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THE EFFECT OF COVID-19 ON RETURN AND VOLATILITY SPILLOVERS AMONG DEVELOPED AND DEVELOPING STOCK MARKETS

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The Effect of COVID-19 on Return and Volatility Spillovers among Developed and Developing Stock Markets

COVID-19'un Gelişmiş ve Gelişmekte Olan Hisse Senedi Piyasalarında Oynaklık Yayılımına Etkisi

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ABSTRACT

This paper aims to examine the effect of the COVID-19 pandemic on return and volatility spillovers on stock markets among developed countries taking US, the UK, Germany and Canada, and developing countries taking Brazil, Mexico, Turkey and India.

The mentioned effect is estimated by calculating the return and volatility spillovers combining the Stochastic Volatility Model (SV) with the Diebold and Yilmaz Model (2009) which focuses on the variance decomposition from the Vector Autoregressive (VAR) models using the daily indices' logarithmic returns. This paper covers the period from January of 2018 to December of 2021 and is divided into two sub- periods: before COVID-19 from Jan 3rd 2018 to March 10th 2020, and during COVID-19 from March 11th 2020 to Dec 23rd 2021.

The findings support the idea of previous researches that stock markets from developing countries present an increase on return spillover during COVID-19 for developing countries, and as a consequence, it implies a decrease in the benefits obtained from portfolio diversification. Conversely, the findings also suggest that return and volatility spillover for developed countries decreases during the pandemic, as well as the volatility spillover for developing countries.

KeyWords: Return and Volatility Spillover, Developed and Developing Countries, Stock Markets, COVID-19 Pandemic, VAR Model.

ÖZET

Bu çalişma ABD, İngiltere, Almanya ve Kanada gibi gelismis ülkeler ile Brezilya, Meksika, Türkiye ve Hindistan gibi gelişmekte olan ülkelerden COVID-19'un hisse senedi piyasalarının getiri ve oynaklık yayılımları üzerindeki etkisini incelemeyi amaçlamaktadır.

Söz konusu etki, Stokastik Oynaklık Modeli (SV) ile günlük endekslerin logaritmik getirilerini kullanan Vektör Otoregresif (VAR) modellerinden varyans ayrıştırmasına odaklanan Diebold ve Yılmaz Modeli (2009) ile birleştirilerek getiri ve oynaklık yayılma etkileri hesaplanarak tahmin edilmektedir. Bu yaklaşim getiri ve oynaklık yayılma etkileri hesaplanarak tahmin edilmektedir. Bu yaklaşim, tek bir yayılma metriğini belirlemede değerlidir ve 3/1/18'den 23/12/21'e giden tüm örneklem için, COVID-19 öncesi 3/1/18'den 10'1 giden dönem için uygulanacaktır, 10/3/20 ve COVID-19 sırasında 11/3/20'den 23/12/21'e giden dönem için.

Bulgular, önceki araştırmalarını hisse senedi piyasalarının gelişmesinin krizler sırasında getiri yayılmalarını arttırgığı ve bunun sonucunda ülkeler arasında portföy çeşitlendirmesinden elde edilen faydalarda azalma anlamına geldiği fikrini desteklemektedir. Tersine, bulgular pandemic sırasında gelişmis ülkeler için getiri ve oynaklik yayılımının, gelişmekte olan ülkeler için oynaklık yayılımının da azaldığını gösteriyor.

Anahtar Kelimeler: Getiri ve Oynaklık Yayılımı. Gelişmiş ve Gelismekte olan Ülkeler, Borsa, COVID-19 Pandemisi, VAR Modeli.

INTRODUCTION

History shows that local events can reach a global dimension through time, from natural disasters, wars, political instabilities, to diseases. All these circumstances usually born within local environments, can spread to universal magnitudes due to globalization and integration between nations.

The COVID-19 pandemic which started in Wuhan, China, rapidly spread to the rest of the world impacting significantly the global economy with outstanding outcomes for the financial markets. In particular, there has been an increasing interest over the effects of the pandemic in the stock markets spillovers. Therefore, this paper seeks to investigate the extent to which COVID-19 affected the return and volatility spillovers among developed and developing countries.

The concept of return and volatility spillover refers to the transmission of return and volatility shocks from one financial market to another (Forbes and Rigobon 2002). Previous studies have shown that spillovers can take place among developed and developing countries, as well as across different sectors and asset classes (Dutta et al., 2019).

Researchers and investors interested in efficient portfolio allocation have contributed to the recent rise in return and volatility spillover studies. This can be attributed to the fact that stock markets tend to become more correlated over time as a result of globalization which has diminished the diversification benefits, especially during times of crisis. Moreover, researches have shown that the correlation between markets is higher when they tend to move downwards together (Solnik and Fur 1996).

As previously mentioned, a significant shock to the global economy and financial markets was caused by the COVID-19. The pandemic caused a sharp contraction in the economic activity of many countries which led to a decline in the demand for goods and services, as well as a decline in the supply chains affecting the profitability of many industries. Therefore, different stock markets from diverse countries experienced significant volatility and declines in returns (Zhang, Hu, and Ji 2020)

The impact of the pandemic on the return and volatility spillovers among developed and developing countries has not been fully quantified yet. While some authors have suggested that this event could have led to an increase in spillovers due to the pandemic's worldwide extent (Si et al. 2021). Others authors have suggested that the pandemic may have caused a temporary decrease in volatility spillovers during certain periods after the outbreak of COVID-19 due to low levels of correlation between certain countries, however, the financial markets are becoming more volatile and returns are trending upward in the long run (Deka and Vashishtha 2021)

In addition, stock markets were affected by the COVID-19 through a change in the investor's behavior. The pandemic brought an uncertainty shock greater than the one brought by the 2008 financial crisis (Baker et al. 2020), leading to an increase in the markets volatility and shifting the investor's sentiment towards a more risk-averse behavior. In developing countries, where there are fewer institutional and regulatory safeguards and it is easier to weaken market trust, this shift in investor behavior was more pronounced. Due to the outbreak, investors withdrew funds from the markets in multiple developing countries, which resulted in a decline in stock prices and an increase in volatility (Cevik et al. 2022)

Furthermore, given the influence of COVID-19 on financial markets, it's crucial to comprehend the nature and scope of the pandemic's spillover effects on the return and volatility of stock markets. As well, it’s an essential area of study for this paper the degree to which the pandemic led to a change in correlations between financial markets among different countries.

In the economies integration scope, some theories predict that international financial integration promotes growth only in countries with solid institutions and policies because it allows investors easier access to markets around the world than in countries with weaker financial systems (Edison et al. 2002). However, other authors have shown that for developing countries, the integration of financial markets is generally followed by a significantly larger and more liquid equity market, more volatile returns and more correlated with world market returns, lower cost of capital, improved credit ratings, currency appreciation, and increased economic growth (Balls 1999). Hence why both developed and developing economies have looked forward to broadening their financial integration to the world which results in higher markets correlations that affect the portfolio diversification benefits during crises.

To further examine the effect of the COVID-19 on the spillover between markets, this paper will use a sample consisting of four developed and four developing countries for a total of eight economies to be studied based on the representation their stock markets have on their regions including North America, Europe, Asia and South America.

To compose the total return and volatility spillover indices, this paper uses the Diebold and Yilmaz (2009) taking the daily logarithmic returns from the stock markets’ indices from the eight selected countries. This model uses the variance decompositions of the vector autoregressive (VAR) model to measure the connectedness between financial markets and provide a time-varying estimation of the correlation between markets.

The findings of this thesis are expected to contribute to the understanding of the impact of COVID-19 on return and volatility spillovers between developed and developing countries. The study may shed light on the extent to which certain markets are susceptible to the pandemic, as well as implications for investors who must take spillover risk into account while diversifying portfolios.

The rest of this paper is structured as follows. Part I contains the Literature review, Part II presents the Methodology, and Part III presents the Data and Descriptive Statistics. The IV section goes to the Empirical Results, followed by the Conclusion section on the part V of this paper.

1. LITERATURE REVIEW

During the past years, the research of return and volatility spillovers between financial markets has been increasing due to its importance for an enhanced portfolio allocation through diversification, for the application of value at risk and hedging strategies. This phenomenon has also led to an increase in research of contagion effects between stock markets among developed and developing countries, particularly during crises. The goal of this literature review is to give a summary of the studies that looked at the impact of COVID-19 on return and volatility spillover and the correlation between developed and developing economies.

The literature on spillover effects has been typically concentrated on the leading and most influential stock markets, including the NASDAQ, S&P, FTSE, TSE, and DAX (Statista 2023) from developed nations (such as the United States, Japan, the United Kingdom, Canada, and Germany), by modeling the interdependence of them in terms of returns and volatility.

The interdependence between developed economies tends to be higher when compared to emerging economies. For example, after the formation of the European union, which was accelerated by the removal of the exchange rate between some of the nations that comprised the EU, evidence suggests that ties between European countries and the US strengthened following the introduction of the EURO in 1999 (Melle 2004).

For example, the UK and Germany are the two nations in the Euro zone that are most affected by the US when it comes to volatility spillover, according to a study that employed a dynamic correlation approach (Syriopoulos, 2005), which is also supported by related studies.

As well, another study conducted by Nikkinen and Sahlström (2004) that sought to determine how uncertainty is transmitted internationally between stock markets discovered a significant degree contagion effects and volatility spillover, among stock markets from the US, the UK, Germany, and Finland.

On this basis, the linkage between stock markets from developed countries started with the liberalization of capital controls in the United States in 1975 when the *U.S. Securities Act Amendments* deregulated the stock brokerage commission rates (Gillis 1975). After the US, other developed countries started the path toward stock market liberalization, including the UK abolishing exchange controls on capital outflows in 1979 (Wong et al. 2004), and Japan, whose introduction of the Foreign Exchange and Foreign Trade Control Law in 1980 (Japanese Law) removed most capital controls and allowed for the unrestricted exchange of foreign financial assets.

The easing of capital controls in developed economies boosted the worldwide interconnectedness of the stock markets, providing investors with additional alternatives for portfolio allocation to increase the reward-to-volatility ratio. The advantages of diversification have, however, diminished over time as financial markets have become more correlated, particularly during economic downturns when there is a higher risk of contagion (Sandoval and Franca 2012)

Due to the previously mentioned financial market liberalization, technological improvements, and globalization, the significance of stock markets from developing economies has also expanded during the last years. Particularly, the 2008 financial crisis, brought on by the bankruptcy of Lehman Brothers, had a higher level of contagion effect from the US to financial markets from other developed countries than it did to developing ones. Therefore, the financial markets of emerging economies became more appealing to investors in terms of diversification benefits (Boubaker, Jouini, and Lahiani 2016).

In relation to developing countries' financial markets, Bekaert and Harvey (1997) demonstrated that they tend to have higher volatility, lower correlation, and more predictable returns. As well, it was found that the degree to which volatility spreads from developed to developing stock markets depends on how susceptible the latter are to external influences (Mohammed, 2011).

According to a research lead by Bala and Takimoto (2017) with the aim of finding the stock market's volatility spillovers during crises between developed and emerging financial markets using a GARCH (MGARCH) model for the years 1994 to 2016, found that correlations between emerging markets are lower when compared to correlations between developed markets suggesting greater interconnectedness between the last ones. In addition, the results exhibit that the volatility in emerging markets is more strongly influenced by prior shocks than the volatility of developed markets showing. Lastly, the authors found that the effects of a shock take longer to fade for emerging countries, it suggesting that they are less effective than developed markets.

1.1 EVIDENCE OF COVID-19 EFFECTS ON RETURN AND VOLATİLİTY SPILLOVERS

On March 11th, 2020, the WHO declared COVID-19 a global pandemic, and most countries around the world-initiated isolation and lockdown measures to stop the virus' spread. The lockdown restricted social and economic activities, which had a major impact in the demand for goods/services and supply chains. Consequently, the pandemic has had a significant impact on the global economy including financial markets which presented fluctuations in assets' prices, decrease in returns and increase in volatility.

On this basis, studying the degree to which the COVID-19 has affected the return and volatility spillovers and the sub sequential contagion across countries has gained more interest. The following part of the literature review focuses on the findings related to the effects of COVID-19 on spillovers between developed and developing economies.

