breaks by using the GARCH model. The results of the study are found different from many of the previous research findings of volatility persistence in oil prices.

Necula & Radu (2012) evaluated the persistence of East Europe's eight emerging stock indices. The research has been employed the ARFIMA-FIGARCH model. The result has shown long-term dependence in each stock index. Corsi (2009) has investigated the long-memory model of realized volatility by using the AR-type model and HAR-RV. This study has not addressed volatility persistence in a time series. However, the application of the HAR-RV model has achieved a better in detecting the long memory, and good forecasting performance. Tayefi & Ramanathan (2012) have studied the theoretical conceptions and the applications related to the FIGARCH model. By this, this study has shown the property of volatility persistence in exchange rates, option prices, and stock prices as well as inflation rates by applying the

FIGARCH model. McMillan & Thupayagale (2011) have investigated the characteristics of volatility persistence with the existence of structural breaks in African stock indices using the standard GARCH model. The evidence reported that persistence in stock index volatility is overrated while structural changes are not considered. Thus, as shown above, the characteristics of persistence of stock indices are heavily dependent on structural changes exist or not and methodological tools researchers have used. In the following, the property of long memory in market efficiency is reviewed.

1.2.4 Long Memory in the View of Market Efficiency

One of its most relevant themes in finance is market efficiency. Market efficiency is determined by measuring specific efficiencies of different stock markets. In fact, there are some efficient market theories in the last twenty years. The existing financial pieces of literature indicate that the proliferation of several theoretical frames is accompanied by the existence of some conflicting accounts of investigating long memory in market efficiency. In market efficiency, from the fact that price levels always reflect all information. They have important implications for studying long memory. Hence, selective critical reviews of the existing financial works of literature are found important to clarify how long memory works in market efficiency.

Fama (1969) explains three theories working for testing efficient market hypotheses. These are weak, semi-strong, and strong theories that are categorized in such a way based on the different degrees of information. The empirical evidence of Sadique & Silvapulle (2001) shows that these theories are applicable for studying the persistence of equity indices in Japan, Korea, New Zealand, Malaysia, Singapore, the US, and Australia. In this study, Sadique & Silvapulle have shown the existence of persistence in stock prices, but they have not addressed one of the controversial issues of the relatedness between long memory and market efficiency. The results of their study have indicated that Malaysian, Singapore, Korean, and New Zealand stock prices are persistent.

Interdependence among stock prices has influenced the market efficiency of securities. Attesting this, Barkoulas, Baum & Travlos (2000); Kasman & Torun (2007a); and Kasman, Turgutlu & Ayhan (2009) explain when stock returns have an existence of persistence, the market does not respond immediately to the flow of information into capital markets, but rather gradually over time. The long-term dependence on stock prices is an indispensable part of stock price behavior. According to Ural & Küçüközmen (2011) assessment, an effect of structural changes on the persistence of stock indices can be tested by Iterated Cumulative Sums of Squares (ICSS) algorithm and the GARCH model. They demonstrated the effects of structural changes in persistence variance in the US, UK, Germany, France, and Turkey. Perhaps, it is the use of the ICSS algorithm that all the stock markets under consideration have a weak level of efficiency. Moreover, it has been observed that structural breaks in variability enhance the effectiveness of predicting volatility dynamics and effectively reduce volatility persistence.

Baciu (2014) has investigated the capital market efficiency and persistence of twenty European Stock indices. The findings indicated that the advanced indices are closer to efficiency than the emerging markets. For instance, the UK, Sweden, Switzerland, and France are the most efficient markets, whereas Bulgaria, the Czech Republic, Greece, and Slovakia are the least efficient markets in Europe. Kristoufek & Vosvrda (2014b) have examined market efficiency by targeting the three variables for the efficiency of the market by raking 38 stock markets. The results revealed that the Netherlands, France, and Germany are the most efficient markets of the total 38 markets. Venezuela and Chilean stock markets are found the least efficient markets. Before this study, the same authors Kristoufek & Vosvrda (2013a) have analyzed the capital market efficiency of 41 stock markets by considering the long-term, short-term memory, and fractal dimension measures. European markets are indicated as the most efficient capital markets by correlation structure measures. Whereas Latin America and Asia have shown the least efficient markets.

Kang, Cho, and Yoon (2009a) investigated structural breaks in volatility arising from global financial and political events, as well as the persistence of volatility in Japanese and Korean stock markets between 1986 and 2008. The FIGARCH model and the ICSS algorithm were used in the study. They confirmed that structural breaks can significantly reduce volatility persistence. Turhan et al. (2009) have analyzed long memory by employing the ICSS algorithm and ARFIMA-FIGARCH model in Istanbul Stock Exchange (ISE). The study evaluated the dual persistence of equity prices in Turkey. As shown in the results, persistence does not exist in the equity return but exists in volatility. As such, the weak form efficient market did not reflect Istanbul's Stock Exchange (ISE) due to volatility. Hence, investigation of long memory in association with market efficiency of stock indices returns is found vitally important. In the following, the significance of investigating the property of long memory particularly for investors is presented.

1.2.5 Significance of Long Memory for Investors

Studying the issues of persistence in the view of structural changes is obviously beneficial particularly for investors. In relatively earlier work, Markowitz (1952) has explained the benefits of diversification of assets that an investor in the international arena seeks to better understand. More importantly, in the highly competitive stock markets, understanding the long-term effects on financial markets and predictability rates is unquestionable. With the advent of globalization and of the many financial crises the world has experienced, investors informed decisions are determined by their time series analysis of long memory. Hence, in a global and/or a regional level investment, critical views on portfolio selections and thoroughly done evaluations on diversification of assets by considering long memory are mandatory.

Hassen, Maroney, El-Sady, and Telfah (2003) studied the stock indices in the Middle East and Africa in the sample periods 1984–1999. The result of the study indicates that the financial and economic risks and the political instabilities significantly determine the stock volatility and predictability. The study has recommended for an international investor can get financial advantages by spreading those markets. According to Cajueiro and Tabak (2006), the Asian stock markets, along with the United States and Japan, have a greater long-term dependence than the Latin American markets. They discovered a positive relationship between long memory and structural breaks when studying the relationship between long memory and structural breaks. Cajueiro and Tabak's study found a positive relationship between market capitalization and long-term dependence, but the opposite is true for the relationship between trading costs and long memory in the A and B shares. In contrast, Share B has been opened up for foreign investors, whose investments have indicated strong evidence of long memory.

Critical investigations on the persistence of stock indices markets do not respond instantly to information. As few works of literature such as Bhattarai & Margariti (2018) indicate, the persistence in stock prices overturns the theory of an efficient market. Hence, past return data would be used for predicting future returns, and this offers a prospect for knowledgeable investors to make consistent speculative profits. Gil-Alana & Caporale (2008) have compared short-term predictability with long-term predictability of long memory. Accordingly, Ding and Granger's (1996) study indicates, how returns are generated by a random walk process, inferring that it is impossible to predict stock returns using historical data to generate consistent abnormal profit. Thus, investors' critical evaluations of long memory especially of its long-term effects on financial markets and predictability rates are vitally important. However, there are a few financial studies that particularly describe the benefits of persistence for investors engaged in equity markets and exchanges. In the following section, a brief historical review of major financial crises in Europe in association with the effects of long memory in the assumed structural breaks is presented.

1.2.6 A Historical Review of Major Financial Crises in Europe

The financial crisis of 2008/2009 has affected European Central Bank (ECB). Some central banks have not yet overcome the impacts of the financial crises. Hodson & Quaglia (2009) have summarized what happened on the European Central Bank (ECB). The overall GDP has declined by an estimated 4 percent in 2009. In early 2007, the global financial crisis was caused by the collapse of the US subprime mortgage market. Because the granted loans for the US homeowners had been given with poor credit ratings, the borrowers were unable to make payments even after interest rate hikes and starting to fall property prices. The sub-prime mortgage crisis in the US had spread into Europe and other countries. The government of Germany was enforced to bail out giant Industry Bank in August 2007. The UK mortgage provider had challenged serious liquidity problems. The government was obligated to support the Bank of England.

Balaz (2011) has recalled how the Deutsche Aktien Index (DAX) was the major stock index and benchmark index for the German equity market. Based on market capitalization and trading volume was comprised of the 30 biggest German companies.

Yendi & Çetin (2012) have also investigated the Turkish economy which had been impacted by the successive financial shocks since the 1990s due to national and global macroeconomic volatilities. Next to the 2001 crisis, the volatile financial markets in 2007 that began in the US have escalated into a global financial crisis that affected Turkey’s economy. Even if Turkey had shown a better growth trend as compared to many other countries in 2010, the country faced chronic unemployment and currency deficit issues after the 2001 crisis. As indicated in financial historical accounts, the economic problems required enactments of structural changes.

Masselink & van den Noord (2009) had evaluated the economic shock and its impacts on the Dutch economy. It was a relatively untouched overseas problem. In 2007, the economic growth was about three and a half percent, which was greater than the average of countries in the Eurozone. However, in 2008, economic growth was affected negatively by the financial crisis. GDP growth is recorded as negative in 2009. Howarth (2013) states "the CAC40 stock index was originally operated on the Paris Stock Exchange. The CAC40 Index was regarded as the benchmark index for the performance of the Paris Stock Exchange. The index was managed by the Euronext exchange group that reflected the performance of the 40 largest and the most actively traded shares. CAC40 index was officially launched on June 15, 1988, with a base value of 1,000."

Hodson & Mabbett (2009) have studied the United Kingdom's monetary program and its challenges. Before the crisis started, the country had price stability and fiscal prudence due to the government advocating financial regulation. The global economic shock in 2007/2008 pushed the economic policy of the United Kingdom. During the crisis, the government allowed unconventional monetary policies to prevent the influence of the global financial crisis. This study assessed and focused on Peter Hall's theory of policy paradigms with its crisis. Riley et al. (2014) have studied the financial crisis, bank lending, and the United Kingdom's productivity. The study indicated that the crisis affected the banking sector and credit mismanagement which is a cause of bank shocks.

Cencig (2012) has evaluated Italy's economy in the Eurozone crisis. Moreover, the country of Italy has faced a crisis as Euro area due to the country's debt crisis and the country's bond yields raised in the country. Then, structural economic problems in the country affected the financial markets. The economic and political situation received attention in Italy during the country's debt crisis. Quirico (2010) has assessed the global economic crisis in Italy. Italy's financial system had been deteriorated and had been affected by the global crisis. The country had faced economic decline and political instability. Big firms and Banks were billed out by the government as well as cutting public expenditure during the crisis. It also shaped the political balance in Italy. Borghi (2013) has evaluated the legal and economic measures to solve the financial crisis in the country of Italy. The study has shown that temporary revives in 2010/2011. The country was accompanied by a high level of debt; Italy had a country's debt crisis. Legal and economic solutions were taken to reduce the effect of the spillover.

Hodson & Qualia (2009) have evaluated European perspectives on the global economic shock. The global financial crisis that began in 2007 with the collapse of the US sub-prime mortgage market had brought $4.1 trillion worldwide losses. The financial turmoil had affected the world economy and economy contracting in 2009.

Ramadhan & Naseeb (2010) have evaluated the global economic shock and the causes. The credit shock and insolvency of many banks in the US occurred due to the mortgage market bubble. Deregulation of the Financial market and lack of follow-up were the major causes of the housing bubble. In the following final section, suggested causes for the financial crises in the past two decades and the possible coming challenges in the future are addressed.

1.2.7 Suggested Causes for the Financial Crises and Forecasts of Future Challenges

This section addresses the future challenges for a financial crisis such as shadow banking, financial innovation, and financial regulation of the financial system. Then, it reviews some of the suggestions given by scholars on the possible reasons for the economic crises and the future challenges of the financial crises.

Financial Stability Board (2020) has assessed shadow banking or non-bank financing. Shadow banking offers a valuable option for banking finance and enables the economic function. It also offers other options of sources of credit. Shadow banking involves converting maturity/liquidity, building leverage, and bank funding activities. It can thus directly establish undiversified risks. The board has described that shadow banking was intensifying and increasing the divergence of activity and market sizes. The board has performed an eight-annual analysis of financial developments and threats in the shadow banking system. It has been reported that the shadow bank had grown their assets estimated dollar about 56.1 billion of Turkey, 651.7 billion of Italy, 579.7 billion of the Netherlands, 1.9 trillion of UK, 2.05 trillion of Germany, 1.635 trillion of France, and 14.894 trillion of the United States, which has the largest asset of it. However, shadow banking has not been enough regulation, for it has affected the financial markets.

Mendoza & Boz (2010) has explored financial invention, the detection of risk, and the US credit shock. Financial innovation was claimed as the main factor for the US credit crisis of 2008. The study has demonstrated that a model with a collateral constraint in which learning about the risk of a new financial system interacts with Fisherian amplification induces loops of debts, asset prices, and the demand of boom-busting. Early realization of a high-borrowing-ability system makes agents positive about the longevity likelihood of this system. Meanwhile, the first realization of a low-borrowing-ability regime renders agents unduly pessimistic. The model forecasts significant rises in household debts, land prices, and excess returns in 1998-2006 followed by a crash.

Kim, Koo & Park (2012) have studied the impacts of the global financial crisis, financial regulations, and financial innovations The authors of this empirical study used a financial and macroeconomic dataset from 132 countries to examine the effects of regulations and innovations on the global financial crisis. Regulatory measures in financial systems have limitations on bank operations and entry conditions, which in turn reduced the possibility of a banking crisis. Government banks' ownership and capital controls have increased the probability of crisis in the currency market. Financial innovations have pushed the financial system into the crisis, but the currency crisis has been contained. This study also found that the deliberate execution of regulatory measures is vital to financial stability. Financial regulations can further worsen the crisis if they are enforced simultaneously.

Chen, Lin & Song (2016) have evaluated the relationship between financial innovations, bank growths, and fragility issues of thirty-two countries over the period 1996/2010. The results show that monetary innovations have bank fragility and worsen bank performance during the global financial shock, and these have correlated with faster bank growths. Countries have broader stock markets, they required more stringent regulatory systems. Furthermore, the study reported that financial innovations have positive net impacts on economic growths. The study seems relatively contradictory to other findings. Financial innovations are correlated with higher growth in countries and industries, for they provide greater incentives for developments.

Park, Lee, Villafuerte & Rosenkranz (2017) have assessed Asian Financial Crisis particularly in Thailand, Indonesia, Malaysia, the Republic of Korea, and spreading other countries in July 1999. The initial recession involved both the currency and banking sectors. The causes of the crisis are too many dollars dominated short-term debt instruments, declining exports, and widening current account deficits. These causes created sharp currency depreciation and loss of trust among investors. The region attracted large capital inflows at relatively low-interest rates, as investors sought higher returns from the region's rapid economic growth. Nevertheless, inadequate risk management practices by banks, poor corporate regulation, absence of openness in the financial systems, and restricted absorption capacity have led to the highly inefficient domestic allocation of this borrowed foreign capital.

Kwack’s (2000) study has investigated the determinants of the economic shock in Asian countries of Indonesia, Korea, Malaysia, Philippines, Singapore, Taiwan, and Thailand in the period of 1995 to 1997. The findings reported that the institutions have faced weaknesses in the balance sheet, high international interest rates, and high short-term loans. These lead to cause for Asia crisis. In addition, the empirical result revealed that the 3-month London Interbank Offered Rate regarding interest rate and corporate leverage ratio has been the major determinants that significantly affect the outcome of the Asian financial crisis.

Zestos (2016) has analyzed the global financial crisis. The severe recession occurred because of the US subprime mortgage crisis. Zestos has discussed the root causes of the crisis. What Zestos claimed as the root causes are often disputed, particularly among the adherents of political-economic ideologies. The key difference between these competing political classes is on recognizing the degree of government interference in the economy. However, most of the scholars are persuaded that both policy and market failures played major roles in influencing the US subprime crisis. A vast majority of the experts believe that several factors have been responsible. In the meantime, the US Federal Government cut taxes and raised spending to avoid further worsening of the expected recession. At that time, the expansionary monetary and fiscal policies were too powerful; thereby the low-interest rates and increasing government spending have contributed to the boom. In short, the escalating unsustainable household debts, have caused an unprecedented rise in consumer spending.

Tatlıyer (2017) has assessed the financial crisis of 2008–2009 in a historical context which was the largest since the 1930s' Great Depression along with the theoretical frames applied to explain the reasons. Numerous contradictory arguments have been made about the various causes of the crisis. The mortgage bubble and the consequent subprime mortgage shock were the widely claimed reasons for the global economic crisis. Besides, the fundamental causes are rising from structural issues in the world economy, which surfaced the financial instabilities and crisis. Similarly, Yeoh (2010) has examined the causes of the global financial crisis. The empirical findings illustration that different reasons aggravate the crisis. Among these reasons, a close regulatory oversight, bad macroeconomic conditions, and corporate governance can be mentioned. Financial systems in private and in public sectors have been affected by this financial catastrophe.

European countries' crisis, particularly in Eurozone cannot be explained through one single factor; rather look deep into the collision of myriad elements is essential. Wali Ullah & Ahmed (2014) have investigated the causes and consequences of the European country's debt crisis. The results showed that some of the causes are foreign trade imbalances, the consequences of the 2007-2012 economic crisis, and the inability of bailout solutions to save Europe from global financial distress. Those variables in peripheral countries have adverse financial conditions and demolished global financial markets. Besides, the recession has led to a decrease in consumer confidence in the euro economy and a weakening of the euro against major currencies. Similarly, Beker (2014) has assessed some of the causes of the debt crisis of Europe. Beker has claimed the interest rates of government bonds have not been of significant differences among European countries. In addition, interest rates were of a low level due to the adoption of the euro which was the cause of interest rates fall in those countries. Interest rates on government bonds by the governments of Greek and Italy showed that these countries were highly interested and participated in government bonds to react to the low-interest rates by increasing their borrowing. Furthermore, an exclusive claim of the US subprime mortgage as the cause for the European debt crisis has raised another problem. As such, the adoption of the euro has been a significant contributing factor, for the adoption has impacts on external competitiveness, mounting imbalances, and accumulation of debts in non-core or peripheral countries.

Alhumoudi (2018) has studied the causes and effects of the European sovereign credit shocks. The empirical result shows that the mismanagement of public borrowing and spending in the government of Greek, also it had failed to control tax evasions. Moreover, the regulatory mechanism enacted by the European Monetary was not that much tight. Even, it is claimed as a negligent controlling system. Akala (2017) has identified the reasons for the Euro-Zone financial shock. Following the 2008 financial crisis, Euro-Zone has been severely affected; thereby, the crisis would have a continued impact with the threatening development of anti-globalization, nationalism, and Britain's exit. In addition, the shock had an impact on its financial and commercial partners of the European countries. The findings show that Euro-Zone financial regulations have weak and limited capabilities for exercising common actions. In the following, the methodological approaches applied to investigate persistence in the existence of structural changes are addressed in detail.

1.3 METHODOLOGY

This section presents a brief review of sources of data and the applied statistical models for data analysis.

1.3.1 Time Series Analysis

In the preceding two decades, the time series analysis of long memory processes has been used in diversified disciplines. Among these, fields of economics and finance can be mentioned as primary users of such advanced statistical tools. Palma (2007) explains some of the optional methodologies applicable in long-term dependence of analysis. The methodologies in the long-term dependence are found effective for assessments of strong dependence processes and data in long-range time intervals. According to Palma (2007, xiii), time series analysis deals with the analysis of "slowly decaying autocorrelations or by a spectral density exhibiting a pole at the origin". Hence, in this study, the properties of long-term dependence in the existence of structural changes were explained as per the guidelines offered by Palma.

Obviously, for optimal understanding of time series analysis, fundamental knowledge of statistical methods and applications is important. For instance, as Palma (2007) indicates knowledge of statistics is helpful for appropriate application of 'state-space systems. The application of such 'state-space systems' helps for a comparative selection of optional time series models. Critical evaluation of the available models is highly recommended by Palma (2007, xiii) "for calculating estimates and predictors, especially in the presence of data gaps". Palma further notes applications of such systems are important for testing models particularly for 'parameter estimation' of strongly dependent processes, for calculating 'missing values', and for employing 'seasonal models' or cyclical properties of financial behavior in the treatment of long memory. Hence, this study applied likewise for identifying estimates and predictors.

