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Dynamic Spillover and Market Integration between Global Commodities and Pakistan Stock Exchange (PSX) amid COVID-19 and the Russia-Ukraine War

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ABSTRACT
The study fills a critical research gap in the literature by examining the dynamic interlinkages and volatility spillovers between Pakistan's financial market and major international commodities during periods of global crisis, specifically the COVID-19 pandemic and the Russia-Ukraine conflict. Unlike previous studies focused on developed or larger emerging markets, this research centers on Pakistan—a frontier economy with unique vulnerabilities. Using the ARMA-GARCH model, the study effectively captures the mean and volatility dynamics of the MSCI Pakistan Index (MSCI_PAK) and key commodities such as gold, oil, soybean oil, wheat, corn, and rice. This framework is well-suited to model the volatility clustering and time-varying shocks characteristic of crisis periods. The results reveal generally weak return correlations between MSCI_PAK and the selected commodities, suggesting distinct market drivers and opportunities for portfolio diversification. However, strong volatility persistence is observed, particularly in gold and oil, with oil showing quicker mean reversion. Agricultural commodities exhibit prolonged volatility, signaling their sensitivity to sustained external shocks. High GARCH coefficients for soybean oil and wheat indicate lasting volatility spillovers, and extreme kurtosis in rice and corn points to vulnerability to abrupt crisis-induced price shocks. During the COVID-19 pandemic, gold acted as a safe-haven asset with a negative correlation to MSCI_PAK, while oil and agricultural commodities showed weak relationships. Similarly, during the Russia-Ukraine conflict, widespread volatility clustering persisted, with gold and oil remaining volatile and agricultural commodities showing moderate negative correlations to Pakistan's market. In conclusion, the study finds that while return linkages between Pakistan's financial market and global commodities are limited, volatility transmission is significant and persistent. These insights are crucial for investors and policymakers aiming to build resilient portfolios and develop effective risk management strategies in the face of global shocks.

Keywords: Financial market volatility, international commodities, volatility spillovers, COVID-19 pandemic impact, Russia-Ukraine conflict.

Introduction and Literature Review

The global financial landscape is increasingly interconnected, with fluctuations in one market often reverberating across others. The Financial sector is particularly sensitive to economic conditions. It plays a pivotal role in national and international finance. Financial sectors worldwide, including in developing markets like Pakistan, were sensitive to the effects of COVID-19 (Sharif et al., 2020). Furthermore, global stock indices were negatively affected by the conflict between Russia and Ukraine (Boungou & Yatié, 2022). Current, study seeks to find the spillover effects among the international commodities markets (oil, gold, and agricultural products) and the financial market of the Pakistan Stock Exchange, focusing on the significant global events of the COVID-19 and the conflict of Ukraine and Russia.

COIVD-19 virus initially originating in Wuhan, China, rapidly spread across the globe. By early 2020, the infectious disease had surged worldwide and on March 11, 2020 WHO declared COVID-19 as pandemic. Due to pandemic the deaths reached to 139,378 and infected patients globally surpassed 2 million till April 2020 (Ashraf, 2020). Different countries and economies suffered huge losses during the pandemic. It effected different sectors, including economic and financial sectors as highlighted in different research studies See, e.g. (Ajmi et al., 2021; Ashraf, 2020; Elleby et al., 2020; Khan, 2024; Onyeaka et al., 2021; Xu et al., 2020; Zhang et al., 2020).

During the pandemic, lockdowns were imposed by different countries, which reduced oil consumption, hence reducing demand for oil and as a result oil prices declined (Chang et al., 2022). Furthermore, the COVID 19 pandemic also significantly affected the agriculture commodities markets causing volatilities in these markets. Due to lockdowns there was shortage of labors, disruptions in global supply chains and changes in demand dynamics (Elleby et al., 2020; Umar et al., 2022). The COVID 19 also had influence on the gold prices, and during the crisis, investors diverted their investments to safe-haven-assets. As Gold is considered one of the most important safe haven asset, and increase in the demand for gold brought fluctuations in its prices during the pandemic (Tuna & Tuna, 2022; Yousef & Shehadeh, 2020).

The international financial markets recently have gone through multiple periods of crises. As the global financial crisis caused increased risks transmissions among markets, the onset of the COVID-19 further intensified this integration, driving researchers to explore its effects on the interconnectedness of different markets including stocks markets and the spillover of volatility (Khan, 2024). As a result, market integration and volatility spillovers have become significant areas of focus for researchers, especially during periods of crises. Globally the risk of volatility spillovers in financial markets increased during the COVID-19 Pandemic, leading to shocks and risks spreads across different regions and sectors (Ajmi et al., 2021; Laborda & Olmo, 2021). The increased uncertainties in markets were closely related to the pandemic severity, leading to a time varying pattern in risk contagion between different markets globally.

As there was a gradual recovery around the world from the crisis of health, the Ukraine Russia war began on February 24, 2022. The Russian attack on Ukraine led to substantial interruptions to the commodities supply, because both countries export major portion of agriculture and energy products around the world (Khan, 2024). As a result, as compared to April 2020, energy prices roused fourfold till March 2022. Over the same period food prices roused by 84% and fertilizer prices increased by 220% (Khan, 2024). There are significant impacts on the world's financial markets due to Russia-Ukraine war, with studies indicating increased volatility and shifting correlations. Fang and Shao (2022) highlighted increased volatility in agriculture, energy and metal products markets as a result of the Russia–Ukraine conflict.

