economies

MDPI

Article

Cross-Market Correlations and Financial Contagion from Developed to Emerging Economies: A Case of COVID-19 Pandemic

Taufeeque Ahmad Siddiqui [1], Mazia Fatima Khan [1], Mohammad Naushad [2,*] and Abdul Malik Syed [3]

[1] Centre for Management Studies, Jamia Millia Islamia, New Delhi 110025, India; taufeeque@gmail.com (T.A.S.); maziafkhan@gmail.com (M.F.K.)
[2] Management Department, College of Business Administration, Prince Sattam Bin Abdulaziz University, Alkharj 11942, Saudi Arabia
[3] Finance Department, College of Business and Administration, University of Business and Technology, Jeddah 21448, Saudi Arabia; a.syed@ubt.edu.sa
* Correspondence: n.mohammad@psau.edu.sa

Abstract: In the event that the COVID-19 pandemic spreads across various stock markets, this study may be deemed as one of the primary studies to evaluate cross-market interactions. The study examines the spread of contagious effects originating from developed economies (the United States, the United Kingdom, and Japan) to selected emerging markets (China, India, Thailand, Taiwan, Egypt, South Africa, Saudi Arabia, and the United Arab Emirates). The countries studied are classified into three regions: developed economies, Asia, and Africa and the Middle East. The crisis period is identified with the deployment of the Markov regime-switching model. The conditional correlations are compared before and after the crisis episode using the time-varying multivariate DCC-GARCH model. The findings confirm that certain emerging markets are experiencing contagion from developed markets, while others remain unaffected. Overall, investors in the two regions examined (Asia, and Africa and the Middle East) have comparable diversification options. The findings are expected to bolster policymakers and international agencies in developing post-crisis measures.

Keywords: co-movement; COVID-19; DCC-GARCH; financial contagion; stock markets

JEL Classification: G11; G12; G13; G15; G17

Citation: Siddiqui, Taufeeque Ahmad, Mazia Fatima Khan, Mohammad Naushad, and Abdul Malik Syed. 2022. Cross-Market Correlations and Financial Contagion from Developed to Emerging Economies: A Case of COVID-19 Pandemic. *Economies* 10: 147. https://doi.org/10.3390/economies10060147

Academic Editors: Andreia Dionísio and Ştefan Cristian Gherghina

Received: 29 March 2022
Accepted: 8 June 2022
Published: 16 June 2022

1. Introduction

The COVID-19 pandemic is responsible for reshaping the economies of developed and emerging markets, particularly financial markets. For example, a decline in equity markets is cited in the OECD's 2020 report (OECD Report 2020), whereas an article in Mckinsey (2021) claims that "the COVID-19 pandemic precipitated a freefall in share prices". The COVID-19 pandemic originated in China and later unfolded in the rest of the world and has the potential to propagate crisis episodes across different geographical markets. The empirical research on COVID-19 has broadened since the outbreak (Conlon et al. 2020; Zaremba et al. 2020; Akhtaruzzaman et al. 2021; Luo et al. 2021). Several articles analyzed the implications of the pandemic relating to different variables, such as international stock market linkages, regional impact, number of cases reported, and macroeconomic news components (Guo et al. 2021; Bakry et al. 2022).

For decades, one of the most popular research topics in finance has been the co-movement or interdependence of financial markets during periods of market turmoil. King and Wadhwani (1990) and Calvo et al. (1996) report that during a financial crisis, this cross-market dependence changes. Dungey et al. (2005) also describe the spread of a financial crisis as a disruption in the interconnectedness of equity markets. In addition, the literature on contagion is extensive and covers the Asian crisis, the global financial crisis of 2008, and the Eurozone crisis; (Baig and Goldfajn 1999; Berg 1999; Ahmad et al. 2013; Hwang 2014; Corbet et al. 2021).

The purpose of this research is to enrich the literature on contagion and examine the shocks emerging from developed markets to developing markets during the corona pandemic (COVID-19). Our first contribution is to review the role of three major mature equity markets in crisis transmission. Secondly, emerging markets provide diversification opportunities, and due to the inclusion of such markets in investment opportunities, the decoupling hypothesis remains to be explored (Yarovaya and Lau 2016). The Asia, and Middle East and Africa regions are considered in the research to identify diversification opportunities. The market structure of two regions is unique. China and India represent the highest market capitalization among emerging markets, whereas Giovannetti and Velucchi (2013) advocate emerging African markets as attractive for investment opportunities. One of the reasons for selecting these two developing geographical regions for the analysis is that they have rarely been studied together. Moreover, Van Royen (2002) suggests that crises are regional.

Jin (2016) found contagion in the Asian region during the global financial crisis, whereas Zhang et al. (2022) reported contagion effects in the stock markets of the same region during the course of the COVID-19 pandemic. Although the results are critical, they do not aid in the identification of disparity with other regions. (Bello et al. 2022) conclude that financial contagion was transmitted in the Africa region during the 2008–2009 financial crisis and find no evidence of contagion transmission during the recent crisis episode.

Another contribution of the research is that most studies on the COVID-19 pandemic have relied on the media to identify the crisis period. However, this study applies the Markov regime-switching model to establish a turbulent period following Ahmad et al. (2013). The turbulent period for empirical analysis begins on 23 January 2020 and runs through 30 June 2020. The study quantifies the contagion effect using Forbes and Rigobon's (2002) definition. Furthermore, to the best of our knowledge, only a few studies relating to COVID-19 have used the multivariate GARCH model to detect financial contagion. The DCC-GARCH model is applied to overcome the problem of heteroskedasticity, as reported by Chiang et al. (2007).

The structure of the paper is as follows: Section 2 discusses a literature review on financial contagion, followed by Section 3, which represents the research methodology; Section 4 shows the results of the model. In contrast, Section 5 is dedicated to discussion; conclusion and implications are presented in Section 6.