Furthermore, Palma (2007, xiii) illustrates, to figure out long memory processes, "a time series must exhibit slowly decaying autocorrelations." In fact, it is difficult to get unique values of autocorrelations that are devoted to the analysis of several parameter estimation methods and for testing strongly dependent time series models. The natural limitations of these parameter estimation methods have been minimized in this study as per the recommendation offered by Palma (2007, xiii). This was done by employing methods that require measurements of specific properties such as the use of methods for assessing 'algorithm efficiency and numerical complexity.'

Unlike that of short memory analysis of dependent processes, the ‘parameter estimation’ of long memory applies the major time-series approaches. By this, fundamental concepts of calculus that deal with limits, consistency, and probability theory that deal with the maximum likelihood occurrences of events were considered. Moreover, statistical inferences of the values of volatility and dependence were extensively done. Thus, the time series analysis of long memory has utilized heteroskedastic time series models for investigating long-range dependent processes. This agrees with Palma's (2007, xiii) statement illustrating the applications of models that are commonly employed in moving economic and financial data.

In the same vein, this study seriously considered the existence of conditional variance with time. The utmost statistically supported prediction capability can be obtained by using heteroskedastic time series models. Supporting this, Beran et al. (2013) illustrate, a peculiar type of nonstationary may be observed in the financial time series. Beran et al. (2013, 555) point statistical inference of long-range dependence may assume certain characteristics of nonstationary. This implies, there are challenges in differentiating “stationary long-memory behavior and nonstationary structures.” Hence, it is essential to distinguish the two in statistical inferences. Though the task of differentiating these two aspects was not an easy one, the testing, estimation, and prediction of long memory processes and components were all done with a critical view of the differences between them.

More importantly, supported by what Palma (2007, 212) has stated about the benefits of linear regression model described as “a stationary long-memory process with spectral density”, this study applied the regression model likewise. By this, the study checked the patterns of consistency, asymptotic normality, and efficiency wherein the observed series of disturbances were harmonized with the assumed stationarity processes. In the following section, the sources of the financial data are presented.

1.3.2 Data Sources

In this study, we used active and major trade stock indices of European Countries and the US such as DAX30 (German), CAC40 (France), FTSE100 (England), AEX (the Netherlands), FTSEMIB (Italy), and Bist100 (Turkey) with S&P500 (US). These stock indices were used to investigate persistence with and without structural breaks of those observed stock indices between 23 January 1998 and 27 December 2019. Since this study covered long years (i.e., for about 21 years) of stock indices, considering the daily values of the various indices would not be manageable and high-frequency data has full of noise. In addition, daily data have come missing values. To make the financial data as manageable as possible, the daily values of the indices were not taken. Rather, the weekly values of the indices were used instead. Thus, Germany, France, England, Netherland, Italy, and Turkey, and the US stock indices prices have been taken from the Thomson DataStream database.

We analyzed the stock indices for the periods from 23/01/1998 to 27/11/2019, which gave us 1146 observations. The weekly returns were computed as the difference among the logarithms of the closing prices of two consecutive sessions. We used the formula below

$$R_{i,t} = 100 * log\left(\frac{p_{i,t}}{p_{i,t-t}}\right) \tag{1.1}$$

In fact, we also used some extant sources for verification's sake. In the following section, how the unit root test within the stationarity aspect of long memory processes was conducted is offered.

1.3.3 Unit Root Test

The stationarity test in financial time series was conducted thinking about the existence of stationarity in the processes of long memory. Originally, the time-series data were tested, and the financial data appeared as non-stationary. For this reason, the unit root test was conducted using the ADF and PP test models developed by Dickey & Fuller (1981) and Phillips & Perron, (1988). To determine the variables' stationarity, one regression formula was considered.

$$\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \sum_{i=1}^{p} y_j \, \Delta y_{t-j} + \varepsilon_t \quad \text{with constant} \quad 1.2$$

For all t = 1,2, ,,,,,,,,,,,,120 and ε_t is white noise.

Where, Δ is the first lag operator, α and β refers to constant and coefficient of time trend, respectively. Also, ρ is the lag order. The null hypothesis is $\rho = 0$ against the alternative $\rho < 0$. H_0: is non-stationarity. Each variable is expressed in logs return. The choice of the lag length required for the test is based on the Akaike Information Criterion (AIC). The ADF and PP test for the null hypothesis of I(0) are conducted in ways: based on a regression on constant. The results of the ADF and PP unit root test in Table 1.2 indicated that all variables are stationary at level, the null hypothesis is rejected due to all the returns series being significant. Probability-value is less than 1% for each index. Finally, the null hypothesis of non-stationarity can be rejected at a 1%

level for all the variables with a constant. In the following section, the preferred FIEGARCH model from the other GARCH family models is presented.

1.3.4 ARFIMA-FIEGARCH Model

The FIEGARCH model is found a more flexible class for measuring persistence processes in the volatility of equity markets. This family model accommodated the time dependence analysis of the variance and allowed for calculating the gradual hyperbolic frequency of decline in the variance functions for lagged squared or absolute innovations. In fact, this study applied the joint ARFIMA-FIEGARCH model to examine the behavior of persistence. The integrated Fractional EGARCH approach established by Bollerslev & Mikkelsen (1996) was used, for it was assumed as a more reliable and consistent to detect the persistence of volatility as in the European and the US stock indices. This model surpassed the GARCH (p, q) and IGARCH (p, q) models in terms of estimation. As a result, the FIEGARCH (p, d, q) is specified as follows:

$$\ln(\sigma_t^2) = \omega + \theta(L)^{-1} (1 - L)^{-d}[1 + \alpha(L)]\, g(z_{t-1}) \tag{1.3}$$

$$\text{With} \quad g(z_t) = \gamma_1 z_t + \gamma_2[(z_t) - E(z_t)] \tag{1.4}$$

The fractional integrated exponential GARCH model (p, d, q) is reduced to the EGARCH model for the case where $d = 0$, and to the integrated exponential GARCH model in case $d = 1$. By analogy to the ARFIMA models' class, $\{ln(\sigma_t^2)\}$ is in stationary covariance and invertible for 'd' within the interval (−0.5, 0.5) (Bollerslev & Mikkelsen, 1996). The persistence properties, on the other hand, would dissipate for all values of d<1.

$$\gamma_t = \alpha_0 + \alpha_1\gamma_{t-1} + \varepsilon_t \tag{1.5}$$

$$\theta(L)(1 - L)^d\, ln(\sigma_t^2) = A + \sum_{j=1}^{q}\left(b_j\left|x_{t-j}\right| + \gamma_t x_{t-j}\right) \tag{1.6}$$

where $\gamma_t \neq 0$, enables to forecast the leverage effect, x_t are standardized errors:

$$x_t = \frac{\varepsilon_t}{\sigma_t} \tag{1.7}$$

Similar to what was shown in Box-Steffensmeier, Freeman, Hitt & Pevehouse (2014), Bollerslev & Mikkelsen (1996), the ARFIMA-FIEGARCH model used in this study to demonstrate the stationarity if $0 < d < 1$. The coefficient "d" was used to quantify the degree of shock persistence to volatility. Consequently, the FIEGARCH is

0<d<1. d was a fractional estimator, and L is the lag operator, ε_t is white noise residual, and $(1-L)^d$ is the fractional differencing lag operator. In the following final section of the methodology, how the structural break test in the mean is indicated.

1.3.5 Structural Break Test in Mean

The previous literature was more focused on a single test of structural change. But the financial time series data have more than one structural regime change. Due to this reason, this study applied multiple structural changes of Bai-Perron's (2003) dynamic programming algorithm which detects breakpoints. Bai-Perron sequential test suggests, the null hypothesis is no structural change (m = 0) alongside an alternative hypothesis of a fixed number of breaks (m = k).

This study employs a mean multiple structural break test. To test for the null hypothesis, no breaks (m=0) against alternative hypothesis, the number of breaks(m=k). Finally, the researchers use the sequential method among Bai-Perron test alternative ways. A sequential method proposed five maximum fixed breakpoints at a 5% confidence interval and the clipping ε rate. Hence, the sequential method helps the researchers to the consistent estimation of the number of breakpoints present. The model detects breakpoints in the time series data of seven indices of Bist100, DAX30, CAC40, AEX, FTSE100, S&P500, and FTSEMIB. According to Bai-Perron (1998, 2003), a multiple linear regression model with m breaks and m+1 regimes was described:

$$y_t = c_j + u_t \tag{1.8 }$$

$$t = T+1, \dots \dots \dots T_j \tag{ 1.9}$$

$$R_t = \alpha + D_j \tag{1.10}$$

Where $j = 1, \dots \dots . m+1$. Under this model, the logarithmic realized volatility at time t and mean c_j is the breakpoints that are explicitly treated as unknown. In addition, R_t represents the return for each series; α and D_j are represented the mean intercept and the dummy variable for the regime shift in mean for each stock market return.

1.4 EMPIRICAL RESULT AND DISCUSSION

This chapter provides the empirical results of the persistence of shocks and structural breaks of stock market returns of six European and US markets. We used the weekly price indices from the data stream. The period for which all financial data was sampled was between 23 January 1998 and 27 December 2019. By this, some 1,146 observations of the weekly closing prices were considered. Hence, we considered the official accounts of the closing prices of seven countries' national stock exchanges. Those stock indices were identified as Bist100, CAC40, DAX30. AEX, FTSE100, FTSEMIB, and S&P500. The weekly stock index returns of the closing prices were defined in logarithmic differences of stock price indices. Thus, this empirical result and discussion section are organized in sub-sections: results of the descriptive statistics, model assumption test result analysis, Bia-Perron test multiple structural breaks, and finally long memory's volatility analysis.

1.4.1 Descriptive Statistics Results

As a result, descriptive statistics shown in Table 1.1, all the return distributions are negatively skewed. The data is skewed to the left which is longer than the right-hand tail. The distribution of the other seven indices is not symmetrical. The mean distribution of these sample stock indices is less than the median of the distribution indices. Except for DAX30 and Bist100 indices, the results revealed a strong amount of excess kurtosis.

In stock return distributions, statistical measures of skewness and kurtosis are common. They both show that the stock return series has a fatter tail and a higher peak distribution than a normal distribution. The Bist100 has the highest standard deviation at 4.9 % over the sample period, which is followed by the FTSEMIB, DAX30, AEX, CAC40, S&P500 and FTSE100 with 3.24 %, 3.18%, 3%, 2.94%, 2.41%, 2.37% display, respectively. Moreover, the Jarque-Bera statistical inference shows each of the models, the test value is incredibly significant. This indicates that the financial data has not-normal distribution. Thus, the null hypothesis of the Jarque–Bera test's normality is rejected for all indices.

Notable financial models illustrate stock prices are distributed normally as like the distribution pattern in the framework of Gaussian processes of long memory. However, the stock returns are frequently characterized by skewness and kurtosis in practice. The weekly stock returns of the considered countries have not normally been distributed as well as they are highly leptokurtic.

Table 1.1 *Descriptive Statistics Results for European and US Stock Indices*

Stock Indices	AEX	Bist100	CAC40	DAX40	FTSE100	FTSEMIB	S&P 500
Mean	0.000316	0.00307	0.000618	0.001012	0.000326	-0.000102	0.001061
Std. Dev.	0.030014	0.049076	0.02937	0.031808	0.023703	0.03236	0.02411
Skewness	-1.0796	-0.17091	-0.78963	-0.63942	-0.98347	-0.72678	-0.81657
Kurtosis	9.0187	4.7242	5.8480	4.9144	10.859	5.7439	6.5482
Jarque-Bera	4102.9*	1070.3*	1750.5*	1230.3*	5810.1*	1674.8*	2172.9*
Obs.	1145	1145	1145	1145	1145	1145	1145

Note: * represents 1% significance level.

Thus, the above table condenses the explanatory statistics of the stock return data of the seven countries. Accordingly, all the stock returns have shown, negative skewness and a high degree of excess kurtosis. This entails the distribution of stock returns time series analysis fatter tail and higher peak distribution than a normal one. The statistical results of the Jarque-Bera confirm that there is a non-normality distribution pattern. As a result, the Jarque–Bera approach reflects that the null hypothesis has been rejected for all indices. In the following, the outcomes of the model assumption testing are presented.

1.4.2 Model Assumption Test Result Analysis

Often, the unit root test is associated with testing to differentiate stationary and nonstationary variables. Before applying a long-term dependence approach, the researcher distinguished stationary and nonstationary variables using statistical inferences. Hence, the distinguished stationery and nonstationary are the preludes to conduct a unit root test that can be applied for valuation, and prediction of persistence processes. All the series were checked by applying the Augmented Dickey-Fuller and Phillips-Perron tests. They are being employed to determine whether a variable is stationary or not. The regression formula was used to check the stationarity of the variables.

The ADF and PP unit root test results in table 1.2 show that all variables are stationary at level, the null hypothesis is rejected due to all the returns series being significant. Probability-value is less than 5%. The ADF and PP tests for the null hypothesis of I(0) are performed using a regression on constant. Furthermore, the study used the minimum value of the Akaike Information Criterion (AIC) to identify the best ARFIMA.

Table 1.2 *Summary of Unit Root and ARCH Tests for European Stock Markets*

Stock Market Indices	Unit Root Test			Serial Correlation test	
	ADF	**PP**	**ARCH**	**Q1(10)**	**Q2(10)**
AEX	9.2199***	33.684***	11.038***	16.55**	160.29***
Bist100	21.33***	33.36***	19.932***	21.71**	364.24**
CAC40	-9.1167***	35.987***	12.239***	37.856***	264.75***
DAX 30	12.523***	34.708***	29.67***	27.45**	377.57***
FTSE 100	-8.164***	36.15***	16.125***	57.054***	244.6***
FTSEMIB	12.449***	33.541***	23.126***	19.02**	209.6***
S&P500	13.484***	36.45***	28.802***	29.86***	290.01***

Note *** indicate significance level at 1%, respectively. ADF and PP denote the Augmented Dickey-Fuller and Phillips Perron tests. Q_1 and Q_2 are serial correlation test results. Q1 refers to statistics on raw data and Q2 indicates statistics on squared data.

This study employed the Lagrange multiplier (ARCH-LM) to detect the ARCH effect. Through applying ARCH-LM developed Engle (1982), we found the ARCH effect in each series of the index. The null hypothesis is based on the assumption that there is no ARCH effect in stock index returns. However, the probability values of all indices are significant: thereby, H_0 was rejected. This implies the GARCH model proposed by Engle (1982) is appropriate for describing the variance of residual change with time The null hypothesis is rejected for all samples, indicating that we can apply the GARCH family model to these data as well. European and US indices have the ARCH effect. Thus, the data fulfilled the assumption of the GARCH family model.

Furthermore, before running the FIEGARCH model, we check the fitness of the model. Researchers test residuality to remove misspecification and inconsistency of estimating parameters. According to the result of the null hypothesis, there is no serial correlation and heteroscedasticity in the stock series. We proposed Lagrange Multiplier (ARCH-LM) and Box-Pierce (the standardized residuals and squared standardized residual tests).

As illustrated in Appendix Table A1 and A2, the finding of diagnostic tests of stock indices of European and US countries. In the proposed model, the residuals are tested whether the existence of serial correlation and heteroscedasticity or not. Then, we applied the Lagrange Multiplier to detect the existence of heteroskedasticity. The results show that the Lagrange multiplier is very insignificant. The null hypothesis cannot be rejected. The residuals are free from heteroskedasticity.

As shown in Tables A1 and A2, the Q-statistics on standardized and squared standardized residuals would help to test the serial correlation of each variable in the specified model. The Box-Pierce test detects correlation in a proposed model. The null hypothesis states that there has no serial correlation. The Probability estimate of all series is more than 5 percent. The null hypothesis was rejected. We found no evidence of serial correlation in the residuals. Therefore, the GARCH family model is fitted and fulfilled to use the sample of European and US stock indices.

As shown in Figure 1.1 below of the return graphs, the volatility periods can be detected. The graphical representations of the volatility periods are witnesses to the consequential patterns in the processes of long memory. These graphical descriptions show that each country's stock return series display volatility clustering. It means that large volatility trends are followed by large volatility regardless of sign and small volatility trends are followed by small volatility.

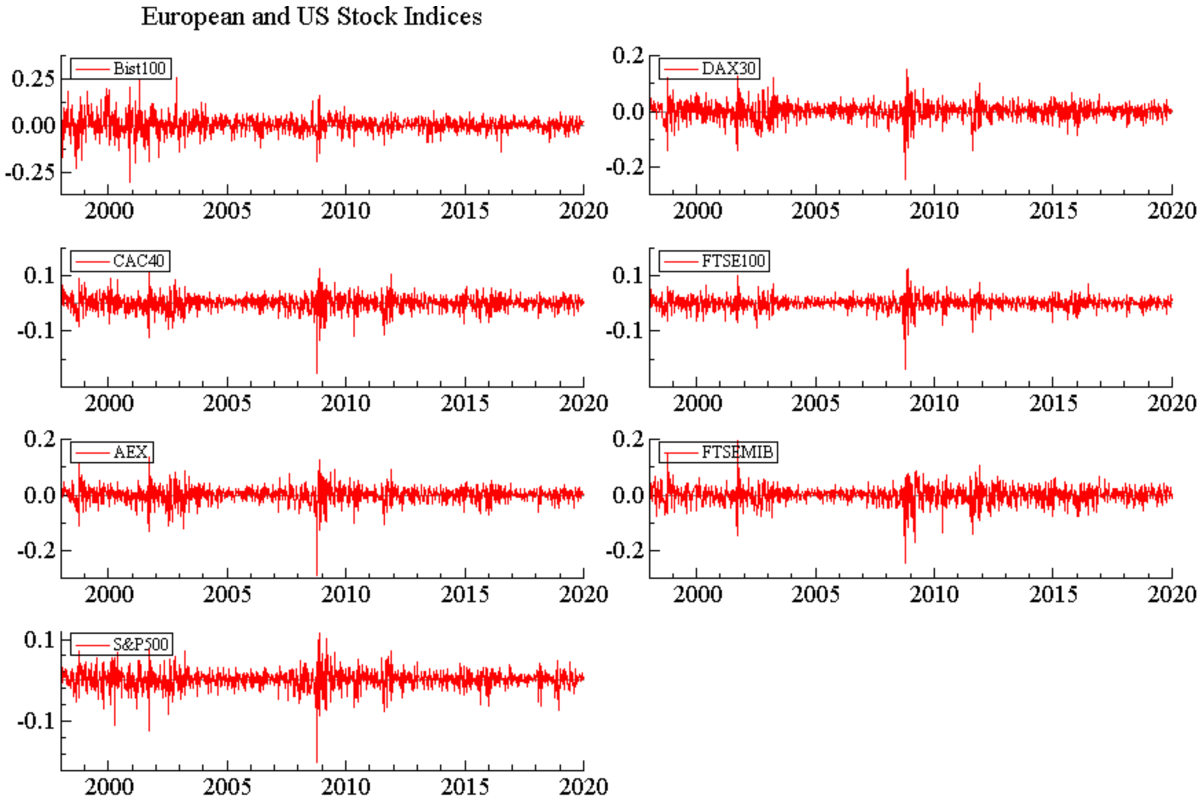

Figure 1.1 *Weekly Returns for National Stock Indices of European and US Countries*

The above Figure 1.1 illustrates the Bist100 (Turkey), DAX30 (Germany), CAC40 (France), AEX (the Netherlands), FTSE100 (United Kingdom), FTSMIB (Italy), and S&P500 (US), the weekly conditional volatility, and the volatility clustering effects. As the graphical representations of these seven countries' stock indices indicate, volatility is time-variant. Hence, the displayed results confirm that there have been tendencies for shocks to persist, with large (small) innovations followed by similar ones.

The study used the minimum Akaike information criterion (AIC) to classify the orders and select a better model among the ARFIMA with FIGARCH, FIEGARCH, and HYGARCH models. The Lagrange multiplier test (ARCH-LM) is also used to test the ARCH effect. By considering AIC, we selected the FIEGARCH model from the three alternative models. The comparison of these models is illustrated in Table A1 in the appendix below Bist100, CAC40, DAX30, and AEX; in Table A2 in the appendix below FTSE100, FTSEMIB, and S&P500.

Moreover, the estimation results show the persistence of stock returns which is different from zero for all models; namely, the FIGARCH, FIEGARCH, and HYGARCH. There exists long memory in volatility in all the indices: Bist100, CAC40, DAX30., AEX, FTSE100, FTSEMIB, and S&P500. An interesting observation is that to AIC and SIC values of the FIEGARCH model are noticeably lower than the FIGARCH and HYGARCH models. It suggests that the model fits the weekly data to distinguish long-term dependence in stock return volatility.

