CHAPTER THREE

Dynamics of Volatility Spillover between Stock Market and Exchange Rate among Developed Countries during the COVID-19 Pandemic

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Abstract

This study explored volatility spillover between the exchange rate market and the stock market of developed countries, namely Australia, Japan, Germany, Russia, and the United Kingdom for during the COVID-19 pandemic. The study uses daily stock return data and exchange rate changes from 01/11/2019 to 31/10/2021, and the EGARCH model was employed to measure the volatility. By employing EGARCH, the study captured the asymmetric shock in the data series. The Granger Causality test provides the results for the volatility spillover. According to the findings, Australia, Russia, and the UK have significant bidirectional volatility spillover between stock and exchange rate markets. Only Japan is significant for unidirectional volatility spillover in inter volatility spillover effect. This study also analyzes the intra-volatility effect between other countries. The results prove that only the Austrian stock market and exchange rate market are significant for the bidirectional volatility spillover with other countries' stock markets and exchange rate markets. Japan and German have significant unidirectional volatility spillover with the other two markets besides Australia. Russia does not have a significant intra-volatility spillover effect. Therefore, this study gives evidence of volatility spillover during the COVID-19 pandemic. The findings will provide valuable information for fund managers, policymakers, investors, and future researchers. Especially investors who invest in diversified stock markets can get an idea about the stock market volatility and its spillover effect to make the most rational decision regarding the portfolio investment.

Keywords: *COVID-19, EGARCH Model, Exchange Rate, Granger Causality Test, Volatility Spillover.*

1. Introduction

With globalization and financial liberalization, interdependency between nations and the stock markets has increased over the past years. Mukherjee & Mishra (2010) states that the most focused factor is regional economic integration; the lower geographical distance, similar economic patterns, and similar cultural aspects increase the interdependency between countries. Along with removing restrictions in the stock market, foreign investment has become more popular among investors. The increase in foreign investment triggers the usage of foreign currency too. So the demand for the currencies and equity flow create a link between the exchange rate and the stock return. Through that linkage, these two become interdependent and develop a relationship between two financial markets.

It is evidenced that along with the increasing interdependency of the two markets (Stock and currency market), volatility transmission has also increased between the stock market and the foreign currency market. Therefore, it is vital for rational investors to be in touch with the two-market behavior because the volatility transmission can create an international portfolio risk. It will not be rational if investors go for investing in the global market without considering foreign currency market information.

Information plays a significant role in volatility co-movement and volatility spillover. When new information arrives in the stock market, volatility changes (Ross, 1989). Similar to Markowitz's theory, fundamental financial theories explain that investors should diversify their investments and portfolio to reduce risk. Investors have many opportunities to make foreign investments and profit in highly developed markets. With that perception, many researchers are curious about the relationship between these two markets, and much literature explain that there is a relationship between the two markets (stock and currency).

Generally, countries' foreign currency market environment is very dynamic as much as the stock market. These two markets are highly susceptible to economic environment (like both macro and microeconomic environments). Given the importance, many articles analyze the exchange rate volatility and the stock market relationship in academic history. Specially, these two markets are susceptible to trends like disasters, crises, political uncertainty, environmental events, and economic shock (Hillier & Loncan, 2019) as well as macroeconomic factors like economic growth, recessions, inflation, and interest rate. Hence, that is why, with new information; two markets show the volatility than usual.

Several literature revealed the impact of unexpected events like shutdowns, terrorism, and crisis government decisions. That event contains information that can improve the variability of specific markets (Narayan, 2018). Based on that point, this report hypothesizes that the

COVID-19 situation improves the dynamic relationship between the stock market and the foreign currency market.

As an unanticipated disease, the COVID-19 outbreak and its quick spread throughout the world had led the countries into a severe crisis creating economic and financial uncertainties due to great lockdowns and loss of human capital. The COVID-19 outbreak has spread to several sectors, triggering heavy losses, especially in banks and finance, energy and gas, industrials, airlines, and travel, showing the adverse impact on equity indices. Considering the statistics provided by the World Health Organization (WHO), many developed countries have suffered more compared to some other countries. On the other hand, countries like the UK. Japan, Germany, Australia, and Russia contribute to the world trading process. Many countries of the world satisfy their importing needs from these countries and the five countries listed in the top 20 countries having the most extensive stock market capitalization globally.