There were abrupt changes in important global commodities prices, such as gas, oil, fertilizer and grains etc. (Tuhin, 2024). The conflict between the two countries, caused volatilities in the prices of these commodities, because both the countries are the key exporters of these commodities (Tuhin, 2024). Alam et al. (2022) reported, that there is a historical rise in the prices of agricultural and energy products, due to the conflict. He stated that in 2022 the prices of crude oil raised to $100 per barrel which was a 40% increase in the price from last year. On the other hand at the agricultural side, there was a 40% increase in the price of wheat as Ukraine is one of the largest exporter of wheat around the globe (Alam et al., 2022). Russia and Ukraine are key producer and exporters of the global energy markets (Huang et al., 2023). Russia is one of the chief oil producers and exporters in the world (Zhang et al., 2024).

During the conflict amongst Russia and Ukraine the impact of gold on the financial markets received a considerable attention of the researchers. Traditionally gold is considered as a safe haven asset especially during the times of geographical tensions arising from conflicts. A place of refuge and safety is called a haven and the asset having the quality to maintain or increase its value during the crisis periods qualify as a safe haven. Such kind of assets provide investors protection during negative and worse market conditions (Khan, 2024). Fluctuations in gold prices, during the Russia-Ukraine war, significantly affected the financial stock markets, showing interconnectedness between the two markets. The research study of Ha (2023) stated that volatility in the prices of gold transmitted and increased fluctuations and volatilities in the stock markets. Different research studies confirm that during crises periods, gold prices exhibit sharp increase as investors move their investments from other markets including stock markets to safe assets markets like gold markets, resulting high volatilities in the financial markets (Triki & Maatoug, 2021).

The countries from the South Asian region including Pakistan, are importer of gold and oil commodities. Therefore, any issue that arises in these commodities market will affect the region's stock market (Khan, 2024). Due to expanded financialization in the markets of global oil and gold markets, these commodities now have significant impact on the overall regional and international commodities and stock markets. Therefore, it is very critical and crucial to examine the effects of global commodity markets on the markets of South Asian regions including Pakistan, especially in the context of their interconnectedness with important commodities and financial markets.

Agricultural products such as, wheat, corn, rice and soybean are also selected in the study because, these crops are very crucial for international food security. The prices of these agricultural products have effects on the economies worldwide including Pakistan importing a significant fraction of its food supply (Shaheen et al., 2022). Wheat, corn and rice are globally the most used staple crops, providing food to billions of peoples around world and most widely consumed in Pakistan (Asma et al., 2023; Sendhil et al., 2023; Shahzad et al., 2022; Yaheliuk et al., 2024). Soybean, though, is not a staple food but it is very important for the production of oil and for feeding in livestock and act as potential source of food and health benefits (Islam et al., 2022). Soybean acts as a key player in food security globally (Dilawari et al., 2022). Rice is one of the most important cereals that provides energy source and food to almost 50% of the world's population (Pradhan et al., 2023; Tagliapietra et al., 2024). Ahmad et al. (2024) argues that rice is one of the major globally traded commodities and also one of the major exporting commodities of Pakistan that contribute significantly to Pakistan's economy.

Russia and Ukraine are key producers and suppliers of agricultural products, including fertilizer, wheat, and corn etc. around the globe. The fact has been reported by different studies (Aliu et al., 2023). In recent years in order to meet the domestic demand for wheat and ensure its food security, Pakistan imports significant portion of wheat (Shaheen et al., 2022) The corn is also a widely consumed food globally and also in Pakistan. Pakistan fulfill a significant portion of its corn needs through imports (Waris et al., 2023). Similarly, soybean is a major and key oil seed that has been produced and widely consumed globally. It is one of the major commodities trading in the worlds market and the largest importers of the soybean oil are the Asian countries (Ahsan et al., 2019; Wilcox, 2004). In the same way the major portion of Pakistan's need for soybean is accomplished through imports (Abbas et al., 2023). All these studies highlight that Pakistan imports a significant portion of corn, soybean and wheat and have significance impact on Pakistan's economy.

As one of the important parts of the financial mechanism, financial firms are the valuable entities that perform certain important functions. The financial firms performs very important functions of utilizing idle resources, diversifying exposure to risk and aiding in providing the financial resources to the economy productive sectors efficiently (Madura, 2020; Viney & Phillips, 2012). Activities of these financial firms are not restricted to the domestic country and local individuals only but from previous few decades the functions of the financial firms have been evolved. The financial firms are aiding in promoting international trade across different countries, due to evolving globalization trends. These financial firms perform different transaction amongst the countries at international level at a relatively minimum cost (Abaidoo & Agyapong, 2023).

Financial firms perform a very important role in mediating between different parties in markets, including commodity markets. These financial firms provide platforms for different parties to perform different financial transactions including, import and export parties. Through different formal and informal agreements, the trading activities of commodities in commodity markets are financialized through different financial firms. Due to such a dynamic relationship between the financial firms and commodities markets, it is possible that shocks in the prices of international commodities and volume of international transactions may affect the development of financial firms (Abaidoo & Agyapong, 2024).

In current years, market integration has become a critically important topic for both academicians, researchers and market participants. The return and volatility in a market can be affected by a spillover of shocks from other markets due to increased connections between these markets. The spillovers of these volatilities and shocks have significant repercussions for diversification of investments, risk management and allocation of assets. Therefore, analyzing interconnectedness across various markets is very important for policy makers and investors (Khan, 2024). The spillover of volatilities between markets has significant repercussions for diversification and risk management by investors. The presence of spillover effects shows that there is integration and interconnectedness between different markets. Events in one market can affect the other market (Aziz et al., 2020). Furthermore, with greater integration benefits derived from diversification diminishes (Attia et al., 2023; Gilmore & McManus, 2002). With increased integration, benefits of diversification decrease and research studies to explore the level of integration becomes extremely important for researchers, investors and policy makers.