Even if the results are shown in Tables A1 and A2 attest, the presence of persistence property in the returns of the volatility of Bist100, DAX30, CAC40, AEX, FTSE100, S&P500, and FTSEMIB index, we attempted to ratify these incidents by further statistical inferences. In so doing, we assumed sudden changes in the series to circumvent the spurious level of shift effect. Sudden changes can result from the financial shock, sovereign crisis, and monetary strategy variations. Thus, we proceeded to multiple breakpoints analysis employing the Bai-Perron Test.

The study proposed and implemented the sequential multiple structural Bai-Perron test which enables the estimation model consistently to distinguish spurious one. The previous literature was more focused on a single test of structural change. But the financial time series data have more than one structural regime change due to different reasons. Hence, this study applied multiple structural change Bai-Perron dynamic programming algorithm which detects some breaks and their dates. Under the Bai-Perron test, the sequential method suggests, the null hypothesis is that there are no structural breaks ($m = 0$), and the alternative hypothesis is that there are a fixed number of breaks ($m = k$).

The powerful concepts of the Bai-Perron Multiple Structural Breaks Test have been used. Particularly, Bai and Perron’s (2003) sequential testing model has been primarily applied. We followed the sequential method for deciding specified structural changes to determine the maximum breakpoints. Thereby, we have suggested five as the determined number of breakpoints. As such, the results revealed that there were five breaks in each of Bist100, DAX30, CAC40, AEX, FTSE100, FTSEMIB, and S&P500 indices with specified break dates. We found five maximum structural breaks at different dates. The assumed sudden changes have shown substantial increases in volatility. These sudden changes are confirmed in our application of the Bai-Perron sequential method. As such, the changes have shown substantial increases in volatility in major financial stress times. The events that happened in the macroeconomic imbalance, following the 2008 global financial crisis, the Eurozone sovereign debt crisis, and political instability have subsequently brought other financial crises across Europe. In this study, it is implied that the financial crises observed in the selected European countries and the US have also been extensively spreading into other European countries.

Moreover, the detected maximum number of five breakpoints in each index of the stock returns with the specified sample has shown impacts on the long-term dependence of returns. Similarly, the persistence of returns has been detected. In order to identify the properties of long-range dependence, we applied the ARFIMA–FIEGARCH model together with the dummy, which was an appropriate model for investigative the persistence processes in the sample. As some studies suggest, sudden changes or structural breaks do have the potential to offer rises in a spurious long memory in volatility. Therefore, the Bai-Perron structural changes test accompanied by the identification of dummy variables is suitable to investigate breaks in volatility. As shown in the following Table 1.3, the stock market indices have corresponding events that happened on the respective change points.

Table 1.3 *Structural Breaks in Volatility*

Stock Market Index	Change Points/date	Events
Bist100	6/22/2001, 10/15/2004, 1/25/2008 8/19/2011, 1/09/2015	Turkey financial crisis, global financial crisis, the Eurozone's debt crisis, political instability
CAC40	9/07/2001, 8/26/2005, 5/15/2009 9/07/2012, 9/23/2016	The deterioration in export performance, Euro area sovereign debt crises, global financial crisis, the Irish real estate, and banking crisis, the Spanish real estate and banking crisis
DAX30	10/05/2001, 1/14/2005, 4/25/2008 8/05/2011, 11/14/2014	Stagnation of macroeconomic, Euro area sovereign debt crises, global financial crisis, the Irish real estate and banking crisis, the Spanish real estate, and banking crisis
AEX	9/07/2001, 2/10/2006, 5/22/2009 6/14/2013, 9/23/2016	Macroeconomic imbalance, Euro area sovereign debt crises, global financial crisis, the Irish real estate, and banking crisis, the Spanish real estate and banking crisis
FTSE100	7/19/2002, 4/28/2006, 2/26/2010 6/07/2013, 9/23/2016	Macroeconomic imbalance, Euro area sovereign debt crises, global financial crisis, the Irish real estate, and banking crisis, the Spanish real estate and banking crisis, Brexit in UK
FTSEMIB	3/15/2002, 6/24/2005, 12/05/2008 3/16/2012, 6/26/2015	Political instability and macroeconomic imbalance, Euro area sovereign debt crises, global financial crisis, the Irish real estate and banking crisis, the Spanish real estate, and banking crisis, the problems of nonperforming loans in Italy
S&P500	7/13/2001, 10/22/2004, 9/26/2008, 5/01/2009, 1/11/2013, 9/23/2016	Terrorist attacks, Euro area sovereign debt crises, global financial crisis, following the presidential election, and recession of the economy.

At 5% significance level and a maximum of 5 breaks detected

1.4.4 Long Memory Volatility Analysis

In this section, the findings of the persistence of equity prices in volatility are measured by the combined ARFIMA-FIEGARCH model. Following Bollerslev & Mikkelsen (1996) model, all possible ARFIMA (n, ξ, s) combinations with n = 0, 1, 2 and s = 0, 1, 2 are considered. The estimations of the FIEGARCH (p, d, q) model, all the stock return indices fit the ARFIMA (1, ξ,1) model for estimating long memory processes. The FIEGARCH specifications are considered in modeling the procedures of long-term dependence with different arrangements of (p, d, q).

The FIEGARCH model performs as the best fitting specification for all cases based on the model selection criteria. The findings in Table 1.4 and Table 1.5 below illustrate the suitability of the combined ARFIMA-FIEGARCH parameters for estimations with and without structural breaks. The applied ARFIMA-FIEGARCH (1, d, 1) model has provided the weekly volatility and has exhibited the fractional dynamics therein the indices Bist100, CAC40, DAX30, AEX, FTSE100, FTSEMIB, and S&P500. Estimation of the fractional integration value (d) is greater than zero in each of the series. As such, the estimation is statistically significant in the six European and the US stock prices. Cognizant of this, the study suggests that the returns in those stock indices exhibit long memory. In fact, the presence of long memory in each volatility index varies in a relative sense. Exceptional to the Turkish stock market, the fractional integration value of German, France, Italy, Netherland, England, and US stock indices has greater than 0.5. So , those stock indices have shown strong persistence of volatility. This result agrees with what is indicated in Ural & Küçüközmen (2011). Almost a decade has passed since Ural & Küçüközmen studied this case, but as the results of this study show, the Turkish stock index has less persistence in volatility. Such exception of the Turkish stock market standing at the bottom level of persistence of volatility as compared to the other stock indices invites further investigations. According to is Box-Steffensmeier (2014), the integrated value of persistence is less than 0.5, it will revert to the mean of short memory.

Moreover, the applied ARFIMA-FIEGARCH model has assessed the relative difference between developed markets and emerging markets. Accordingly, as shown in Tables 1.4 and 1.5, the most efficient markets are positioned in the European stock markets particularly the Netherlands, Germany, France, Italy, and England. Also, the least efficient one is the Turkey stock market. In this empirical study, the developed markets are found with a stronger long memory in stock prices than the emerging markets. This agrees with the report by Baciu, (2014) that has measured stock markets based on persistence and, fractal measurement. The developed markets have a closer to better efficiency market than the emerging markets. While Turkey is relatively the least efficient stock market among them. The finding also disagrees with the report by Kasman & Torun, (2007) has the existence of long-term dependence on the Turkish stock index. Therefore, the FIEGARCH model seems a suitable model for investigating the long-term dependence of stock prices' volatility on the European and the US markets under the influences of the assumed structural breaks. Even if Several studies have been conducted to assess the efficiency of various stock markets based on specific criteria and/or combined measurements of variables, the applied ARFIMA-FIEGARCH model is plausibly successful since the integration of structural breaks into the investigation of efficiency.

Yalama & Celik, (2013) explains that long-range dependence is analyzed whether it has correlations of volatility in real or in spurious stock markets data. Similarly, we have considered breakpoints in the time series of long memory analysis. The investigation empirically distinguished between true and fictitious asset prices persistence characteristics. We have compared the long memory volatility both with and without the existence of structural changes by employing the FIEGARCH model. The findings are mixed. By considering structural changes in the return volatility of the national index series of German (DAX30), France (CAC40), England (FTSE100), and the Netherlands (AEX) stock indices, the empirical evidence of long memory appeared as 0.6827, 0.7399, 0.66204, and 0.46932, respectively. The result also describes how the assumed structural breaks effectively reduced the persistence of volatility or long memory. Hence, stock returns persistence has been affected by the structural breaks in Germany, France, England, and the Netherlands. On the other hand, without the consideration of structural changes, Germany, France, England, and the Netherlands stock indices' long-memory values are calculated as 0.6856, 0.7405, 0.772788, and 0.601, respectively. Thus, the ARFIMA-FIEGARCH model with or without structural changes, almost all series has strong long-range dependence except for Turkey. This entails how empirical evidence of long-term dependence processes in consideration of structural changes in time series is vitally fruitful.

Obviously, many stock markets have predictable structures. This implies that the return series violates weak financial performance. The results agree with the reports Ural & Küçüközmen (2011). The persistence of volatility of all six European countries including the US stock indices has a strong long memory except for Turkey's Bist100 index. In this case, the long memory is observed declining without structural breaks against the existence of structural breaks. Hence, Turkey's BIST100 index has the weakest persistence of volatility; thereby, the BIST100 index cannot be said that it has a predictable structure.

Table 1.4 *ARFIMA-FIEGARCH Parameters without Structural Breaks*

	Without Structural break consideration						
	Bist100	CAC40	DAX30	AEX	FTSE100	FTSEMIB	S&P500
d	0.36577	0.74050	0.6856	0.601	0.772788	0.69868	0.60337
	(0.0054)	(0.000)	(-0.79)	(0.00)	(0.000)	(0.000)	(0.0095)
α	-0.78205	-0.62877	-0.80516	-0.8411	-0.79816	-0.899117	-0.08874
	(0.0000)	(0.000)	(0.000)	(0.00)	(0.000)	(0,000)	(0.5807)
β	0.98866	0.86823	0.95158	0.976	0.901687	0.969086	0.35922
	(0.000)	(0.000)	(0.000)	(0.168)	(0.000)	(0.000)	(0.1063)
J. B	307.49	25.925	86.49	44.013	64.162	85.991	281.83
Ln(L)	2070.21	3883.21	3457.114	3596.7	3593.15	3217.294	3416.88
AIC	-3.588142	-6.954955	-6.01068	-6.399	-6.448289	-5.59178	-5.94214
SIC	-3.51767	-6.684482	-5.940208	-6.1841	-6.177817	-5.521308	-5.876074
Q1(50	56.51	58.277	41.5426	39.26	60.1671	53.27	56.55
	(0.1869)	(0.147)	(0.73312)	(0.89)	(0.11183)	(0.24569)	(0.1858)
Q2(50)	66.186	59.902	52.778	36.58	42.1368	46.0762	39.57
	(0.07)	(0.1163)	(0.29464)	(0.811)	(0.7108)	(0.55199)	(0.8014)
ARCH	1.013	0.64032	1.3006	0.410	0.4089	1.3465	0.21424
	(0.4085)	(0.669)	(0.2612)	(0.84)	(0.8428)	(0.242)	(0.9565)

Note: P-values are stated in the parentheses; * and ** indicate significance levels at 5% and 10%, respectively.

As the results have shown the long-range dependence of Italy (FTSEMIB), Turkey (BIST100), and the US's (S&P500) national indices the consideration of structural breaks is 0.8008, 0.3889, and 0.68028 values, respectively. In contrast, without the consideration of structural breaks, the long memory values for each index of FTSEMIB, BIST100, and S&P500 indices are 0.7087, 0.9264, and 0.8426, respectively. The results show that little increments of persistence of volatility have been experienced. This implies the stock returns in time series have strong persistence of volatility; thereby, they are of predictable structures. However, the rest three countries' Turkey, Italy, and the US persistence of volatility was not affected by the structural changes of financial time series.

The long memory of each index DAX30, CAC40, AEX, and FTSE100 is found lower with structural breaks in the fractional integration model than without structural breaks. Hence, the persistence of volatility of stock indices was affected by sudden changes in Germany, the England, France, and the Netherlands. This implies the assumed structural breaks can reduce the persistence of volatility or long memory. This would mean that those stock markets' long-range dependence was affected by structural changes in the sample periods.

Table 1.5 *ARFIMA-FIEGARCH Parameters with Structural Breaks*

	With Structural break consideration						
	Bist100	CAC 40	DAX30	AEX	FTSE100	FTSEMIB	S&P500
d	0.388937	0.739953	0.68266	0.469328	0.662042	0.800787	0.680282
	(0.0101)	(0.000)	(0.000)	(0.0168)	(0.000)	(0.000)	(0.000)
α	-0.79559	-0.626379	-0.80303	-0.789388	-0.118933	0.438252	-0.734837
	(0.000)	(0.0041)	(0.000)	(0.0000)	(0.0499)	(0.2170)	(0.000)
β	0.9870	0.873066	0.953389	0.986779	-0.011085	0.088417	0.89051
	(0.000)	(0.0000)	(0.000)	(0.0000)	(0.2301)	(0.3643)	(0.000)
J. B	288.04	27.576	85.451	39.268	67.99	92.494	258.26
Ln(L)	2072.115	3883.204	3459.215	3601.2	3670.36	218.618	3340.3
AIC	-3.58972	-6.754941	-6.012602	-6.262318	-6.381407	-5.592346	-5.80315
SIC	-3.514844	-6.684469	-5.937725	-6.191846	-6.30653	-5.517469	-5.72387
Q1(50	57.61	58.4374	41.7329	36.8294	64.3639	55.6346	49.66
	(0.161294)	(0.14377)	(0.68987)	(0.87968)	(0.54362)	(0.209373)	(0.36769)
Q2(50)	70.10	59.7436	57.7519	39.6246	38.871	47.8319	35.8126
	(0.27229)	(0.119079)	(0.158188)	(0.79987)	(0.8236)	(0.47983)	(0.90294)
ARCH	1.045	0.66029	1.2885	0.48205	0.24642	1.3018	0.51298
	(0.3896)	(0.6537)	(0.2664)	(0.7899)	(0.9417)	(0.2607)	(0.767)

Note: P-values are reported in the parentheses; * and ** indicate significance levels at 5% and 10%, respectively.

Moreover, as the estimation results of all the national indices reveal, the indices do not really proceed in a random walk technique. They do not support the weak form of a well-organized market. In fact, though all the indices have a certain level of predictable behavior, they have significantly varying degrees of it. In a relative sense, the Turkish national index does not represent the predictable behavior compare to the other six indices. Hence, it can be concluded that Turkey engages in a random walk technique. On other hand, the Turkish index does not violate the weak form of a well-organized market. This market emphasizes asset returns should be considerate of market information as efficiently and as quickly as possible at any point in time. This is because information on past stock prices would not be applicable to estimate future market price movements. By this, the Turkish national stock index may not require strategists’ high-level technical analysis offering information that enables investors to allocate portfolios appropriately. This does not mean that investors would not use the pieces of information from the Turkish national stock index at any rate. Rather, it is meant that investors would be selective to the kind of information evaluating its being of the remote past, or the real-time.

Furthermore, the findings of this study presented in Tables 1.4 and 1.5 that the European major national stock indices of Germany, France, the England, the Netherlands, Italy, and the US index show the existence of long memory of returns. This is because of autocorrelation functions of volatility; markets have a decreasing tendency at a hyperbolic. It can be said that the slow mean reversion and decay characteristics of equity indices. This agrees with Cerqueti & Rotundo's (2015) report in this regard. Historical stock prices can estimate the future. They have a predictable structure. Investors can observe historical data and identify changes in the stock markets. If the stock return series revealed persistence of volatility, the weak form of market efficiency is violated. Therefore, the existence of long-term dependence of volatility helps the technical analysis strategies.

The findings suggest that the fractional integration showed the existence of long-range dependence of each stock index. Thus, it has increased the attractiveness of diversification strategy for risk minimization method by jointly holding assets in the portfolio. Besides, the asset allocation strategy by diversification would be subtle to the investment time duration when long-term dependence existence. This is supported by early studies such as by Cheung & Lai (1995) and by Wilson & Okunev (1999). Diversification could be beneficial in the short- and medium-term horizons when long memory is present. Therefore, this can help investors who make in the national stock markets of the Netherlands, Germany, France, US, Italy, and the England by considering investment horizon due to the presence of persistence. The existence of long-term dependence in the stock index returns the link to the theory of an efficient market. Hence, returns of stock can be used for predicting future returns. Thus, for knowledgeable investors to make consistent speculative profits. The long memory characterization of series does not support the argument of a weak efficient market.

The presence of persistent volatility enables investors to consider alternative investment opportunities, hedge, and allocate assets to reduce risks in stock markets. The investors` behavior is very much important in anticipating the effects and the way they react to a shock. The modern portfolio concept argues that stockholders can advantage by diversification and investing in financial assets with negative or lower correlations and predictable markets.

1.5 CONCLUSION

This study investigated the long-range dependence of stock volatility of the DAX30, CAC40, BIST100, FTSE100, AEX, FTSEMIB, and S&P500 indices with and without structural breaks. We used the Bai-Perron structural break approach. Following the selection of the best-fitting distribution for seven return series, all long memory analyses were carried out using the FIGARCH, FIEGARCH, and HYGARCH models. The study classified the orders and selected the best model from FIGARCH, FIEGARCH, and HYGARCH models. Then after by combining with the ARFIMA model and in consideration of the Akaike Information Criterion (AIC), the study investigated long memory processes. This study employed Bai-Perron's (2003) structural breakpoints test to reduce the influences of counterfeit long memory.

To enhance the reliability of the findings, the investigation determined the best fitting distribution and model for the return series. Hence, the persistence of stock returns in volatility was measured by the combined ARFIMA-FIEGARCH model. Following the seminal work of Bollerslev & Mikkelsen (1996), all the possible ARFIMA (n, ξ, s) combinations with $n = 0, 1, 2$ and $s = 0, 1, 2$ were assumed. According to FIEGARCH (p, d, q) model the estimation results, all stock indices return to fit the ARFIMA (1, ξ,1) model for the persistence processes. The FIEGARCH parameters were assumed in modeling long-term dependence volatility processes with different orders of (p, d, q). As the model selection criteria. the FIEGARCH (1, d, 1) model was selected for the study.

To meet the objectives of the study, we examined the persistence of properties in European and US stock indices with and without structural breaks. The findings reported that return series revelation long-term dependence. Hence, the sample indices returns were dependent on the extent of time. When the volatility of returns has long-term dependence, past information of asset returns would enable to forecast future returns. They do not in line with the efficiency market performance philosophy. They make a cause a crucial encounter to the concept of random walk concept characters of the asset returns. The findings of this study proposed that the volatility of stock returns was highly persistent by employing the ARFIMA-FIEGARCH approach in almost all the European and the US stock indices. This would mean that stock returns could be predictable. These markets contradict the weak form of the efficiency market philosophy. Moreover, the study has presented evidence of prolonged volatility that has significant influences on the behavior of the weekly stock returns on the stock markets of Europe and the US.

Furthermore, the study considered structural changes in the series of long memory investigations. By employing the ARFIMA-FIEGARCH model with or without structural changes, almost all series have strong long rang dependence except for Turkey. They provided that empirical evidence of long-term dependence in the time series. However, all-encompassing of structural breaks, the findings were mixed characteristics. The result described those structural breaks can effectively reduce the long-term dependence of volatility in the European countries, such as DAX30, CAC40, FTSE100, and the AEX. Whereas the long memory value for each index of FTSEMIB, BIST100, and S&P500 is not reduced by structural changes. This would mean that Germany, France, the United Kingdom, and the Netherlands stock markets' long-range dependence was affected by structural changes in the sample period. However, the rest three countries' Turkey, Italy, and the US persistence of volatility was not affected by the structural changes.

To sum up, the finding of long-range dependence in the volatility of indices returns has suggested that the characterization of the stock market does not react immediately to the available information. Rather, Investors react it slowly. Besides that, the existence of long-range dependence of volatility nullifies the concept of weak stock market efficiency due to the causes of dependence in the moments of the time series due to the causes of dependence in the moments of time series. The price would be anticipated components in the series of stock. Thus, the past data of indices price would be employed for predicting upcoming price; thereby, the historical view opens opportunities and make consistent speculative profits for investors.