Moreover, this pandemic has caused substantial investment losses in the world market (Zhang, 2020). During a crisis, stock market volatility generally rises sharply, resulting in spillovers identified across markets. Hence, it is confirmed the European stock market interdependence during COVID-19. Likewise, Hung (2020) investigates the pre and during COVID-19 spillovers between crude oil prices and five developed stock markets in Europe; the study states more spillover effects between crude oil prices and the stock market. Many finance researchers are interested in volatility spillover, and international transmissions have existed between countries recently (Garg, 2021).

The COVID-19 pandemic is the most significant pandemic that was experienced in recent history, showing an overwhelming effect on economies more than the other health crises in the past. With such heightened economic and financial risk and uncertainty during this severe, terrible COVID-19 pandemic, great lockdowns, and other travel restrictions, investors and portfolio managers are keen to understand the transmission of shocks across equity markets and diversification of portfolios at a minimum risk. Thus, it is crucial to investigate the volatility spillovers during COVID-19 for early alarm and to track the degree of the current crisis. Hence, the objective of this study is to examine the developed countries' interactions and volatility spillover between the stock market and foreign exchange market during the COVID-19 outbreak and before the outbreak. The UK, Japan, Russia, Germany, and Australia represent the developed countries.

This paper employed the EGARCH model and used the daily data of six countries' stock market indices and the foreign currencies rate, from 1st January 2011 to 30th September 2021, to address the arguments. The findings will help investors and portfolio managers manage

risk, determine decisions in the allocation of assets, and diversify their portfolios to achieve maximum benefit. The governments can maintain economic and financial stability by designing effective policies by uncovering the spillover effects among these stock markets.

2. Previous Literature

In recent years, globalization and technological growth have interconnected all the aspects of the world such as finance, economy, education, health, politics, etc. Hence, countries influence each other with different proportions. This is also exemplified by the financial market. Financial and trade linkages will provide a foundation for market integration and volatility spillover. Most countries relaxed the restrictions of capital markets, and exchange through the market became accessible to transactions. Those things make space for new information in the capital markets, leading to increased market behaviors on prices and return. Interrelationships of the equity market worldwide have increased, and many studies have focused on stock market integrations and the volatility spillover.

The exchange rate gives the international price for the domestic currency, and it reflects the purchasing power of the countries in the international market. Studying the exchange rate can interpret a lot of information about the fundamental economy of countries. Stock price indices are very sensitive and open to the real economy of the countries and show changes along with the sudden changes in the country's economy. So exchange rate and the stock market indices are essential parts of the country's economy and should give more attention to controlling the economic fluctuation in the countries.

With close economic indicators and integrations, financial market indicators show more intimate relationships. With that relationship, exchange rate fluctuation (volatility) and stock market fluctuation (volatility) show integration. All the levels are interlinked, and any changes in any level will cause fluctuation in other levels. If there are no external shocks, most levels are generally hard to see considerable fluctuation (Jiahong, 2020).

Importantly two theoretical perspectives describe the relationship between the exchange rate and the stock market price indices. "Flow oriented" model (Fischer, 1980) and the "Stock oriented" model (Frankel, 1983).

The flow-oriented model describes that exchange rate fluctuations influence international trade as well as domestic trade, and in terms of that, final real output and stock price as well (Fang, 2002; Wongbangpo, 2002 and Phylaktis, 2005). When the domestic stock prices increase, foreign direct investors tend to demand domestic stock and increase the money

demand for the assets transactions (Frankel, 1983; Branson, 1985; Tai, 2007 and Koulakiotis, 2015).

By studying the stock-oriented and flow-oriented models, this study can get the fundamental theoretical background for identifying the relationship between two financial markets (exchange rate and stock market). In the two models, transmission mostly happens through the country's capital and current accounts. When the two orient models combine, we can get an idea about the relationship between the two markets. An uncontrolled stock market, and the exchange rate market significantly influence each other.