For starters, a research made by Ammy-Driss and Garcin (2020) to measure the impact of COVID-19 on financial markets using a time-varying parameter model of fractional stable dynamics, found that all stock markets in study experienced a significant reduction in efficiency, with an increase in the volatility levels during the pandemic. The findings also suggest that S&P (the US) was the least impacted market by the COVID-19 outbreak, followed by European markets such as DAX (Germany) and FTSE100 (the UK).

A related research looking to compare the impact of COVID-19 on emerging and developed markets made by Topcu and Gulal (2020), found that Asian stock markets were more negatively impacted than European stock markets in regards of volatility.

In a similar vein, a research employing the GARCH and Diebold-Yilmaz models revealed that, in terms of contagion effects and volatility spillovers, the US dominated the international financial markets during COVID-19 and it was found that spillover effects are transmitted more widely in developed economies. Lastly, the authors' state that distortions in predicted cash flows may be related to the comparatively higher stress, enhanced spillovers, and contagious effects among developed markets (Gunay and Can 2022).

Li (2021) employing the Diebold-Yilmaz spillover Index between the US, Japan, Germany, the UK, France, Italy, Canada, China, India and Brazil, found that among the examined global markets (which were highly correlated according to his results), the developed markets serve as the primary risk transmitters (being the US is the risk enhancer), and developing markets are the main risk receivers.

In addition, a research developed by Malik, Sharma, and Kaur (2021) concerning the contagion between the US and the BRICs during COVID-19 using a GARCH model found that, the US, China and Brazil presented the highest levels of volatility levels compared to Russia and India. These findings align with a study made by Rai and Garg (2021) whom using another GARCH model found that, with the exception of Brazil and Russia, there is a sizable dynamic link between stock returns of the four BRICS (India, Indonesia, China and South Africa), and suggests the existence of significant risk transfer between all the BRICS strengthened during COVID-19.

Moreover, Rakshit and Neog (2021) through a robustness test exhibit that during the pandemic there is a negative impact on the market returns of Brazil (BOVESPA), Chile (IPSA), India (SENSEX), Mexico (IPC) and Russia (MOEX). Additionally, the authors found that the market returns of India and Brazil were more volatile during the pandemic compared to the 2008 financial crisis.

In conclusion, evidence has shown through the years, especially after the last financial crises, that financial markets from most countries have been becoming more correlated, specially the developed ones. As well, financial markets from developing countries have been becoming more significant to investors in the light that they present less correlation with their pears and when compared to those from developed countries.

Nevertheless, empirical results show that during COVID-19, financial markets from both developed and developing economies presented an increase in return and volatility spillover and a rise in contagion effects between each other. These findings have important implications for investors in terms on portfolio allocation and diversification.

2. METHODOLOGY

To calculate the volatility spillovers, the Diebold and Yilmaz model (2009) is used which employs a metric based on forecast error variance decomposition produced using vector autoregressive (VAR) models showed on the Data and Descriptive Statistics part of this paper. For the VAR model estimation, the lag orders of the variables are determined by Akaike Information Criterion (AIC). For all the markets, the VAR order series is 2.

Then, Diebold and Yilmaz (2009) assume a covariance stationary in first order for the two-variable VAR model

$$y_t = \varphi y_{t-1} + \varepsilon_t, \qquad (1)$$

Where $y_t = (y_{1,t}, y_{2,t})'$ and Φ is a 2X2 matrix of parameters. The moving average representation of the VAR is given by

$$y_t = \theta(L)\varepsilon_t, \qquad (2)$$

Where θ(L) =$(I - \theta L)^{-1}$. Re-writing the equation based on the Cholesky decomposition definingK$(L) = \theta(L)B_t^{-1}, u_t = B_t\varepsilon_t$, where $E(u_t u_t^{'}) = I$and $B_t^{-1}$is the only lower-triangular Cholesky factor of the covariance matrix ofε_t, the equation reduces to

$$y_t = K(L)u_t, \qquad (3)$$

Where the optimal one-step-ahead forecast is

$$y_{t+1,t} = \phi y_t, \qquad (4)$$

With its corresponding one-step-ahead forecast error vector,

$$e_{t+1,t} = y_{t+1} - y_{t+1,t} = K_0 u_{t+1} = \begin{bmatrix} k_{0,11} & k_{0,12} \\ k_{0,21} & k_{0,22} \end{bmatrix} \begin{bmatrix} u_{1,t+1} \\ u_{2,t+1} \end{bmatrix}, \qquad (5)$$

Which has the following covariance matrix

$$E\left(e_{t+1,t}e'_{t+1,t}\right) = K_0K_0', \text{ (6)}$$

There are two possible spillovers in a VAR system with two variables; 1, from variable 1 to variable 2 with a contribution of $k_{0,21}^2$,; 2, from variable 2 to variable 1 with a contribution of$k_{0,12}^2$. Therefore, the total spillover effect is $k_{0,21}^2+ k_{0,12}^2$ meaning that the total spillover index is the ratio of the total spillover to total forecast error variation equal to $trace(k_0k_0')$, shown as

$$S = \frac{k_{0,12}^2 + k_{0,21}^2}{trace(k_0k_0')} \; x \; 100, \text{ (7)}$$

The generalized version of the spillover index in a system with N variables is

$$S = \frac{\sum_{i \neq j}^{n} j=1 k_{0,ij}^2}{trace(k_0k_0')} \text{ x } 100, \text{ (8)}$$

The variance decomposition is estimated at times t+1, t+5, t+10, t+15, t+20 before and during COVID-19 pandemic periods. This estimation allows observing changes in the spillover effect arising from the crisis generated by the COVID-19 pandemic over time.

3. DATA AND DESCRIPTIVE STATISTICS

This paper aims to study the effects of COVID-19 on the return and volatility spillover among eight economies before and during the pandemic, taking the indices' daily returns in local currency units from the Yahoo Finance data center. The countries chosen for this paper are the United States, the United Kingdom, Germany, and Canada in the developed countries group, and Mexico, Brazil, Turkey, and India in the developing countries group.

The countries selection was based as follows: The United States was chosen for this study since is the world's largest economy, the United Kingdom and Germany were chosen for being the leading economies in Europe, and Canada was chosen for being one of the more stable economies in the world. On the other hand, Mexico and Brazil were chosen as the growing economies from the LATAM region, India was chosen because for being one of the most important emerging markets, and Turkey for being a European/Asian developing economy. Table 3.1 shows the stock indices information from the chosen countries

Table 3.1 Selected stock markets and the respective indices

Country	Stock Index	Symbol
US	Standard&Poor´s (S&P 500)	S&P
UK	The Financial Stock Exchange (FTSE)	FTSE
Germany	Deutscher Aktienindex (DAX 30)	DAX
Canada	The TSX Alpha Exchange	TSX
Brazil	Sao Paulo Stock Exchange (BOVESPA)	BVSP
Mexico	Mexican IPC Index	IPC
Turkey	Borsa Istanbul (BIST 100)	BIST100
India	Nifty National Stock Exchange (NSE)	NIFTY50

Moreover, the sample has been divided into three periods: the whole sample, before, and during COVID-19 pandemic. The whole sample goes from Jan 3rd 2018 to Dec 23rd 2021, the before-COVID-19 period goes from Jan 3rd 2018 to Mar10th 2020, and during COVID-19 period from Mar11^{th,} 2020 to Dec23rd 2021.

The first part of the study starts with the calculation of the indices logarithmic daily returns calculated as the change in log prices from day t to day t+1 as shown on the following formula

$$r_t = \log\left(\frac{P_t}{P_{t-1}}\right) = \log(P_t) - \log\left(P_{t-1}\right), \quad (9)$$

3.1 RETURNS' DESCRIPTIVE STATISTICS AND INTERPRETATIONS

With that being said, Table 3.1.1 to Table 3.1.3 show the descriptive statistics of the daily indices returns of developed and developing countries

Table 3.1.1 Summary of descriptive statistics of the indices returns from developed countries for the whole sample

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 23rd December 2021				
Mean	-0.000666	0.000051	0.00022	0.000311
Median	-0,001303	-0,000725	0,000723	0,000869
Maximum	0,127652	0,115124	0,104143	0,112945
Minimum	-0,088808	-0,047999	-0,130549	-0,131758
Std. Dev.	0,013815	0,012257	0,014712	0,012319
Skewness	1,296,121	1,621,214	-1,078,824	-1,681,281
Kurtosis	2,058,883	1,632,644	1,729,408	4,212,184
Jarque-Bera	10948,01	6,536,730	7,261,924	53578,43
Probability	0	0	0	0
Sum	-0,555132	0,042814	0,183580	0,259344
Sum Sq. Dev.	0,158983	0,125145	0,180296	0,126406
Observations	834	834	834	834

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively.

Table 3.1.2 Summary of descriptive statistics of the indices returns from developing countries for the whole sample

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 23rd December 2021				
Mean	0,000355	0,000067	-0,004992	0,000582
Median	0,000972	-0,000071	0,001656	0,001334
Maximum	0,130223	0,042931	0,058103	0,084003
Minimum	-0,159930	-0,066381	-4,602,084	-0,139038
Std. Dev.	0,018887	0,011980	0,160214	0,013812
Skewness	-1,016,350	-0,557901	-2,837,717	-1,743,303
Kurtosis	1,795,202	6,838,898	8,147,224	2,472,628
Jarque-Bera	7,912,394	5,553,798	23008475	16785,18
Probability	0	0	0	0
Sum	0,296277	0,056025	-4,163,313	0,483985
Sum Sq. Dev.	0,297140	0,119545	2,138,183	0,158525
Observations	834	834	834	834

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.1.3 Summary of descriptive statistics of the indices returns from developed countries before COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 10th March 202				
Mean	-0,001004	-0,000068	-0,000475	-0,000305
Median	-0,001678	-0,001134	0,000885	0,000611
Maximum	0,127652	0,115124	0,033144	0,021439
Minimum	-0,088808	-0,047999	-0,096943	-0,108339
Std. Dev.	0,016086	0,014729	0,012411	0,008390
Skewness	1,519,432	1,644,624	-1,999,566	-5,469,834
Kurtosis	1,992,006	1,394,167	1,405,857	6,594,114
Jarque-Bera	5,553,369	2,453,050	2,598,605	76693,73
Probability	0	0	0	0
Sum	-0,452829	-0,030679	-0,214234	-0,137382
Sum Sq. Dev.	0,116439	0,097623	0,069320	0,031675
Observations	451	451	451	451

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany, and Canada, respectively.

Table 3.1.4 Summary of descriptive statistics of the indices returns from developing countries before COVID-19

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 10th March 2020				
Mean	0,000195	-0,000560	-0,000309	0,000003
Median	0,001239	-0,000278	0,000126	0,000445
Maximum	0,053597	0,033660	0,044313	0,051825
Minimum	-0,129811	-0,066381	-0,069539	-0,050195
Std. Dev.	0,015597	0,011123	0,015481	0,009672
Skewness	-1,664,772	-1,163,552	-0,483811	-0,333458
Kurtosis	1,497,699	8,990,553	4,874,557	7,150,926
Jarque-Bera	2,903,954	7,761,360	8,362,778	3,321,421
Probability	0	0	0	0
Sum	0,088016	-0,252373	-0,139253	0,001454
Sum Sq. Dev.	0,109473	0,055671	0,107853	0,042096
Observations	451	451	451	451

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.1.5 Summary of descriptive statistics of the indices returns from developed countries during COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 11th March 2020 through 23rd December 2021				
Mean	-0,000267	0,000192	0,001039	0,001036
Median	-0,000816	-0,000187	0,000457	0,001526
Maximum	0,038259	0,048767	0,104143	0,112945
Minimum	-0,056929	-0,028424	-0,130549	-0,131758
Std. Dev.	0,010539	0,008486	0,017008	0,015717
Skewness	0,156236	0,628353	-0,675714	-0,885308
Kurtosis	6,117,032	6,584,770	1,640,479	2,839,799
Jarque-Bera	1,566,076	2,302,769	2,896,671	10344,08
Probability	0	0	0	0
Sum	-0,102303	0,073493	0,397814	0,396726
Sum Sq. Dev.	0,042432	0,027507	0,110501	0,094359
Observations	383	383	383	383

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively.