II. ANALYZING CONTAGION EFFECT IN STRUCTURAL BREAKS

2.1 INTRODUCTION

In the last two decades, the world has experienced some financial crises. Scholars have suggested varied factors that caused the crises, and they have proposed solutions. Nonetheless, almost all financial systems in the world were affected severely by the escalating crises. Stoian & Becherescu, (2013) indicate the causes as fragile financial institutions, inappropriate banking regulations, and policies, inefficient management, lack of transparency in financial activities are to name but a few. They state the complexity to explain all the possible causes for the continued shocks in the last two decades. These scholars trace back the financial crisis of East Asia (1997) that affected several Asian countries' financial systems, currencies, and security markets. Following that, the financial crisis of 2008 had widely regarded as one of the worst crises since the Economic Depression(the 1930s) has impacted financial sectors worldwide. Many claim the crisis originated from the housing bubble in the US exercised as of the last quarter of 2007. The crisis had severe consequences in the whole world, but as Kenourgios & Dimitriou, (2014) illustrate its ubiquitous strong impacts have been in the US and European financial sectors and economic systems.

In a historical view, many scholars write about the chain-like events of the major financial crises. Ali (2012) recalls the outbreak of the European crisis of public debt of 2010 that occurred after the global financial crisis had been resolved. Ali states after the assumed recovery from the 2008 global recession, the Eurozone witnessed the new crisis that originated from Greece's sovereign debt crisis of 2010. This crisis has spread out to almost all European Countries. Greece was the epicenter of the devastating European crisis of public debt. As such, most of the European financial sectors and economic systems were affected by the crisis. Ali, (2012) indicates Portugal, Ireland, Italy, Greece, and Spain have been among the European nations severely affected by the Eurozone public debt crisis. This crisis had the cause of recording high values of volatility in asset markets. Hence, the root causes for the successive waves of financial crises have not been explained in depth.

Despite the frequent mention of the term contagion and its effects on financial systems, little scholarly attention is given explicating the characteristics of contagion in depth. Correlation properties of contagion are also unattended. Contextual matters of identifying contagion, of exploring channels of contagion, and the speed of transmission, are not studied to the level of importance they deserve in the academic discourse. Nor there is a consistent theoretical frame for estimation, prediction, testing the existence of contagion, and for investigation of contagion along with structural breaks.

Porras (2016, 4) explains how contagion works in line with the interdependence of markets operational at the global financial system. In this sense, contagion denotes issues of risk transmission. By this, financial contagion refers to a phenomenon that two markets are of a causal relationship wherein the asset prices in one country are affected by the changes in another country's asset prices.

The stock market is one of the most important activities in the capital market that has been impacted by the financial crisis. The issue of a contagion effect in capital markets, many researchers have been inspired by capital markets in the last decade, particularly after the last US-born global financial crisis in 2008. Months later and during the recovery from the 2009 global recession, the Eurozone witnessed a new crisis that originated from Greece's sovereign debt. This crisis spread throughout the European Union countries. The major consequences of the Eurozone debt crisis felt severely in Ireland, Italy, Portugal, Greece, and Spain. The European public debt crisis adversely affected the region's economy. The effect of the global financial crisis had not entirely solved when the European Sovereign Debt Crisis occurred in Greece. As Syllignakis & Kouretas (2011) highlight most economies of Europe were affected by the crisis. The countries' stock market lost its value against another one. In consideration of the magnitude of the capital interactions between the US and the Eurozone countries, studying contagion is mandatory effect.

There is little consensus offering a single definition of contagion. Accordingly, Porras (2016) states the plurality of meanings given for contagion and the varied mechanisms of its transmissions. Forbes and Rigobon (2002) emphasize the concepts related to a unidirectional shift-contagion. They relate shift-contagion just after a shock in a country or group of countries, there is a significant increase in cross-market linkages. By this, according to Forbes and Rigobon's definition of contagion underscores the linkages between two independently standing markets. By implication, they do not identify as a contagion; wherein, both in stable and crisis periods, two markets show a high level of co-movement.

The main purpose of the study is to investigate the shift-contagion of the US mortgage crisis on the European stock indices and their capacity to respond to it. It shows the differentiated impact and transmission mechanisms. The spillover of the crisis from the US to European markets as well as the rest world through several channels. Besides, financial integration enables the diversification of risk but also may increase the transmission of crises across countries of Europe. Financial integration is an opportunity and a challenge to the current financial market. As Devereux & Yu (2014) illustrate increases global leverage would double the probability of balance sheet crises and would aggravate financial contagion across countries. The dependency among financial assets across the countries is more considered by investors and researchers. Besides, the existing literature is more focused on financial contagion because they offer significant implications in investment strategy, risk diversification, and risk mitigation which are all aspects of asset management for regulators and investors.

In many financial studies, issues of contagion have been addressed. Among these studies, BenSaïda (2018); Guesmi et al. (2013); Celik (2012); Wang & Thi (2006); Forbes & Rigobon (2001, 2002); and Dornbusch et al. (2000) are only a few. They indicate that the major financial crises have brought devastating effects on the global financial systems. Chittedi (2015) illustrates how contagion spreads across countries, and how it affects the economies of these countries. Chittedi further shows how financial systems and firms tried to mitigate the risks associated with this event.

In many of the studies, the definition of contagion itself varies significantly as per the econometric models adopted in these studies. These studies identified the very presence of contagion and the transmission channels in accord with the statistical methods applied therein. In these studies, the 'traditional' Pearson's correlation method, the GARCH model, and the co-integration approach have been the most common statistical methods. More importantly, many of these studies have tested contagion effects based on the empirical literature, for instance, Forbes & Rigobon's (2001) study has evaluated the conventional tests for measuring contagion. As the results show the use of secondary data instead of the primary data particularly using Pearson's correlation coefficient is biased. The same authors' publication a year later, Forbes & Rigobon's (2002), explicitly denies the existence of contagion. In this work, they claim, there is no such thing as contagion, only interdependence. Attesting this, Dungey et al. (2011, 3) criticize the work of Forbes & Rigobon, for its use of 'adjusted correlation test', which is more of a traditional testing method. Hence, Forbes & Rigobon's study left some indeterminacies and conflicting accounts about contagion along with an indication of suitable statistical methods applicable for investigating shifts in contagion.

Dungey et al. (2011) employed Forbes and Rigobon's (2002) concept of shift-contagion which is the increase in correlation between two variables during a crisis period. As Dungey et al. (2011, 22) indicate Forbes and Rigobon tested the correlation between two countries by statistically adjusting values to fit the test. Dungey et al. (2011, 22) state the obvious “as crisis periods are typically characterized by an increase in volatility, a test based on the (conditional) correlation is biased upwards resulting in evidence of spurious contagion.” Hence, Dungey et al. moderately criticized the methodological approach adopted by Forbes and Rigobon. Furthermore, Dungey et al. (2011, 30) state “the potential simultaneity biases arising from the presence of endogenous variables are more evident when the Forbes and Rigobon test is cast in a linear regression framework.” Hence, Dungey et al. imply the limitations of such a methodological approach, for it ignores the bidirectional nature of economic interactions; thereby, resulting in simultaneity biases.

However, this study has applied an advanced statistical tool referred to as the Dynamic Conditional Correlations (DCC) in addition to the Pearson’s Correlation method, a prolonged form of the GARCH approach, and the Stochastic Volatility model for estimating the correlations. These developed statistical methods have been adopted mainly to overcome the problems of heteroskedasticity of the Pearson correlation coefficient and the resultant biasedness.

This study has examined shift contagion across six stock markets of European countries, namely, Germany, France, Italy, Britain, the Netherlands, and Turkey against the US stock index, and has compared the indies returns between the crisis period and the tranquil period. As such, it has identified shift-contagion during the financial turmoil by employing different methods, namely, the Pearson Correlation Coefficient, the Dynamic Conditional Correlations (DCC), the GARCH model, and the Stochastic Volatility model. More importantly, the Dynamic Conditional Correlation (DCC) has been combined with the GARCH model of Engle (2002) the utmost testing of the shift-contagion. The combined model has enabled the appropriate valuation of the correlation of pair stock indices. Hence, this study has compared the correlation coefficients in the crisis period differ from the pre-crisis and post-crisis periods. In addition, Bai & Perron’s (2003) statistical method has been used to explicate the breakpoints at times of the crises.

The general objective of this study has been to understand how to shift contagion worked with the presence of structural breaks between the European and the US stock indices. The specific objectives of this study are: -

✓ To investigate whether shift-contagion effects exist or not among the six European and the US stock indices during the financial turmoil period.

✓ To determine the breakpoints of each stock index during the financial crisis

✓ To analyze the shift contagion results of stock indices from the perspective of asset allocations and their implications on risk management.

To meet the above specific objectives, this study would focus on the following research questions and hypotheses.

✓ Does shift contagion exist between European and the US stock indices during the global financial crisis?

✓ Do the breakpoints of each stock index exist during the crisis period?

✓ Does the shift contagion have an implication on portfolio diversification between European and the US stock indices?

By answering the above research questions, this study provides the following contributions to the empirical literature on the financial economy. It aims to investigate the existence of a contagion effect between the US stock market and the major European stock markets. The paper has vital implications for investors from the perspective of portfolio diversification. Due to non-perfect positive co-movement between the returns of the portfolio assets, the financial market investors employ international diversification to reduce the total risk of a portfolio. If there is an increase in equity prices in the period of financial market turmoil, these stock markets' co-movement can reduce the benefit of internationally diversified portfolios. Analysis of contagion is also an implication for financial investors and the monetary policy authorities. Focusing on stock markets enables investors to look at the negative effects which are caused by the markets' different time zones. Because these markets are among the most liquid financial markets. Investors can understand the conditions under which contagion may occur; the responses can be enacted on time. Shift contagion is a concern of risk in the capital markets as well as multinational corporations around the world. Investors should also assess contagion when they are diversifying their portfolios. Furthermore, investors try to reduce risk by using stock derivatives as risk management strategies for hedging.

2.2 LITERATURE REVIEW

This chapter of the literature review, theoretical overviews of the financial contagion effect, and reviews of empirical studies are presented. Under the theoretical overviews, two sub-sections deal with the historical background of the financial contagion effect and transmission of contagion channels in the same order.

2.2.1 Financial Contagion: Theoretical Overviews

The conception of contagion begins from an understanding of the etymological root of the term. The interdisciplinary nature of powerful concepts is realized in financial literature. By this, the commonly used terminologies in other disciplines, in our case contagion, which was commonly used in varied disciplines of medical sciences and epidemiology, have been applied in the field of finance and economics. Hence, conceptual frames of financial contagion are offered followed by reviews of the major transmission channels of contagion.

2.2.1.1 Historical Background of Financial contagion

Before the 1990s, the term ‘contagion’ was rarely used in the literature of economic and financial studies. It was mainly used in epidemiology Kolb (2011), in social and/or clinical psychology, and to some extent, in sociology and philosophy with different meanings. As such, Kolb (2011) indicates that contagion has metaphorical implications. In this sense, the term contagion implies different constructed meanings and interpretations that could vary according to contextual matters of its usage.

In the last two decades, the world has shown several economic crises, many of which had regional or even global ramifications as depicted by the contagion effects. In much of the financial literature, the term contagion has no universally accepted definition. Often, scholars reflect their varied views and standpoints about financial contagion. Forbes and Rigobon (2001); some of the different understandings of the same term, contagion. Some economists define contagion as an association with financial shocks. By this, these scholars view contagion of any level of shocks. If a shock is transmitted from one country to another. But there may not be important changes in cross-market relationships; thereby, the spread of the shock is said to be a contagion. On the other hand, other scholars have argued that simple tests of changes in cross-markets cannot describe contagion. Rather, they try to understand how a shock propagates across countries' markets. As a result, only specific types of financial markets spread regardless of the extent of the shock can define contagion. Concerning this, Porras (2016, 4) explains the possible difference between contagion and spillover.

Porras implies that the speed of transmission matters in the discussions of contagion. Contagion unlike spillovers represents ‘significant immediate impacts. If impacts appear gradual or exist infusions to bring about significant financial impacts, then they are more considered as spillovers.

Furthermore, the contestation of defining financial contagion goes to the detection of the levels of contagion. According to the World Bank, contagion is defined and is distinguished into three categories. These categories identify levels of contagion into a broad sense, a restrictive sense, and a very restrictive sense. In a broad sense, contagion is the process of shock transmission across countries both in tranquil and in crisis periods. According to this definition, contagion is linked to negative and positive shocks spillover effects. Contagion, in a narrow sense, is the transmission of shocks between two countries or groups of countries, beyond any fundamental and common shocks among these countries or cross-country correlations. In a very restrictive sense, Contagion is described as a shift in transmission mechanisms that occurs during a time of turmoil. Similarly, Billio & Pelizzon (2003) define contagion as any level of the increase that occurred in cross-country correlations. By this, they imply that Contagion is a significant relation between 'crisis times' and 'tranquil times.' This definition of contagion is widely used in many empirical studies of contagion.

According to Forbes and Rigobon (2002), the contagion effect is a significant increase in cross-market linkages induced by a shock to a country or group of countries. Instead, Forbes and Rigobon proposed contagion as a manifestation of interdependence between two markets. Hence, Forbes and Rigobon's definition of contagion is contrary to the widely claimed assumption of shift-contagion as a strong consequential linkage between two markets or economies. On the other hand, Naoui et al. (2010) contagion is defined as a substantial increase in relationships across markets as well as an adjusting correlation coefficient to account for heteroskedasticity.

Similarly, Dornbusch et al. (2000) define shift-contagion as the spread of market disturbances from one country to another. The processes of co-movements are revealed by calculating the spreads’ level in exchange markets, the stock markets, the sovereign spreads, and the capital flows. Dornbusch et al. further indicate that sudden increases in the co-movements between markets do not reflect arbitrary decisions and irrational behavior of investors. If a country experiences a shock, the possibility of liquidity constraints may prompt investors to withdraw funds from other countries. In line with this, the roles played by incentives in triggering volatility are significantly higher.

Dornbusch et al. explain how incentives can affect volatility from the fact that many financial activities were carried out by commissioned agents as opposed to principals. In the following sub-section, reviews of some major transmission channels of contagion are offered.

2.2.1.2 Channels of Contagion

Kolb (2011) claims there is no agreement on the definition of contagion, yet many scholars have written about transmission channels of contagion. For the sake of simplicity, we have assumed the brief definition of contagion offered by Dungey et al. (2011, vii). Accordingly, Dungey et al. describe contagion as “the spread of shocks through asset markets within countries and across national borders during times of financial crises.” In fact, Kolb emphasizes the need know how to distinguish the channels of contagion transmission. Furthermore, Kolb states the mere description of the occurrence of contagion and channels of diffusion is not enough. Transmission channels of contagion may not necessarily be implied looking at increases in volatility. Similar to Kolb (2011), Dungey et al. (2011) accentuate the need for theoretical analysis and for suitable methods applicable for testing the presence of contagion.

Dungey et al. (2011, vii) criticize many of the previous empirical studies on contagion, for they were not conducted using a consistent theoretical framework for estimation and identification of contagion. Testing the presence of contagion is a prelude to estimating the extent of contagion and describing its transmission channels. Furthermore, Dungey et al. (2011, vii-viii) indicate the possible challenges in testing the presence of contagion. It is difficult to measure contagion in isolation. Since contagion stands in association with issues of volatility, it is difficult to measure its independent impact on asset prices. As such, the presence of contagion at times of financial crises “was always inferred and never directly measured.” Cognizant of this, Dungey et al. (2011, vii-viii) propose the use of analytical tools generally categorized under latent factor analysis. By this, the transmission channels of contagion particularly at times of financial crises can be identified. Testing the presence of contagion is necessarily combined with identifying the transmission channels of contagion. Dungey et al. (2011, vii-viii) advocate latent factor analysis for it “provides a useful and flexible way to quantify both the size and the significance of contagion in affecting volatility in times of financial crises.”

Many of the previous empirical works discuss different contagion channels at times of financial crises. According to Forbes and Rigobon (2001), there are two major theories called the crisis-contingent and the non-crisis-contingent concepts. The primary theory is defined as the crisis-contingent theory, which explains Transmission methods change throughout a crisis, and cross-market interdependencies strengthen after a shock. In addition, the crisis-contingent theory proposes a variety of way channels. Often, such theoretical analysis employs methods of multiple equilibriums. Accordingly, the transmission mechanisms are assessed center on investors' psychology, endogenic-liquidity shocks, and political economies that could potentially affect the financial markets. As such, shocks are propagated in the crisis period. On the contrary, in a stable period, they do not exist at all. Hence, the crisis-contingent theory supports the concepts in a shift-contagion.

In contrast, the non-crisis-contingent theory assumes the uniformity of transmission mechanisms both at times of crisis and at stable times. Also, it does not have an increase in the time of a shock among cross-market relationships. Thus, the non-crisis-contingent theory does not support the concepts in a shift-contagion. Shocks have the potential to spread globally, but they may not cause shift-contagion effects. According to this theory, Claessens & Forbes (2001b) states there are several contagion channels, such as trade, policy coordination, country re-evaluation, and random aggregate shocks. Similarly, Dornbusch et al. (2000) describe contagion could also spread through trade links and competitive devaluations. The crisis can be triggered through trade links and currency fluctuations. Thus, this has an impact on the economy of other countries and experienced declining asset prices, large capital outflows, and speculative attacks due to the close integration of the financial market of the countries.

Dornbusch et al. (2000) and Kaminsky & Reinhart (1998) illustrate contagion can propagate in different channels; the channel of shift-contagion can be expressed in different ways. Contagion can be generated from the normal interdependence among market economies. Shocks are occurred in a global or local nature across countries due to their real and financial linkages. This type of crisis propagation is real and fundamental that can be linked to different country's cross-border flows of goods, services, and capital. When shocks outbreak in one corner of the nation, this economic interdependence can occur cause of the crisis. Calvo & Reinhart (1996) indicate these fundamental causes are common shocks, trade links, and competitive devaluations. For instance, Eichengreen et al. (1996) explain how a significant change in oil price and the Federal Reserve System interest rate affect global phenomena or the economic fundamentals of several economies simultaneously.

Pritsker (2001) explored the channels for financial contagion in the severity of economic crises. the researcher found macroeconomic rationalizations for their propagation and have fueled fears of unjustified contagion and prompted demands for additional financial market regulation. New regulations can be used to prevent contagion until we have a theoretical foundation understanding of the mechanisms by which shocks are conveyed among markets as well as knowledge of which theoretical channels are empirical research relevant. In the following sub-section, reviews of some important empirical studies are done.

2.2.2 Reviews of Empirical Studies

Many of the previous empirical studies investigated changes in correlation coefficients to measure contagion among two markets during stable and turmoil times. Kazi et al. (2014) examine shift-contagion in 16 OECD member countries by using multivariate asymmetric dynamic conditional correlation. The result suggested that there was shift-contagion in the global financial crisis. In the contrast, in the time of the European debt crisis, it does not show shift-contagion. Chittedi (2015) applied the DCC–Bivariate of GARCH model to examine contagion between the US economy to India during the US subprime mortgage. The conditional correlation of stock returns was positive between US and Indian markets in the time of crisis. Besides, the conditional correlation coefficient has increased significantly. Thus, it indicated a contagion effect.

Naoui et al. (2010) explored crisis and financial contagion in ten emerging markets. As a result of the DCC-GARCH model, the results revealed a significant conditional correlation between emerging market returns and the US index during subprime shocks. They demonstrated that there was no financial contagion in China's Shanghai market. The results showed that a significant conditional correlation between the emerging market returns and the US index during the subprime shocks. They showed that there was no existence of contagion for the Shanghai market of China. The findings demonstrated that the contagion effects spread from the US to Argentina, Brazil, Korea, Hong Kong, Malaysia, Mexico, and Singapore. Celk (2012) used the DCC-GARCH analysis to explore the occurrence of financial contagion of developed-country currency markets against emerging-country currency markets. During the US subprime crisis, researchers noted a contagion effect for many developed and emerging countries. In a relative sense, the contagion effects had most influenced the emerging markets in the time of the US mortgage crisis.

Ahmad et al. (2014) examined the contagion effects on the European stock markets by employing the DCC-GARCH model. The empirical results revealed a strong contagion effect in France, Belgium, Austria, Germany, the UK, Sweden, and Denmark. Hwang et al. (2010) had been using 38 countries to investigate the effects of the US subprime crisis on international stock markets in the time of the US subprime crisis. DCC-GARCH model, they discovered indications of financial contagion not only in emerging markets but also in developed markets. They also detected evidence of the impact of news about sovereign credit ratings during the US subprime crisis. Chihi Bouazizi (2012) tested the contagion effects of the US stock market against the stock markets of developed countries during the subprime crisis by using the DCC-GARCH model. They concluded that during the US subprime crisis, correlations between markets increased dramatically. As a result of the DCC-GARCH model, the crisis spread to several marketplaces. Therefore, there has been evidence of contagion effects.