2. Literature Review

In due course, several definitions have been proposed for financial contagion, and exhaustive literature has developed. For example, Claessens et al. (2001) define contagion as the proliferation of financial shocks accompanied by an increase in asset class correlation, whereas Forbes and Rigobon (2000) divide contagion into three types. As a starting point, the term "contagion" refers to a "shift" in the interrelationship between financial markets during times of crisis and non-crisis. Following that, the transmission mechanism of the crisis is explained as investors' irrational behavior. Additionally, contagion is defined as "any channel connecting countries and causing markets to move in unison."

Additionally, Viale et al. (2014) assert that contagion is related to economic fundamentals. Finally, according to Hwang (2014), contagion is the spread of a crisis from one national market to another. However, most prior studies on the interconnections define contagion, as proposed by Forbes and Rigobon (2002), as a rise in co-movements during a crisis period compared to the calm time frame.

The investigation of cross-market movement is of prime importance in risk reduction and portfolio diversification strategies. Prior research explored correlation structure changes at the onset of crisis period (Chiang et al. 2007; Aloui et al. 2011; Ahmad et al. 2013; Hwang 2014).

There have been numerous studies investigating the past financial downturn. Some authors developed studies on major crisis episodes that impacted world stock markets. The global financial crisis of 2007–2008 is studied (e.g., Guo et al. (2011); Dimitriou et al. (2013); and Yarovaya and Lau (2016)). Aloui et al. (2011) compute the virulent impact of the financial meltdown in 2007–2008 in a similar fashion. Orlowski (2012) examined the tail behavior of stock indices, foreign exchange rates, and interbank lending rates in seven European countries to determine whether financial contagion existed. The G.A.R.C.H.-M-GED model indicated that the systematic risk associated with interbank lending rates increased to maximum. Neaime (2012) notes the existence of spillovers from developed markets to the MENA region.

Several studies have considered the Greek sovereign debt crisis, e.g., Lane (2012), Ahmad et al. (2013), Tortola (2015), and Aizenman et al. (2016). Smeets (2016) examines the E.G.A.R.C.H. and models the Eurozone crisis's contagion effects on regional indices including Greece, Ireland, Portugal, Italy, Spain, Germany, and Austria, concluding that the contagion effects will soon fade. Similarly, Castagneto-Gissey and Nivorozhkin (2016) examine the spread of contagion in several developed and emerging markets after the Russian crisis (2014–2015). The study discovers no evidence of a contagion effect, and DCC-GARCH and (VCC) A.R.-Multivariate G.A.R.C.H. models are extracted. On the other hand, few studies have considered Turkey's currency and debt crisis; Arbaa and Varon (2019) examine the banking sector's equity indices in the European region. The output of the Fama and French five-factor models indicates that Turkey's currency and debt crisis affected indices in Greece, the Netherlands, Italy, Spain, Germany, and France in 2018.

The spread of the COVID-19 pandemic, which is still ongoing, is also documented in the literature; Conlon et al. (2020) argue that new asset classes did not provide diversification opportunities during the recent financial crisis. At the same time, Wu et al. (2020) compiled evidence indicating that no herding occurred in China's equity index during the COVID-19 period. In a similar vein, He et al. (2020) demonstrate the presence of spillovers during the COVID-19 period using data from China, Italy, South Korea, France, Spain, Germany, Japan, and the United States. Other notable work includes (Sharif et al. 2020; Corbet et al. 2020; Conlon and McGee 2020; Siddiqui et al. 2020; Zainudin and Mohamad 2021; Xie et al. 2021; Huynh et al. 2021; Kwapień et al. 2021; and Wątorek et al. 2021). Finally, Corbet et al. (2021) extend the DCC GARCH model to examine the pandemic's outcome.

Several methods are reported in the literature to examine contagion. Forbes and Rigobon (2001) argue that examining financial contagion through the lens of economies' direct links will not yield robust estimates. A method proposed for the measurement of cross-market turbulence is the correlation technique. To estimate varying time correlations among the markets DCC-GARCH model proposed by Engle (2002) is deployed in studies (Corsetti et al. 2005; Chiang et al. 2007; Celık 2012; Syllignakis and Kouretas 2011; Ahmad et al. 2013; Corbet et al. 2021). DCC measures a non-linear correlation structure; additionally, the model's parameters are not dependent on the selected variables. A measurement bias in contagion tests is heteroskedasticity. Utilizing the DCC-GARCH model, the issue is resolved as the residuals generated by the modelling technique are uniform.

Several questions regarding the role of developed markets in the transmission of financial shocks during the COVID-19 pandemic remain to be addressed. Although there are numerous studies on previous crises' contagion effects, the nature of pandemics is unique. The impact of the COVID-19 pandemic on developing markets and their linkages with developed markets are previously not assessed for the Asia, and Africa and Middle East regions in particular. However, these markets play a dominant role in the risk reduction of international portfolios. Therefore, the current study has stalled the notion of filling the gap by assessing the impact of the COVID-19 pandemic on the integration of developed markets into Asia's developing markets and the Africa and Middle East region.

3. Research Methodology

The data for this study are classified into two categories: developed and emerging markets. The developed and emerging markets are based on their S&P classification and market capitalization. In the developed market category, the S&P 500 Index (U.S.A.), FTSE 100 Index (U.K.), and Nikkei 225 Index (Japan) are considered; developing markets are represented by the Shanghai SE Composite Index (China), SENSEX (India), SET. 50 Index (Thailand), TAIEX Index (Taiwan), EGX 30 Index (Egypt), FTSE/JSE Top 40 Index (South Africa), Tadawul All Share Index (Saudi Arabia), and ADX General Index (U.A.E.). The augmented Dickey–Fuller test and the Phillips and Perron tests are deployed to check the stationarity of the series. The daily price series is turned into log returns so that it can be analyzed and tested for contagion in more detail.