Besides, the open market concepts and globalization and countries' political and trade policies create a lot of linkages between countries. Linkage defines as the ability to buy and sell goods or securities in the common market by any country. So trade linkage is an association built by countries for the purpose of trading goods and services. Financial linkage is one of the country's stock markets that allow trading of foreign country stock in their market, and these exchanges create financial linkages between countries. Cote (1994) explains trade linkage based on how one nation's currency matches another nation's currency depreciation and how price volatility raises among trading countries and their market conditions. Forbes (2002) addresses how linkage transmits the crisis from one country to another and whether it is a determinant of the transmission of the financial crisis.

While the theoretical perspective shows both positive and negative relationships between the stock market and exchange rate, a considerable number of empirical works reference the volatility spillover between the two markets. Kanas (2015) references the volatility spillover of six countries; Japan, the United States, the United Kingdom, Germany, France, Canada stock market, and the exchange rate market. It states that there is significant influence from the stock market to the exchange rate market except for Germany. However, it also results in a weak influence from the exchange rate market to the stock market. In addition, Chang (2009) found significant volatility spillover from the stock market to the exchange rate market. Yet, it hardly discusses the spillover effect from the exchange rate market to the stock market. Chen (2004) also discusses the significant volatility spillover between the stock and exchange rate markets. Besides, Aloui (2007), Andreou et al. (2013), Chkili (2012), Choi (2010), Francis et al. (2006), Mishra (2007), Qayyum (2006), and Xiong (2015) conclude that there is bidirectional flow volatility between the stock market and the exchange rate market.

This study analyzes the volatility spillover between stock market indices and exchange rates during the COVID-19 pandemic in selected developed economies. Developed countries contribute much more to the world economy; with the unexpected shock created by COVID-

19 leading to stock price fluxions and exchange rate fluctuation (OECD, 2020). Many empirical studies are done during unforeseen events, like financial crises, government lockdowns, terrorism, and health issues, and prove that there are influences from those unexpected situations (Narayan, 2018). Accordingly, Baker et al. (2020) identified the impact of the current pandemic on stock market volatility and documented that the government's limitations on commercial activity and consumer restrictions are the primary reasons for increased volatility. The government's response to COVID-19 could maintain the international stock market volatility (Zaremba et al., 2020). It states that the countries that take server action to mitigate COVID-19 increase volatility. Onali (2020) concluded that in the USA, along with the increase of positive cases and death in COVID-19, stock market volatility also increased

3. Data and Methodology

This study used daily stock market return and exchange rate data from 01/11/2019 to 31/10/2021 to capture more detailed and informative information from the period of the COVID-19 pandemic. In addition, six stock market indices and daily foreign currency prices in the exchange market were used from each selected country (United Kingdom, Australia, Japan, Russia, and Germany) as secondary data.

The first step was to calculate the daily index returns using the closing stock price index of each stock market. Thus, returns were calculated by using the following function:

$$R_y = (I_t - I_{(t-1)}) / I_{(t-1)} \quad (1)$$

$$R_{er} = P_t - P_{(t-1)} \quad (2)$$

Equation (1): Measurement for the stock return

Equation (2): Measurement for the foreign currency change

Equation (1) denotes stock price returns, the index price of day t, and t-1 represents the index value of the day. Equation (2) represents the change in foreign currencies.

After calculating the return for each country, to commence the volatility modeling, the first step was to check whether the data set is stationary to prove that there is no time impact on mean and auto-covariance. The stationary was tested using the Unit root tests such as Augmented Dickey-Fuller (ADF) and Phillip and Perron (PP) criteria at a 95% confidence level. The following hypothesis was used for determining the stationary/ non-stationary pattern.