Problem Statement

The global financial landscape is highly interconnected, with financial markets and commodities markets influencing each other, particularly during periods of significant global crises (Aziz et al., 2020; Basher & Sadorsky, 2016; Morema & Bonga, 2020). In the context of Pakistan's emerging economy, there is limited research work focusing on spillovers of volatility and price shocks among the international commodities markets (such as gold, oil and agricultural products) and the financial markets of the Pakistan Stock Exchange (PSX). Setiawan et al. (2022) suggested to extend research studies to include multiple concurrent periods of crises to examine the spillover effects. Therefore, this study aims to address a critical research gap by examining, whether spillover effects exist between the financial market of the PSX and international commodities markets during periods of global disruption, particularly focusing on the geographical conflict between Ukraine and Russia and the COVID-19 crisis. As Pakistan's economy is closely tied to global oil and agricultural markets, this makes it crucial to explore how such external shocks influence the Pakistan Stock Exchange (PSX).

Research Question

To what extent are spillover effects exist and the financial markets of the PSX integrated with international commodities markets during periods of economic instability and geopolitical crises?

Research Objective

To evaluate the spillover effects and integration between the financial market of the Pakistan Stock Exchange (PSX) and international commodities market during periods of economic instability and geopolitical crises.

Research Hypothesis

H1. There is significant volatility spillover from the international commodities markets into the financial markets of the Pakistan Stock Exchange during the periods of economic instability, such as COVID-19 pandemic

H2. There is significant volatility spillover from the international commodities markets into the financial markets of the Pakistan Stock Exchange during geographical tensions, such as Ukraine-Russia Conflict.

H3. The volatility spillovers between the international commodities markets, and the financial markets of the Pakistan Stock Exchange differs significantly during crises reflecting crisis-specific spillovers dynamics.

Significance of Research Work

This study is aimed to contribute to current literature, by giving fresh evidence on the linkages between international commodities markets and the financial market of Pakistan stock exchange (PSX) during the significant global events. The study offers insights into the time varying nature of these relationships by using DCC-GARCH model. The study assists investors, policymakers, and financial analysts in understanding and responding to market risks during periods of global uncertainty.

Theoretical Support

A theoretical framework is the review of existing theories that serves as foundations and support for the proposed study and provide a road map to develop different arguments in the study. Theories that are relevant to the study are briefly discussed below.

Spillover Theory

Spillover theory, is a theory about the transmission of shocks and volatilities between different markets. Initially the theory of spillover between stock markets was proposed by Eun and Shim (1989) and further validated by Hamao et al. (1990) in their research studies. A key study regarding spillovers was conducted by Diebold and Yilmaz (2009) to measure the extent of volatility spillovers between markets where they developed volatility spillover index, revealing that shocks in one market can affect others.

Modern Portfolio Theory (MPT)

Modern Portfolio Theory (MPT) is a framework for investment strategy introduced by Harry Markowitz, an economist in the 1950s. The theory stresses on reducing the risk of investment through diversification. According to MPT, the investors can construct an "efficient portfolio" by the combination of different assets. This combination of assets is managed in such a way, that expected returns at a given risk level get maximized, or for a given expected returns the risk gets minimized. The core principle of MPT is that all assets, at the same time, not move in the same direction. Therefore, holding a diverse set of investments reduces the effect of a single asset's underperformance on the overall portfolio.

MPT also presents the idea of the efficient frontier; a curve that shows the optimal portfolio set, and for a specific risk level provides a highest expected return. Depending upon their risk tolerance, investors can choose portfolios, along this frontier. The theory relies on key metrics such as expected returns, the correlation between assets and standard deviation (risk measure). By focusing on risk and return relationship, MPT helps investors make informed decisions about how to allocate assets and balance risk in their portfolios.

Conceptual Framework

The conceptual framework is the graphical and visual presentation of factors and their relationship to be studied. It consists of factors, variables and their relationship in the proposed study.

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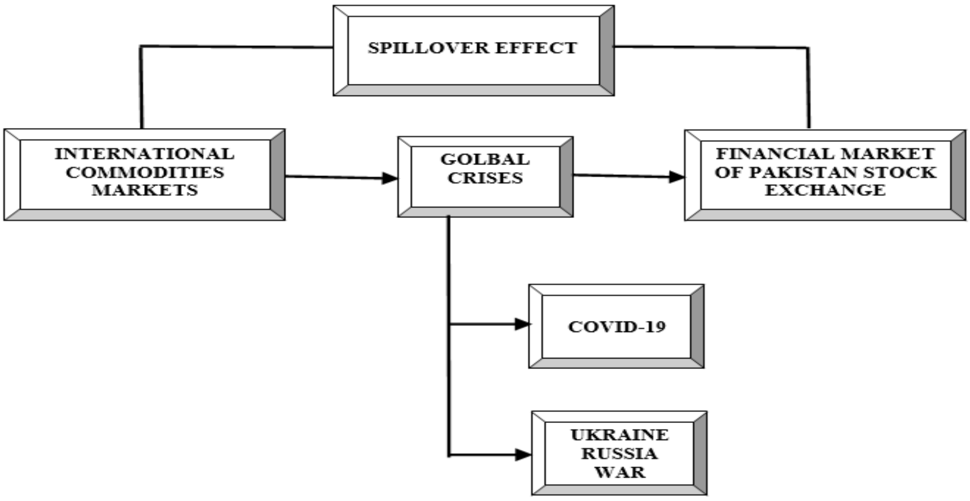
Figure 1.1: Conceptual Framework