The crisis period for the coronavirus economic and financial crisis has been detected using a regime-switching model from 23 January 2020 to 30 June 2020. The WHO declared COVID-19 as a pandemic in March 2020 (Akhtaruzzaman et al. 2021). The pre-crisis period is from 1 April 2019 to 31 December 2019. Data from Bloomberg have been utilized for analysis. The study uses the Dynamic Conditional Correlation, GARCH (DCC-GARCH) Model. This model has an advantage over the BEKK GARCH model as there is no dimensionality issue in the DCC-GARCH model, and it can include many variables. Another competing model, the constant conditional correlation (CCC) model, is unsuitable for our study as it does not capture variables' dynamic interaction. Several studies, such as Yousaf et al. (2021), deployed DCC-GARCH to examine financial contagion.

The estimation of the DCC-GARCH model involves a two-step process. GARCH parameters are calculated followed by time-varying conditional correlations. The following equations must be solved to obtain the results of the analysis. In the first equation, X_{t-1} demonstrates lagged returns, and ε_{it} is the error term with conditional variance ${h_{it}}^{-\frac{1}{2}}$, whereas γ_{it} represents a vector of residuals.

$$X_t = a + cX_{t-1+}\ \varepsilon_{it} \tag{1}$$

$$\varepsilon_{it} = {h_{it}}^{-\frac{1}{2}}, \gamma_{it} \tag{2}$$

$$H_t = D_t R_t D_t, \tag{3}$$

In Equation (3), time-varying conditional correlations are estimated (Ahmad et al. 2013). D_t is a diagonal $(s \times s)$ matrix of conditional standard deviations from univariate GARCH. R_t is $(s \times s)$ dynamic correlation matrix, whereas H_t represents multivariate conditional variance.

$$D_t = diagonal\left(h^{-\frac{1}{2}}{}_{11t} \ldots\ldots, h^{-\frac{1}{2}}{}_{sst}\right) \tag{4}$$

$$R_t = \varrho_t^{*-1} \varrho_t \quad \varrho_t^{*-1} \tag{5}$$

ϱ_t^* is the diagonal matrix consisting the square root of diagonal element in ϱ_t.

$$\varrho_t \ = diagonal(q^{\frac{1}{2}}{}_{11t}, q^{\frac{1}{2}}{}_{22t} \ldots\ldots q^{\frac{1}{2}}{}_{2lmt})$$

Here, $\varrho_t = \left(q_{ij,t}\right)$ is ${}_{s\times s}$ positive definite matrix of ε_t and ϱ_t should meet a condition.

$$q_{i,j,t} = \overline{\rho}_{i,j}\left(\frac{1-\alpha-\beta}{1-\beta}\right) + \alpha \sum\nolimits_f^\infty \beta^f \varepsilon_{it-f}\varepsilon_{jt-f} \tag{6}$$

Conditional correlation is computed with estimates of the univariate GARCH (1,1) model, wherein α and β are the two parameters of model (Engle 2002).

$$\varrho_t = (1-a-b)\overline{\varrho} + a_{1\varepsilon_{t-1}}{\varepsilon'}_{t-1} + b\varrho_{t-1}$$

The multivariate DCC parameters a and b are non-negative. Additionally, $a+b$ should lie between zero and one.

D_t in Equation (4) it can be estimated as $\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}, q_{jj,t}}}$.

The likelihood function for estimating the two-step DCC-GARCH model of Engle (2002) is described as:

$$l_n(L(\theta)) = -1/2 = \sum_{t=1}^{T} \{n \ln (2\pi) \} + \ln\left|D_t^2\right| + \ln|R_t| + \varepsilon_t' D_t^{-2} \varepsilon_t \tag{7}$$

The log likelihood function estimates the sum of the volatility component and correlations component (Engle 2002).

For estimating contagion, mean dynamic conditional correlations are derived from DCC-GARCH model. T-test is deployed following Forbes and Rigobon (2002) and Ahmad et al. (2013). The hypothesis is presented for testing contagion as

$$H_o = \rho^{crisis} > / \rho^{pre-crisis} \tag{8}$$

$$H_1 = \rho^{crisis} < / \rho^{pre-crisis} \tag{9}$$

where ρ^{crisis} shows the mean conditional correlation coefficients in the crisis period, and $\rho^{pre-crisis}$ represents mean dynamic conditional correlation coefficients before the crisis. The null hypothesis states no change in the crisis period as compared to the pre-crisis period.

The two-state regime-switching model is represented below.

$$Y_t = \alpha_0 + \beta_{X_{t-1}} + \varepsilon_t \tag{10}$$

$$Y_t = \alpha_0 + \alpha_1 + \beta_{X_{t-1}} + \varepsilon_t \tag{11}$$

whereas Equation (10) depicts regime one, Equation (11) shows regime two. Notably, these equations have been adopted from Tsay (2005).

4. Results

4.1. Regime Switching Model

Table 1 reports the outcomes of the Markov regime-switching model proposed by Hamilton (1989). The results are shown for Equations (10) and (11). The variable in the model is in a transitory state, S_t. The range of this state lies between the probability of zero and one. The regime one and regime two parameters are at a statistically significant level, and this confirms the existence of two regimes—the crisis and non-crisis periods. The transition of regimes is identified by a Markov process.

Table 1. Regime-switching model for corona economic and financial crisis.