H_0 = Data series has a unit

H_1 = Data series does not have a unit root

After checking the stationary of the data series, for developing the mean equation modeling, and measuring volatility generally, the mean equations were developed as starting points, like the Auto-regressive model (AR), Moving Average model (MA), and ARMA models. Combining Auto-regressive and moving averages, form ARMA (p,q) equation; can be identified as mean models.

$$Y_t = \alpha+\alpha_1 Y_{(t-1)}+\alpha_2 Y_{(t-1)}+\cdots+\alpha_p Y_{(t-p)}-\theta_1 \varepsilon_{(t-1)}-\theta_2 \varepsilon_{(t-2)}-\ldots-\theta_q \varepsilon_{(t-q)} \quad (3)$$

So to identify the conditional mean in the data series, the model that is developed by using the ARMA approach should be used.

$$R_{(y/er)} = \alpha_0+\alpha_1 R_{(y/er-1)} \quad (4)$$

As a first approach to the main modeling, two market data analyses for mean modeling AR(1) model (equation 04). After fitting the mean model for each data, conditional mean equations (5) and (6) can be used.

$$R_y = \alpha_0+\alpha_1*R_{(y-1)}+\alpha_2*R_{(er-1)} +\varepsilon_t \quad (5)$$

$$R_{er} = \alpha_0+\alpha_1*R_{(er-1)}+\alpha_2*R_{(y-1)}+\varepsilon_t \quad (6)$$

Equations (5) and (6) represent the return of stock prices and changes in exchange rate prices. $\alpha_0$intercept, $\alpha_1$impact of the previous day's stock return, and $\alpha_2$impacts from the exchange rate to the stock market. After analyzing the conditional mean, it was essential to determine whether these data have the ARCH effect of further analysis of volatility spillover.

The Autoregressive Conditional Heteroscedasticity (ARCH) model analyzed the volatility after getting a significant mean model. Before that, it is essential to test whether the fitted mean equation has an ARCH effect or not; for that, the Lagrange Multiplier test (ARCH LM) is used.

H_0 = ARCH effects are not significant

H_1 = ARCH effects are significant

If the ARCH test; p-value is less than 0.05, ARCH effects are significant, and the heteroscedasticity effect is significant; that means the variance of residuals is not equal at the different lag levels. The central analytical part can be started with the confirmation of the ARCH effect.

EGARCH Model

This study's main objective is identifing volatility spillover between two financial markets (exchange rate and stock markets). This study employed the Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) (Nelson, 1991). Unlike GARCH modeling, the EGARCH model can potentially capture both symmetric and asymmetric information. Here, symmetric shocks were also described as positive and asymmetric shocks; negative shocks. Most studies argue that negative shocks are most likely to make more volatile than positive shocks. Therefore, the EGARCH model was selected to capture symmetric and asymmetric volatility shocks between the stock and exchange rate markets as per the study's objectives. Many empirical studies have used the EGARCH model for analyzing volatility spillover (Kanas, 2000; Beer, 2011; Adjasi, 2008; Choi, 2010; Mishra, 2007; Morales, 2008; O'Donnell, 2009; Okpara, 2012; Qayyum, 2006 and Yang, 2004).

The following equation describes the EGARCH(1,1) model;

$$H_t = \beta_0+\beta_1 H_{(t-1)}+\beta_2 |(\varepsilon_{t-1})/\sqrt{(H_{(t-1)})}|+\vartheta (\varepsilon_{t-1})/\sqrt{(H_{(t-1)})} \quad (7)$$

In equation (7), H_t represents the log of conditional variance of markets (stock market /exchange rate market) β_0 is constant volatility and $\beta_1 H_{(t-1)}$ describes the function of volatility $\beta_2|(\varepsilon_{t-1})/\sqrt{(H_{(t-1)})}$ capture the reaction of volatility toward information and $\vartheta (\varepsilon_{t-1})/\sqrt{(H_{(t-1)})}$ measure the asymmetric volatility of effect.