The DCC-Bivariate GARCH was used by Wang and Thi (2006) to investigate the impact of the Asian financial crisis on the Chinese Economic Area. The empirical study found that the conditional coefficient values of stock market returns were positive. Besides, there were some co-movements between the Thailand and Chinese Economic Area stock markets. The Asian economic crisis affected the region's stock markets. The variations were higher in the post-crisis period than in the pre-crisis period for all countries. The Asian financial crisis significantly shocked the stock markets in the region. For all the markets, the variances were higher in the post-crisis period than in the pre-crisis period. The conditional correlation coefficient in the post-crisis period increased at a significant level. So, it is providing evidence of the contagion effects. During the credit crunch, Lee (2012) explored contagion in international stock markets. The study used twenty international stock indices and examined the contagion effects that occurred across international markets. The findings showed the existence of the contagion effects in Hong Kong, Taiwan, Australia, and New Zealand.

BenSada (2018) investigated multidimensional dependence in financial markets during periods of turmoil and stability using the Markov regime-switching model. A total of twelve US government bonds and eleven Eurozone bonds were analyzed in the study. There was evidence for the existence of contagion effects. The dependency dynamics were superior to the single-regime copula. The contagion effects on Eurozone bond markets have been severe due to the global financial crisis and credit crunch crisis. The dependency dynamics were superior to the single-regime copula. The contagion effects on Eurozone bond markets have been severe due to the global financial crisis and credit crunch crisis. Chittedi (2015) tested the contagion effects between the US and India using the DCC-Bivariate GARCH model in the time of January 2002–December 2011. The study offered the existence of contagion between the US and Indian markets.

Guesmi et al. (2013) examined the existence of contagion effects during the financial crisis between the US stock market and the OECD ones. The result provided contagion as a significant increase in correlations in stock returns after a shock. The study used the Bai-Perron (2003) and the (DCC) Multivariate GARCH Model. They found the mean coefficients of the DCC in the post-crisis period differed from the pre-crisis stable period. Syllignakis & Kouretas (2011) Syllignakis & Kouretas (2011) explored the conditional correlations of seven emerging stock markets of Central and Eastern Europe by using the Multivariate GARCH model in the time of the 2007/2009 financial crisis. The empirical evidence revealed a substantial increase in conditional correlations between US stock returns and Germany as well as Central and Eastern Europe. Furthermore, emerging markets were shown to be more vulnerable to external shocks.

Kenourgios et al. (2011) investigated financial contagion in Brazil, Russia, India, China, the United States, and the United Kingdom using the multivariate regime-switching Gaussian copula and the asymmetric generalized dynamic conditional correlation (AG-DCC) model during five recent financial crises. The analysis of the study showed that there was evidence for the existence of contagion effects from the crisis country to all others at times of the financial crisis. The empirical evidence also indicated that during the crisis, the BRIC markets were particularly vulnerable to financial contagion. The contagion effect of industry-specific instability has a greater impact than a country-specific crisis.

Dungey and Gajurel (2014) explored the occurrence of stock market contagion between the United States and emerging markets during the crisis period using latent factor analysis. The findings provided strong evidence of contagion effects both in the advanced and emerging equity markets. Taken together stock markets of both advanced and emerging markets were affected by contagion from the US. Markwat et al. (2009) tested the ordered logit regressions to examine the contagion effect of equity markets that occurred as a domino effect. The result confirmed local crisis advanced to a more prevalent level in regional and global crashes. Besides, contagion and interdependence showed in different markets such as interest rates, bond returns, and stock market volatility.

Boubaker & Nadia (2016) examined the contagion among the developed and emerging equity markets in the time of 2005/2014 focusing on the subprime crisis of 2008. The research used the co-integration model as well as the Granger causality test. Following the global financial crisis, the study found strong indications of contagion effects between the US and emerging equity markets. Dimitriou et al. (2013) used the FIAPARCH model to examine the contagion impacts of the global financial crisis from 1997 to 2012. The findings indicated that there were no contagion effects on most equity indices of the emerging during the early stages of the crisis. Besides, there was an increased dependence among all BRICS and the US in bullish than in bearish markets from early 2009. These findings did not confirm the contagion effects for all the BRICS markets.

As described above, many of the previous empirical studies addressed the changes of correlation coefficients measuring contagion effects and shift-contagion among markets and were comparing contagion effects during stable and turmoil periods. Similarly, there have been many empirical studies dealing with portfolio diversifications. For example, Vermeulen (2013) examined global diversification in a time of crisis. The study applied a gravity model for 42 destination countries in 2001/2009. The finding provided a strong negative association during the financial crisis. However, before the crisis, there was no significant correlation between them. In addition, during the crisis period, equity investors optimize return-risk utility, which magnified the active rebalancing approach. Hence, investors tried to reposition to markets that have a lower correlation. García & Vázquez (2013) evaluated international diversification gains and home bias of 38 global banks from 1995–2004. The empirical findings showed that the banks with a larger share of asset allocations achieved higher risk-adjusted returns in the emerging markets. The returns were reduced in international expansion strategies due to the concentration of bank subsidiaries in specific geographical regions.

Balli et al. (2013) analyzed asset equity returns and diversification of portfolios among the GCC markets. The result showed that the Gulf Cooperation Council (GCC) Global and regional shocks influenced equities returns across each GCC market. The GCC equity markets were mostly determined by their volatilities. Further, the empirical result exhibited a decreasing result of the volatility of GCC market returns. Regional shocks were positively and were significantly affected in the sector indices. Demirer (2013) investigated diversification risk at equity indices in the Gulf Cooperation Council countries by employing diversification measures of the correlation index and return dispersion. The empirical findings provided a strong association between indices volatility and return dispersion, except for Bahrain. Thus, the GCC stock markets have a significant amount of market risk that was eliminated by allocating domestic portfolios in advanced markets. Besides, the result showed that global diversification enabled local investors in the frontier markets to minimize risk and magnify benefits.

Goetzmann & Kumar (2008) investigated equity portfolio diversification in the US stock market. Equity investors hold under-diversified portfolios. The study indicated that diversification and investment choices are also strongly related. Besides, the stocks encompassed over-weight, higher volatility, and higher skewness which were less diversified by investors. Meanwhile, to some extent portfolio size or transaction cost affects diversification. Although a small number of investors participated under the diversification portfolio, it was costly for most investors. Driessen and Laeven (2007) analyzed international portfolio diversification across nations. According to the study, there are certain benefits for investing outside of one's home country. These global channels have been most noticeable in countries with high country risk. Also, diversification opportunities alter over time as sovereign risk varies.

Chollete et al. (2012) investigated diversifying assets in international markets using correlations and strong dependence measurements. Diversification is a technique used by investors that has both costs and benefits. The findings revealed that dependency develops with time, with large tails in individual countries. Furthermore, the downside risk is differed by region. the study found that Latin American returns had little downside risk and a high degree of correlation complexity. Berger et al. (2011) assessed frontier market equities in the global market integration and diversification. The study employed structural break tests that identify breakpoints in the integration of markets. The research confirmed that Frontier markets illustrated a weak association of markets integration. The frontier markets did not show integration increments through time in the developed and emerging markets. Besides, individual frontier market countries did not reveal consistent rates of changing integration.

Huang & Lin (2011) examined the diversification of international markets in the foreign stock indices and Exchange-Trades. The study used the Value at Risk model developed by Campbell et al. (2001). The Exchange-Trade Funds (ETFs) offered effective international diversification. The findings showed that international diversification was a reasonable strategy to follow. Moreover, Exchange-Trade Funds were good measures than stock market indices in the emerging markets. In addition, the diversification benefits were found the same before and after the US subprime crisis. In the following section, the methodologies used in the study are presented.

2.3 METHODOLOGY

In this section, the rationale for using the latent correlation analysis in dealing with contagion effects, data sources, and the implemented models are discussed in the same order.

2.3.1 Rationale for Using Latent Correlation Analysis

In this section, the rationale for using latent correlation analysis is addressed. Latent correlation analysis used in this study of contagion effects associated with the existence of structural changes is not a different type of analysis from the commonly known description as latent factor analysis. Rather, latent correlation analysis was used to emphasize the version of correlation applied in this study of contagion effects. Hence, it was to focus on the peculiar characteristics of correlation in association with linearity in the sense of mutual interdependence.

Porras (2017, 20) emphasizes the importance of the correlation between variables in studying contagion. Implicitly, Porras indicates there are several versions of correlation analyses, which demonstrate variations of associations between the variables. In the conventional understanding of linearity, there would not be the search for what caused what directly. Rather, the central point in linear correlation is to show evidence of relationships between the variables; thereby, the movements in financial markets are defined by the computed correlation coefficients.

Dungey et al. (2011) emphatically address the appropriateness of latent factor analysis in dealing with the identification of contagion and its effects. In fact, the commonly used phrase, Latent Factor Analysis is modified slightly for particular reference of latent correlation analysis. Obviously, Latent Factor Analysis is a complex methodological approach in the quest for unobserved variables and their level of impact in explicating a phenomenon. Not far from this, latent correlation analysis proposed in this study focused on the identification of correlation attributes suitable for testing the presence of contagion; consequently, to determine the possible interfaces between contagion effects and structural breaks. Hence, the minor modification only at a phrase level is done with a particular purpose to pinpoint the peculiar characteristics of the correlation attributes applied in this study.

Intuitive understanding tells there may be some modifications in methodological approaches for specific purposes. In fact, these modifications do not suggest alterations from the original methodology. Even at times, the modifications cannot be said as modifications; rather, they are versions within the same methodology to focus and to emphasize purposes. Though Kolb (2011) has not specifically mentioned the concepts of latent correlation analysis, he implicitly highlights the existence of varied correlation types. As such, Kolb (2011, 1) underscores for a better understanding of financial contagion, appropriate selection of method is "the key to understanding contagion lies in the concept of correlation"; thereby, the selection is vitally important to identify the presence of contagion.

Darolles & Gourieroux (2015, 45) explore the comparative relevance of the observed and the latent variables investigating contagion. They compare the two cross-market correlations using latent factor analysis. In fact, they also indicate the challenges in applying latent factor analysis, for it "is more complicated to estimate and analyze, it is more appropriate for the prediction and management of future risks." Darolles & Gourieroux (2015, 50-51) further explain the widely held misappropriation of considering the idiosyncratic factors; thereby, the unobservable variables are put aside, even at times are understood as errors. In such practice then, the observable variables, which are inconsiderate to the importance of assessing the factor dynamics, are exclusively used for estimations and predictions.

By explicating the difference between the semi-parametric and parametric perspectives for estimations and predictions, Darolles & Gourieroux (2015, 50-51) denounce the conventional approach of investigating contagion effects exclusively based on observable variables. They emphatically claim, "this practice has to be avoided in contagion analysis." Furthermore, they put their rationale for criticizing the conventional approach. Accordingly, Darolles & Gourieroux (2015, 50-51) indicate, the conventional practice "never confirms the homogeneity of the observable factors." By this, the estimations and predictions would be fallacious since the observable factors are not treated as exogenous. They also propose the importance of considering "the common factor dynamics to predict the future risks." Hence, they conclude consideration of 'latent common factors' is essential to address 'the uncertainty on risk dependence'. In the same vein, this study of contagion effects accompanied with structural changes adopted the suitable approach of latent factor analysis.

Darolles & Gourieroux (2015, 46) emphasize the need to distinguish between 'common shocks and contagion effects. For this purpose, consideration of an appropriate dynamic model should necessarily be critical of the specific properties of the model. Attesting this, they suggest some characteristics of a dynamic model are indispensable. They claim that the dynamic model should necessarily include assumptions of 'lagged variables. They explain the particular purpose of including the 'lagged variables' as this helps 'to identify the propagation mechanism.' Equally, it is important to evaluate the model whether it is open to incorporate varied factors as common and as latent or not. According to them, the common factors are representatives for 'undiversifiable risks', whereas the latent factors are distinctive representations for 'diversifiable risks. More importantly, they claim that assessing the heterogeneity qualities of factors is essential for a convincing determination of shocks affecting the assumed factors. Finally, Darolles & Gourieroux (2015, 46) deduce "if a factor is exogenous, a shock on this factor is external to the system and cannot be partially a consequence of contagion."

To sum up, this study of contagion effects accompanied with structural changes adopted the latent factor analysis for a pragmatically oriented empirical test of contagion. The methodological approach attended in this study harmonized with Dungey et al. (2011, 2-3) illustration of the benefits of applying latent factor analysis. More importantly, the rational developments in the academic discourse to identify contagion have passed through the empirical tests conducted in this study. The comparative analysis of contagion effects in between the turmoil and the tranquility periods is possible for our use of the latent factor analysis. Cognizant of this, the adopted latent correlation analysis was significantly an extension of the correlation analysis widely promoted by Forbes and Rigobon (2002). By such extension, we are confident that we captured the variations of contagion effects between the crisis time and the non-crisis time. More importantly, for detecting the contagion effects accompanying structural changes, we used the multivariate test modeling along with the treatment of endogenous variables. Therefore, the adopted latent correlation analysis agreed with Dungey et al. (2011, 2) claim, "the latent factor approach has the advantage of quantifying the effects of contagion, as well as providing a test for its existence, unlike many alternatively available tests." In the following sub-section, brief accounts of data sources are stated.

2.3.2 Data Source

This study investigated the contagion effects and risk management strategies with the presence of structural breaks between the European and the US stock indices from June 1998 to December 2019. Especially, we attempted to examine the shift contagion of six stock markets in Europe, namely, Germany, France, Italy, the Netherlands, the England, and Turkey with the US stock index. The sample period was subdivided into three episodes to consider the interaction of these series during stable, and turmoil periods. The stable periods were defined as the pre-crisis period and post-crisis period, and the turmoil period was defined as the active crisis period. Hence, we considered the years between January 1998 and December 2007 as the pre-crisis period, the years in between January 2008 and December 2009 as the crisis period, and the years in between January 2010 and December 2019 as the post-crisis period.

The Thomas Reuter Database has been used to gather all the data for this research. In fact, the database is a comprehensive archive of national stock indices of all known countries in the world. Hence, the extraction of data was done only by the countries selected in this study. As such, stock indices of Turkey (Bist100), of Germany (DAX30), of France (CAC40), of Italy (FTSEMIB), of the Netherlands (AEX), of England (FTSE100), and of the US (S&P500) were particularly considered. The facts obtained from this virtual archive were enough to show all the stock index prices weekly. To make the big data of the stock markets as manageable as possible, we chunked the aggregate financial data into the weekly basis exactly corresponding to the timelines.

I calculate stock returns as $In(\frac{P_t}{P_{t-1}})$ where P_t is the price level of for stock index at time t.

Hence, we had informed segmentation of the big data into three categories: namely, the pre-crisis period, during the crisis, and the post-crisis period. Only the data for stock markets from the period 23.01.1998 to 31.11. 2019 was used. To explore the impact of the US stock index's contagion on European stock indices, the application of the DCC-GARCH model tuned by the latent factor analysis was deemed as successful. We compared the correlation coefficients in the three sub-periods. The Bai-Perron structural break test version was employed to detect breakpoints in the entire sample period. In the following sub-section, the implemented models are briefly indicated.

2.3.3 Implemented Models.

In this study, some combined statistical tools were used to detect contagion effects and to compare the computed values in between the periods. Accordingly, Pearson's Bivariate correlation coefficient was primarily used. In such a case, the letter r denoted the association between the two variables. This was quantified with numbers that range between -1 and $+1$. It was deduced that when r approached zero, it was meant that there was no correlation between the variables. In line with this, when r denoted 1, it was meant that there was a perfect association between the variables. Furthermore, the value of r indicated the possible directions of the correlation. By this, when r approached 0 to +1, and 0 to −1, it was meant that there were strong correlations between the identified variables.

Regarding the Dynamic Conditional Correlation version of the GARCH model, we applied what Engle (2002) had developed. By this DCC GARCH model, we would be able to test the contagion effect in the time of the financial crisis. In addition, this model allowed us to compute the heteroskedasticity and the time-varying correlation processes in market returns. As Hwang et al. (2010) acclaimed this model was well-designed modeling for higher-dimension applications. Moreover, as Syllignakis & Kouretas (2011) indicated the benefits of applying this modeling, we were able to obtain all the possible values of the pair-wise correlation coefficients. By this, we were able to determine the values of the index returns in the sample data, and we were able to investigate the index returns behavior at times of financial crises.

To ascertain the presence of contagion impact induced by the subprime mortgage crisis. We agree with (Forbes & Rigobon, 2002), who describe contagion as a substantial increasing market link following a country shock. Moreover, the term interdependence is used to characterize interactions between markets, without a clear pattern of relationship in crisis times. I check the existence of contagion across the European and US stock indices by analyzing the conditional correlations for the possibility of a change contagion.

Furthermore, we were benefited from the other advantage of the DCC-GARCH model of which Chiang et al. (2007) recommended its application to estimate the correlations of the residuals and directly account for heteroskedasticity. Then, we tested the conditional correlations between the European and the US stock indices. As such, we compared the calculated increments as positive or negative with the estimated correlation between the tranquil and turmoil periods. To determine the existence of contagion effects, which were possibly caused by the subprime crisis, we adopted the extended version of Forbes & Rigobon (2002), who described contagion as substantial increases in market ties after a country experienced a shock. Moreover, the concepts of interdependence were used to characterize interactions between markets, without a clear pattern of relationships in crisis times. By this, we checked the existence of contagion across the European and US stock indices by analyzing the conditional correlations for the possibility of changes drawn from contagion effects.

Engle's DCC-GARCH model follows two steps, such as the estimation of the univariate GARCH model, and the conditional correlations. The following is the definition of the multivariate DCC-GARCH model.

$$X_t = \mu_t + H_t^{1/2}\varepsilon_t \tag{2.1}$$

$$\begin{cases} H_t = D_t R_t D_t \\ R_t = \{diag\{Q_t\}\}^{-\frac{1}{2}} Q_t \{diag\{Q_t\}\}^{-1/2} \\ D_t = diag\{\sqrt{h_{11,t,}}\sqrt{h_{22,t,\dots}}\sqrt{h_{NN,t}}\ \} \end{cases} \tag{2.2}$$

Where $X_t = \{X_{1t}X_{2t} \dots . X_{Nt}\}$ is the vector of the past observations, H_t is the multivariate conditional variance, $\mu_t = \{\mu_{1t}\mu_{2t} \dots \dots \mu_{Nt}\}$ is the vector of conditional returns, $\varepsilon_t = \{\varepsilon_{1t}\varepsilon_{2t} \dots . \varepsilon_{Nt}\}$ is the vector of the standardized residuals, R_t is a NxN symmetric dynamic correlations matrix and D_t is a diagonal matrix of conditional standard deviations for return series, obtained from estimating a univariate GARCH model $\sqrt{h_{ii,t}}$ on the i^{th} diagonal, $i = 1,2, \dots . N$. The DCC specification is as follows.

$$Q_t = \{1 - \psi - \zeta\}Q + \zeta Q_{t-1} + \psi \delta_{i.t-1}\delta_{j,t-1} \tag{2.3}$$

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \tag{2.4}$$

Where $Q_t = \{q_{ij,t}\}$ is NxN time-varying covariance matrix of standardized residuals $\delta_{it} = \frac{\varepsilon_i}{\sqrt{h_{it,}}}Q$ is unconditional correlations of $\delta_{it}\delta_{jt}$ and $\psi\ and\ \zeta$ are nonnegative scalar parameter. $\psi + \zeta\{1. Q_t^* = \left\{q_{ii,t}^*\right\} = \sqrt{q_{ii,t}}$ is a diagonal matrix with the square root of the i^{th} diagonal element of Q_t on its i^{th} diagonal position. Thus, for conditional correlation at time t can be defined as:

$P_{ij,t}$ =Where q_{ij} is the element on the i^{th} line and j^{th}a column of the matrix Q_t. The measurements are projected employing the quasi-maximum likelihood method presented by (Bollerslev, 1986) the log-likelihood of the estimators is under the Gaussian assumption.

$$L\{\vartheta\} = -\frac{1}{2}\sum^{T}[\{n\log\{2\pi\} + log|D_t| + \varepsilon_t D_t^{-1} D_t^{-1}\varepsilon_t + \{log|R_t| + \delta_t R_t^{-1}\delta_t - \delta_t\delta_t\}] \quad 2.5$$

Where n is the number of equations, T is the number of observations, ϑ is the vector of parameters to be estimated. To test contagion, we had taken t-statistics to test the consistency of correlation coefficients between stock indices in the time of financial crisis.