Regimes	Variable	Coefficient	Std. Error	z-Statistic	Prob.
Regime1	log(sigma)	−4.816	0.088	−54.272	0.000
Regime 2	Log(sigma)	−3.669	0.159	−22.974	0.000
Common	Return(–1)	−0.062	0.096	−0.649	0.515
Transition Matrix Parameters					
	Variable	**Coefficient**	**Std. Error**	**z-Statistic**	**Prob.**
	P11-C	3.602	0.796	4.523	0.000
	P21-C	−2.675	0.927	−2.884	0.003

Table 2 demonstrates the transition probability of the state variable. The probability of the variable being in regime one is 0.97.

Table 2. Transition summary.

Constant Transition Probabilities		
$P(i,k) = P(s(t) = k \mid s(t-1) = i)$		
(row = i/column = j)		
	1	2
1	0.973	0.026
2	0.064	0.935

Figure 1 depicts the smoothed probability graphs of regime one and regime two for the corona economic and financial crisis. The X-axis depicts the period, and the Y-axis shows conditional variance.

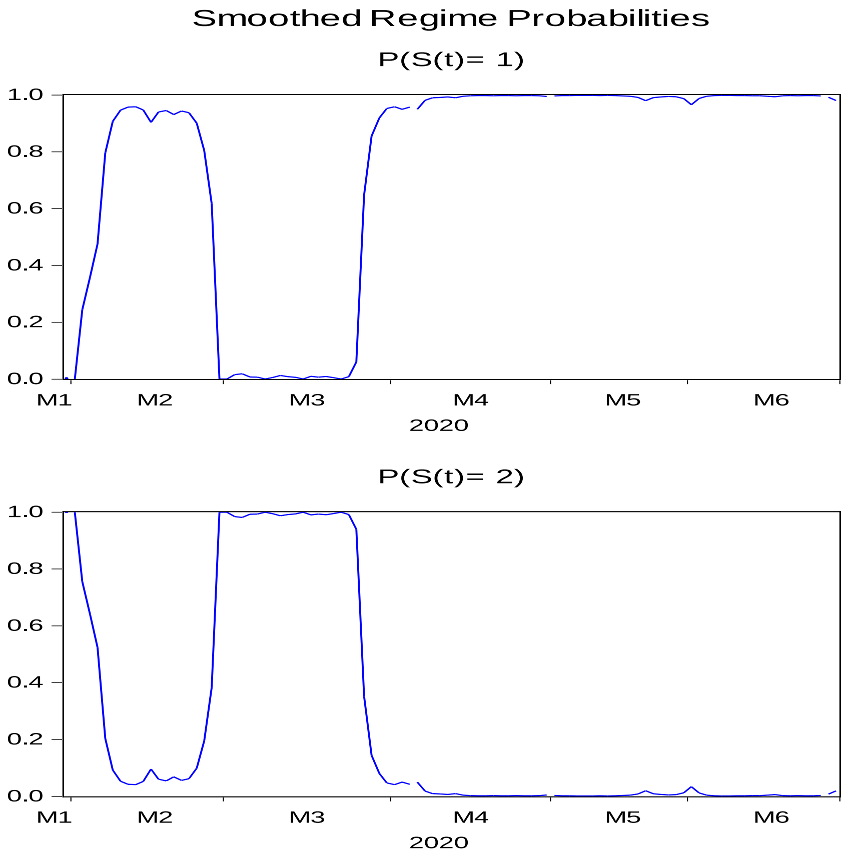

Figure 1. Smooth regime probabilities.

4.2. DCC-G.A.R.C.H. Results

Table 3 indicates the DCC GARCH model outcome for U.S. and emerging markets from Asia, namely China, India, Taiwan, and Thailand, as depicted by Equation (3). The parameters of univariate GARCH α (alpha) and β (beta) indicate autoregressive conditional heteroskedasticity and generalized autoregressive conditional heteroskedasticityas, shown in Equation (6).The sum of the parameters ($\alpha + \beta$) depicts high persistence in the crisis period (0.90, 0.99, 0.97, 0.84, and 0.98), while the non-crisis period reports persistence as (0.87, 0.86, 0.98, 0.71, and 0.99). The estimates of the multivariate DCC parameters are calculated using Equation (7).The DCC (b) coefficient is statistically significant at a 5% level for both time frames; while the results differ for DCC (a) parameters, they are statistically insignificant during the selected period. The sum of DCC (a) and DCC (b) is less than one, suggesting mean reversion (Sadorsky 2012). The values in parentheses are p-values, which are significant at a 5% level.

Table 3. DCC GARCH model (Asian region and U.S.).

Variance Equation				
	CRISIS		PRE-CRISIS	
Country	**α**	**β**	**α**	**β**
U.S.	0.361 (0.168)	0.548 (0.002)	0.167 (0.000)	0.717 (0.050)
India	0.231 (0.020)	0.767 (0.000)	0.097 (0.000)	0.774 (0.000)
China	0.007 (0.611)	0.976 (0.000)	0.0815 (0.260)	0.901 (0.000)
Taiwan	0.115 (0.181)	0.737 (0.000)	0.098 (0.368113)	0.624 (0.000)
Thailand	0.223 (0.065)	0.760 (0.000)	0.000 (0.786)	0.998 (0.000)
Multivariate DCC	**Equation**			
DCC(a)	0.000 (0.999)		0.000 (0.999)	
DCC(b)	0.919 (0.000)		0.910 (0.000)	

Table 4 provides the interaction of the U.S. with Egypt, the U.A.E., Saudi Arabia, and South Africa in a dynamic framework. The findings of MVDCC-GARCH are dissimilar for the multivariate DCC equations; DCC (a) is statistically insignificant for the turmoil and non-crisis period, and DCC (b) is significant at a 5% significant level during the periods. The sum of DCC parameters is less than one for the period under analysis. The values in parentheses represent *p*-values at a 5% level.

Table 4. DCC GARCH model (Africa and Middle East region, and U.S.).