This study analyzes the volatility spillover from the stock market to the exchange rate market and the exchange rate market to the stock market.

$$H_{(t(sm))} = \beta_0+\beta_1 H_{(t-1)}+\beta_2 |(\varepsilon_{t-1})/\sqrt{(H_{(t-1)})}|+\vartheta (\varepsilon_{t-1})/\sqrt{(H_{(t-1)})} \quad (8)$$

Equation (8) is the conditional variance for the volatility spillover from the foreign exchange rate to the stock market.

$$H_{(t(er))} = \beta_0+\beta_1 H_{(t-1)}+\beta_2 |(\varepsilon_{t-1})/\sqrt{(H_{(t-1)})}|+\vartheta (\varepsilon_{t-1})/\sqrt{(H_{(t-1)})} \quad (9)$$

Equation (9) is the conditional variance for the volatility spillover from the stock market to the foreign exchange rate.

Granger Causality Test.

Granger (1969) introduces the Granger Causality test for dependent variables' time series data characteristics in economics and econometrics. Using the Granger causality test, any researcher can identify if any information from past and current values contained by one variable represents the additional information of the future value of another variable. There is

a lot of empirical evidence for practical use; Chen (2004), Okunev (2000), Okunev JW (2000), Cees Diks (2006), Jian Ke (2010) and Umm E.Habiba (2020).

Accordingly, this study's main purpose is to prove the directional volatility spillover between the two financial markets (exchange rate and the stock exchange). However, to prove the direction (bidirectional or unidirectional) since the EGARCH model was not enough to identify the definite relation, this study used the Granger Causality test. Using the Granger Causality test results, this study interprets the direction of the volatility spillover. Volatility generated by EGARCH will be the variable for the Granger causality test.

H_0 = Variables does not granger cause

H_1 = Variables does granger cause

4. Results and Discussion

This study used data of two years since the first case record of the COVID-19 outbreak (11/01/2019 – 10/31/2021). The volatility model was used to analyze the secondary data collected using invwsting.com. The Exponential Generalized Autoregressive Conditional Heteroscedasticity (EGARCH) model was employed to identify the volatility spillover between the two financial markets.

Descriptive Statistics

The primary analysis that was employed to identify the behavior and patterns of the data. Descriptive statistics were helpful in observing the general characteristics of the data. The following tables summarize the statistical output of the two financial markets. Table 1 present the descriptive statistical summary of the foreign exchange rate market.

Table 1: Descriptive statistics summary

	Exchange rate					Stock market				
	AUD_USD	EUR_USD	GBP_USD	JPY_USD	RUB_USD	YAUR	YGMN	YJPN	YRUSS	YUK
Mean	0.0001	5.51	9.00	8.11	0.0001	0.0002	0.0004	0.0003	0.0009	0.0001
Median	0	0	0	0	0	0	0	0	0	0
Std. Dev.	0.0055	0.0034	0.0048	0.0039	0.0072	0.0118	0.0132	0.0098	0.0136	0.0115
Skewness	-0.7823	-0.2607	-0.5766	1.1275	1.8861	-1.2778	-0.7883	0.1782	0.3429	-1.1018
Kurtosis	10.7297	6.8474	10.8659	22.2488	19.901	18.8566	23.748	10.6903	9.4471	21.7942
Jarque-Bera	1894	459	1925	11440	9133	7857	13187	1805	1280	10906
Prob.	0	0	0	0	0	0	0	0	0	0

Most countries skewed negatively, indicating that data sets were asymmetrical and not distributed normally according to the kurtosis value of all countries in both markets. Further, both markets reject the assumption of normality because the Jarque-Bera test was significant (p-value <0.05) by rejecting the null hypothesis. Thus, the data sample was not normally distributed. Dayaratne (2010), Garg (2021) and Iqbal (2016) also provided the same findings in their studies.

Unit root test

Unit root test aimed to identify whether the data is stationary or not. In time series analysis, measuring data stationarity was a prevalent assumption. Stationary data means that the data series did not have any trend or intercept, and the mean and standard deviation were the same at any point of the data series.

Table 2: Unit root test summary

	Exchange rate market		Stock market	
	PP	ADF	PP	ADF
Australia	-23.4799*	-23.3507*	-32.0737*	-32.3388*
Japan	-29.2276*	-29.2276*	-25.8369*	-16.4245*
Germany	-25.0397*	-16.1112*	-27.6062*	-27.519*
Russia	-27.0696*	-16.5302*	-25.7418*	-25.7418*
UK	-23.2592*	-23.2592*	-26.936*	-26.9171*

*-5% significant level.