Research Methodology

Depending on the nature of the study, quantitative approach is employed in the study, to analyze the spillover effect amongst international commodities markets (gold, oil, and agricultural products) and Pakistan's stock exchange financial market, during global crises. Time-series data of the stock indices and commodity prices is collected from Datastream and analyzed using the DCC model of GARCH. It is used by different researchers including (Basher & Sadorsky, 2016; Baur & Lucey, 2010; Büyükkara et al., 2020; Uddin et al., 2013).

Size of Sample

The size of the sample for the study is composed of a daily dataset about the financial market of Pakistan's stock exchange and international commodities markets (oil, gold, and agricultural products), from January 2018 to June 2024. Furthermore, agriculture products that are selected in this study are soybean oil, wheat, corn and rice. Wheat, corn and rice are globally the most used staple crops, providing food to billions of peoples around world and most widely consumed in Pakistan (Asma et al., 2023; Sendhil et al., 2023; Shahzad et al., 2022; Yaheliuk et al., 2024).

Soybean is not a staple food but it is very important for the production of oil and for feeding in livestock and act as potential source of food and health benefits (Islam et al., 2022). Soybean oil is a key player in food security globally (Dilawari et al., 2022). Keeping in view the importance and consumption levels of these crops and products worldwide, these are selected from the agriculture sector of international commodity market. Prices of these agricultural products have significant effects on the economies worldwide including Pakistan importing a significant fraction of its food (Shaheen et al., 2022). The sample for this study is composed of daily data from December, 2019 to June 2024. The study is divided in to two different sample periods, COVID-19 period and Russia Ukraine war periods in line with previous studies such as (Younis et al., 2024; Zhang et al., 2023). Total observations for each variable in the study, are 559 for COVID-19 Period from 02-12-2019 to 31-01-2022 and 622 for Russia and Ukraine War Period from 21-02-2022 to 28-06-2024

Data Collection

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Secondary daily timeseries data is used in the study collected from the reliable international source as given below. Daily data regarding MSCI PAK and Pakistan Financial Stock Market and daily data for oil, gold, and selected agricultural products (soybean oil, wheat, corn and rice) is collected from Datastream an international database.

Analytical Techniques

In order to check the stationarity of the data series Augmented Dickey-Fuller (ADF) test is used and fit univariate GARCH models to each series to model volatility. To estimate the spillovers effects between the international commodities markets and financial market of Pakistan Stock Exchange, DCC model is used. This model is widely used by different researchers, in their research studies to examine the spillover effects between different assets and markets (Joyo & Lefen, 2019; Mishra, 2019; Sajeev & Afjal, 2022) etc. The models are further discussed below in detail

DCC-GARCH Model

The DCC GARCH model was developed by (Engle, 2002). According to Sadiq et al. (2022) and (Lang et al., 2021) researchers preferred the Engle DCC-GARCH model for its computational advantages. Therefore, DCC GARCH Model is used in the current study to check the volatility spillovers between international commodities markets and financial markets of Pakistan Stock Exchange. This model has been widely used by different researchers to analyze the spillover effects between various financial assets and markets, such as research studies of (Basher & Sadorsky, 2016; Baur & Lucey, 2010; Büyükkara et al., 2020; Uddin et al., 2013) etc.

Engle (2002) developed DCC-GARCH model may be insufficient for heavy tailed distribution because it assumes gaussian distribution. For heavy tailed data a DCC GARCH model was developed by (Pesaran & Pesaran, 2010) that assumes t-distribution of multivariate. (Jaffar et al., 2018; Najeeb et al., 2015).

Equation (1) shows the general form of DCC GARCH model.

$$H_t = D_t R_t D_t \qquad (1)$$

H_t denotes the matrix of conditional variance and D_t containing conditional variance $\sqrt{h_{it}}$, at its diagonals is a k x k diagonal matrix. R_t is off diagonal elements of matrix that represents the time varying effects. Using GARCH (X, Y) a univariate model for assets the conditional variance (h_{it}) are estimated as given in equation (2).

$$h_{it} = \omega_i + \sum_{x=1}^{X_i} \alpha_{ix} r_{it-x}^2 + \sum_{y=1}^{Y_i} \beta_{iy} h_{it-y,} \qquad \text{i varies from 1 to k} \qquad (2)$$

ω_i, α_{ix}, β_{iy} will be non-negative and $\sum_{x=1}^{X_i} \alpha_{ix} + \sum_{y=1}^{Y_i} \beta_{iy} < 1$; α_{ix} shows the persistence of shocks in return in the short run. Y shows persistence of shocks in returns in the long run which are the GARCH effects. k shows the number of assets. Additionally, we obtain the standard deviation ($\sqrt{h_{it}}$) and the residuals(ε_t). The D_t, diagonal matrix shows the conditional standard deviation The conditional standard deviation is shown where D_t, on its diagonal contain the elements $\sqrt{h_{it}}$) as shown below in equation (3).

elements on its diagonals as shown in Equation (3).

$$D_t = \begin{bmatrix} \sqrt{h_{11,t}}0 & 0 & \cdots & 0 \\ 0 & \sqrt{h_{22,t}} & \cdots & 0 \\ \vdots & \vdots & \vdots & 0 \\ 0 & 0 & \cdots & \sqrt{h_{33,t}} \end{bmatrix} \quad (3)$$

The standardized residuals ($\sigma_{it} = {}^{\varepsilon_{it}}\!/\!\sqrt{h_{it}}$) are further used for estimating time-varying (dynamic) correlation matrix R_t(Lim & Masih, 2017).