Table 3.1.6 Summary of descriptive statistics of the indices returns from developing countries during COVID-19

	BVSP	IPC	BIST100	NSEI
Full sample period: 11th March 2020 through 23rd December 2021				
Mean	0,000544	0,000805	-0,010507	0,001266
Median	0,000870	0,000163	0,002879	0,002199
Maximum	0,130223	0,042931	0,058103	0,084003
Minimum	-0,159930	-0,054889	-0,002084	-0,139038
Std. Dev.	0,022163	0,012892	0,235870	0,017479
Skewness	-0,701727	-0,140374	-1,933,606	-1,896,984
Kurtosis	1,634,762	5,093,095	3,769,028	2,059,342
Jarque-Bera	2,874,554	7,117,204	2254894	5,142,271
Probability	0	0	0	0
Sum	0,208261	0,308398	-4,024,060	0,482530
Sum Sq. Dev.	0,187642	0,063488	2,125,244	0,116099
Observations	383	383	383	383

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

The logarithmic daily returns were taken from the indices closing price as a measure of the percentage change in the value of the stock indices over time. The statistics of the logarithmic daily returns are detailed explained below.

Among the eight stock indices including developed and developing countries, all the markets except for the US (-0.000666) and Turkey (-0.004992) have a positive average daily return for the whole sample. The average returns range goes from -0.000666 (the US) to 0.000311 (Canada) for the developed countries group, and from -0.004992 (Turkey) to 0.000582 (India) for the developing countries group.

Before COVID-19, all the developed countries presented negative mean returns, as well as Mexico (-0.000560) and Turkey (-0.000309) from the developing countries. For this period, the highest daily return achieved by the developed countries was 0.127652 by the US, and the lowest return was -0.108339 by Canada;

the highest return achieved by the developing countries was 0.053597 and the lowest was -0.129811 both by Brazil.

During COVID-19, the US (-0.000267) poses the only stock index with a negative mean return from the developed countries group, as well as Turkey (-0.010507) from the developing countries group. For this period, the highest and lowest daily returns achieved by the developed countries were 0,112945 and -0.131758 both from Canada. As well, from the developing countries group, 0,130223 and -0.159930 were the highest and lowest daily stock returns, respectively, both coming Brazil.

In regards to the standard deviation, Canada (0.008390) and the UK (0.008486) presented the lowest variability before and during COVID-19, respectively. As well, India (0.009739) and Mexico (0.013264) presented the lowest variability before and during COVID-19, respectively. On the other hand, the US (0.016086) and Brazil (0.015597) had the highest variability before COVID-19, and Germany (0.017008) and Turkey (0.235870) had the highest variability during the pandemic.

In overall, Germany (0.014712) and Turkey (0.160214) had the highest standard deviation for the whole sample indicating that the stock indices from these two countries were more spread out and less clustered around the mean than the other six indices.
As well, the Jarque-Bera test confirms that none of the returns follow a normal distribution since the tests shows values higher than zero, this is true for all stock indices before and during COVID-19.

3.2 RETURNS' CORRELATIONS COEFFICIENTS AND INTERPRETATIONS

Table 3.2.1 to Table 3.2.6 present the correlations coefficients among the daily stock returns from the indices the all the periods in study.

Table 3.2.1 Stock return correlation coefficients for developed countries for the whole sample

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 23rd December 2021				
S&P	1	-	-	-
FTSE	0,404389	1	-	-
DAX	0,067250	0,020075	1	-
TSX	0,050319	0,023010	0,085326	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.2.2 Stock return correlation coefficients for developing countries for the whole sample

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 23rd December 2021				
BVSP	1	-	-	-
IPC	0,551801	1	-	-
BIST100	-0.00498	0.0034	1	-
NSEI	0.423143	0.411565	0.050262	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.2.3 Stock return correlation coefficients for developed countries before COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 10th March 2020 December 2021				
S&P	1	-	-	-
FTSE	0.444303	1	-	-
DAX	0.105695	0.046792	1	-
TSX	0.05719	0.023222	0.38366	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.2.4 Stock return correlation coefficients for developing countries before COVID-19

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 10th March 2020 December 2021				
BVSP	1	-	-	-
IPC	0,501534	1	-	-
BIST100	0.224944	0.323975	1	-
NSEI	0.247071	0.30941	0.262101	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.2.5 Stock return correlation coefficients for developed countries during COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 12th March 2020 through 23rd December 2021				
S&P	1	-	-	-
FTSE	0,281887	1	-	-
DAX	0.024227	-0.016603	1	-
TSX	0.05461	0.030043	-0.054025	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.2.6 Stock return correlation coefficients for developing countries during COVID-19

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 12th March 2020 through 23rd December 2021				
BVSP	1	-	-	-
IPC	0.593222	1	-	-
BIST100	-0.018197	-0.014442	1	-
NSEI	0.508198	0.481315	0.049377	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

As shown in the tables above, for the developed countries, the strongest relation for both periods is between the US and the UK (0.444303), and the weakest relation is between the UK and Canada (0.023222) before COVID-19. During COVID-19, the weakest correlation is between Germany and Canada (-0.054025), which also indicates that the stock markets of these two countries move in opposite directions.

For the developing countries group, for both periods, the strongest correlation is between Brazil and Mexico, and the weakest is between Brazil and Turkey. In this case, the results show that the correlation between Brazil and Mexico increased during COVID-19, and the correlation between Brazil and Turkey goes from 0,224944 before COVID-18 to -0,018197 indicating that during COVID-19 the stock markets of these countries tended to move in opposite directions.

In general, for the developed countries group (except for the relationship between UK and Canada) the results show a decrease in the correlation coefficients during the pandemic, indicating that the movements of these markets are becoming less similar to each other.

The decrease in the correlation can be explained either by a change in the investor's behavior that whom are becoming more selective, or because investors are becoming more risk averse while diversifying their portfolios. İn both scenarios, the decrease in the correlation of these stock markets leads to diversification opportunities for the developed countries group except for UK and Canada.

In regards to the developing countries, the results show a mix between and increase and a decrease in the correlation between these markets. The correlation between Brazil-Turkey, Mexico-Turkey and India-Turkey decreased during COVID-19. On the other hand, the correlation between Brazil-Mexico, Brazil-India and Mexico-India increased during COVID-19 meaning that these stock markets are becoming more similar, therefore diversification benefits became more limited.

3.3 RETURNS' ADF TESTS AND INTERPRETATIONS

In this analysis, to examine the stationarity of the data series it is used the Augmented Dickey Fuller test (ADF). The ADF test determines the presence of unit root. Table 3.3.1 and Table 3.3.2 provide the ADF test for both developed and developing economies for the whole sample.

Table 3.3.1 Unit root test results of selected stock markets' price and return series for developed countries

ADF Test Statistics Null Hypothesis: Unit root (individual unit root process)			
Return series		**Price series**	
Countries	Prob.	Countries	Prob.
US	0,000000	US	0,9746
UK	0,000000	UK	0,4385
Germany	0,000000	Germany	0,7041
Canada	0,000000	Canada	0,7908

Table 3.3.2 Unit root test results of selected stock markets' price and return series for developing countries

ADF Test Statistics Null Hypothesis: Unit root (individual unit root process)			
Return series		**Price series**	
Countries	Prob	Countries	Prob
Brazil	0,000000	Brazil	0,3752
Mexico	0,000000	Mexico	0,6182
Turkey	0,000000	Turkey	0,6993
India	0,000000	India	0,9547

The results show that all the stock price indices have a unit root. Therefore, the null hypothesis cannot be rejected in the presence of unit root (non-stationarity) at the level. However, when the logarithmic return of the closing prices from the stock indices is taken, the results show that all the return series are stationary which confirms that the data of the eight countries is integrated in order one, I (1). All the same, the results suggest that all the indices are stationary and the null hypothesis is rejected.

This paper uses Diebold and Yilmaz's model (2009) to generate a volatility spillover index based on the forecast of error variance decompositions derived from the vector autoregressive (VAR). This approach collects the shocks that spillover from one stock markets to another, which is valuable in determining a single spillover metric.

The first step to filter volatilities is estimating the Stochastic Volatility (SV) model established by Taylor (1982, 1986) given as

$$r_t = \exp\left(\frac{\lambda t}{2}\right) \varepsilon t, \qquad (10)$$

$$\lambda_t = \gamma + \delta\lambda_{t-1} + \nu\eta_t, \quad (11)$$

Where r_t indicates the return and λ_t indicates de volatility at time 1→T, and where the random variables εt and η_t are standard normal, N (0, 1). Both equations (1) and (2) draw a Gaussian non-linear dynamic state space model. The non-linear dependence of $r_t$on $\lambda_t$in (1) forbids the application of the Kalman Filter therefore an Efficient Importance Sampling (EIS), introduced by Richard and Zhang (2007), is applied to determine the likelihood function of the Stochastic Volatility (SV) model since EIS generates accurate Monte-Carlo estimations of likelihood functions for an extensive range of SV models (Liessenfeld and Richard, 2003 and 2006).

3.4 VOLATILITIES' DESCRIPTIVE STATISTICS AND INTERPRETATIONS

Table 3.4.1 to Table 3.4.6 show the descriptive statistics of the volatilities for the eight chosen countries divided into developed and developing.

Table 3.4.1 Summary of descriptive statistics of the indices' volatilities from developed countries for the whole sample

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 23rd December 2021				
Mean	0.985769	0.969029	0.734862	0.928818
Median	0.971668	0.929667	0.704209	0.882339
Maximum	1.661583	1.663464	3.617491	2.31918
Minimum	0.899894	0.775752	0.623588	0.749399
Std. Dev.	0.074846	0.142154	0.201215	0.180091
Skewness	5.133376	2.171447	9.519533	3.813117
Kurtosis	38.06208	8.540693	108.4247	21.74511
Jarque-Bera	46382.76	1722.21	398820.5	14231.47
Probability	0	0	0	0
Sum	822.131	808.1705	612.8751	774.6343
Sum Sq. Dev.	4.666407	16.83302	33.72594	27.01642
Observations	834	834	834	834

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively.

Table 3.4.2 Summary of descriptive statistics of the indices' volatilities from developing countries for the whole sample

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 23rd December 2021				
Mean	0.941872	0.969029	0.734862	0.98295
Median	0.911984	0.929667	0.704209	0.965255
Maximum	2.215467	1.663464	3.617491	1.747396
Minimum	0.76625	0.775752	0,623588	0.890331
Std. Dev.	0.166242	0.142154	0.201215	0.079844
Skewness	4.053247	2.171447	9.519533	4.82238
Kurtosis	24.54096	8.540693	108.4247	33.0626
Jarque-Bera	18408.06	1722.21	398820.5	34638.14
Probability	0	0	0	0
Sum	785.5208	808.1705	612.8751	819.7804
Sum Sq. Dev.	23.02125	16.83302	33.72594	5.310411
Observations	834	834	834	834

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.4.3 Summary of descriptive statistics of the indices' volatilities from developed countries before COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 10th March 2020				
Mean	0.973636	0.941499	0.713737	0.880429
Median	0.969817	0.908896	0.705357	0.865014
Maximum	1.39733	1.536194	1.003007	1.250811
Minimum	0.904133	0.795438	0.663725	0.766478
Std. Dev.	0.037436	0.115176	0.04485	0.076749
Skewness	3.813212	2.402746	3.740621	1.537104
Kurtosis	39.69641	10.05161	19.16329	6.290972
Jarque-Bera	26398.32	1368.371	5961.112	381.1185
Probability	0	0	0	0
Sum	439.1097	424.6159	321.8955	397.0734
Sum Sq. Dev.	0.63065	5.96952	0.905169	2.65069
Observations	451	451	451	451

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively.