Stochastic volatility modeling is a non-normal conditional residual distribution. It is suggested by several authors, Nakajima and Omori, (2012) describe, predict correlation matrices of time series. In addition, they state that latent factor models reduce the number of latent observations and improve an efficient estimation of the model. We applied Stochastic Volatility (SV) in the correlation of stock market series. The model follows three stochastic differential equations:

$$\{\ d\sigma_t = k_\sigma(m_\sigma - \sigma_t)^{dt} + v_\sigma\, \sigma_t^{\beta}\, dw_t \quad 2.6$$

$$d\rho_t = k_\rho\left(m_\rho - \rho_t\right)^{dt} + v_\rho\sqrt{1-\rho_w^2}\, dz_t \quad 2.7$$

$$dw_t = \rho_w dz_t + \sqrt{1-\rho_w^2}\, dz_t \quad 2.8$$

where σ and ρ are stochastic volatility and stochastic correlation at the time t. $k_{(\sigma,\rho)}$ and $m_{(\sigma,\rho)}$ are mean-reverting rate and long-term mean, respectively, within a local volatility framework. $v_{(\sigma,\rho)}$ is denoted diffusion coefficient the positive skew in σ and a power parameter β.

Moreover, the previous literature is more focused on a single test of structural change. But the financial time series data have more than one structural regime change. Due to this reason, this study applied multiple structural changes of Bai-Perron's (2003) dynamic programming algorithm which detects some breaks and their dates. Bai-Perron sequential test suggests, the null hypothesis is no structural breakpoints (m = 0) and an alternative hypothesis is a fixed number of breakpoints (m = k).

A test of multiple structural breaks is used in this study. To test the null hypothesis, no breaks (m=0) are formed against the alternative hypothesis, the number of breaks(m=k). Finally, the researchers use the sequential method among Bai-Perron test alternative ways. A sequential method proposed 5 as the maximum number of fixed breaks at 5% confidence interval and the trimming ε rate. Hence, the sequential method helps the researchers to a consistent estimation of the number of breakpoints present. The model detects breakpoints in the time series data of seven indices of Bist100, DAX30, CAC40, AEX, FTSE100, S&P500, and FTSEMIB. The Bai-Perron (1998, 2003) introduced the subsequent multiple linear regression model with m breakpoints and m+ 1 regimes:

$$y_t = c_j + u_t \tag{2.9 }$$

$$t = T + 1, \quad T_j \tag{ 2.10}$$

$$R_t = \alpha + D_j \tag{2.11}$$

Where $j = 1, \dots\dots m + 1$. In this approach, is the logarithmic realized volatility at time t; and the mean of the logarithmic realized volatility. c_j are the breakpoints that are explicitly treated as unknown. In addition, R_t represents the return for each series; α and D_j are represented the mean intercept and the dummy variable for the regime shift in mean for each stock market return.

2.4 EMPIRICAL FINDINGS

In this chapter, the empirical findings of descriptive statistics and discussion on them are presented. Before proceeding to the discussions of the estimated values using the models, we carried out assumptions and diagnostic tests. Figure 2.1 displays the stock index returns of the indices: Bist100, DAX30, CAC40, FTSE100, AEX, FTSEMIB, and S&P500.

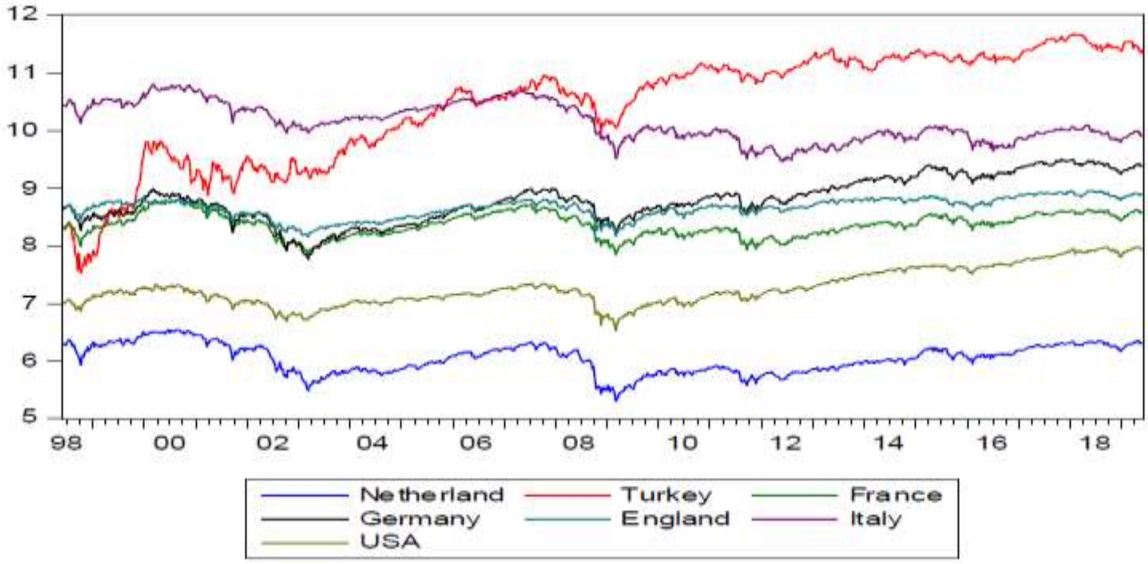

Figure 2.1 *Stock Indices Price Volatility for Europe and US from 1998 to end of 2019. Note: The colors indicated in the legend are correspondingly representing the price index for each country. The data source of the above pictorial representation of the countries' stock prices is Thompson Reuters.*

As shown in Figure 2.1, there are significant variations among the countries' stock indices. As such, the stock index returns for Europe and the US have been extremely volatile during the financial crisis (2007/2009). This crisis affected all our samples of the European and US financial stock indices. The stock indices prices of Europeans and the US had declined during the crisis. In addition, in the equity markets, the US and Europe lost more than 30% of their market capitalization. The magnitude of the crisis effect in most emerging markets, however, is relatively low. Turkey also lost its equity market capitalization. All these markets had exhibited negative returns during the crisis, and their market volatility (standard deviation) nearly doubled when compared to the pre-crisis period. US financial sector volatility increased by approximately twofold. These facts indicate the severity of this crisis.

The descriptive statistics in Table 2.1 show the pre-crisis, during the crisis, and the post-crisis period. In this study, a selected sample of European and the US stock indices had experienced negative returns over the whole crisis period due to global financial shocks. During the non-crisis period, those stock indices have higher returns than in the crisis period. The mean return of sample countries is positive except for the Netherlands in the pre-crisis period. Furthermore, the mean return of all selected sample countries is positive in the post-crisis period. Nevertheless, during the crisis, those markets were more volatile than the pre-crisis. All stock indices volatility (standard deviation) approximately doubled in the turmoil time against the Pre-crisis period. Turkey's market returns experienced 4.5%, and 5.5% the highest volatility during the stable and turmoil period because the crisis adversely affected the Turkish economy mainly through the channel of trade and finance. Turkey’s financial institutions recovered from Turkey’s financial crisis at the beginning of 2010, but they are not strong. Therefore, Turkey’s stock market is more vulnerable to global financial shocks.

Table 2.1 *Statistical Descriptive Result*

Pre-crisis Sample Period (June 1998–December 2007)						
Stock İndex	Sample	Mean	Std Dev	Skewness	Kurtosis	Jarque-Bera
Bist100	500	0.005379	0.04488526	-0.22614	3.6633	136.38*
DAX30	500	0.0007658	0.03299501	-0.44848	2.9767	85.086*
CAC40	500	0.0006753	0.02857607	-0.17999	3.1595	111.61*
FTSE100	500	0.001174	0.02195147	-0.82131	2.3804	48.594*
AEX	500	-0.000087	0.03034263	-0.45971	3.0712	88.446*
FTSEMIB	500	0.000212	0.02830916	-0.59047	3.8470	110.76*
SP500	500	0.0005929	0.02259746	-0.31185	1.6811	38.914*
Crisis Period (January 2008–December 2009)						
Stock İndex	105	Mean	Std Dev	Skewness	Kurtosis	Jarque-Bera
Bist100	105	-0.0007435	0.05461573	-0.22106	1.4316	10.699*
DAX30	105	-0.003126	0.03926558	-0.58322	1.5858	9.8776*
CAC40	105	-0.003949	0.03739796	-0.58998	1.0370	6.8630**
FTSE100	105	-0.001549	0.03747668	-0.54965	0.76848	5.6685***
AEX	105	-0.0044906	0.4375196	-0.74851	1.5044	9.7496*
FTSEMIB	105	-0.005106	0.04322121	-0.60362	1.1269	7.3003**
SP500	105	-0.002952	0.04446417	-1.1434	7.0389	49.896*
Post Crisis Period (January 2010–December 2019)						
Stock İndex	Sample	Mean	Std Dev	Skewness	Kurtosis	Jarque-Bera
Bist100	541	0.005496	0.06532	-0.23009	6.60567	270.307*
DAX30	541	0.00075	0.03322	-0.44744	5.9184	190.629*
CAC40	541	0.00074	0.02872	-0.1876	6.14475	205.201*
FTSE100	541	0.00136	0.02181	-0.8302	5.510	185.292*
AEX	541	2.46E-05	0.03042	-0.4682	6.1094	215.739*
FTSEMIB	541	0.000291	0.02843	-0.59944	6.8524	333.031*
SP500	541	0.00066	0.02262	-0.32856	4.7261	69.7863*

Note: *, ** & *** represents at 1%, 5%, and 10%, respectively

Ivanovski, Stojanovski & Narasanov (2015) apply financial models on asset prices by fulfilling an assumption of Gaussian distribution. However, the practice of asset returns distributions is experienced by skewness and kurtosis. Therefore, the study tested the Gaussian distribution of stock returns, then measure the kurtosis and skewness of European and US stock indices. All stock indices are characterized by high volatility and non-Gaussian behaviors. During the turmoil period, except for the USA stock index return, they have a low value of kurtosis. While in the post-period, stock indices are the extremely leptokurtic and high value of kurtosis. Therefore, the findings from the Jacque Bear test revealed that the distribution of stock market returns is not normal. It means that all stock indices return residuals are not normally distributed. As a result, the null hypothesis can be rejected, and the alternative hypothesis accepted. Besides, all stock return series are negatively skewed in all periods, which indicates long left tails distributions.

Moreover, checking the adequacy of a fitted model is important for model selection, removing misspecification and inconsistency of estimating parameters. Before applying the DCC-GARCH model, it is necessary to examine the data for the presence of heteroskedasticity (ARCH effect). The null hypothesis proposes that there is no ARCH effect in stock series. The probability value of ARCH-LM tests for European and US stock indices (Chi-squared) is less than 5%. So, the null hypothesis is rejected, and the alternative hypothesis is considered. Table 2.2 shows that all stock index returns have an ARCH effect. Therefore, the ARCH effect test shows that the squared residuals are conditional volatility and volatility clustering. GARCH family models can be fulfilled in this stock series. Hence, we can run the DCC-GARCH approach. The weekly returns of all series have common characteristics in fulfilling to run the GARCH family model such as volatility clustering and ARCH effect.

Table 2.2 reports the unit root tests of European and US stock indices. The research explored the unit root in order to determine the stationary of stock returns. To determine the order of integration for each sample period, ADF tests are used. Table 2.2 shows the result of Augmented Dickey-Fuller (ADF). It enables the proper estimation of the GARCH model. At a 5% significance level, the test statistics reject the null hypothesis of a unit root at a level. As a result, the return series in all variables are stationary.

Table 2.2 *Unit Root and ARCH-LM Test Result for European and US Stock Markets*

Stock Market Indices	Index Price		Index Return		ARCH-LM
	ADF	P-Value	ADF	P-Value	Chi-squared
Bist100	-3.636*	0.0250	-16.97**	0.000	166.72**
DAX30	-2.196	0.4641	-19.14**	0.000	143.98**
CAC40	-1.914	0.6263	-19.59**	0.000	139.67**
FTSE100	-2.533	0.3752	-17.76**	0.000	160.4**
AEX	-1.683	0.7530	-19.09**	0.000	203.75**
FTSEMIB	-2.258	0.5215	-18.77**	0.000	132.95**
S&P500	-1.095	0.9390	-19.68**	0.000	248.29**

Note: * and ** represents 5% and 1%, respectively.

Table 2.3 below illustrates the finding of diagnostic tests of stock indices of European and US countries in the pre-crisis, crisis, and post-crisis periods. In the DCC¬-GARCH model, we propose Lagrange Multiplier (ARCH-LM) and Box-Pierce. The residuals are tested for the existence of serial correlation and heteroscedasticity. Also, the Lagrange Multiplier (LM) test is frequently used in the GARCH literature, such as in Engle & Kroner (1995) and Bollerslev et al. (1988). The Box-Pierce test statistics detect serial correlation in a multivariate conditional model. In addition, we applied the Lagrange multiplier to examine the existence of heteroskedasticity. The results show that both Lagrange multiplier and Box-Pierce statistics are very insignificant. At a 5% significance level, it is revealed that the null hypothesis of both tests cannot be rejected. There is no serial correlation and heteroskedasticity in the residuals. Therefore, the DCC-GARCH model is fitted and fulfilled to use the sample of European and US stock indices.

Table 2.3 results show that GARCH coefficients are found to be significant and positive. This suggests that the GARCH method accounts for volatility. The effect of GARCH and ARCH are expressed by the β and α parameters, respectively. The volatility parameter coefficients, which estimate the intensity of conditional volatility at European and US stock indices. Table 2.3 results reported that the GARCH effect (β) of coefficients are positive and significant in all-stock indices. Similarly, past information of stock indices has a positive effect on the co-movement of current stock indices. On the other hand, the ARCH effect (α) coefficients of stock indices are also statistically significant and positive except Turkey and Italy stock indices. This suggests that the past volatility of stocks had a positive effect on current stock indices prices. For stock indices' variance coefficients β and α are positive and statistically significant. So, ARCH and GARCH effects react and persist in all the equity markets' volatility (Table 2.3). The finding also indicates that own spillovers are larger and significant in each stock market.

Table 2.3 *Results of the GARCH model for the US and European Stock Indices*

Pre-crisis Sample Period (June 1998–December 2007)							
Stock İndex	**DCC GARCH (1,1)**				**Diagnostics Test**		
	Mean (μ)	ω	(α)ARCH	(β) GARCH	Q1(10)	Q2(10)	ARCH
Bist100	0.005451	0.000011	0.029990	0.964105*	14.903	15.113	6.172462
					(0.1356)	(0.128)	(0.2898)
DAX30	0.002553	0.000047	0.15997*	0.801908*	7.4117	7.5476	3.124537
					(0.6861)	(0.6729)	(0.6808)
CAC40	0.001999	0.000041	0.163002*	0.789515*	5.1377	5.2049	1.829472
					(0.8818)	(0.8771)	(0.8722)
FTSE100	0.002010	0.000070	0.120730**	0.731447*	4.5603	4.6387	1.057098
					(0.9186)	(0.914)	(0.9578)
AEX	0.001603	0.000051	0.176883**	0.769145*	22.128	22.453	4.427890
					(0.01447)	(0.0131)	(0.4896)
FTSEMIB	0.001399	0.000021	0.130860	0.845682*	15.88	16.19	8.434851
					(0.1031)	(0.0943)	(0.1338)
S&P500	0.001181	0.000003	0.045023**	0.948428*	5.7033	5.789	6.550986
					(0.8395)	(0.8327)	(0.2562)
Crisis Period (January 2008–December 2009)							
Stock İndex	Mean (μ)	ω	(Α)ARCH	(Β)GARCH	Q1(10)	Q2(10)	ARCH
Bist100	0.008257	0.000315	0.268141	0.619086*	11.465	11.638	0.277626
					(0.3224)	(0.31)	(0.9980)
DAX30	0.000340	0.000055	0.201485**	0.766455*	10.423	10.53	8.342455
					(0.4042)	(0.3953)	(0.1383)
CAC40	-0.000073	0.000076	0.196161**	0.743536*	8.5194	8.6534	7.055408
					(0.5782)	(0.5653)	(0.2166)
FTSE100	0.000239	0.000139	0.122315**	0.767230*	17.957	18.227	0.792867
					(0.0557)	(0.0513)	(0.9775)
AEX	0.000831	0.000151	0.234842**	0.678758*	6.8015	6.9132	4.012272
					(0.744)	(0.7336)	(0.5477)
FTSEMIB	-0.004482	0.000127	0.201313	0.735849**	7.818	7.929	3.039814
					(0.6466)	(0.6358)	(0.6938)
S&P500	0.001143	0.000069	0.321198**	0.677802*	17.636	17.896	1.743579
					(0.0614)	(0.0568)	(0.8834)

Note: *, **, and*** represents 1%, 5%, and 10% respectively. Q1 & Q2 represents Standardized Residuals & Squared Standardized Residuals

Table 2.4 Results of the GARCH model for the US and European Stock Indices

Post Crisis Period (January 2010–December 2019)

Stock İndex	Mean (μ)	ω	(α)ARCH	(β)GARCH	Q1(10)	Q2(10)	ARCH
Bist100	0.005877	0.000014	0.031774	0.961821*	9.2278	11.419	1.1787
					(0.5106)	(0.3258)	(0.3185)
DAX30	0.002655	0.000049	0.161165**	0.799419*	6.2576	2.2552	0.6004
					(0.7932)	(0.9939)	(0.6997)
CAC40	0.002165	0.000042	0.164219*	0.788347*	9.2014	12.4374	0.1449
					(0.5131)	(0.2568)	(0.982)
FTSE100	0.002169	0.000076	0.127521**	0.709235*	10.686	9.5328	0.2033
					(0.38247)	(0.4824)	(0.96)
AEX	0.001752	0.000051	0.180405**	0.765213*	12.709	20.204	0.5376
					(0.2404)	(0.02738)	(0.748)
FTSEMIB	0.00151	0.000022	0.135168	0.84061*	9.3575	15.913	0.2738
					(0.4985)	(0.10215)	(0.927)
S&P500	0.001232	0.000002	0.042625**	0.950832*	10.914	15.4394	0.44607
					(0.3643)	(0.11684)	(0.816)

Note: *, **, and*** represents 1%, 5%, and 10% respectively. Q1 & Q2 represents Standardized Residuals & Squared Standardized Residuals.

The correlation estimation employs to compare the relationship between major European countries indices with the US stock index whether the shift contagion occurs or not in the period of crisis against the stability period. We adopt the Forbes and Rigobon term of definition[1]. If there is no significant trend of co-movements or shift contagion in stock markets during the crisis period, they are described as interdependence dynamics between markets. Hence, we investigated the shift contagion of stock indices and applied the time-varying conditional correlation model of Engle (2002). The classification of the period enables us to specify a stable and crisis period among European and US stock indices. Moreover, the research examined the possibility of contagion in the European and US stock markets by employing the unconditional and conditional correlations to find out shift contagion inline of Tran, (2018), Gravelle, Kichian & Morley (2006), Forbes & Rigobon's (2002).

In the literature of time series, researchers have given attention to the correlation coefficient. It is a statistical approach, which uses to test a defined quantitative association between two stock markets. This method as Erdem, Ceyhan & Varli (2014) indicate is a critical estimator for financial functions. On the contrary, misuse of correlation has been taken in some researchers to link financial markets. This study

[1] Forbes and Rigobon (2002), contagion is defined as a significant increase in market co-movement after a shock to one country, this suggests that contagion occurred during the crises period.

applied advanced models of DCC-GARCH and Stochastic volatility. As a result, we found an appropriate estimation of correlation in capital market research.

Tran, (2018), Gravelle, Kichian & Morley (2006), Forbes & Rigobon (2002) argue that the correlations significantly positive increase during a crisis time compared to a stability time. They call the existence of contagion. I applied Pearson’s correlation coefficients, Stochastic Volatility, and time-varying conditional correlation. They allow all pair-wise conditional correlation coefficients for the sample index returns and discuss the possible effects of financial contagion between the US and European stock indices.