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (4)$$

$$Q_t^* = \begin{bmatrix} \sqrt{q_{11}}0 & 0 & \cdots & 0 \\ 0 & \sqrt{q_{22}} & \cdots & 0 \\ \vdots & \vdots & \vdots & 0 \\ 0 & 0 & \cdots & \sqrt{q_{kk}} \end{bmatrix} \quad (5)$$

where Q_t^* is a diagonal matrix consisting of its diagonal elements as shown below in equation (5). $\mathcal{Q}_t$ is a symmetric and positive definitive conditional.
covariance matrix $\mathcal{Q}_t = (q_{ij,t})$, and $\overline{Q}$ represents the unconditional covariance of the standardized residual from univariate GARCH model.
unconditional covariance of the standardized residual of univariate GARCH model.

$$\mathcal{Q}_t = (1 - a - b)\overline{Q} + a\varepsilon_{t-1} - 1\varepsilon'_{t-1} + b\mathcal{Q}_{t-1} \quad (6)$$

The conditional correlation $\rho_{ij,t} = \frac{q_{i,j,t}}{\sqrt{q_{i,j,t} q_{i,j,t}}}$ can be expressed in typical correlation form by putting $\mathcal{Q}_t = (q_{ij,t})$ as follows:

$$\rho_{ij,t} = \frac{(1 - a - b)\overline{Q} + a\varepsilon_{t-1} - 1\varepsilon'_{t-1} + b\mathcal{Q}_{t-1}}{\sqrt{(1 - a - b)\overline{Q} + a\varepsilon_{t-1} - 1\varepsilon'_{t-1} + b\mathcal{Q}_{t-1}}\sqrt{(1 - a - b)\overline{Q} + a\varepsilon_{t-1} - 1\varepsilon'_{t-1} + b\mathcal{Q}_{t-}}} \quad (7)$$

In contrast the t-DCC GARCH model of Pesaran and Pesaran (2010) utilizes the devolatised returns $r_{i,t-1} = \frac{r_{it}}{\sigma_{i,t-1}^{realized}}$ and simultaneously estimates the correlation model against DCC-GARCH model, which utilized the standardized returns $r_{it-1} = \frac{r_{it}}{\sigma_{i,t-1}}$ and estimates the model in two steps. The conditional correlation parameters can be estimated by using the GARCH (1,1) model for conditional volatility $\sigma_{i,t-1}^2$ as shown in equation (8) which may be utilized in the correlation matrix to determine the conditional correlations.

$$V(r_{it}|\Omega_{t-1}) = \sigma_{i,t-1}^2 = \overline{\sigma_i^2}(1 - \lambda_{1i} - \lambda_{2i}) + \lambda_{1i}\sigma_{i,t-2}^2 + \lambda_{2i} r_{i,t-1}^2 \quad (8)$$

Here, $\overline{\sigma}_t^2$shows the unconditional variance of assets returns. λ_{1i}, and λ_{2i} represents the parameters of volatility that are specific for as asset. (1 $-\lambda_{1i}-$ λ_{2i}) indicates the restriction to test if the volatility is mean reverting. If the term (1 $-\lambda_{1i}$ $-$ λ_{2i}) is equal to zero and in this situation the model represents the integrated GARCH (IGARCH) process.

Reasons and Justification for Using DCC GARCH Model

The DCC-GARCH model is a powerful econometric tool widely adopted in empirical finance for capturing time-varying correlations across multiple financial time series. One of its primary advantages is computational efficiency, as it requires a constant number of parameters regardless of the number of assets, making it scalable for high-dimensional systems (Salem et al., 2024), Unlike fully parameterized models like BEKK or VECH, DCC-GARCH decouples the estimation of variances and correlations, reducing computational burden (Mishra, 2019). This study employs the DCC-GARCH model to analyze co-movements and volatility spillovers between the Pakistan Stock Exchange (PSX) and global commodities (e.g., oil, gold, soybean oil, wheat, rice) during periods of global disruption. The model is particularly suitable for such analysis due to its precision in estimating dynamic correlations and volatility interdependencies. Studies such as Ji et al. (2022) confirm the model's usefulness in modeling complex inter-asset relationships under volatile market conditions. Additionally, Pesaran and Pesaran (2010) introduce the t-DCC variant to account for asymmetric responses, highlighting the model's adaptability. While this study employs the standard DCC model, its potential extension to asymmetric forms provides flexibility for future research. (Sajeev & Afjal, 2022). also emphasize its accuracy in approximating large covariance matrices, further validating its robustness. DCC-GARCH model achieves superior results compared to other models (Tuominen, 2024).

Assumptions of DCC GARCH Model

Model identification begins with testing for stationarity to ensure the time series has a consistent distribution over time, which is essential for reliable forecasting. Time series plots and unit root tests, particularly the Augmented Dickey–Fuller (ADF) test, are used to assess stationarity. If a series is non-stationary, differencing is applied until it becomes stationary, and the order of differencing (d) is noted. The adequacy of the selected AR or MA model is further evaluated through tests for autocorrelation and heteroskedasticity. While heteroskedasticity is tolerated in this phase due to the subsequent use of GARCH models, the Ljung–Box test is applied to detect residual autocorrelation and assess the model's fit. Before applying GARCH, it is necessary to confirm the presence of ARCH effects, as they indicate volatility clustering, a typical feature of financial time series.