Table 3.4.4 Summary of descriptive statistics of the indices' volatilities from developing countries before COVID-19

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 10th March 2020				
Mean	0.908196	0.941499	0.713737	0.965546
Median	0.902738	0.908896	0.705357	0.962303
Maximum	1.670754	1.536194	1.003007	1.141393
Minimum	0.76916	0.795438	0.663725	0.909594
Std. Dev.	0.084185	0.115176	0.04485	0.031199
Skewness	2.195164	2.402746	3.740621	1.808877
Kurtosis	17.90661	10.05161	19.16329	9.45001
Jarque-Bera	4537.847	1368.371	5961.112	1027.731
Probability	0	0	0	0
Sum	409.5964	424.6159	321.8955	435.4613
Sum Sq. Dev.	3.189235	5.96952	0.905169	0.43802
Observations	451	451	451	451

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.4.5 Summary of descriptive statistics of the indices volatilities from developed countries during COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 11th March 2020 through 23rd December 2021				
Mean	1.000056	1.001448	0.759738	0.985799
Median	0.974674	0.955852	0.70215	0.91846
Maximum	1.661583	1.663464	3.617491	2.31918
Minimum	0.899894	0.775752	0.623588	0.749399
Std. Dev.	0.100927	0.162757	0.291155	0.240343
Skewness	3.971689	1.853079	6.589816	2.798416
Kurtosis	21.97551	6.741263	51.7013	11.90976
Jarque-Bera	6753.042	442.5671	40622.24	1766.721
Probability	0	0	0	0
Sum	383.0213	383.5546	290.9796	377.561
Sum Sq. Dev.	3.891188	10.11915	32.3825	22.06618
Observations	383	383	383	383

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.4.6 Summary of descriptive statistics of the indices volatilities from developing countries during COVID-19

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 11th March 2020 through 23rd December 2021				
Mean	0.981526	1.001448	0.759738	1.003444
Median	0.927214	0.955852	0.70215	0.972791
Maximum	2.215467	1.663464	3.617491	1.747396
Minimum	0.76625	0.775752	0.623588	0.890331
Std. Dev.	0.221361	0.162757	0.291155	0.109436
Skewness	3.142253	1.853079	6.589816	3.518877
Kurtosis	14.2193	6.741263	51.7013	17.54878
Jarque-Bera	2638.993	442.5671	40622.24	4168.267
Probability	0	0	0	0
Sum	375.9244	383.5546	290.9796	384.3191
Sum Sq. Dev.	18.71831	10.11915	32.3825	4.574924
Observations	383	383	383	383

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Mean daily volatilities were taken as a measure of the average degree of variation of the stock indices' returns for the periods in study, they were calculated as the standard deviation of the daily logarithmic returns from Jan 2018 to Dec 2021. For all periods, the mean daily volatilities for all markets were greater than zero. This is consistent with the norm in financial markets where stocks frequently exhibit a degree of volatility as a result of changes in stock prices.

For the whole sample, the average daily volatility range goes from 0.735% (Germany) to 0.986% (the US) for the developed countries group. For the developing countries group, the daily volatility varies between 0.734% (BIST100 from Turkey) to 0.982% (NIFTY50 from India). From Jan 2018 to Dec 2021, the highest and lowest daily volatility presented was 3.617% by Germany and Turkey with the same percentages by both countries.

Furthermore, for the whole sample, the highest standard deviation was 0.201% from Germany and Turkey, meaning that the stock indices from these two countries were more spread out and less clustered around the mean than the other six indices. Consequently, both the Germany and Turkey presented the highest level of variability for the entire sample.

Before COVID-19, the average daily volatility ranges between 0.713% (Germany) and 0.973% (the US) for the developed countries, highest daily volatility presented was 1.536% by the UK, and the lowest one was 0.663% by Germany. On the other hand, from the developing countries group, the average daily volatility goes from 0.713% (Turkey) to 0.965% (India), and the highest and lowest daily volatility presented were 1.670% and 0.663% from Brazil and Turkey, respectively.

Moreover, the highest standard deviation before COVID-19 was 0.115% from the UK and Mexico, meaning that the stock indices from these two countries were more spread out and less clustered around the mean than the other six indices.

Therefore, both the UK and Mexico presented the highest level of variability before the pandemic.

Ultimately, during COVID-19 the average daily volatility ranges between 0.759% (Germany) and 1.001% (the UK) for the developed countries. In addition, the highest and the lowest daily volatility presented were 3.617% and 0.663%, respectively, both coming from Germany.

On the other hand, during COVID-19 the average daily volatility from the developing countries goes from 0.759% (Turkey) to 1.0035% (India), and the highest and lowest daily volatility presented were 3.617% and 0.623%, respectively, both from Turkey.

In regards to the standard deviation, during COVID-19 the highest level presented was 0.291% from Germany and Turkey, meaning that the stock indices from these two countries were more spread out and less clustered around the mean than the other six indices. Therefore, both the Germany and Turkey presented the highest level of variability during the pandemic.

The results demonstrate positive skewness, which assesses the symmetry of the values and indicates that the distribution of the volatilities for this study is skewed to the right, with a longer tail on the right-hand side. This is true for all markets and for all time periods.

Lastly, the results exhibit a positive kurtosis higher than three, indicating that the distribution of the daily volatility values is more peaked and has higher number of outliers than a normal distribution. Furthermore, the Jarque-Bera test confirm that none of the indices follow a normal distribution since the tests shows values higher than zero.

3.5 VOLATILITIES' CORRELATION COEFFICIENTS AND INTERPRETATIONS

Table 3.5.1 to Table 3.5.6 provide the correlations among the indices' volatilities of the eight countries for all the periods.

Table 3.5.1 Indices' volatilities correlation coefficients for developed countries for the whole sample

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 23rd December 2021				
S&P	1	-	-	-
FTSE	0.69868	1	-	-
DAX	-0.000924	-0.042075	1	-
TSX	0.771211	0.715438	-0.019707	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.5.2 Indices' volatilities correlation coefficients for developing countries for the whole sample

	BVSP	IPC	BIST100	NIFTY50
Full sample period: 3rd January 2018 through 23rd December 2021				
BVSP	1	-	-	-
IPC	0.735866	1	-	-
BIST100	0.008003	-0.042075	1	-
NSEI	0.831072	0.684327	-0.027945	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.5.3 Indices' volatilities correlation coefficients for developed countries before COVID-19

	S&P	FTSE	DAX	TSX
Full sample period: 3rd January 2018 through 10th March 2020 December 2021				
S&P	1	-	-	-
FTSE	0.375581	1	-	-
DAX	0.164063	-0.005041	1	-
TSX	0.335739	0.260271	0.14933	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.5.4 Indices' volatilities correlation coefficients for developing countries before COVID-19

	BVSP	**IPC**	**BIST100**	**NIFTY50**
Full sample period: 3rd January 2018 through 10th March 2020 December 2021				
BVSP	1	-	-	-
IPC	0.403555	1	-	-
BIST100	0.161727	-0.005041	1	-
NSEI	0.403482	0.225402	0.189594	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

Table 3.5.5 Indices' volatilities correlation coefficients for developed countries during COVID-19

	S&P	**FTSE**	**DAX**	**TSX**
Full sample period: 12th March 2020 through 23rd December 2021				
S&P	1	-	-	-
FTSE	0.818409	1	-	-
DAX	-0.034499	-0.086286	1	-
TSX	0.825418	0.864174	-0.068462	1

Note: S&P, FTSE, DAX & TSX are the stock indices in the US, the UK, Germany and Canada, respectively

Table 3.5.6 Indices' volatilities correlation coefficients for developing countries during COVID-19

	BVSP	**IPC**	**BIST100**	**NIFTY50**
Full sample period: 12th March 2020 through 23rd December 2021				
BVSP	1	-	-	-
IPC	0,858443	1	-	-
BIST100	-0.03048	-0.086286	1	-
NSEI	0.879252	0.828195	-0.070198	1

Note: BVSP, IPC, BIST100 and NIFTY50 are the stock indices in Brazil, Mexico, Turkey and India, respectively.

As the tables exhibit, the strongest correlation before COVID-19 is between the US and the UK (0.375581) from the developed countries group, during COVID-19 the strongest correlation is between the UK and Canada (0.864174). As well, the lowest correlation before and during the pandemic is -0.054025 and -0.086286, respectively, both between the UK and Germany. The negative correlations between these last two countries indicate that their stock markets move in opposite directions.

Overall for the developed countries, the correlation coefficients indicate that the US and the UK, as well as the US and Canada, have a positive link. The US and Germany as well as Germany and Canada, do not significantly correlate with one another. While there is a somewhat positive link between the UK and the Canada, there is a marginally negative correlation between the UK and the Germany. This apply for the whole sample.

For the developing countries group, the strongest correlation before COVID-19 is between Brazil-Mexico (0.403555), and during the pandemic the strongest correlation is between Brazil-İndia (0.879252). For both periods, before and during the pandemic, the weakest correlation is -0.005041 and -0.086286, respectively, between still Mexico-Turkey (0.086286) and given the correlation between these two countries is negative, their stock markets tend to move in opposite directions.

In general, the correlation coefficients suggest that there is a significant degree of interdependence between the volatilities of the stock markets in these four emerging economies. In detail, for the whole sample, Brazil-Mexico, Brazil-India and Mexico-India have a strong positive linear relationship, however, the correlation Turkey-India, and Turkey-Mexico indicate a negative linear relationship.

The link between stock markets from developed and developing countries has increased and decreased, in general, according to the findings. From the developed countries, the correlation between Germany-US, and the UK-Canada decreased after COVID-19, as well as the relationship between Turkey-Brazil, and Mexico-India from the developing countries group.

The decrease in the correlation between Germany and Turkey with the other stocks markets from their respective groups can be explained either by a change in the investor's behavior whom are becoming more selective or more risk averse seeking to diversify their portfolios. İn both scenarios, the decrease in the correlation of these stock markets leads to diversification opportunities from both countries.

3.6 VOLATILITIES' ADF TESTS AND INTERPRETATIONS

Table 3.6.1 and Table 3.6.2 provide the Augmented Dickey-Fuller test for determine the presence of unit roots for all the indices volatilities. According to the results, all the indices' volatilities series are stationary which confirms that the data of the eight countries are integrated in order one, I (1). All the same, the null hypothesis is rejected.

Table 3.6.1 Unit root test results of selected stock markets' volatilities series for developed countries

ADF Test Statistics Null Hypothesis: Unit root (individual unit root process)		
Countries	**T-statistic**	**Prob**
US	-5.716811	0.0000
UK	-4.222476	0,0006
Germany	-7.807180	0.0000
Canada	-3.781318	0.0032

Table 3.6.2 Unit root test results of selected stock markets' volatilities series for developing countries

ADF Test Statistics Null Hypothesis: Unit root (individual unit root process)		
Countries	**T-statistic**	**Prob**
Brazil	-4.215193	0.0007
Mexico	-4.222476	0.0006
Turkey	-7.807170	0,0000
India	-4.991596	0.0000

4. EMPIRICAL RESULTS

To analyze the relationship, in terms of return and volatility spillover, among the eight selected stock indices in light of the COVID-19 pandemic, the Diebold and Yilmaz's (2009) model was employed. This study also provides a breakdown of the spillover index into all of the forecast error variance components for variable i originating from countries to variable j, for all i and j.

4.1 RETURNS' EMPIRICAL RESULTS

The starting point is to calculate the return spillovers for all the periods (whole sample that goes from 3/1/18 23/12/21, before COVID-19 from 3/1/18 to 10/3/20 and during COVID-19 from 3/11/20-23/12/21), then the time variation of the spillovers is tracked using an estimation window.

The total return spillover index presented below is obtained by dividing the Contribution to others by the Contribution including own taken from the Return Spillover tables (Table.34 to Table.39).

Table 4.1.1 contains the Total Return Spillover Index for the whole sample, before and during COVID-19 for the developed countries group.

Table 4.1.1 Total Return Spillover Index Table for developed countries

	Total Return Spillover Index for Developed countries		
Time	Whole sample	Before-COVID-19	During-COVID-19
t+1	0,04	0,08	0,04
t+5	0,08	0,15	0,16
t+10	0,11	0,19	0,18
t+15	0,12	0,20	0,19
t+20	0,12	0,20	0,19

Note: The numbers are the total return spillover indexes

The total return spillover index (TRSI) was taken as measure of the extent to which returns in one country are influenced by returns in the other countries. Table.30 captures the spillover effect across the US, the UK, Germany and Canada and the level of interdependence before and during COVID-19.

As shown on Table.30, during the pandemic, the TRSI was 0.04 for t+1 and increased to 0.19 by t+20 meaning that at the beginning 4% of the returns were influenced by returns of the other developed countries and gradually increased to 19%.