Table 2.5 *Results of Unconditional and Correlation Coefficients*

Stock Market Indices	**Unconditional Correlation**					**Dynamic Conditional Correlation Coefficient**				
	Pre-crisis (1)	Crisis (2)	Post-crisis (3)	% Difference		Pre-crisis (1)	Crisis (2)	Post-crisis (3)	% Difference	
	p	p	p	1&2	2&3	p	p	P	1&2	2&3
Bist100	0.3145	0.58541	0,3105	86.13	-46.96	0.005451	0.008257	0.005877	51.48	-28.8
DAX30	0.7548	0.80355	0,7549	6.45	-6.054	0.002553	0.000340	0.002655	-86.68	688.9
CAC40	0.7569	0.76395	0,7550	0.933	-1.17	0.001999	-0.000073	0.002165	-136.2	-396.6
FTSE100	0.65094	0.61483	0,6512	-5.55	5.92	0.002010	0.000239	0.002169	-88.11	807.3
AEX	0.74026	0.73036	0,7381	-1.34	1.06	0.001603	0.000831	0.001752	-48.16	110.8
FTSEMIB	0.70574	0.67902	0,7030	-3.786	3.53	0.001399	-0.004482	0.00151	-420.37	-133.7

We test Pearson’s correlation approach. The unconditional correlations between US and European stock indices returns are shown in Table 2.4. Our findings on Pearson’s correlation are strong and positive correlation coefficient each sample of a European country with US stock index returns. The intensity and direction of associations between stock indices are defined by correlation coefficients. In the three periods, the highest correlation is between the US stock index with France and Germany indices, the lowest of which is between Turkey and the US stock indices.

In this section, the study compared changes in correlation coefficients across the crisis and stability periods. In the turmoil time, the unconditional correlation of stock indices is higher than the pre-crisis periods between Turkey, France, and Germany with the US. On the other hand, the unconditional correlation after-crisis time is greater than the turmoil time between the United Kingdom, Netherland, and Italy with US stock indices. The analysis of the result is carried out based on Pearson's correlation. It is not a good measurement method of the dependencies among stock indices. This is consistent with what has been found in a previous study by Forbes and Rigobon (2002).

They found that Pearson’s correlation parameter is positive volatility and overestimation of the relations between rates of return during a crisis period.

This study identified the shift contagion from the perspective of a positive increase of correlation between stock indices in the crisis time compared to the stability time. The result now provides in Table 2.4 that some European and US stock indices are an increment of positive correlation coefficient from tranquil to turmoil period between markets. As result, the findings look like a contagion effect between US’s-German, US’s-France, US’s-Turkey stock indices in the crisis period. However, the estimation of cross-market Pearson correlation coefficients is biased due to heteroskedasticity in market returns (Forbes and Rigobon, 2002). To reduce the problem of heteroskedasticity, we applied stochastic volatility and DCC-GARCH models which are motivating this academic research to get reliable estimates of the correlation between the return series.

We proceed with further findings on shift-contagion with the consideration of the global financial crisis phase. The research specified sub-periods that display contagion effects for the US stock index on European stock indices using dummy parameters. We construct dummies to explain the characteristics of dynamic conditional correlation. Here, we compare the findings of the proposed DCC-GARCH method with those of the Person method. Table 2.4 reports the dynamic conditional correlation and unconditional correlation coefficients over the three periods. The results provided that unconditional correlation increased during the crisis period in almost Turkey, Germany, and France. However, for the England, Netherlands, and Italy, the result of the unconditional correlation decreases during the crisis period. After the crisis period, unconditional correlation is the reverse of the crisis period for all European countries’ stock indices.

On the contrary, the evidence from the time-varying parameter estimation model shows in Table 2.4 that conditional correlation coefficients decrease in the crisis period for all stock indices except for Turkey. Thus, the German, England, France, Netherlands, and Italy stock indices did not generate the shift contagion from the US subprime crisis. However, Turkey's stock index is significantly affected by the contagion effect of the US mortgage crisis. These findings confirm that Turkey’s equity market is a strong positive relationship with the US equity market. Yendi & Çetin (2012) state when any change happens in the US financial sector, this has a substantial impact on the Turkish stock market. Turkey adopted a macroeconomic structural

Economy Program in line with the IMF agreement to stabilize macroeconomic factors through tight monetary and fiscal policies following 2000 Turkey's financial crisis. The fact that Turkey experienced a stronger growth pattern relative to many other countries. It has exercised the reforms. However, the volatility in the financial markets of the United States in 2007 escalated into a global economic crisis, which affects more Turkey's financial markets.

Among European and US stock markets, unconditional correlations are strong and positive values in all indices. Nevertheless, Pearson correlation is more biased due to heteroscedasticity. Dynamic conditional correlations are also positive in the period of pre-crisis and post-crisis. However, in crisis time, the stock indices of France and Italy were negative. Furthermore, the dynamic conditional correlations on average are weak between European and US indices. The weak values of correlations suggest that there is a long-term benefit to diversifying over across markets. Providing that the lower correlation between the European and US stock indices, they would achieve a greater advantage of diversification.

Table 2.6 *The Result of SVM Correlation and DCC-GARCH Correlation*

Stock Index	**Stochastic Volatility Model Correlation (SVM)**					**Dynamic Conditional Correlation Coefficient**				
	Pre-crisis (1)	Crisis (2)	Post crisis (3)	% Difference		Pre-crisis (1)	Crisis (2)	Post-crisis (3)	% Difference	
	p	p	p	1&2	2&3	p	p	P	1&2	2&3
Bist100	0.40	0.42	0.39	5	-7.14	0.005451	0.008257	0.005877	51.48	-28.8
DAX30	0.68	0.68	0.72	0	5.9	0.002553	0.000340	0.002655	-86.68	688.9
CAC40	0.71	0.71	0.78	0	9.86	0.001999	-0.00073	0.002165	-136.2	-396.6
FTSE100	0.63	0.64	0.59	1.59	-7.8	0.002010	0.000239	0.002169	-88.11	807.3
AEX	0.65	0.68	0.72	4.6	5.9	0.001603	0.000831	0.001752	-48.16	110.8
FTSEMIB	0.64	0.64	0.69	0	7.8	0.001399	-0.004482	0.00151	-420.37	-133.7

DCC-GARCH model and stochastic volatility approach were employed. Meanwhile, the Stochastic Volatility Model does not generate shift-contagion from the US subprime crisis to European stock indices. Because those indices, do not increase the positive correlation between the turmoil period against with stability period. However, the contagion effect propagated to the Turkey stock index after the US subprime crisis by comparing pre-crisis against turmoil period. Indeed, the strongest conditional correlation is observed especially in Turkey and the US stock indices. This would mean that a higher level of relationship between indices would reduce the diversification benefits in the period of crisis. The time-varying correlation indicates a slight decrease during post-crisis in Turkey, France, and Italy. While the conditional correlation of Germany, the England, and the Netherland shows a slight increase in the period of post-crisis.

Generally, studies of cross-market correlations between returns and volatility as well as shocks transmission among markets are critical areas in finance. since they have a substantial impact on the international stock market and portfolio investment. Indeed, investors can assign the least partially integrated assets, which is an appropriate approach for risk-return portfolio management. While a higher level of relationship between markets would reduce the diversification benefits. As result, investors have shifted their attention to other lower co-movement financial markets.

While German, France, Netherland, England, and Italy do not show a shift-contagion effect persuasively. But high variance exists in the turmoil period. It also indicates the continuation of financial interdependence. This immediately leads to deterioration in the stock indexes in all European markets. However, the change and increase in volatility happened in the crisis time. It does not have the existence of shift-contagion. Diversification does not guarantee against all losses in a declining economy and financial stress. Investments in stocks are susceptible to interest rates and inflation risks. Furthermore, international investment brings huge risks, particularly currency volatility and political instability. The findings do not show a trend of shift contagion in cross-market volatility. However, those sock indices are interdependent which cannot affect the effectiveness of portfolio diversification.

The study's results have significant implications for stock investors in these financial markets. The finding has been acknowledged in conventional financial literature that international diversification can decrease the overall risk of a portfolio. During the turbulence of the financial market, the co-movement relationship between European and US stock indices did not increase except Turkey and US stock indices. At this time, they enhanced the advantage of globally diversified investment portfolios. We compared the results for each of the models based on stock indices returns of the US, England, Germany, Netherlands, France, Italy, and Turkey when creating asset allocation and risk management in optimal portfolios. Our findings sugest that the dynamic conditional correlation GARCH Model is more capable as well as achieving better performance than the Stochastic Volatility Model. Hence, in the sample period, the Dynamic Conditional Model enables investors to find a realistic estimation of correlation and minimize portfolio risk and increase the realized returns.

This study concludes that it does not provide a better output by applying the Stochastic Volatility model and Person correlation. The findings are not directly in line with the previous findings (Chib, Nardari, and Shephard, (2006). Investors benefit from diversification by maintaining a lower investment portfolio composed of various stocks. Obviously, cross-market correlations increase during the recession time, which hurts assets. In addition, the advantages of portfolio diversification will be substantially reduced during periods of market crashes. However, this study found that there is no shift contagion England, France, Germany, the Netherlands, and Italy stock indices, which originate from the US subprime crisis. Thus, international portfolio diversification is most required. The allocation of assets and portfolio composition should be considered those stock indices.

The conditional correlation of the DCC-GARCH model was reported below in Figures 2.2, 2.3, and 2.4. Those figures draw some clear results suggesting that the correlation between the returns of stock indices shifts dynamically over time. The spread of market disturbances from one country to another can have different fundamental causes such as macroeconomic, political, and financial shocks. Co-movements in stock returns are evidence of this process.

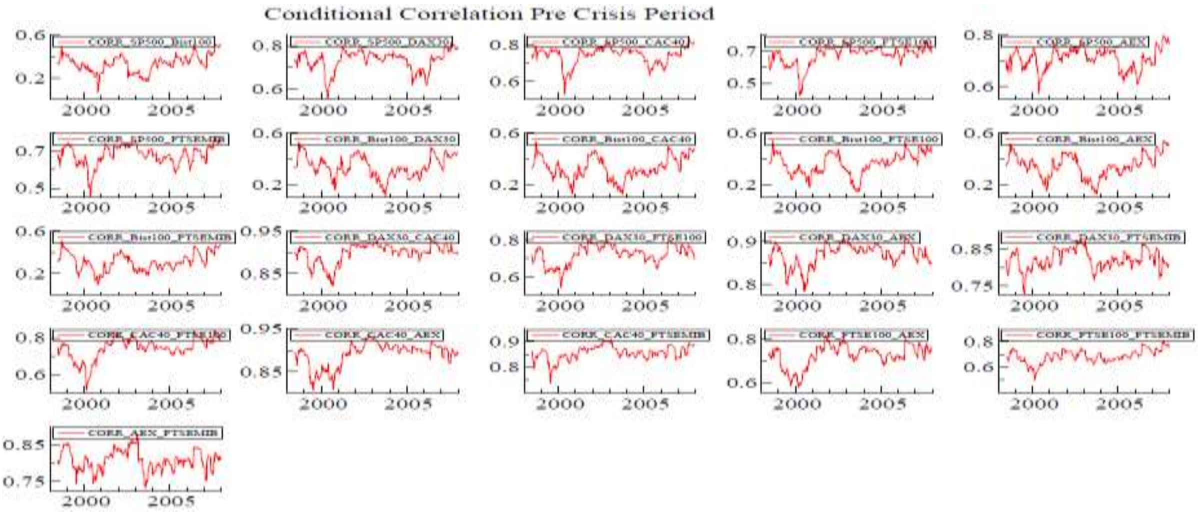

Figure 2.2 *Pre-Crisis Conditional Correlations*

The graphs illustrated in Figure 2.2, the dynamic conditional correlations for the six European stock indices with the United state stock index in the pre-crisis period. Indeed, in the Q2 of 1998, conditional correlations of the six countries sharply decline in each six-stock index. They reached the bottom in the Q4 of 2000. After that, they began surging during in the Q1 of 2001. Figure 2.2 shows all graphs sharply raised in the Q2 of 2001 and reached on the pick level conditional correlations in all six European stock indices. Then, the correlation coefficients between 2001Q4 and 2005Q1 were stable for a long-time. Lastly, the graphs of correlation fluctuated between 2005Q4 and 2007Q4. It is not possible to say that the existence of contagion where the correlation increases within the fixed period.

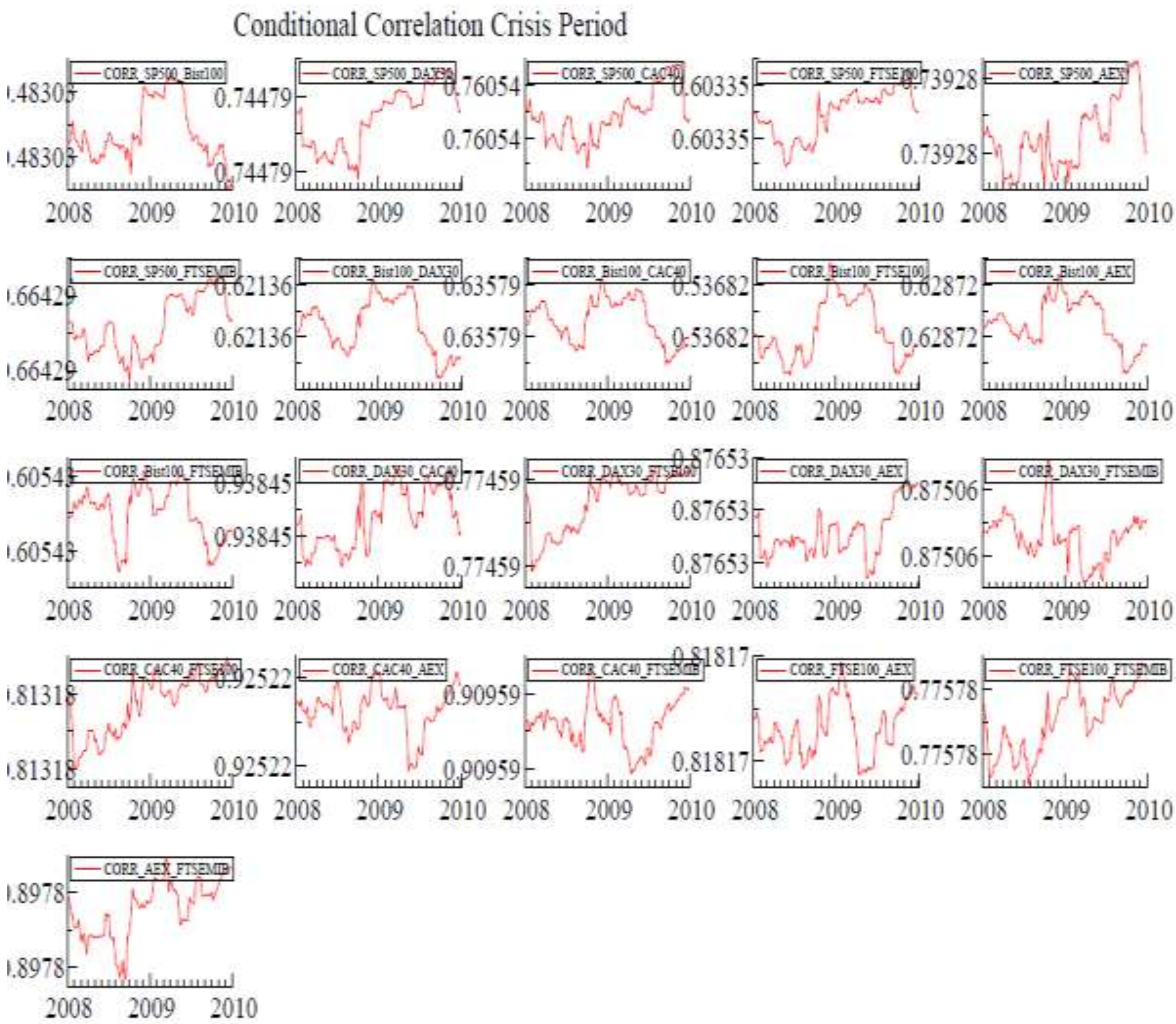

Figure 2.3 *Crisis Conditional Correlations*

Figure (2.3) displays the graph of the conditional correlations between the contagion source of US and European stock indices. Because of the US subprime crisis, the European stock indices’ conditional correlations sharply decreased at the 2008Q1 and 2010Q1 as well as they reached the bottom level in 2008Q4. Turkey's stock market rose sharply in the Q4 of 2008. However, the rest of the stock markets' conditional correlations were increasing gradually in the Q4 of 2008. Except for Turkey, the rest stock markets conditional correlations of Germany, France, England, the Netherland, and Italy reached their peak during Q4 of 2009. While the graph of conditional correlations of Turkey stock market was reach pick and a little bit stable in the Q2 of 2009.

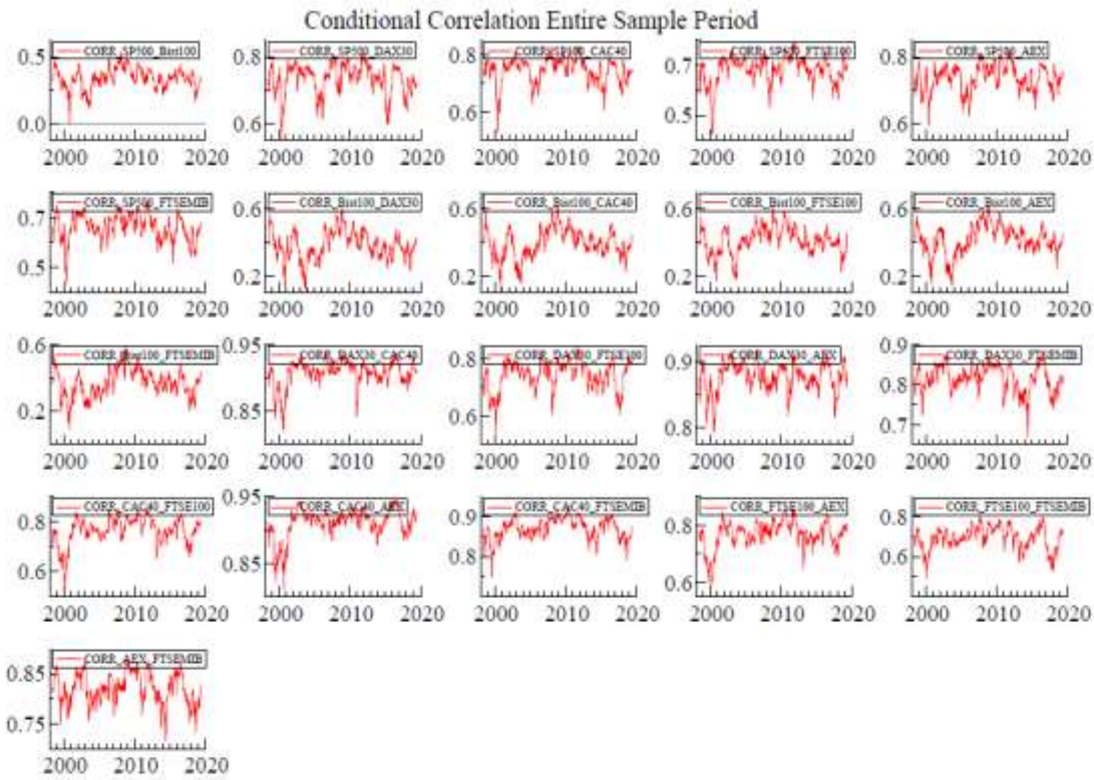

Figure 2.4 *Entire Sample Period Conditional Correlations*

To illustrate the conditional correlations in the entire sample data and period, the graphs reflect the combination of each stock index return correlation with the time of the episode. As displayed in figure 2.4, the case of conditional correlation, the graph of pairwise European index with US index sharply declined at the 2000Q4,2008Q1 and 2016Q1 in every three episodes. The decline of conditional correlations in the European countries are varied in three episodes i.e., 2000Q4, the magnitude of correlations reached the lowest level compared with the other two lower levels of correlations. Clearly, stock markets of the selected samples have been exposed to extreme volatilities. In the Q4 of 2010, the drop of conditional correlations in the countries of Turkey, Garman, France, England, the Netherland, and Italy were slowly rising. All stock markets, conditional correlations in most of the selected countries showed signs of recovery in the Q4 of 2012 and reached pick level. However, another decline of correlations to selected European markets is noticed in the period of 2016Q1.

2.5 CONCLUSION

This study has investigated the contagion effects and the patterns of shift-contagion among six European countries' stock indices and the US stock index link with the global financial crisis. The issues of contagion have been discussed in consideration of the assumed structural breaks. The breakpoints in successive waves of the financial crises have been detected using Bai-Perron’s (2003) method. Then, identifications of the patterns of shift-contagion in the time of financial crisis have been conducted. The statistical models employed in this study, such as the Pearson Correlation, the DCC-GARCH model, and the Stochastic Volatility model had enabled us to figure out how contagion behaved in the presence of structural breaks at times of the financial crises.