Variance Equation				
	CRISIS		PRE-CRISIS	
Country	**α**	**β**	**α**	**β**
U.S.	0.108 (0.000)	0.878 (0.000)	0.167 (0.000)	0.733 (0.000)
Egypt	0.055 (0.039)	0.933 (0.000)	0.000 (0.999)	0.998 (0.000)
U.A.E.	0.144 (0.182)	0.854 (0.000)	0.000 (0.886)	0.996 (0.000)
Saudi Arabia	0.086 (0.039)	0.912 (0.000)	0.000 (0.963)	0.997 (0.000)
South Africa	0.100 (0.002)	0.891 (0.000)	0.000 (0.999)	0.999 (0.000)
Multivariate DCC equations				
DCC(a)	0.001 (0.798)		0.011 (0.134)	
DCC(b)	0.815 (0.001)		0.928 (0.000)	

DCC-GARCH model results comprising Japan and the U.K. with both regions are not presented here, as the purpose of running DCC GARCH is to generate a series of conditional correlations. Contagion is tested by comparing the crisis period and calm period using *t*-test.

4.3. Test of Contagion

4.3.1. Contagion in Asia Region

Table 5 shows the pairwise conditional correlations among the Asian and selected developed markets. Forbes and Rigobon (2002) define contagion as a significant increase in linkages during a turbulent episode. The mean of DCC coefficient is estimated for the crisis and tranquil periods and tested using a one-sided *t*-test. Equations (8) and (9) examine whether DCC coefficients increase in the crisis time frame. N represents no contagion from the U.S., Japan, or U.K. towards the Asian region, whereas C stands for the presence of contagion. The critical value for the *t*-test at a 5% significance level is 1.65. The test statistic values greater than the critical value demonstrate the presence of contagion (Forbes and Rigobon 2002). Out of 12 cases, in 6 cases, the test statistics are more than the critical value. Contagion is reported in six pairs, whereas no contagion is observed in six pairs. The results show that Japan causes no contagion effect in India, China, Taiwan, or Thailand. The U.S. brings contagion towards the equity markets of India and Thailand. However, the U.K. causes financial contagion in India, China, Taiwan, and Thailand.

Table 5. Pairwise conditional correlations of the Asian region.

Country	(Mean) Pre-Crisis	(Mean) Crisis	*t*-Test	Contagion
Japan–India	0.965	0.529	−78.02	N
Japan–China	0.965	0.529	−78.02	N
Japan–Taiwan	0.980	0.681	−82.536	N
Japan–Thailand	0.976	0.567	−110.33	N
U.S.–India	−0.011	0.196	73.086	C
U.S.–China	−0.013	−0.038	−10.374	N
U.S.–Taiwan	−0.017	−0.000	−4.6896	N
U.S.–Thailand	−0.009	0.258	156.38	C
U.K.–India	−0.726	0.576	38.3	C
U.K.–China	−0.663	0.363	24.5	C
U.K.–Taiwan	−0.710	0.433	30.988	C
U.K.–Thailand	−0.701	0.555	33.337	C

4.3.2. Contagion in Africa and Middle East Region

Table 6 reports pairwise conditional correlations in the Africa and Middle East region, and the selected developed markets. N represents no contagion from the U.S., Japan, and the U.K. towards the Africa and Middle East region, whereas C stands for the presence of contagion. The results demonstrate that Japan induces contagious effects only in the U.A.E., whereas the equity markets of Egypt, South Africa and Saudi Arabia remain unaffected. The U.S. leads to contagious effects only in Egypt, South Africa, and the U.A.E. Contagion flows from the U.K. towards Egypt, Saudi Arabia and South Africa only. Contagion is reported in seven pairs, whereas no contagion is observed in five pairs.

Table 6. Pairwise conditional correlations of the Africa andMiddle East region.

Country	(Mean) Pre-Crisis	(Mean) Crisis	*t*-Test	Contagion
Japan–Egypt	0.967	0.415	−77.359	N
Japan–South Africa	0.909	0.585	−21.808	N
Japan–Saudi Arabia	0.844	0.357	−22.151	N
Japan–U.A.E.	−0.020	0.402	160.59	C
U.S.–Egypt	0.000	0.075	26.149	C
U.S.–Saudi Arabia	0.725	0.458	−8.0159	N
U.S.–U.A.E.	−0.013	0.142	77.80	C
U.S.–South Africa	−0.005	0.153	154.5	C
U.K.–Egypt	−0.721	0.288	30.108	C
U.K.–U.A.E.	0.055	0.436	−40.012	N
U.K.–Saudi Arabia	−0.641	0.416	24.877	C
U.K.–South Africa	−0.597	0.776	28.35	C

5. Discussion

Our analysis shows that developed markets transmit financial disturbances in the equity markets of emerging economies. The results are also supported by the works of Hwang (2014) and Samarakoon (2011), who also described the impact of the U.S. on other markets after applying the DCC-GARCH model in previous crisis episodes. Celık (2012) points out that the crisis has many effects on emerging markets, also supports our results. The study is similar to Forbes and Rigobon (2002); Fry-McKibbin et al. (2014); and Dungey and Gajurel (2014), wherein the researchers investigated major geographical regions during a financial crisis episode devoid of the application of the multivariate GARCH model.

The region-wise analysis yields results for portfolio diversification and policy implications. In our detailed examination of the Asian region, the flow of financial downturn from the U.S. is observed in India and Thailand only. Similarly, in the Asian region, Zhang et al. (2022) found the presence of contagion in the equity markets. Huong (2021) also observed the proliferation of the COVID-19 pandemic in equity indices. The empirical analysis in the current study also found that the U.K. causes contagion in all the sample markets within this region. However, Yarovaya and Lau (2016) reported only interlinkages and no significant contagious effects from the U.K. in previous crisis episodes. This difference could be due to the higher impact of the current crisis in the European region. Lastly, it is indicated that Japan did not cause any change during the COVID-19 pandemic in India, China, Taiwan, or Thailand. Similar evidence is available for Miyakoshi (2003).