Comparing before and during COVID-19, the table indicates that TSRI was higher before at times t+1, t+10, t+15 and t+20, and only at time t+5 the total return spillover was higher during the pandemic as the literature predicts. This indicates that for most times, the impact of the returns from other countries to one country decreased during COVID-19. Overall, the table suggests that there is a high level of interdependence among developed countries' financial markets, with returns in one country being significantly influenced by returns in other countries.

Figure 4.1.1 shows the plot of the Total Return Spillovers for developed countries for a more comprehensive understanding of the results.

Figure 4.1.1 Total Return Spillover Plot Developed Countries

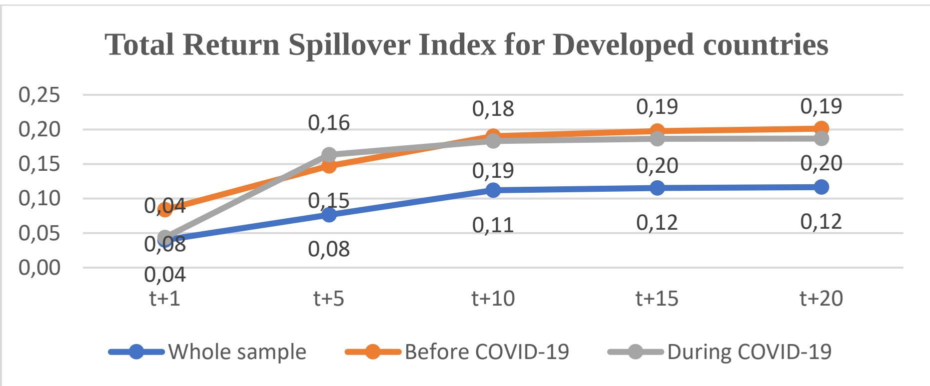

Figure 4.1.1 shows that both the whole sample and before COVID-19 data follow an increasing-continuous trend from t+1 to t+20. On the other hand, during COVID-19 data has sharped movements throughout the time being t+1 its lowest point (0.04) and reaching a peak at time t+15 which remains constant until time t+20.

Table 4.1.2 contains the Total Return Spillover Index for the whole sample, before and during COVID-19 for developing countries group.

Table 4.1.2 Total Return Spillover Index Table for developing countries

	Total Return Spillover Index for Developing countries		
Time	Whole sample	Before COVID-19	During COVID-19
t+1	0.13	0.12	0.15
t+5	0.16	0.13	0.16
t+10	0.16	0.13	0.16
t+15	0.16	0.13	0.16
t+20	0.16	0.13	0.16

Note: The numbers are the total return spillover indexes

Table 4.1.2 presents the total return spillover index for developing countries (TRSI), the results reflect the estimated index values for various time horizons, with t+1 representing the spillover effect in the following period, t+5 representing the spillover effect in five periods, and so on. The results range from 0.13 to 0.16, indicating that the spillover impact is moderate across emerging countries for the whole sample.

As the results show, during the pandemic, the TRSI was 0.15 for t+1 and slightly increased to 0.16 by t+20 meaning that at the beginning 15% of the returns were influenced by returns of the other developed countries and gradually increased to 16% from time t+50 to t+20.

The spillover effect level has remained relatively constant over time, with only slight differences between the whole sample and the period before COVID-

19, as shown in the table. However, the spillover effect appears to have been slightly higher during the COVID-19 when compared to the period before pandemic, suggesting that shocks to financial market returns have had a stronger and more immediate impact on developing countries during the pandemic.

The increase in the total return spillover for developing countries aligns with the findings from previous researches mentioned in the literature review part of this paper, which suggests that during crises there is an increase in uncertainty leading to greater cross-border shock transmissions producing higher spillover levels. As well, the interconnectedness between financial markets leads to an increase as well.

In summary, the return spillover for developing countries may have raised during COVID-19 due to an increase in uncertainty, interconnectedness and interdependence of financial markets, and policy actions that can amplify spillover effects.

Figure 4.1.2 shows the plot of the Total Return Spillovers for developing countries to visually represent the data for a more comprehensive understanding of the results

Figure 4.1.2 Total Return Spillover Index for Developing countries

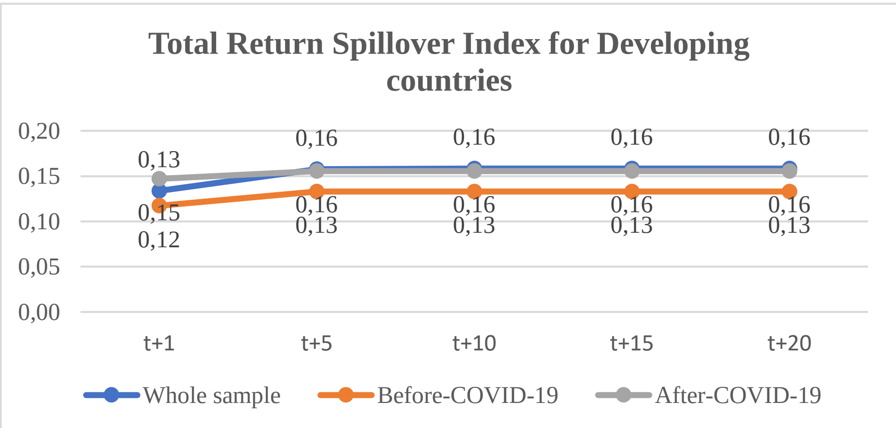

Figure 4.1.2 shows that the total return spillover from the developing countries followed an almost no-variant tendency throughout the time which reached its peak at time t+5 for all periods and then followed a continuous tendency until time t+20, for both before and after COVID-19. These results indicate that the return spillover for the developing countries group was slightly affected by the COVID-19 pandemic.

In general, the return spillover from Brazil, Mexico, Turkey and India is higher during the pandemic and the tendency remains constant through all times. For these countries, the results suggest that during the COVID-19 pandemic, diversification in the portfolio allocation does not grant higher gain for the investors since the stock markets became more correlated.

The following part of this paper covers the analysis of the return and volatility spillover series for the whole sample, before and during COVID-19 among the developed countries group (the US, the UK, Germany and Canada) and the developing countries (Brazil, Mexico, Turkey and India).

Table 4.1.3 to Table 4.1.5 show the Return Spillover for developed countries.

Table 4.1.3 Return spillover table for the Developed Countries for the whole sample

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	98.40	0.63	0.79	0.18	1.60
	t+10	94.60	3.15	1.60	0.65	5.40
	t+15	94.16	3.31	1.75	0.77	5.84
	t+20	94.03	3.35	1.78	0.84	5.97
UK	t+1	14.21	85.79	0.00	0.00	14.21
	t+5	22.54	76.48	0.40	0.58	23.52
	t+10	21.71	73.22	3.23	1.84	26.78
	t+15	21.70	72.85	3.29	2.15	27.15
	t+20	21.66	72.68	3.33	2.34	27.32
Germany	t+1	0.58	0.00	99.42	0.00	0.58
	t+5	0.60	0.19	97.10	2.10	2.90
	t+10	0.77	0.19	93.74	5.29	6.26
	t+15	0.77	0.20	93.58	5.44	6.42
	t+20	0.78	0.21	93.51	5.52	6.50
Canada	t+1	0.39	0.05	0.75	98.80	1.20
	t+5	0.67	0.13	1.79	97.41	2.59
	t+10	0.63	0.29	5.35	93.74	6.26
	t+15	0.69	0.30	5.61	93.40	6.60
	t+20	0.69	0.32	5.78	93.21	6.79
Contribution to others	t+1	15.18	0.05	0.75	0.00	
	t+5	23.82	0.96	2.98	2.85	
	t+10	23.10	3.63	10.17	7.78	
	t+15	23.17	3.82	10.65	8.36	
	t+20	23.12	3.87	10.89	8.69	
Contribution including own	t+1	115.18	85.85	100.17	98.80	
	t+5	122.21	77.43	100.09	100.26	
	t+10	117.70	76.85	103.92	101.53	
	t+15	117.33	76.67	104.23	101.76	
	t+20	117.16	76.55	104.40	101.90	
Net spillover	t+1	15.18	14.26	1.33	1.20	
	t+5	25.42	24.48	5.88	5.44	
	t+10	28.50	30.41	16.43	14.04	
	t+15	29.01	30.97	17.07	14.97	
	t+20	29.09	31.19	17.39	15.48	

Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20

Table 4.1.4 Return spillover table for the Developed Countries before COVID-19

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	97.16	0.75	0.80	1.30	2.84
	t+10	90.51	5.49	1.97	2.02	9.49
	t+15	89.79	5.86	2.05	2.29	10.21
	t+20	89.41	5.90	2.25	2.44	10.59
UK	t+1	14.87	85.13	0.00	0.00	14.87
	t+5	25.99	72.37	0.19	1.45	27.63
	t+10	25.02	69.81	3.23	1.94	30.19
	t+15	24.91	69.26	3.36	2.46	30.74
	t+20	24.83	69.02	3.52	2.64	30.98
Germany	t+1	1.40	0.00	98.60	0.00	1.40
	t+5	1.59	0.93	93.01	4.47	6.99
	t+10	1.84	1.54	87.08	9.55	12.92
	t+15	1.93	1.59	86.28	10.20	13.72
	t+20	1.93	1.62	85.75	10.70	14.25
Canada	t+1	0.77	0.01	16.44	82.79	17.21
	t+5	1.06	0.64	19.66	78.63	21.37
	t+10	1.17	1.23	21.01	76.58	23.42
	t+15	1.51	1.46	21.33	75.71	24.29
	t+20	1.59	1.53	21.47	75.40	24.60
Contribution to others	t+1	17.03	0.01	16.44	0.00	
	t+5	28.65	2.32	20.65	7.22	
	t+10	28.03	8.26	26.22	13.51	
	t+15	28.35	8.91	26.75	14.95	
	t+20	28.35	9.06	27.24	15.78	
Contribution including own	t+1	117.03	85.14	115.04	82.79	
	t+5	125.81	74.68	113.66	85.85	
	t+10	118.54	78.07	113.30	90.09	
	t+15	118.14	78.17	113.03	90.66	
	t+20	117.76	78.07	112.99	91.18	
Net spillover	t+1	17.03	14.88	17.84	17.21	
	t+5	31.50	29.95	27.64	28.58	
	t+10	37.52	38.45	39.14	36.92	
	t+15	38.55	39.65	40.46	39.25	
	t+20	38.95	40.04	41.49	40.37	

Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20

Table 4.1.5 Return spillover table for the Developed Countries during COVID-19

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	93.14	3.37	3.34	0.14	6.86
	t+10	91.37	3.88	4.04	0.71	8.63
	t+15	91.16	3.94	4.11	0.79	8.84
	t+20	91.14	3.94	4.13	0.79	8.86
UK	t+1	9.53	90.47	0.00	0.00	9.53
	t+5	14.03	83.76	0.58	1.63	16.24
	t+10	15.06	81.64	1.23	2.08	18.36
	t+15	15.19	81.44	1.27	2.10	18.56
	t+20	15.19	81.40	1.28	2.14	18.60
Germany	t+1	0.27	0.37	99.36	0.00	0.64
	t+5	1.28	2.95	66.73	29.04	33.27
	t+10	1.67	3.09	66.14	29.10	33.86
	t+15	1.75	3.16	65.85	29.25	34.15
	t+20	1.84	3.15	65.79	29.21	34.21
Canada	t+1	0.09	1.31	5.87	92.73	7.27
	t+5	0.84	1.87	6.15	91.14	8.86
	t+10	2.30	2.41	7.75	87.54	12.46
	t+15	2.43	2.45	8.06	87.07	12.93
	t+20	2.46	2.45	8.09	87.01	12.99
Contribution to others	t+1	9.89	1.68	5.87	0.00	
	t+5	16.15	8.20	10.07	30.81	
	t+10	19.03	9.39	13.01	31.89	
	t+15	19.36	9.54	13.44	32.14	
	t+20	19.49	9.54	13.49	32.15	
Contribution including own	t+1	109.89	92.15	105.23	92.73	
	t+5	109.29	91.96	76.80	121.95	
	t+10	110.40	91.02	79.15	119.43	
	t+15	110.52	90.98	79.29	119.21	
	t+20	110.63	90.94	79.28	119.15	
Net spillover	t+1	9.89	11.20	6.51	7.27	
	t+5	23.00	24.43	43.34	39.67	
	t+10	27.66	27.75	46.88	44.35	
	t+15	28.20	28.10	47.59	45.08	
	t+20	28.35	28.14	47.70	45.14	
Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20						

Table 4.1.3 to Table 4.1.5 show the variance decompositions for the returns at different times the developed countries group.