There are no special models or criteria to prove the stationary of data series in econometrics. Most empirical studies have used the unit root test to check the stationary. Consequently, this study employed the unit root test for all the research variables. The summary of the output of the unit root test is described in table 2. The provided output exchange rate change and the stock return index were stationary at the levels. Simultaneously, it proved that the data series has stationary data by rejecting the null hypothesis under Augmented Dickey-Fuller (ADF) test and Phillips – Perron (PP) test at 5% significant level. This proved that there were no biased data and this data series's output.

Model Fitting

Volatility models are mostly generated using the ARMA model, as explained in section 03 the first step to analyzing the data series for ARMA modeling (mean model). After fitting a model for ARMA most important analysis is the ARCH LM test. Performing the ARCH LM test helps to identify whether there is a heteroscedasticity effect.

Table 3: Mean model and ARCH effect of two markets

	AR(1)	AR(2)	AR(8)	ARCH effect	AR(1)	AR(2)	AR(8)	ARCH effect
Australia	0.1429*			4.3420*	-0.1790*			28.9615*
Japan	-0.07901*			48.2870*	0.0462*			38.9893*
Germany	0.0747*			22.8475*			-0.1493*	0.2707
Russia		0.0799*		11.8923*	0.0487*			22.2490*
UK	0.1465*			42.0101*			-0.1794*	8.8302*

Australia, Japan, Germany, and the UK were significant for AR(1) mean model and only Russia was significant for AR(2) model for the exchange rate. Besides, Australia, Japan, and Russia were significant for AR(1) model, while Germany and the UK were significant for the AR(8) model for stock markets.

EGARCH Modeling

Table 4: EGARCH results from one country's exchange rate market to another country's stock market

	Australia	Japan	German	Russia	UK	ARCH	leverage	GARCH
Australia	0.1776*	0.3153*	-0.1749	-0.0396	0.0843	0.0850*	-0.1279*	0.9856*
Japan	0.4011*	0.6454*	-0.0232	-0.0341	0.0790	0.0551*	-0.1137*	0.9818*
Russia	0.2020	-0.0014	0.0226	0.0827	-0.3077*	0.5635*	-0.1148*	0.0615
UK	0.1693*	0.1245	0.1143	-0.0979	-0.2554*	0.0757*	-0.1218*	0.9887*

* 5% significant level.

Table 5: EGARCH results from one country's stock market to another country's exchange rate market

	Australia	Japan	Russia	UK	ARCH	leverage	GARCH
Australia	-0.0098	0.0914*	0.0161	-0.0496*	0.4215*	-0.0597	0.0948
Japan	-0.0008	-0.0299*	0.0093	-0.0152	0.1524*	-0.0803*	0.9592*
German	0.0247*	0.0434*	-0.0075	0.0014	0.3719*	0.0080	-0.0962
Russia	0.0223	-0.0401	-0.0119	0.0028	0.1032*	0.0766*	0.9797*
UK	0.0153	0.0711*	0.0076	-0.0309*	0.5004*	-0.0863*	-0.2934*

* 5% significant level.

Table 4 summarizes the EGARCH calculations for volatility from the foreign exchange rate market to the stock market. The ARCH parameter was significant in Russia, Australia, Japan, and the UK and gave positive volatility from the exchange rate market to the stock market. In addition, the five exchange rate market provides asymmetric shock for the four stock markets. This is because four leverage parameters give negative results for all the stock markets. The GARCH parameter believed that the Russian stock market is insignificant. It states that other countries' past volatility of the exchange rate market does not help to forecast the Russian stock market's present volatility.

Table 5 summarizes the cross-volatility analysis results from the stock market to the exchange rate market. In this volatility combination, the Australian and Russian exchange rate were not significant for the volatility forecasting from the past data of the stock market past information. These two countries also did not show significant leverage. However, the other three countries: Japan, Germany, and the UK were significant for the GARCH and leverage parameters; for the leverage, all three countries showed negative shock for the volatility during COVID-19. Besides, all five exchange rate markets showed positive volatility with other countries' stock markets.