The exploration of the Africa and Middle East region's results suggests that Japan introduces no contagion in Egypt, South Africa, or Saudi Arabia. However, the U.S. causes no contagion to Saudi Arabia. On the other hand, the U.K. brings financial contagion to all except the U.A.E. The results corroborate Al-Yahya et al. (2020), who observed the same influence in the Middle East region. Furthermore, Giovannetti and Velucchi (2013) reported on the transfer of crisis from the U.S. and the U.K. towards Africa. Similarly, Abou-Zaid (2011) also found an impact of the U.S. and U.K. on the Middle East and Africa region.

6. Conclusions and Implications

This study examines the contagion effect emanating from the three largest developed markets (the United States of America, the United Kingdom, and Japan) in terms of market capitalization, toward four emerging markets in Asia (China, India, Thailand, and Taiwan) and Africa and the Middle East (Egypt, South Africa, Saudi Arabia, and the U.A.E.). The Markov regime-switching model's deployment aided in identifying the crisis period. The multivariate DCC-GARCH model was used to extract pairwise conditional correlations and test for contagion. The hypothesis of no contagion was rejected in some cases. The empirical analysis indicates that contagion is present in six pairs in the Asian region, while seven pairs in the Africa and the Middle East region exhibit a contagion effect. The current study's findings are consistent with the studies Akhtaruzzaman et al. (2021); Corbet et al. (2021); and He et al. (2020). Zhang et al. (2022) also report a significant impact of the COVID-19 crisis on equity markets after considering several variables under the study. Our study contributes to the literature on COVID-19, as the previous studies mainly focused on one geographical region. Here contagion is studied during the early stages of a crisis, and the study improves understanding of shock propagation at the onset of financial turmoil.

The study's findings are significant as the transmission of financial contagion from developed markets to emerging markets and its role in driving the world equity markets is noted. The findings are also crucial for policymakers, as contagion affects monetary policy, real economic variables, and asset pricing (Celık 2012). There is a significant difference in crisis transmission at the onset of the crisis and the pre-crisis periods. Portfolio weights and hedging strategies can be constructed in the international equity markets with the study's finding. There is a discernible opportunity for diversification in both regions, as the number of pairs with contagion is nearly equal.

The study is limited to the stock markets of two regions; however, future studies may include additional regions. Future research may also make use of more advanced computing techniques. The impact of COVID-19 on frontier markets can be examined. The impact of the Ukrainian war on equity markets can also be investigated in future studies.

Author Contributions: Conceptualization, T.A.S. and A.M.S.; methodology, T.A.S. and M.N.; software, T.A.S. and A.M.S.; validation, M.N., T.A.S. and A.M.S.; formal analysis, T.A.S., M.F.K. and A.M.S.; investigation, T.A.S., M.F.K. M.N.; resources, M.N. and A.M.S.; data curation, M.F.K., T.A.S. and A.M.S.; writing—M.F.K. and T.A.S.; writing—review and editing, M.N. and T.A.S.; visualization, T.A.S., M.F.K. and A.M.S.; supervision, T.A.S.; project administration, M.N.; funding acquisition, M.N. and A.M.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

References

Abou-Zaid, Ahmed S. 2011. Volatility spillover effects in emerging MENA stock markets. *Review of Applied Economics* 7: 107–27.

Ahmad, Wasim, Sanjay Sehgal, and N. R. Bhanumurthy. 2013. Eurozone crisis and B.R.I.I.C.K.S. stock markets: Contagion or market interdependence? *Economic Modelling* 33: 209–25. [CrossRef]

Aizenman, Joshua, Yothin Jinjarak, Minsoo Lee, and Donghyun Park. 2016. Developing countries' financial vulnerability to the eurozone crisis: An event study of equity and bond markets. *Journal of Economic Policy Reform* 19: 1–19. [CrossRef]

Akhtaruzzaman, Md, Sabri Boubaker, and Ahmet Sensoy. 2021. Financial contagion during COVID-19 crisis. *Finance Research Letters* 38: 101604. [CrossRef]

Aloui, Riadh, Mohamed Safouane Ben Aissa, and Duc Khuong Nguyen. 2011. Global financial crisis, extreme interdependence, and contagion effects: The role of economic structure? *Journal of Banking & Finance* 35: 130–40. [CrossRef]

Al-Yahya, AbdulRahman A. I., Mohammed Asad, Abdulmoniem Sadaby, and Mohammed Sanad Alhussaini. 2020. Repeat oral dose safety study of standardized methanolic extract of Boswellia sacra oleo gum resin in rats. *Saudi Journal of Biological Sciences* 27: 117–23. [CrossRef]

Arbaa, Ofer, and Eva Varon. 2019. Turkish currency crisis-Spillover effects on European banks. *Borsa Istanbul Review* 19: 372–78. [CrossRef]

Baig, Taimur, and Ilan Goldfajn. 1999. Financial market contagion in the Asian crisis. *I.M.F. Staff Papers* 46: 167–95. [CrossRef]

Bakry, Walid, Peter John Kavalmthara, Vivienne Saverimuttu, Yiyang Liu, and Sajan Cyril. 2022. Response of stock market volatility to COVID-19 announcements and stringency measures: A comparison of developed and emerging markets. *Finance Research Letters* 46: 102350. [CrossRef]

Bello, Jaliyyah, Jiaqui Guo, and Mohammad Khaleq Newaz. 2022. Financial contagion effects of major crises in African stock markets. *International Review of Financial Analysis* 82: 102128. [CrossRef]

Berg, A. 1999. *The Asian Crisis: Causes, Policy Responses, and Outcomes*. Working Paper No.99/138. Washington DC: IMF. [CrossRef]