The diagonal elements of the table show the percentage of each country's return that may be attributed to its own historical values, or the country's own contribution. For instance, the US explains the 100% of its own return spillover before and during COVID-19. As well, the UK, Germany and Canada own return spillover increased during the pandemic when compared to the period before COVID-19.

According to Table 4.1.3, the US is the greatest return spillover contributor to others at all times and is as well the least contributed from others. On the other hand, the UK has by far the highest return spillover contribution from others at all times, and has as well the highest net spillover for times t+10-t+20 and US has the highest net spillover for times t+1-t+5.

Before COVID-19, as exhibit on Table 4.1.4, the US has the biggest return spillover contribution to others, and is as well the least contributed country from others, yet the highest net spillover comes from Germany except at time t+5 where the UK has the highest net spillover. Conversely, Canada has the highest contribution from others at time t+1, however, for times t+5-t+20, the UK is the most contributed.

During COVID-19 period, as presented on Table 4.1.5, the US has still the highest return spillover contribution to others at time t+1 , from t+5-t+20 Canada has the highest contribution to others. As well, the US persists as the least contributed country from others briefly by Canada. On the other hand, Germany has the highest contribution from others at all times, hence, Germany has the highest net return spillover during COVID-19, except at time t+1 where the UK has the highest net spillover.

Table 4.1.6 to Table 4.1.8 show the Return Spillover for developing countries for the whole sample, before and during COVID-19

Table 4.1.6 Return spillover table for the Developing Countries for the whole sample

Countries	Time	Brazil	Mexico	Türkiye	India	Contribution from others
Brazil	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	97.30	1.27	0.52	0.92	2.70
	t+10	97.23	1.30	0.53	0.94	2.77
	t+15	97.23	1.30	0.53	0.94	2.77
	t+20	97.23	1.30	0.53	0.94	2.77
Mexico	t+1	30.58	69.42	0.00	0.00	30.58
	t+5	30.56	68.11	0.31	1.03	31.89
	t+10	30.55	68.07	0.32	1.06	31.93
	t+15	30.55	68.07	0.32	1.06	31.93
	t+20	30.55	68.07	0.32	1.06	31.93
Türkiye	t+1	0.04	0.01	99.95	0.00	0.05
	t+5	0.32	0.79	98.77	0.12	1.23
	t+10	0.33	0.80	98.74	0.13	1.26
	t+15	0.33	0.80	98.74	0.13	1.26
	t+20	0.33	0.80	98.74	0.13	1.26
India	t+1	18.97	3.64	0.25	77.13	22.87
	t+5	22.75	3.95	0.50	72.80	27.20
	t+10	22.79	4.03	0.54	72.64	27.36
	t+15	22.79	4.04	0.54	72.63	27.37
	t+20	22.79	4.04	0.54	72.63	27.37
Contribution to others	t+1	49.59	3.65	0.25	0.00	
	t+5	53.62	6.01	1.33	2.06	
	t+10	53.67	6.14	1.39	2.12	
	t+15	53.67	6.14	1.39	2.12	
	t+20	53.67	6.14	1.39	2.12	
Contribution including own	t+1	149.59	73.08	100.20	77.13	
	t+5	150.92	74.12	100.10	74.87	
	t+10	150.90	74.20	100.14	74.76	
	t+15	150.90	74.21	100.14	74.75	
	t+20	150.90	74.21	100.14	74.75	
Net spillover	t+1	49.59	34.23	0.30	22.87	
	t+5	56.32	37.90	2.56	29.26	
	t+10	56.44	38.07	2.65	29.49	
	t+15	56.45	38.08	2.65	29.49	
	t+20	56.45	38.08	2.65	29.49	

Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20

Table 4.1.7 Return spillover table for the Developing Countries before COVID-19

Countries	Time	Brazil	Mexico	Turkey	India	Contribution from others
Brazil	t+1	100.000	0.000	0.000	0.000	0.00
	t+5	99.796	0.009	0.119	0.076	0.20
	t+10	99.796	0.009	0.119	0.076	0.20
	t+15	99.796	0.009	0.119	0.076	0.20
	t+20	99.796	0.009	0.119	0.076	0.20
Mexico	t+1	24.709	75.291	0.000	0.000	24.71
	t+5	25.698	73.459	0.731	0.111	26.54
	t+10	25.698	73.459	0.731	0.111	26.54
	t+15	25.698	73.459	0.731	0.111	26.54
	t+20	25.698	73.459	0.731	0.111	26.54
Turkey	t+1	4.607	5.312	90.081	0.000	9.92
	t+5	6.985	5.363	87.472	0.180	12.53
	t+10	6.985	5.363	87.472	0.180	12.53
	t+15	6.985	5.363	87.472	0.180	12.53
	t+20	6.985	5.363	87.472	0.180	12.53
India	t+1	5.700	4.004	2.579	87.717	12.28
	t+5	6.732	4.633	2.559	86.076	13.92
	t+10	6.732	4.633	2.559	86.076	13.92
	t+15	6.732	4.633	2.559	86.076	13.92
	t+20	6.732	4.633	2.559	86.076	13.92
Contribution to others	t+1	35.015	9.316	2.579	0.000	
	t+5	39.42	10.01	3.41	0.37	
	t+10	39.42	10.01	3.41	0.37	
	t+15	39.42	10.01	3.41	0.37	
	t+20	39.42	10.01	3.41	0.37	
Contribution including own	t+1	135.02	84.61	92.66	87.72	
	t+5	139.21	83.46	90.88	86.44	
	t+10	139.21	83.46	90.88	86.44	
	t+15	139.21	83.46	90.88	86.44	
	t+20	139.21	83.46	90.88	86.44	
Net spillover	t+1	35.02	34.03	12.50	12.28	
	t+5	39.62	36.55	15.94	14.29	
	t+10	39.62	36.55	15.94	14.29	
	t+15	39.62	36.55	15.94	14.29	
	t+20	39.62	36.55	15.94	14.29	
Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20						

Table 4.1.8 Return spillover table for the Developing Countries during COVID-19

Countries	Time	Brazil	Mexico	Turkey	India	Contribution from others
Brazil	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	98.91	0.80	0.13	0.16	1.09
	t+10	98.91	0.80	0.13	0.16	1.09
	t+15	98.91	0.80	0.13	0.16	1.09
	t+20	98.91	0.80	0.13	0.16	1.09
Mexico	t+1	30.83	69.17	0.00	0.00	30.83
	t+5	30.81	68.79	0.02	0.38	31.21
	t+10	30.81	68.79	0.02	0.38	31.21
	t+15	30.81	68.79	0.02	0.38	31.21
	t+20	30.81	68.79	0.02	0.38	31.21
Turkey	t+1	0.10	0.00	99.90	0.00	0.10
	t+5	0.35	0.09	99.43	0.13	0.57
	t+10	0.35	0.09	99.43	0.13	0.57
	t+15	0.35	0.09	99.43	0.13	0.57
	t+20	0.35	0.09	99.43	0.13	0.57
India	t+1	22.98	4.56	0.33	72.12	27.88
	t+5	23.96	4.81	0.55	70.68	29.32
	t+10	23.96	4.81	0.55	70.68	29.32
	t+15	23.96	4.81	0.55	70.68	29.32
	t+20	23.96	4.81	0.55	70.68	29.32
Contribution to others	t+1	53.91	4.56	0.33	0.00	
	t+5	55.13	5.70	0.71	0.68	
	t+10	55.13	5.70	0.71	0.68	
	t+15	55.13	5.70	0.71	0.68	
	t+20	55.13	5.70	0.71	0.68	
Contribution including own	t+1	153.91	73.74	100.23	72.12	
	t+5	154.03	74.48	100.13	71.35	
	t+10	154.03	74.48	100.13	71.35	
	t+15	154.03	74.48	100.13	71.35	
	t+20	154.03	74.48	100.13	71.35	
Net spillover	t+1	53.91	35.39	0.43	27.88	
	t+5	56.22	36.91	1.28	30.00	
	t+10	56.22	36.91	1.28	30.00	
	t+15	56.22	36.91	1.28	30.00	
	t+20	56.22	36.91	1.28	30.00	

Note: The numbers are the variance decompositions for the returns at time t+1, t+5, t+10, t+15 and t+20

Among other information, the tables show the net spillover values between developing countries measuring the net impact of each country on the volatility of the other countries while taking into consideration the impact of the country's own volatility.

For instance, at time t+1 during COVID-19, the net spillover values are 53.91 for Brazil, 35.39 for Mexico, 0.43 for Turkey and 27.88 for India, these values indicate that Brazil is the largest contributor to the return spillover among these countries accounting for the 53.91% of the total spillovers, followed by Mexico, India and Turkey, respectively.

Table 4.1.6 shows that for the whole sample, Brazil has the highest return spillover contribution to others for the whole sample, mainly to Mexico, therefore, Brazil carries the highest return net spillover. On the other hand, Mexico is the most contributed country in terms of return spillover, and Turkey is the least contributed from Jan 2018 to Dec 2021.

Before COVID-19, according to 4.1.7, Brazil had the highest return spillover contribution to others and is the least contributed country from others, hence it carries the highest net spillover from the developing countries group. On the other hand, Mexico was the most contributed country from others.

During the pandemic, as shown on 4.1.8, Brazil is still the country with the highest return spillover contribution to others by far. For this period, Turkey has the lowest spillover contribution from others shortly followed by Brazil, therefore Brazil has the highest net spillover. Lastly, Mexico briefly followed by India are the countries which stock indices have the highest spillover contribution from others.

In overall, the results suggest that highest return spillover contributor for all periods was Brazil with a sizeable difference. As well, the most contributed stock index from others, in terms of return spillover, was IPC from Mexico both before and during the pandemic

4.2 **VOLATILITIES' EMPIRICAL RESULTS**

The total volatility spillover is a measure of the degree of volatility transmission among different financial markets among countries. The total spillover index table shows the values of the volatility for the countries in study over different time horizons. Table 4.2.1 contains the Total Volatility Spillover Index for the whole sample, before and during COVID-19 for the developed countries group.

Table 4.2.1 Total Volatility Spillover Index Table for developed countries

	Total Volatility Spillover Index for Developed countries		
Time	Whole sample	Before COVID-19	During COVID-19
t+1	0.14	0.22	0.08
t+5	0.18	0.22	0.09
t+10	0.25	0.24	0.15
t+15	0.28	0.27	0.18
t+20	0.31	0.30	0.20

Note: The numbers are the total volatility spillover indexes

Table 4.2.1 shows the total volatility spillover index values at times t+1, t+5, t+10, t+15, and t+20 for the entire sample period, as well as for two sub-periods: before and during COVID-19. The index values range from 0 to 1; a higher index value indicates that a greater proportion of volatility is being transmitted from one country to others.

According to the results, the total volatility spillover significantly decreased during the COVID-19 pandemic, for instance, at t+1 the index value was 0.22 before and 0.08 during pandemic, demonstrating a huge decline in overflow during COVID-19. On the other hand, the total volatility spillover index increased across all time horizons (from t+1 to t+20) before and during the COVID-19 pandemic.

Moreover, the total spillover index is higher for the whole sample period than for the sub-periods before and during the COVID-19 pandemic, indicating that the spillover effects were more significant during the pre-pandemic period. As well, the table suggests that the volatility spillover effects become more pronounced over longer periods.

Figure 4.2.1 shows the plot of the Total Volatility Spillovers for developed countries to visually represent the data for a more comprehensive understanding of the results.