ARCH LM test was run for all EGARCH models to confirm any heteroscedasticity effect in the data series. However, the data did not become significant for the heteroscedasticity effect. It proves that there is no more heteroscedasticity effect to check.

Granger Causality Test

According to the results, the United Kingdom's two financial markets have bidirectional volatility spillover. Japan's exchange rate market and stock market were not significant for the bidirectional volatility spillover during the COVID-19 pandemic. Results state that stock-oriented model did not become significant while the flow-oriented model was significant for the volatility spillover. Volatility spillover showed bidirectional spillover between two financial markets in Russia and Australia.

Table 6: Granger causality test for each country

Null Hypothesis:	Obs	F-Statistic	Prob.
YUKS does not Granger Cause POUND	728	42.8677	0.0000*
POUND does not Granger Cause YUKS		9.63223	0.0000*
YJPNS does not Granger Cause JPYS	728	0.17291	0.8412
JPYS does not Granger Cause YJPNS		82.2671	0.0000*
RUB does not Granger Cause YRUSS	727	10.8802	0.0000*
YRUSS does not Granger Cause RUB		10.8727	0.0000*
YAUS does not Granger Cause AUD	637	19.8044	0.0000*
AUD does not Granger Cause YAUS		18.4389	0.0000*

Table 7: Intra volatility spillover

Null Hypothesis:	Obs	F-Statistic	Prob.
YAUS does not Granger Cause AUD	637	19.8044	0.0000*
AUD does not Granger Cause YAUS		18.4389	0.0000*
YJPAN does not Granger Cause AUD	728	34.1711	0.0000*
AUD does not Granger Cause YJPAN		22.0313	0.0000*
YRUS does not Granger Cause AUD	727	0.39404	0.6745
AUD does not Granger Cause YRUS		2.13916	0.1185
YUKC does not Granger Cause AUD	728	26.9844	0.0000*
AUD does not Granger Cause YUKC		17.9028	0.0000*
YAUS does not Granger Cause EURO	637	23.3702	0.0000*
EURO does not Granger Cause YAUS		0.22994	0.7946
YJPAN does not Granger Cause EURO	728	25.2138	0.0000*
EURO does not Granger Cause YJPAN		2.05449	0.1289
YRUS does not Granger Cause EURO	727	0.14402	0.8659
EURO does not Granger Cause YRUS		0.70754	0.4932
YUKC does not Granger Cause EURO	728	26.6784	0.0000*
EURO does not Granger Cause YUKC		0.59129	0.5539
YAUS does not Granger Cause YEN	637	3.85655	0.0216*
YEN does not Granger Cause YAUS		64.8598	0.0000*
YJPAN does not Granger Cause YEN	728	0.16512	0.8478
YEN does not Granger Cause YJPAN		82.8624	0.0000*
YRUS does not Granger Cause YEN	727	0.93989	0.3911
YEN does not Granger Cause YRUS		2.20829	0.1106
YUKC does not Granger Cause YEN	728	2.01439	0.1341
YEN does not Granger Cause YUKC		87.2478	0.0000*
YAUS does not Granger Cause RUB	636	14.2741	0.0000*
RUB does not Granger Cause YAUS		31.6258	0.0000*
YJPAN does not Granger Cause RUB	727	27.8021	0.0000*
RUB does not Granger Cause YJPAN		5.83129	0.0031*

YRUS does not Granger Cause RUB	727	0.56043	0.5712
RUB does not Granger Cause YRUS		2.72196	0.0664
YUKC does not Granger Cause RUB	727	28.3135	0.0000*
RUB does not Granger Cause YUKC		4.37913	0.0129*
YAUS does not Granger Cause POUND	637	65.7909	0.0000*
POUND does not Granger Cause YAUS		28.7634	0.0000*
YJPAN does not Granger Cause POUND	728	25.1434	0.0000*
POUND does not Granger Cause YJPAN		0.48486	0.616
YRUS does not Granger Cause POUND	727	0.69437	0.4997
POUND does not Granger Cause YRUS		0.61731	0.5397
YUKC does not Granger Cause POUND	728	37.5134	0.0000*
POUND does not Granger Cause YUKC		10.7157	0.0000*