Calvo, Guillermo A., Leonardo Leiderman, and Carmen M. Reinhart. 1996. Inflows of Capital to Developing Countries in the 1990s. *Journal of Economic Perspectives* 10: 123–39. [CrossRef]

Castagneto-Gissey, Giorgio, and Eugene Nivorozhkin. 2016. No contagion from Russia toward global equity markets after the 2014 international sanctions. *Economic Analysis and Policy* 52: 79–98. [CrossRef]

Celık, Sibel. 2012. The more contagion effect on emerging markets: The evidence of DCC-GARCH model. *Economic Modelling* 29: 1946–59. [CrossRef]

Chiang, Thomas, Bang Jeon, and Huimin Li. 2007. Dynamic correlation analysis of financial contagion: Evidence from Asian markets. *Journal of International Money and Finance* 26: 1206–28. [CrossRef]

Claessens, Stijn, Rudiger Dornbusch, and Yung Chul Park. 2001. Contagion: Why crises spread and How This Can Be Stopped. In *International Financial Contagion*. Boston: Springer, pp. 19–41. [CrossRef]

Conlon, Thomas, and Richard McGee. 2020. Safe haven or risky hazard? Bitcoin during the COVID-19 bear market. *Finance Research Letters* 35: 101607. [CrossRef]

Conlon, Thomas, Shaen Corbet, and Richard McGee. 2020. Are Cryptocurrencies a Safe Haven for Equity Markets? An International Perspective from the COVID-19 Pandemic. May 10. Available online: http://dx.doi.org/10.2139/ssrn.3601045 (accessed on 12 January 2021).

Corbet, Shaen, Charles Larkin, and Brian Lucey. 2020. The contagion effects of the COVID-19 pandemic: Evidence from gold and cryptocurrencies. *Finance Research Letters* 35: 101554. [CrossRef]

Corbet, Shaen, Yang Hou, Yang Hu, Brian Lucey, and Les Oxley. 2021. Aye Corona! The contagion effects of being named Corona during the COVID-19 pandemic. *Finance Research Letters* 38: 101591. [CrossRef]

Corsetti, Giancarlo, Marcello Pericoli, and Massimo Sbracia. 2005. 'Some contagion, some interdependence': More pitfalls in tests of financial contagion. *Journal of International Money and Finance* 24: 1177–99. [CrossRef]

Dimitriou, Dimitrios, Dimitris Kenourgios, and Theodore Simos. 2013. Global financial crisis and emerging stock market contagion: A multivariate FIAPARCH-DCC approach. *International Review of Financial Analysis* 30: 46–56. [CrossRef]

Dungey, Mardi, and Dinesh Gajurel. 2014. Equity market contagion during the global financial crisis: Evidence from the world's eight largest economies. *Economic Systems* 38: 161–77. [CrossRef]

Dungey, Mardi, Renée Fry, Brenda González-Hermosillo, and Vance L. Martin. 2005. Empirical modelling of contagion: A review of methodologies. *Quantitative Finance* 5: 9–24. [CrossRef]

Engle, Robert. 2002. Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics* 20: 339–50. [CrossRef]

Forbes, Kristin, and Roberto Rigobon. 2000. *Contagion in Latin America: Definitions, Measurement, and Policy Implications*. Cambridge: National Bureau of Economic Research. [CrossRef]

Forbes, Kristin, and Roberto Rigobon. 2001. Measuring Contagion: Conceptual and Empirical Issues. In *International Financial Contagion*. Edited by S. Claessens and K. J. Forbes. Boston: Springer, pp. 43–66. [CrossRef]

Forbes, Kristion J., and Roberto Rigobon. 2002. No contagion, only interdependence: Measuring stock market co- movements. *Journal of Finance* 57: 2223–61. [CrossRef]

Fry-McKibbin, Renée, Cody Yu-Ling Hsiao, and Chrismin Tang. 2014. Contagion and global financial crises: Lessons from nine crisis episodes. *OpenEconomies Review* 25: 521–70. [CrossRef]

Giovannetti, Giorgia, and Margherita Velucchi. 2013. A spillover analysis of shocks from US, UK and China on African financial markets. *Reviewof Development Finance* 3: 169–79. [CrossRef]

Guo, Feng, Carl R. Chen, and Ying Sophie Huang. 2011. Markets contagion during financial crisis: A regime-switching approach. *InternationalReview of Economics & Finance* 20: 95–109. [CrossRef]

Guo, Yanhong, Ping Li, and Aihua Li. 2021. Tail risk contagion between international financial markets during COVID-19 pandemic. *International Review of Financial Analysis* 73: 101649. [CrossRef]

Hamilton, James D. 1989. A new approach to the economic analysis of nonstationary time series and the business cycle. *Econometrica: Journal of the Econometric Society* 57: 357–84. [CrossRef]

He, Qing, Junyi Liu, Sizhu Wang, and Jishuang Yu. 2020. The impact of COVID-19 on stock markets. *Economic and Political Studies* 8: 275–88. [CrossRef]

Huong, Le Thi Minh. 2021. The contagion between stock markets: Evidence from Vietnam and Asian emerging stocks in the context of COVID-19 Pandemic. *Macroeconomics and Finance in Emerging Market Economies*, 1–17. [CrossRef]

Huynh, Toan Luu Duc, Matteo Foglia, Muhammad Ali Nasir, and Eliana Angelini. 2021. Feverish sentiment and global equity markets during the COVID-19 pandemic. *Journal of Economic Behavior& Organization* 188: 1088–108. [CrossRef]

Hwang, Jae-Kwang. 2014. Spillover Effects of the 2008 Financial Crisis in Latin America Stock Markets. *International Advances in EconomicResearch* 20: 311–24. [CrossRef]