Figure 4.2.1 Total Volatility Spillover Plot for Developed Countries

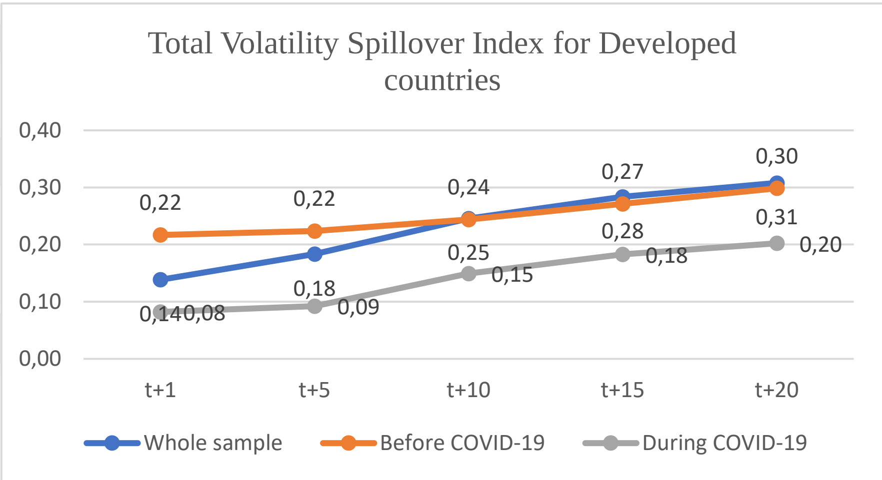

Figure 4.2.1 shows that the total volatility spillover from the developed countries followed an upward tendency for both periods in study, yet during COVID-19 the spillover had more sharp movements from time t+5 until time t+20. The plot suggests that the volatility spillover had an upward trend, however, the spillovers were significantly greater before the pandemic.

In general, the results indicate during the pandemic, the US, the UK, Germany and Canada could grant higher gain through portfolio diversification since the volatility decreased considerably.

Table 4.2.2 contains the Total Volatility Spillover Index for the whole sample, before COVID- and after COVID-19 for developing countries group.

Table 4.2.2 Total Volatility Spillover Index Table for developing countries

	Total Volatility Spillover Index for Developing countries		
Time	Whole sample	Before COVID-19	During COVID-19
t+1	0.12	0.22	0.09
t+5	0.18	0.25	0.17
t+10	0.24	0.29	0.23
t+15	0.27	0.27	0.27
t+20	0.30	0.36	0.29

Note: The numbers are the total volatility spillover indexes

The results found on Table 4.2.2 give evidence that the total volatility spillover index is generally higher before than during the COVID-19 pandemic. This means that the volatility spillover from the global financial market to developing countries was higher before the pandemic. As well, the total volatility increased slightly during the pandemic especially at time t+1 and t+5. Overall, the table indicates that during COVID-19 the volatility effects between developing countries were minimized.

Figure 4.2.2 shows the plot of the Total Volatility Spillovers for developing countries to visually represent the data for a more comprehensive understanding of the results.

Figure 4.2.2 Total Volatility Spillover Plot for Developing Countries

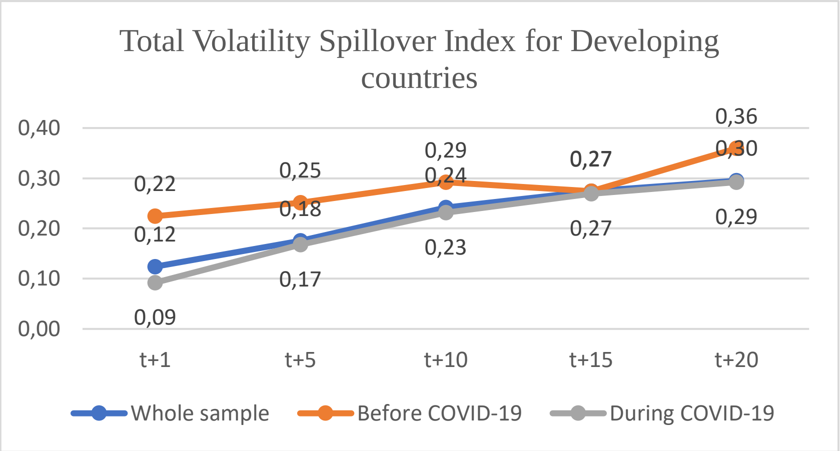

Figure 4.2.2 shows that the total volatility spillover from the developing countries followed an upward tendency for both periods in study, yet the spillover index decreases before COVID-19 from t-10 to t-15. As well, the spillovers were significantly greater before the pandemic except at time t+15 where the spillover index was the same before and during COVID-19 (0.27).

In overall, the plot gives evidence that during the pandemic, Brazil, Mexico, Turkey and India could grant higher gain through portfolio diversification since the volatility decreased considerably.

Table 4.2.3 to Table 4.2.8 show the Volatility Spillover for both developed and developing countries. The direction of the volatility spillover tables is shown diagonally off, the diagonal-off row sum is the directional volatility spillover of country i from country j name as Contribution from others, and the diagonal-off column sum is the directional contribution of country i to country j names as Contribution to others.

The tables provide the variance decompositions for the volatility spillover effects among the developed (the US, the UK, Germany and Canada) and developing countries (Brazil, Mexico, Turkey and India) for the whole sample, before and during COVID-19. The recipient countries that receive volatility are represented in the columns and the source countries that send it are represented in the rows. The time intervals t+1, t+5, t+10, t+15, and t+20 are considered.

As expressed for the return spillover tables, net spillover values between countries measure the net impact of each country on the volatility of the other countries while taking into consideration the impact of the country's own volatility.

Table 4.2.3 to Table 4.2.5 show the volatility spillover developed countries the whole sample, before and during COVID-19

Table 4.2.3 Volatility spillover table for the Developed Countries whole sample

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	99.36	0.14	0.11	0.40	0.64
	t+10	98.63	0.32	0.11	0.94	1.37
	t+15	98.07	0.60	0.09	1.24	1.93
	t+20	97.57	0.81	0.08	1.54	2.43
UK	t+1	31.12	68.88	0.00	0.00	31.12
	t+5	30.49	69.21	0.14	0.17	30.79
	t+10	32.97	66.68	0.19	0.16	33.32
	t+15	39.77	59.73	0.35	0.14	40.27
	t+20	44.38	54.89	0.46	0.26	45.11
Germany	t+1	0.02	0.00	99.98	0.00	0.02
	t+5	0.02	0.10	99.79	0.09	0.21
	t+10	0.16	0.17	99.57	0.10	0.43
	t+15	0.16	0.24	99.48	0.12	0.52
	t+20	0.20	0.30	99.36	0.14	0.64
Canada	t+1	23.27	0.98	0.01	75.75	24.25
	t+5	39.94	1.73	0.02	58.31	41.69
	t+10	62.02	0.97	0.20	36.81	63.19
	t+15	69.20	1.12	0.35	29.34	70.66
	t+20	72.81	1.73	0.47	24.99	75.01
Contribution to others	t+1	54.41	0.98	0.01	0.00	
	t+5	70.45	1.97	0.27	0.65	
	t+10	95.14	1.46	0.50	1.20	
	t+15	109.13	1.96	0.79	1.50	
	t+20	117.39	2.84	1.01	1.94	
Contribution including own	t+1	154.41	69.86	99.99	75.75	
	t+5	169.81	71.18	100.06	58.95	
	t+10	193.78	68.15	100.07	38.01	
	t+15	207.19	61.70	100.27	30.84	
	t+20	214.96	57.73	100.37	26.94	
Net spillover	t+1	54.41	32.10	0.02	24.25	
	t+5	71.09	32.76	0.48	42.34	
	t+10	96.51	34.78	0.93	64.39	
	t+15	111.06	3.89	1.32	72.17	
	t+20	119.82	47.94	1.65	76.95	

Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20

Table 4.2.4 Volatility spillover table for the Developed Countries before COVID-19

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	99.87	0.03	0.10	0.00	0.13
	t+10	99.47	0.14	0.38	0.01	0.53
	t+15	98.97	0.26	0.73	0.05	1.03
	t+20	98.48	0.37	1.05	0.11	1.52
UK	t+1	35.82	64.18	0.00	0.00	35.82
	t+5	38.07	61.69	0.13	0.11	38.31
	t+10	40.72	58.30	0.53	0.45	41.70
	t+15	43.04	54.96	1.06	0.94	45.04
	t+20	44.97	51.91	1.63	1.49	48.09
Germany	t+1	20.95	0.01	79.04	0.00	20.96
	t+5	13.06	0.02	86.43	0.49	13.57
	t+10	9.18	0.02	88.83	1.97	11.17
	t+15	9.99	0.02	86.26	3.73	13.74
	t+20	12.79	0.02	81.92	5.28	18.08
Canada	t+1	27.54	0.46	1.96	70.05	29.95
	t+5	35.86	0.47	1.19	62.48	37.52
	t+10	43.00	0.50	0.73	55.76	44.24
	t+15	47.49	0.56	0.65	51.30	48.70
	t+20	50.30	0.61	0.79	48.29	51.71
Contribution to others	t+1	84.31	0.47	1.96	0.00	
	t+5	87.00	0.52	1.42	0.60	
	t+10	92.90	0.66	1.64	2.44	
	t+15	100.52	0.83	2.44	4.71	
	t+20	108.05	1.00	3.47	6.88	
Contribution including own	t+1	184.31	64.65	81.00	70.05	
	t+5	186.87	62.21	87.85	63.07	
	t+10	192.37	58.96	90.47	58.20	
	t+15	199.49	55.80	88.70	56.01	
	t+20	206.53	52.91	85.39	55.17	
Net spillover	t+1	84.31	36.28	22.91	29.95	
	t+5	87.13	38.83	14.98	38.12	
	t+10	93.43	42.36	12.81	46.67	
	t+15	101.55	1.86	16.18	53.42	
	t+20	109.57	49.09	21.55	58.58	

Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20

Table 4.2.5 Volatility spillover table for the Developed Countries during COVID-19

Countries	Time	US	UK	Germany	Canada	Contribution from others
US	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	97.55	0.57	0.61	1.27	2.45
	t+10	96.75	0.82	0.95	1.48	3.25
	t+15	95.66	0.90	1.49	1.94	4.34
	t+20	94.81	1.15	1.84	2.20	5.19
UK	t+1	20.26	79.74	0.00	0.00	20.26
	t+5	18.26	80.00	0.31	1.43	20.00
	t+10	23.06	73.24	0.35	3.35	26.76
	t+15	29.01	67.22	0.59	3.18	32.78
	t+20	32.29	64.02	0.63	3.06	35.98
Germany	t+1	0.00	0.00	100.00	0.00	0.00
	t+5	0.21	0.18	99.42	0.18	0.58
	t+10	0.34	0.27	99.15	0.24	0.85
	t+15	0.39	0.54	98.75	0.31	1.25
	t+20	0.41	0.78	98.45	0.36	1.55
Canada	t+1	10.80	1.77	0.02	87.41	12.59
	t+5	9.75	4.12	0.03	86.09	13.91
	t+10	25.06	2.92	0.88	71.14	28.86
	t+15	31.14	2.54	1.12	65.20	34.80
	t+20	34.71	2.39	1.08	61.83	38.17
Contribution to others	t+1	31.07	1.77	0.02	0.00	
	t+5	28.22	4.88	0.96	2.88	
	t+10	48.46	4.01	2.18	5.07	
	t+15	60.54	3.99	3.20	5.43	
	t+20	67.40	4.31	3.55	5.62	
Contribution including own	t+1	131.07	81.50	100.02	87.41	
	t+5	125.78	84.88	100.38	88.97	
	t+10	145.21	77.25	101.33	76.21	
	t+15	156.20	71.21	101.96	70.63	
	t+20	162.21	68.33	102.01	67.45	
Net spillover	t+1	31.07	22.03	0.02	12.59	
	t+5	30.67	24.88	1.54	16.78	
	t+10	51.71	30.77	3.02	33.92	
	t+15	64.88	8.33	4.45	40.24	
	t+20	72.59	40.30	5.10	43.80	
Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20						

The volatility spillovers among developed countries is shown in Table 4.2.3, Table 4.2.4 and Table 4.2.5, respectively, before and after COVID-19. The tables demonstrate how one country's contribution to volatility spillover affects other countries and vice versa.

According to Table 4.2.3, the US is the greatest volatility spillover contributor to others at all times and is as well the second least contributed from others after Germany, therefore it carries the highest net spillover from the developed countries group for the whole sample. On the other hand, the most contributed country in terms of volatility spillover is the UK at time t+1, then Canada from t+5 to t+20.