Source: Output of analysis

Australian two financial markets show bidirectional volatility spillover with every country's two financial markets. Japan's exchange rate market showed a bidirectional spillover with the Australian stock market and a unidirectional volatility spillover with the UK stock market. Moreover, the Japanese stock market showed a clear bidirectional volatility spillover between the exchange rate market and Australia, Germany, and Russia. Besides, the exchange rate market of the UK shows unidirectional volatility spillover. Russian stock market did not relate to other countries' exchange rate markets. However, the exchange rate market of Russia showed bidirectional spillover with all other countries stock markets. The German exchange rate market only showed the unidirectional volatility spillover from the other countries stock markets. Accordingly, only the Australian and Japanese stock markets showed a relation with the exchange rate market of the UK. Moreover, Australia has a unidirectional, and Japan has a bidirectional spillover with the exchange rate market of the UK. Lastly, the UK stock market has a bidirectional volatility spillover with Russia and a unidirectional volatility spillover from the Japanese exchange rate market, and Australia and Germany have a unidirectional spillover from the UK exchange rate market.

5. Conclusion

This study aims to find the volatility spillover effect between two financial markets. After developing the ten hypotheses under the two main objectives, this study presents the following findings.

Results of the volatility analysis from the EGARCH model state that there is significant positive volatility between the exchange rate market and the stock market during the pandemic period besides the German stock market. On the other hand, there is a negative shock in the volatility during the COVID-19 pandemic. Further, two financial markets show asymmetric shocks in all five countries.

First objective states that there is bidirectional volatility spillover between foreign exchange and stock markets in each country separately. As for this objective, this study ran an econometric model and stated the finding as three countries besides Japan and Germany, showing the significant bidirectional volatility spillover between the two financial countries. But unexpectedly, Japan showed unidirectional spillover, while German Stock returns do not significantly affect the ARCH effect.

Second objective stated that there was a bidirectional cross-volatility spillover between one country's stock market and other countries' exchange markets. Australian two financial markets showed bidirectional volatility spillover with every country's two financial markets. Japan's exchange rate market showed a bidirectional spillover with the Australian stock market and a unidirectional volatility spillover with the UK stock market. On the other hand, the Japanese stock market showed a clear bidirectional volatility spillover between the exchange rate market and Australia, Germany, and Russia. Besides the exchange rate market of the UK, it showed unidirectional volatility spillover. Although the Russian stock market did not relate to other countries' exchange rate markets Russia showed bidirectional spillover with all other countries' stock markets. The German exchange rate market only showed the unidirectional volatility spillover from the other countries stock markets. Apparently, only the Australian and Japanese stock markets showed a relation with the exchange rate market of the UK. Further, Australia has a unidirectional, and Japan has a bidirectional spillover with the exchange rate market of the UK. Lastly, the UK stock market has a bidirectional volatility spillover with Russia and a unidirectional volatility spillover from the Japanese exchange rate market, and Australia and Germany have a unidirectional spillover from the UK exchange rate market.

Most countries showed significant bidirectional volatility spillover with every two financial markets separately and other countries during the COVID-19 period.

The findings provide investors and fund managers with valuable information on portfolio diversification. They can take advantage of international investments because of the diversification of the market. To benefit from diversification, one should better know other stock markets, exchange rate market behaviors, and volatility transmissions as it can help maximize profit while minimizing risk. The policymakers can develop the most suitable strategies/policies to protect the two financial markets and economies in a critical situation like the COVID-19 health pandemic. Moreover, businesses interested in leading their business can make rational decisions for their companies.

Consequently, this study focused only on the period of the COVID-19 pandemic. As per the future directions, future research can be focused on comparing the results during and after the pandemic. Further, different countries' samples can be applied besides using this study's sample if there is an additional variable for analysis. In addition, since this study used the EGARCH model and Granger causality test to identify the volatility and the volatility spillover, future research can use different statistics and methodologies.

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