The conducted latent correlation analysis showed the relationship between each of the European indices with the US stock index. By this, whether shift contagion has occurred or not in the periods of the crisis against the stability period has been done. We have adopted an extended version of Forbes and Rigobon’s approach in dealing with identifying contagion and its channels of transmission. It should be recalled that Forbes and Rigobon’s approach examined shift-contagion in unidirectional and only in between two countries’ stock indices. In this study, however, we have investigated the characteristics of shift-contagion in line with co-movements and in between seven countries. This has implied the suitability and capabilities of the model we used. As such, the par excellence of the Dynamic Conditional Correlation of the GARCH method has been illustrated.

Succinctly, this DCC-GARCH model has shown better capabilities than the Stochastic Volatility model. In fact, this Stochastic Volatility model has been employed in this research. Also, applying the Stochastic Volatility method has been able to compare its performance with this study that applied the DCC-GARCH model. In other words, the Stochastic Volatility model and the Pearson would not offer plausible results studying contagion effects in the existence of structural changes. This disagrees with the research of Chib, Nardari, and Shephard, 2006) in their critical views on the Stochastic Volatility model as applied in comparing the models for the most advantageous asset allocation had considered. Thus, the Dynamic Conditional Correlation model employed in this study has enabled us to show a realistic estimation of correlations that would suggest minimized portfolio risks and increased stock returns.

As the results have shown, the computed unconditional correlations between the European countries’ indices and the US stock index are found strong and are of positive values in all the indices. The findings of unconditional correlation are overestimating and have shown biased results possibly due to heteroscedasticity. On the contrary, the results of the dynamic conditional correlations have shown reliable estimation values almost in all three periods. The lower values of correlations suggest that it has long-term benefits to diversify over across markets. Providing that the lower correlation between the European and US stock indices, they would achieve a greater advantage of diversification.

Furthermore, this study has explored the shift contagion from the perspective of positive increases in pair-wise comparison of correlations between stock market indices in the crisis period against with the non-crisis periods. The results have shown that there has been a positive increment in unconditional correlations between the European and the US stock indices. By this, positive increments of correlation coefficients from the tranquil to the turmoil periods have been observed in between markets. This contrasts with the reports by Tran, (2018), Gravelle, Kichian & Morley (2006), Forbes & Rigobon's (2002) estimation using the Pearson correlation coefficient. Perhaps, the estimation model of cross-markets has brought biased results due to heteroskedasticity in market returns. Consequently, future studies in financial contagion are expected to apply valid and reliable estimation models about correlations of stock returns in time series. Thus, the Stochastic Volatility and DCC-GARCH models are proposed for better understandings of contagion effects accompanying structural breaks.

Many European financial sectors have been exposed to the aftermaths of financial crises. However, the stock market indices have been observed with low conditional correlations in the three periods. This implied that they have not shown positive increments of correlations in the crisis periods against in the stable periods. By implication, the empirical findings do not support the supposition of the US market's contagion effects on the major European markets except on Turkey’s market. In brief, we have not come up with ample evidence for the existence of contagion effects. This indicates that the markets have shown certain aspects of interdependence, but these markets cannot be said as manifestations of contagion effects in between them.

As discussed in the aforementioned sections, the sample countries’ indices have shown similar characteristics of contagion effects. Many of the points raised by Kolb (2011) agree with the findings in this study. Similarly, what Kolb indicates about identifying a particular channel of transmission has been challenging. Manifestation of similar symptoms makes challenging to identify the specific channel of transmission accountable for the impacts of financial crisis across countries or regions. Similarly, Kolb's claim, contagion effects have been linked to the speed of transmission. By this, financial contagion is exclusively linked to quick transmission of shocks while the slow rate of transmission is attributed to a spillover of the preceding financial crisis. Hence, future studies are expected to distinguish between contagion in a strict sense and spillovers of financial problems after a marking financial crisis.

As a result, the non-existence of contagion effects is meant that investors would be beneficiaries of the international diversification portfolio. Thus, this study has significant implications for multinational firms because diversification through investment in multiple markets has a lower correlation as well as a negative correlation where investors are a desirable for investments. Therefore, an investment strategist should focus on how international diversifications work in the three periods. This study has verified that the volatility of stock indices has been reduced in the post-crisis period. These market indices still surpass in the long track. Hence, the findings of the study would enable policymakers to identify the nonexistence of contagion among stock markets and to strategically manage risks and allocate assets. In the following final section, the conclusions drawn from the two parts: long-term dependence in financial time series and contagion effects in structural changes, are offered. By this, the seemingly independent appearance of the powerful concepts of long memory and contagion effects are explicated how much they are mutually exclusive concepts.

GENERAL CONCLUSION AND SUGGESTION

In this Ph.D. thesis, the two parts have offered a systematic analysis of long memory and contagion of volatility in stock indices. Six European countries' stock indices (i.e., of Germany, France, the Netherlands, England, Italy, and Turkey) and the US index have been examined in the diverse markets weekly. Risk management in the conventional portfolio theory is increasingly challenging when the correlations between assets increase. Hence, this study of long memory and contagion of the markets are found relevant in portfolio selections and risk management practices.

In part one, the ARFIMA-FIEGARCH model has been applied to investigate the long-range dependence of stock index returns by employing weekly data from the period of January 1998 to December 2019. In so doing, aspects of long-term dependence revealed in the stock index returns are discussed in consideration of structural changes and without considering them. By this, the FIEGARCH (1, d, 1) version of the GARCH has proved as it is the best fitting specification and selection criteria for all the indices. Therefore, the FIEGARCH model is a suitable model for investigating the long dependence of stock price volatility on European and the US markets under the effects of structural breaks. Moreover, the long-range dependence stock returns are detected by ARFIMA–FIEGARCH model combined with the consideration of the dummy variables. The dummy variables that are combined with the ARFIMA–FIEGARCH model were found to be the most appropriate for investigating the long memory processes of these markets in the sample. Breakpoints in volatility are detected using the Bai-Perron model. We had detected a maximum of five breakpoints for each stock index return with the specified sample.

The findings suggest that the European major national stock markets of Germany, France, the England, the Netherlands, Italy, and the US index have a strong long memory of returns. Possibly, because the functions of volatility have decreased tendency at hyperbolic in the autocorrelations of the markets, these indices revealed a strong long memory of returns. It could be said that the slow decay in the stock returns and the property of slow mean reversions have influenced the properties of the long memory processes. The national indices of those countries would not accompany a random walk process. Therefore, understanding the existence of persistence of volatility in the return series would help technical analysts and strategists. Stock prices have a high probability of predictable behavior. The Turkey national index is found exceptional, it does not show any predictable behavior. This implies Turkey has followed a random walk process. In fact, this does not argue with the concept of the weak form of efficient market performance.

Obviously, the concept of a weak form of market efficiency emphasizes how asset prices should include information efficiently and quickly at any argument in time. This is because historical stock price data cannot be used to estimate future market price movements. Turkish national stock index may not be suitable for technical analysts and for strategists, who offer information for investors to allocate portfolios. It is concluded that the long-range dependence can explain the behavior of instability in stock market information. In the study, we considered structural breaks in the time series of long memory analysis. Moreover, the study has empirically distinguished between factual and spurious long-term dependence characteristics of volatility by comparing the long memory volatility with or without the existence of structural changes by employing the FIEGARCH model. The study tested long-range dependence by including dummy variables in the ARFIMA-FIEGARCH model. The results are found of mixed nature. The volatility of persistence is slightly reduced in most stock market returns except in Bist100, FTSEMIB, and S&P500. The structural changes seem to have impacts on changing persistence of volatility in certain stock indices of Germany, France, the Netherlands, and the England. The results also show that the assumed structural breaks have reduced the impacts of the long memory processes in those samples. Thus, the volatility persistence of stock indices is affected by the sudden changes in the countries of Germany, France, the Netherlands, and the England.

In the second part, we examined the shift contagion effect with the presence of structural breaks for the determination of asset allocation and investment management between the European stock indices and the US stock index from June 1998 to December 2019. To test the shift contagion between the European countries, specifically, Germany, France, Italy, the Netherlands, the England, and Turkey's indices with the US index, we used the bivariate DCC-GARCH model. The study divided the sample period into three episodes to consider the return series movements in the pre-crisis, the crisis, and the post-crisis periods. Then, we compared the impacts of shift contagion in the three periods.

The findings of this study suggest that between the European and the US stock indices, unconditional correlations are strong and positive values in all indices. However, the Pearson correlation is more biased due to heteroscedasticity. On the contrary, the dynamic conditional correlations on average are weak in both the

European and US indices. The weak values of correlations suggest that there is a long-term benefit to diversifying over across markets. Providing that the lower correlation between the European and US stock indices, they would achieve a greater advantage of diversification.

Studying the cross-market correlations between returns and volatility as well as transmission of shocks from one market to another are essential areas of study in finance so they have a large impact on the international stock market and investment allocation. Indeed, investors can assign the least partially integrated assets, which is an appropriate approach for risk-return portfolio management. DCC-GARCH model and stochastic volatility approach were employed. Meanwhile, the Stochastic Volatility model does not generate shift-contagion from the US financial crisis to European stock markets. Because those indices do not show increases, there has been a positive correlation between the turmoil period against with stability period. However, the contagion effect propagated to the Turkey stock index after the US subprime crisis by comparing pre-crisis against turmoil period. Indeed, the strongest conditional correlation is observed especially in Turkey and US stock indices in the three periods. This would mean that a higher relationship between markets would reduce the diversification benefits in the crisis periods. The time-varying correlation indicates a slight decrease during post-crisis in Turkey, France, and Italy. While the correlation coefficients of Germany, the England, and the Netherlands show a slight increase in the period of post-crisis.

Cognizant of the aforementioned issues, what many scholars advocate claiming for interdisciplinary approaches in dealing with financial crises is plausible. Dealing with both long memory processes and contagion effects is necessarily set up for applications of methodological approaches in a time series analysis. In this study, these powerful concepts of financial crises imbued in structural breaks are verified empirically. Retrospective views of the financial shocks in the past two decades are ratified in association with the assumed historical structural breaks in six European countries and the US. Benefiting from the historical approaches, this study has attempted to show the correlation patterns between stock indices and long memory processes in structural breaks. Hence, the insights are helpful for better understandings of the evolved causal factors to the financial crises and of the currently observable financial performances. In turn, better understandings of countries' economic behavior and deep expertise investigation about determinants of economic performances, would have myriad advantages.

Explication of long memory in a time series analysis is indisouble with an exploration of contagion effects in a latent correlation analysis. By this, investigation on the roles of persistence processes is closely linked with the enacted structural changes at times of financial crises. Contextual matters of temporality are emphasized. Obviously, dealing with temporal dimensions of long memory processes also connotes dealing with spatial dimensions of them. The inseparability of studying long memory and contagion is verified in the interoperability of exploring stock markets and returns, of investigating persistence in volatility at times of crises, of detecting contagion effects along with analyzing the varying degrees of intensity, and of selecting suitable econometric models for reliable and valid measures. Hence, this financial study by combining long memory and contagion effects in the presence of structural breaks is plausibly an insight on postulated sequences of possible monetary events amenable for interventions in the coming decade.

The autocorrelation patterns between long memory and the financial crises seem relatively different from the correlation patterns between contagion effects and the crises. The time series analysis moderately confirms in the event of the persistence of autocorrelations is observed. This implies there are strong dependences of slowly diminishing correlations between the assumed structural breaks and the subsequent financial crises. In brief, the presences of structural breaks are noticeable, strong, active, and are fully developed. In fact, the presences of structural breaks exhibit varying degrees of intensity in the selected countries' indices. Plausibly, some contextual matters have made such differences of magnitudes. To know such contextual variations in the assessments of stock price movements is a necessary prelude to having dependable structural changes at times of financial crises in the coming decade.

Scrutiny on optional variations of methodological approaches and appropriate selection of econometric models for estimations and predictions are equally important. Accordingly, a slight modification on latent factor analysis only to fit the methodological tools employed in this study has been required. The common practice in latent factor analysis has been a quest for unattended or unobserved causal factors understood as variables. Not far from this, latent correlation analysis in this study has promoted the searching for unattended correlation patterns. Actually, there is a myriad of correlation types. As such, the focused selection from these varied correlation types has the utmost significance in determining the entire results of financial studies. For this reason, latent correlation analysis has been used instead of latent factor analysis in a strict sense.

The major contribution of this study to Forbes & Rigobon's (2002) seminal work is that it has critically viewed the correlation types that potentially affect the entire study. Forbes & Rigobon’s (2002) study restricts a correlation type that depicts a direct relation between causes and effects. Thereby, the analysis of stock markets has been done in a unidirectional perspective and in between two countries’ stock price indices. More importantly, as can be deduced from the publication year (i.e., 2002), the contagion effects after the devastating financial crisis in 2008 have not been addressed. In the same vein, the common practices in financial studies reveal that contagion effects at times of financial crises are always evaluated in a relative sense. Perhaps, at the title of their work, “No contagion, only interdependence: Measuring stock market co-movements” indicates, they have not addressed the essences of contagion effects in association with the utmost devastating financial crisis of 2008 only next to the unforgettable Great recession in the 1930s.

This study has contributed to the future research area on international financial contagion. Other researchers should focus on shadow banking, financial innovation, and regulation. Currently, they are causes and challenges of financial crisis and contagion in capital markets. Shadow banks have grown their assets in European countries and the US. However, shadow banking has not been enough regulation, it affected the financial markets. Similarly, investigating long memory and contagion effects is essential to understand the market movement, interdependence, and risk management.

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APPENDIX

Table A1: FIGARCH(a), FIEGARCH(b), HYGARCH(c) Estimates

	Bist100			**CAC40**			**DAX30**			**AEX**		
	a	b	c	a	b	c	a	b	c	a	b	c
d	0.52144	0.36577	0.5587	0.69565(0	0.74050	0.7651	0.81859	0.6856	0.901347	0.771075	0.601	0.9766
	(0.000)	(0.005)	(0.008)	.008)	(0.000)	(0.0119)	(0.000)	(-0.79)	(0.000)	(0.000)	(0.00)	(0.000)
α	0.461936	-0.78205	0.43354	0.136194	-0.62877	0.10296	0.25179	0.80516	0.1968	0.244291	-0.8411	0.0869
	(0.0005)	(0.0000)	(0.026)	(0.1780)	(0.000)	(0.380)	(0.0011)	(0.000)	(0.018)	(0.1055)	(0.00)	(0.343)
β	0.845913	0.98866	0.85118	0.7444	0.86823	0.7754	0.88181	0.95158	0.8957	0.86138	0.976	0.9230
	(0.0000)	(0.000)	(0.000)	(0.0001)	(0.000)	(0.0001)	(0.000)	(0.000)	(0.000)	(0.0000)	(0.17)	(0.000)
J.B	270.07	307.49	268.17	40.629	25.925	41.158	105.67	86.49	108.53	37.26	44.013	43.15
Ln(L)	2112.37	2070.21	2112.83	3948.32	3883.21	3946.5	3522.58	3457.11	3523.35	3675.53	3596.	3678.3
AIC	-3.66528	-3.58814	-3.66433	-6.87216	6.95496	-6.8690	-6.1302	-6.0107	-6.1281	-6.39568	-6.399	-6.3987
SIC	-3.60362	-3.51767	-3.59826	-6.81050	-6.6845	-6.8074	-6.0730	-5.9402	-6.06205	-6.33402	-6.1841	-6.3326
$Q_1(50)$	54.8299	56.51	54.94	54.826	58.277	54.541	41.672	41.5426	44.045	33.7584	9.26	34.577
	(0.23152)	(0.1869)	(0.2283)	(0.23163)	(0.147)	(0.239)	(0.728)	(0.733)	(0.6356)	(0.9405)	(0.89)	(0.927)
$Q_2(5)$	48.0277	66.186	47.769	53.0539	59.902	51.8748	47.533	52.778	44.889	53.2229	36.58	57.38
	(0.47173)	(0.07)	(0.482)	(0.2856)	(0.1163)	(0.325)	(0.492)	(0.295)	(0.6011)	(0.2802)	(0.811)	(0.166)
ARC	0.6987	1.013	0.783	0.44191	0.64032	0.6005	0.56614	1.3006	0.2541	0.93928	0.410	1.1644
H (5)	(0.6245)	(0.4085)	(0.562)	(0.8193)	(0.669)	(0.699)	(0.726)	(0.2612)	(0.9378)	(0.4545)	(0.84)	(0.325)
X^2	79.838	107.51	79.489	43.926	55.314	59.935	43.227	77.7	44.834	63.07	68.87	36.659
	(0.0001)	(0.000)	(0.0001)	(0.01105)	(0.043)	(0.005)	(0.0183)	(0.000)	(0.2404)	(0.0851)	(0.002	(0.047)

Note. Standard errors are within the parenthesis. * and ** indicates the 95% and 99% confidence level, respectively, d: long memory coefficient:α, ARCH coefficient, β: GARCH coefficient. Ln(L): the maximized value of the loglikelihood function, AIC: Akaike Information Criterion, SIC: Schwarz Information Criterion, ARCH (5) is the ARCH test statistic for 7 lag level, Q1 & Q2 (50) is the test statistic for 50 lag level of on standardized and squared standardized residuals, X^2 is the adjusted Pearson Chi-square goodness-of-fit test.

Table A2: *FIGARCH(a), FIEGARCH(b), HYGARCH(c) Estimates*

	FTSE100			FTSEMIB			S&P500		
	a	b	c	a	b	c	a	b	c
d	0.328637	0.772788	0.501709	0.440351	0.69868	0.426357	0.40928	0.600529	0.60337
	(0.0111)	(0.000)	(0.0023)	(0.0000)	(0.000)	(0.0000)	(0.0174)	(0.000)	(0.0095)
α	0.291063	-0.79816	0.245703	-0.204253	-0.899117	-0.230316	-0.08156	0.641425	-0.088738
	(0.1702)	(0.000)	(0.1325)	(0.2352)	(0,000)	(0.1943)	(0.686)	(0.0156)	(0.5807)
β	0.476365	0.901687	0.547459	0.037327	0.969086	0.01134	0.23642	-0.45507	0.35922
	(0.0463)	(0.000)	(0.0177)	(0.8366)	(0.000)	(0.9535)	(0.342)	(0.000)	(0.1063)
J.B	60.239	64.162	59.961	78.98	85.991	80.954	364.74	281.83	281.83
Ln(L)	3667.25	3593.15	3667.81	3269.63	3217.294	3270.03	3415.69	3429.88	3416.88
AIC	-6.381224	-6.448289	-6.380453	-5.688442	-5.59178	-5.685643	-5.941807	-5.963101	-5.94214
SIC	-6.319561	-6.177817	-6.314385	-5.631184	-5.521308	-5.619576	-5.880144	-5.892628	-5.876074
Q1(50)	23.5466	60.1671	23.5597	51.978	53.27	50.1759	55.388	55.527	56.55
	(0.170449)	(0.11183)	(0.16998)	(0.32169	(0.24569)	(0.38719)	(0.215995)	(0.184285)	(0.1858)
Q2(50)	40.8705	42.1368	42.8039	43.861	46.0762	44.2859	38.57	32.787	39.57
	(0.757465)	(0.7108)	(0.6851)	(0.64305)	(0.55199)	(0.625802)	(0.83262)	(0.95418)	(0.8014)
ARCH (7)	0.25929	0.4089	0.26168	0.64623	1.3465	0.60034	0.20189	0.25026	0.21424
	(0.9352)	(0.8428)	(0.934)	(0.6644)	(0.242)	(0.6997)	(0.9617)	(0.9398)	(0.9565)
X^2	55.175	50.4236	48.467	73.8297	98.98	64.747	67.891	40.293	52.939
	(0.0446)	(0.0008)	(0.00221)	(0.0006)	(0.000)	(0.0059)	(0.0028)	(0.01425)	(0.0674)

Note. Standard errors are within the parenthesis. * and ** indicates the 95% and 99% confidence level, respectively. d: long memory coefficient:α, ARCH coefficient, β: GARCH coefficient. Ln(L): the maximized value of the loglikelihood function, AIC: Akaike Information Criterion, SIC: Schwarz Information Criterion, ARCH (5) is the ARCH test statistic for 7 lag level, Q1 & Q2 (50) is the test statistic for 50 lag level of on standardized. and squared standardized residuals, X^2 is the adjusted Pearson Chi-square goodness-of-fit test.