The ARCH model measures the conditional variance as a function of past squared residuals, and the GARCH model extends it by incorporating past variances, allowing for more flexible and realistic modeling of volatility. Engle's ARCH LM test is used to confirm the significance of ARCH effects. In multivariate models like DCC-GARCH, perfect multicollinearity must be avoided, as it causes identification issues and unstable correlations. In cases of near-identical series, one may be excluded or transformed to prevent redundancy. The DCC-GARCH model must also produce a valid positive definite covariance matrix to ensure meaningful dynamic correlations, which may require regularization in high-dimensional systems. GARCH models, especially the common GARCH(1,1), are preferred over ARCH due to their efficiency and better volatility forecasting, as they handle the slow decay of volatility and require fewer parameters.

Granger Causality Test

The Granger causality test examines the causality between time series and identifies the correlation patterns. It measures the ability of one time series to predict the other time series. Generally, given time series X and Y, X is said to Granger-cause Y if Y can yield better predictions using the historical values of both

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X and Y than Y. The Granger causality test is often performed by fitting the time series with the vector autoregressive model (VAR) and identifying the optimal lag to be used.

Data Analysis and Discussion

Descriptive Statistics

Table 4.1 reports summary statistics for the MSCI Pakistan Index (MSCI_PAK), the Pakistan Financial Sector Index (PAK_FINSEC), and key commodities including gold, oil (WTI), soybean oil, wheat, corn, and rice. MSCI_PAK has a negative mean return (-0.0189), while gold (0.03913) and soybean oil (0.031101) show positive average returns. WTI Oil demonstrates the most extreme fluctuations, with a maximum return of 37.66 and a minimum of -305.97. Standard deviations reflect risk, with WTI Oil (8.66) and wheat (2.15) being the most volatile. Skewness values reveal asymmetry, with WTI Oil (-28.05) and rice (-5.40) heavily left-skewed. High kurtosis in WTI Oil (955.32) and other series suggests the presence of extreme values and non-normal distributions.

The Jarque-Bera test results (p = 0.00 for all) confirm that none of the series follow a normal distribution. Stationarity tests (ERS) indicate that most variables are stationary, except PAK_FINSEC and rice. Autocorrelation results from the Q(10) test reveal significant serial dependence in several assets, particularly MSCI_PAK and WTI Oil. The Q2(10) test confirms heteroskedasticity, showing evidence of volatility clustering. Overall, the data highlight significant risks, asymmetries, and dependencies in return behaviors—important considerations for financial modeling, volatility forecasting, and market risk analysis.

Table 4.1: Descriptive Statistics

	MSCI_PAK	PAK_FINSEC	GOLD	WTI_OIL	US_SOYBEAN_OIL	US_WHEAT	CORN	RICE
Mean	-0.0189	0.029877	0.03913	-0.15895	0.031101	0.037495	0.023645	0.027013
Median	-0.06181	0.00	0.048611	0.205773	0.031472	-0.0478	0.00	0.038975
Maximum	6.592644	8.049632	5.760794	37.66234	12.07909	21.7761	7.958163	6.376812
Minimum	-13.2015	-7.62977	-5.02782	-305.966	-9.31256	-10.6823	-17.3865	-25.2433
Std. Dev.	1.475185	1.184392	0.94145	8.662866	1.754043	2.148421	1.724705	1.441803
Skewness	-0.68265	-0.10759	-0.17111	-28.0531	0.040428	0.791973	-1.27388	-5.4027
Kurtosis	9.532052	9.25524	7.17822	955.32	6.187757	10.70003	17.51209	86.45005
Jarque-Bera	3109.801	2735.674	1227.296	63552609	710.0885	4315.652	15160.24	494466.7

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Probability	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***	0.00***
ERS	-4.072***	-4.039***	-17.490***	-16.458***	-12.838***	-19.837***	-18.955***	-9.007**
Q(10)	18.686***	58.257***	15.789***	187.263***	16.271***	9.801*	6.676	7.516
Q2(10)	111.053***	419.613***	147.672***	48.194***	174.376***	418.118***	56.324***	0.081
Sum	-31.6759	50.07378	65.58104	-266.396	52.12567	62.84111	39.62867	45.27434
Sum Sq. Dev.	3645.085	2349.664	1484.599	125700.8	5153.416	7731.321	4982.468	3481.985
Observations	1676	1676	1676	1676	1676	1676	1676	1676

Covariance Statistics

Table 4.2 covariance matrix illustrates the degree of linear dependence between various financial assets, including the MSCI Pakistan index (MSCI_PAK), the Pakistani financial sector (PAK_FIN_SEC), commodities like gold (GOLD), WTI oil (WTI_OIL_), US soybean oil (US_SOYBEAN_OIL), US wheat (US_WHEAT), corn (CORN), and rice (RICE). The diagonal values (e.g., 2.174872 for MSCI_PAK) represent the variance of each asset, indicating how much the asset's values deviate from its mean. For instance, WTI oil has the largest variance (75.00047), signifying it experiences the highest volatility in this group of assets. The off-diagonal values represent the covariance between pairs of assets. For example, the covariance between MSCI_PAK and WTI_OIL_ is -0.58894, indicating an inverse relationship, where increases in MSCI_PAK tend to be associated with decreases in WTI oil prices, and vice versa.