Jin, Xiaoye. 2016. The impact of 2008 financial crisis on the efficiency and contagion of Asian stock markets: A Hurst exponent approach. *Finance Research Letters* 17: 167–75. [CrossRef]

King, Mervyn A., and Sushil Wadhwani. 1990. Transmission of volatility between stock markets. *The Review of Financial Studies* 3: 5–33. [CrossRef]

Kwapień, Jarosław, Marcin Wątorek, and Stanisław Drożdż. 2021. Cryptocurrency Market Consolidation in 2020–2021. *Entropy* 23: 1674. [CrossRef]

Lane, Philip R. 2012. The European sovereign debt crisis. *Journal of Economic Perspectives* 26: 49–68. [CrossRef]

Luo, Changqing, Lan Liu, and Da Wang. 2021. Multiscale financial risk contagion between international stock markets: Evidence from EMD- Copula-CoVaR analysis. *The North American Journal of Economics and Finance* 58: 101512. [CrossRef]

Mckinsey. 2021. The Impact of COVID-19 on Capital Markets. Available online: https://www.mckinsey.com/business-functions/strategy-and-corporate-finance/our-insights/the-impact-of-covid-19-on-capital-markets-one-year-in (accessed on 21 June 2021).

Miyakoshi, Tatsuyoshi. 2003. Spillovers of stock return volatility to Asian equity markets from Japan and the US. *Journal of InternationalFinancial Markets, Institutions and Money* 13: 383–99. [CrossRef]

Neaime, Simon. 2012. The global financial crisis, financial linkages and correlations in returns and volatilities in emerging MENA stock markets. *Emerging Markets Review* 13: 268–82. [CrossRef]

OECD Report. 2020. Available online: https://www.oecd.org/coronavirus/en/policy-responses (accessed on 12 January 2021).

Orlowski, Lucjan T. 2012. Financial crisis and extreme market risks: Evidence from Europe. *Review of Financial Economics* 21: 120–30. [CrossRef]

Sadorsky, Perry. 2012. Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics* 34: 248–55. [CrossRef]

Samarakoon, Lalith P. 2011. Stock market interdependence, contagion, and the U.S. financial crisis: The case of emerging and frontier markets. *Journal of International Financial Markets, Institutions and Money* 21: 724–42. [CrossRef]

Sharif, Arshian, Chaker Aloui, and Larisa Yarovaya. 2020. COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: Fresh evidence from the wavelet-based approach. *International Review of Financial Analysis* 70: 101496. [CrossRef]

Siddiqui, Taufeeque Ahmad, Haseen Ahmed, and Mohammad Naushad. 2020. Diffusion of COVID-19 impact across selected stock markets: A wavelet coherency analysis. *Investment Management and Financial Innovations* 17: 202–14. [CrossRef]

Smeets, Dieter. 2016. Financial contagion during the European sovereign debt crisis. *Journal of Economic & Financial Studies* 4: 46–59. [CrossRef]

Syllignakis, Manolis N., and Georgios P. Kouretas. 2011. Dynamic correlation analysis of financial contagion: Evidence from the Central and Eastern European markets. *International Review of Economics & Finance* 20: 717–32. [CrossRef]

Tortola, Pier Domenico. 2015. Coming full circle: The Euro crisis, integration theory and the future of the E.U. *The International Spectator* 50: 125–40. [CrossRef]

Tsay, Ruey S. 2005. *Analysis of Financial Time Series*. Hoboken: John Wiley&Sons. [CrossRef]

Van Royen, Anne-Sophie. 2002. Financial contagion and international portfolio flows. *Financial Analysts Journal* 58: 35–49. [CrossRef]

Viale, Ariel M., David A. Bessler, and James W. Kolari. 2014. On the structure of financial contagion: Econometric tests and Mercosur evidence. *Journal of Applied Economics* 17: 373–400. [CrossRef]

Wątorek, Marcin, Jarosław Kwapień, and Stanisław Drożdż. 2021. Financial return distributions: Past, present, and COVID-19. *Entropy* 23: 884. [CrossRef]

Wu, Guosong, Boxian Yang, and Ningru Zhao. 2020. Herding Behavior in Chinese Stock Markets during COVID-19. *Emerging Markets Finance andTrade* 56: 3578–87. [CrossRef]

Xie, Lijuan, Mei Wang, and Toan Luu Duc Huynh. 2021. Trust and the stock market reaction to lockdown and reopening announcements: A cross-country evidence. *Finance Research Letters* 46: 102361. [CrossRef]

Yarovaya, Larisa, and Marco Chi Keung Lau. 2016. Stock market comovements around the Global Financial Crisis: Evidence from the UK, BRICS and MIST markets. *Research in International Business and Finance* 37: 605–19. [CrossRef]

Yousaf, Imran, Shoaib Ali, Elie Bouri, and Tareq Saeed. 2021. Information transmission and hedging effectiveness for the pairs crude oil-gold and crude oil-Bitcoin during the COVID-19 outbreak. *Economic Research-EkonomskaIstraživanja*, 1–22. [CrossRef]

Zainudin, Ahmad Danial, and Azhar Mohamad. 2021. Financial contagion in the futures markets amidst global geo-economic events. *The Quarterly Review of Economics and Finance* 81: 288–308. [CrossRef]

Zaremba, Adam, Renatas Kizys, David Y. Aharon, and Ender Demir. 2020. Infected markets: Novel coronavirus, government interventions, and stock return volatility around the globe. *Finance Research Letters* 35: 101597. [CrossRef]

Zhang, Yi, Long Zhou, Yajiao Chen, and Fang Liu. 2022. The Contagion Effect of Jump Risk across Asian Stock Markets during the Covid-19 Pandemic. *The North American Journal of Economics and Finance* 61: 101688. [CrossRef]