Before COVID-19, as exhibit on Table 4.2.4, the US has the biggest volatility spillover contribution to others. For this period, the US is the least contributed country from others thus it has the highest net return spillover at all times. Conversely, the UK has the highest contribution from others at times t+1 and t+5, for times t+10-t+20, Canada is the most contributed country from others.

During COVID-19 period, as presented on Table 4.2.5 , the US has still the highest volatility spillover contribution to others and is the second least contributed country from others briefly after Germany, therefore, the US persists as the country with the higher net volatility spillover. On the other hand, the UK is the most contributed country from others in terms of spillover at times t+1-t+10, then Canada becomes the most contributed for times t+15-t+20.

Overall, the data indicate that when compared to the values displayed prior to COVID-19, the volatility spillover impact declined for all nations, with the exception of the UK, during the pandemic. Additionally, the US was the country that contributed the most to volatility spillover, the UK and Canada were the most contributed. This is true both before and after the pandemic.

Table 4.2.6 to Table 4.2.8 show the volatility spillover developing countries the whole sample, before and during COVID-19.

Table 4.2.6 Volatility spillover table for the Developing Countries for the whole sample

Countries	Time	Brasil	Mexico	Turkey	India	Contribution from others
Brasil	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	99.41	0.11	0.12	0.37	0.59
	t+10	97.87	0.10	0.08	1.96	2.13
	t+15	96.95	0.15	0.11	2.79	3.05
	t+20	96.51	0.15	0.17	3.17	3.49
Mexico	t+1	28.73	71.27	0.00	0.00	28.73
	t+5	29.35	70.21	0.17	0.27	29.79
	t+10	31.93	67.29	0.29	0.48	32.71
	t+15	37.28	61.09	0.57	1.07	38.91
	t+20	41.32	56.02	0.78	1.88	43.98
Turkey	t+1	0.02	0.00	99.98	0.00	0.02
	t+5	0.03	0.12	99.73	0.12	0.27
	t+10	0.09	0.22	99.49	0.20	0.51
	t+15	0.10	0.26	99.45	0.19	0.55
	t+20	0.15	0.30	99.35	0.20	0.65
India	t+1	18.84	2.01	0.01	79.14	20.86
	t+5	36.75	2.67	0.05	60.53	39.47
	t+10	59.43	1.73	0.15	38.68	61.32
	t+15	65.39	1.69	0.19	32.72	67.28
	t+20	67.64	1.96	0.29	30.11	69.89
Contribution to others	t+1	47.59	2.01	0.01	0.00	
	t+5	66.14	2.90	0.34	0.76	
	t+10	91.46	2.05	0.52	2.64	
	t+15	102.77	2.11	0.87	4.05	
	t+20	109.11	2.41	1.24	5.25	
Contribution including own	t+1	147.59	73.28	99.99	79.14	
	t+5	165.54	73.10	100.07	61.28	
	t+10	189.33	69.34	100.01	41.32	
	t+15	199.72	63.19	100.32	36.77	
	t+20	205.62	58.43	100.59	35.36	
Net spillover	t+1	47.59	30.75	0.03	20.86	
	t+5	66.73	32.69	0.62	40.23	
	t+10	93.59	34.76	1.03	63.95	
	t+15	105.82	5.15	1.43	71.34	
	t+20	112.60	46.39	1.89	75.14	

Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20

Table 4.2.7 Volatility spillover table for the Developing Countries before COVID-19

Countries	Time	Brasil	Mexico	Turkey	India	Contribution from others
Brasil	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	99.40	0.01	0.37	0.22	0.60
	t+10	98.35	0.02	1.11	0.52	1.65
	t+15	97.51	0.03	1.81	0.66	2.49
	t+20	96.88	0.03	2.39	0.70	3.12
Mexico	t+1	33.27	66.73	0.00	0.00	33.27
	t+5	38.67	60.61	0.51	0.21	39.39
	t+10	44.83	53.06	1.63	0.47	46.94
	t+15	20.21	46.46	2.73	0.59	23.54
	t+20	54.74	40.97	3.67	0.62	59.03
Turkey	t+1	7.84	1.86	90.30	0.00	9.70
	t+5	5.12	1.59	91.05	2.24	8.95
	t+10	3.76	1.38	88.75	6.11	11.25
	t+15	4.67	1.26	85.59	8.48	14.41
	t+20	7.13	1.18	82.26	9.44	17.74
India	t+1	23.78	2.00	21.03	53.19	46.81
	t+5	32.48	1.71	17.44	48.37	51.63
	t+10	40.84	1.47	14.64	43.05	56.95
	t+15	46.30	1.32	13.30	39.08	60.92
	t+20	49.95	1.23	12.65	36.17	63.83
Contribution to others	t+1	64.89	3.87	21.03	0.00	
	t+5	76.27	3.31	18.33	2.67	
	t+10	89.43	2.87	17.39	7.10	
	t+15	71.17	2.61	17.84	9.73	
	t+20	111.82	2.43	18.71	10.76	
Contribution including own	t+1	164.89	70.60	111.33	53.19	
	t+5	175.67	63.92	109.37	51.04	
	t+10	187.78	55.93	106.14	50.15	
	t+15	168.68	49.07	103.43	48.81	
	t+20	208.70	43.40	100.97	46.94	
Net spillover	t+1	64.89	37.13	30.73	46.81	
	t+5	76.88	42.70	27.28	54.30	
	t+10	91.08	49.81	28.64	64.05	
	t+15	73.67	5.10	32.25	70.65	
	t+20	114.94	61.46	36.45	74.59	

Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20

Table 4.2.8 Volatility spillover table for the Developing Countries during COVID-19

Countries	Time	Brasil	Mexico	Turkey	India	Contribution from others
Brasil	t+1	100.00	0.00	0.00	0.00	0.00
	t+5	99.56	0.07	0.00	0.36	0.44
	t+10	99.02	0.30	0.01	0.67	0.98
	t+15	98.65	0.57	0.01	0.77	1.35
	t+20	98.37	0.81	0.01	0.81	1.63
Mexico	t+1	19.49	80.51	0.00	0.00	19.49
	t+5	26.73	72.92	0.14	0.20	27.08
	t+10	35.17	64.20	0.38	0.26	35.80
	t+15	41.88	57.40	0.51	0.22	42.60
	t+20	46.82	52.44	0.55	0.19	47.56
Turkey	t+1	0.00	0.01	99.99	0.00	0.01
	t+5	0.01	0.05	99.93	0.01	0.07
	t+10	0.01	0.11	99.86	0.02	0.14
	t+15	0.01	0.16	99.81	0.02	0.19
	t+20	0.01	0.19	99.77	0.03	0.23
India	t+1	13.63	3.68	0.05	82.64	17.36
	t+5	35.37	3.83	0.23	60.57	39.43
	t+10	51.85	3.59	0.28	44.27	55.73
	t+15	59.63	3.47	0.26	36.63	63.37
	t+20	63.79	3.45	0.24	32.51	67.49
Contribution to others	t+1	33.13	3.69	0.05	0.00	
	t+5	62.11	3.96	0.38	0.58	
	t+10	87.02	4.01	0.67	0.94	
	t+15	101.52	4.20	0.78	1.01	
	t+20	110.62	4.46	0.80	1.02	
Contribution including own	t+1	133.13	84.20	100.04	82.64	
	t+5	161.67	76.87	100.31	61.14	
	t+10	186.05	68.21	100.53	45.22	
	t+15	200.17	61.61	100.59	37.64	
	t+20	208.99	56.90	100.57	33.54	
Net spillover	t+1	33.13	23.17	0.06	17.36	
	t+5	62.56	31.04	0.44	40.01	
	t+10	88.00	39.81	0.81	56.67	
	t+15	102.87	5.55	0.97	64.38	
	t+20	112.26	52.01	1.02	68.51	

Note: The numbers are the variance decompositions for the volatilities at time t+1, t+5, t+10, t+15 and t+20

The developing countries group, which includes Brazil, Mexico, Turkey, and Canada, is represented in Table 4.2.6, Table 4.2.7 and Table 4.2.8 by the variance decompositions for the volatilities at various times.

As shown on Table 4.2.6, the Brazil is the greatest volatility spillover contributor to others at all times and is the second least contributed from others right after Turkey, therefore Brazil carries the highest volatility net spillover from the developing countries group for the whole sample. Conversely, Mexico is the most contributed country from others at t+1, and India becomes the most contributed from times t+5-t+20.

Before COVID-19, as exhibit on Table 4.2.7 Brazil has the greatest volatility spillover contribution to others and is the least contributed from others, therefore Brazil has the highest net return spillover. On the other hand, India has the highest contribution from others at all times.

During COVID-19 period, as presented on Table 4.2.8, Brazil still presents the highest volatility spillover contribution to others and is the second least contributed country from others after Turkey, making Brazil the highest net spillover holder. On the other hand, Mexico is the most contributed country from others at time t+1, and for times t+5-t+20 India becomes the most contributed country from others in terms of volatility spillover.

Overall, the data indicate that when compared to the values displayed prior to COVID-19, the volatility net spillover impact declined during the pandemic for all countries, with the exception of Brazil and Mexico at time t+15

CONCLUSION

This paper examines how the COVID-19 pandemic has affected the return and volatility spillover among the stock markets from eight countries divided into developed economies taking the US, the UK, Germany and Canada, and developing economies taking Brazil, Mexico, Turkey and India. This analysis employs the model developed by Diebold and Yilmaz (2009) combined with the Stochastic Volatility Model (SV) for the investigation of returns and volatility spillover and concentrate on variance decompositions generated from vector autoregressive (VAR) models.

The logarithmic returns and therefore volatilities used for this study cover the period from Jan of 2018 to Dec of 2021 and is divided into two periods: before COVID-19 pandemic that goes from Jan 3rd 2018 to March 10th 2020, and during COVID-19 pandemic that goes from March 11th 2020 to Dec 23rd 2021.

In detail, it is observed that countries like the US and Brazil were the highest return and volatility spillover contributors to others both before and during COVID-19, as well Mexico was the country that was contributed the most from others in terms of return and volatility spillovers.

The results give evidence that the return and volatility spillovers among developed and developing countries did not increase during the COVID-19 pandemic. Instead, the results suggest that return and volatility spillovers were generally higher prior to the pandemic, with the exception of total return spillovers for developing countries.

In the case of the total return spillover index for developing countries, the findings align with the literature that suggests that during times of uncertainty there is an increase in cross-country risk transmission, therefore the return and volatility spillover is higher during crises. However, the findings for the total return spillover index for developed countries and the total volatility spillover index for both developed and developing countries do not follow the trend shown on the literature review as these spillover indices had a tendency to decrease during COVID-19 when compared to the levels before the pandemic that were significantly higher.

Furthermore, the total spillover indices calculated using the Diebold and Yilmaz (2009) model show that the COVID-19 crisis did not significantly alter the cross-country spillovers of returns and volatility in financial markets for the chosen stock markets. Therefore, the diversification benefits of investing across these countries and regions remain important, as they can help mitigate risks associated with idiosyncratic shocks that affect individual economies.

Investors may, however, need to modify their portfolio allocation strategies based on the countries they choose assets from. For instance, since the study found that total return spillovers increased for developing countries during the pandemic, investors may need to pay closer attention to the risks associated with investing in emerging economies during periods of substantial uncertainty and volatility.

Overall, the study's findings indicate that investors should keep diversifying their portfolios among various countries, but also remain aware of the risks and uncertainties associated with investing in specific countries or regions. As well, it is important to continue monitoring these trends and adjusting policies accordingly, but the results of this study provide some reassurance that the global financial system is resilient to the shocks of pandemics like COVID-19 at least for the countries and periods chosen for the present paper.

Lastly, it is important to highlight that the results presented above are subject to the specific dates and countries chosen for this paper, the results may vary if a larger dataset or different stock markets are examined. For further studies, a larger data set that covers the entire pandemic period that goes from March 11th 2020 to May 5th 2023 could provide detailed insights of the behaviors that the stock markets of developed and developing countries presented during the pandemic and compare their trends with the data before the COVID-19. As well, other stock markets from other developed and developing countries can provide different tendencies coming from the financial markets.

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