Table 4.2 also shows the relationships among commodities. For instance, gold and WTI oil have a covariance of 0.691681, suggesting that they tend to move in the same direction, likely driven by common global factors such as inflation or economic uncertainty. On the other hand, US soybean oil and WTI oil have a negative covariance (-0.18436), indicating that when one tends to rise, the other tends to fall, though the relationship is weak. The covariance between US wheat and corn (0.503778) is positive, suggesting that these agricultural commodities move in a similar direction, potentially influenced by factors like weather conditions or crop prices. In contrast, rice exhibits weak covariance with other assets, suggesting that its price movements are less influenced by the same factors affecting the other commodities in this table.

Table 4.2: Covariance Statistics

	MSCI_PAK	PAK_FINSEC	GOLD	WTI_OIL	US_SOYBEAN_OIL	US_WHEAT	CORN	RICE

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MSCI_PAK	2.174872	0.063763	-0.07149	-0.58894	-0.1382	-0.06339	0.091121	0.019182
PAK_FIN SEC	0.063763	1.401948	-0.01158	0.643181	-0.01352	0.031571	0.0087	-0.02967
GOLD	-0.07149	-0.01158	0.885799	0.691681	0.028836	-0.01898	-0.04077	-0.04887
WTI_OIL	-0.58894	0.643181	0.691681	75.00047	-0.18436	0.125685	0.419648	0.049905
US_SOYBEAN_OIL	-0.1382	-0.01352	0.028836	-0.18436	3.07483	-0.05454	0.037511	0.000469
US_WHEAT	-0.06339	0.031571	-0.01898	0.125685	-0.05454	4.61296	0.503778	0.036463
CORN	0.091121	0.0087	-0.04077	0.419648	0.037511	0.503778	2.972833	0.064227
RICE	0.019182	-0.02967	-0.04887	0.049905	0.000469	0.036463	0.064227	2.077557

Correlations Statistics
Table 4.3 presents the correlation statistics between various financial assets, including the MSCI Pakistan index (MSCI_PAK), the Pakistani financial sector (PAK_FIN_SEC), and several commodities such as gold (GOLD), WTI oil (WTI_OIL_), US soybean oil (US_SOYBEAN_OIL), US wheat (US_WHEAT), corn (CORN), and rice (RICE). The values in the table range from -1 to 1, indicating the strength and direction of linear relationships between the pairs. The correlation between MSCI_PAK and PAK_FIN_SEC is very weak (0.036516), showing almost no relationship. Similarly, MSCI_PAK exhibits weak negative correlations with gold (-0.0515) and WTI oil (-0.04611), suggesting minimal interdependence between these markets. The correlations involving MSCI_PAK and agricultural commodities (e.g., US soybean oil, wheat, corn, and rice) are also weak, with values near zero, indicating limited co-movement with the stock index. This also highlights the correlations among commodities. For instance, WTI oil and gold show a positive but weak correlation (0.084861), implying they have some tendency to move together, though the relationship is not strong. US wheat and corn have a more noticeable positive correlation (0.136039), indicating they may be influenced by similar factors, such as crop conditions or agricultural policy. In contrast, rice shows weak correlations with other assets, reflecting a minimal relationship with both financial markets and other agricultural commodities. Overall, the correlations in this table suggest that these assets largely operate independently from one another, with few significant relationships, especially between the financial and commodity markets.

Table 4.3: Correlations Statistics

	MSCI_PAK	PAK_FINSEC	GOLD	WTI_OIL	US_SOYBEAN_OIL	US_WHEAT	CORN	RICE
MSCI_PAK	1							
PAK_FINSEC	0.036516	1						
GOLD	-0.0515	-0.01039	1					
WTI_OIL	-0.04611	0.062724	0.084861	1				
US_SOYBEAN_OIL	-0.05344	-0.00651	0.017473	-0.01214	1			
US_WHEAT	-0.02001	0.012414	-0.00939	0.006757	-0.01448	1		
CORN	0.035836	0.004262	-0.02512	0.028104	0.012407	0.136039	1	
RICE	0.009024	-0.01738	-0.03602	0.003998	0.000185	0.011778	0.025844	1

Price Movements of Financial Indices and Commodities Markets

Figure 4.1 is set of time series plots depicts the price movements of various financial indices and commodity markets from 2018 to 2024. The MSCI Pakistan index (top-left) shows significant fluctuations over the years, with a noticeable decline during 2020, likely due to the COVID-19 pandemic, followed by a gradual recovery after 2022. Similarly, the Pakistani financial sector index (PAK-FIN-SEC) exhibits a downward trend from 2018 to 2021, reflecting a period of financial instability, before rebounding sharply in 2023 and 2024, suggesting improved market conditions. Gold prices (top-right) exhibit a clear upward trajectory over the six-year period, with sharp increases during periods of global uncertainty, such as the pandemic and geopolitical tensions, underscoring its role as a safe-haven asset.

Among commodities, WTI oil prices (middle-left) display notable volatility, with a dramatic dip in 2020 corresponding to the oil price crash during COVID-19, followed by a sharp rebound and relative stability in later years. Agricultural commodities, including US soybean oil, wheat, corn, and rice, show varied trends. US soybean oil prices spiked significantly in 2021 and 2022, likely due to supply chain disruptions, before stabilizing in 2024. US wheat prices also experienced a sharp rise during the same period, with a noticeable peak in 2022, potentially driven by the Russia-Ukraine conflict, which disrupted global grain supplies. Corn and rice prices show moderate upward trends with periods of volatility, reflecting fluctuations in global agricultural markets influenced by factors like climate change and trade policies. Overall, these time series highlight the distinct

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dynamics of financial indices and commodities during global crises and economic recoveries.

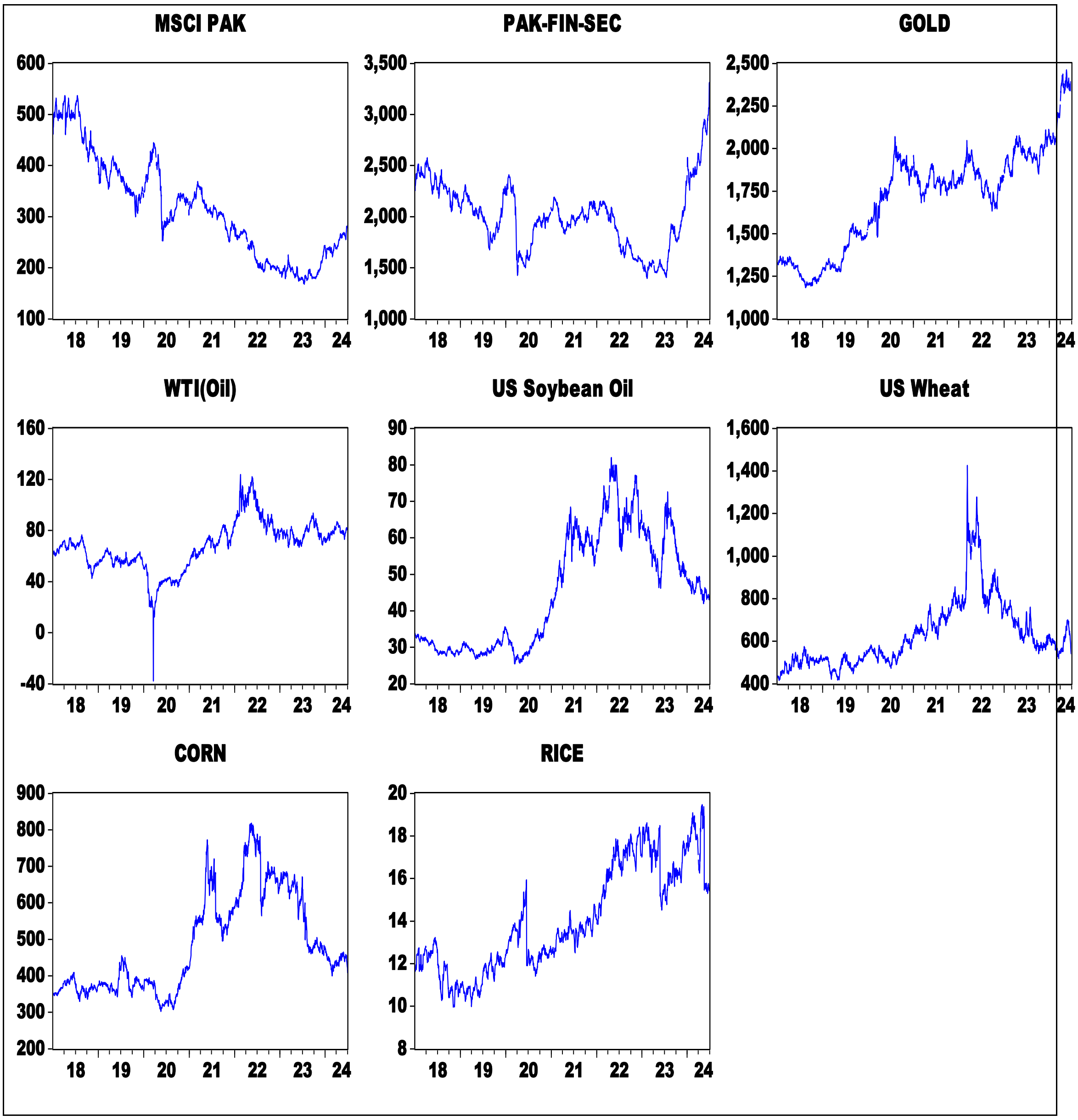

Figure 4.1Time Series Graphs of the Selected Market

Markets Volatility and Dynamics

Figure 4.2 and 4.3 **are** sets of return series plots highlights the volatility and dynamics of daily returns for various financial indices and commodity markets from 2018 to 2024. The MSCI Pakistan and PAK-FIN-SEC indices show moderate fluctuations, with a few notable spikes in returns, reflecting sudden market shocks or events impacting the Pakistani equity markets. Gold returns demonstrate relatively consistent fluctuations over time, with higher volatility during periods of global uncertainty, such as the COVID-19 pandemic in 2020, underscoring its role as a safe-haven asset.

WTI oil returns display extreme volatility, particularly a massive negative spike in 2020, corresponding to the historic crash in oil prices during the early stages of the pandemic. Agricultural commodities such as US soybean oil, wheat, corn, and

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rice exhibit varied return patterns. US soybean oil and wheat returns show higher volatility in 2021 and 2022, likely due to supply chain disruptions and geopolitical tensions, including the Russia-Ukraine conflict. Corn and rice returns exhibit smaller but frequent spikes, indicating sensitivity to global agricultural conditions and market fluctuations. Overall, these return series underscore the varying risk and return profiles of different markets, shaped by global crises and regional economic events.

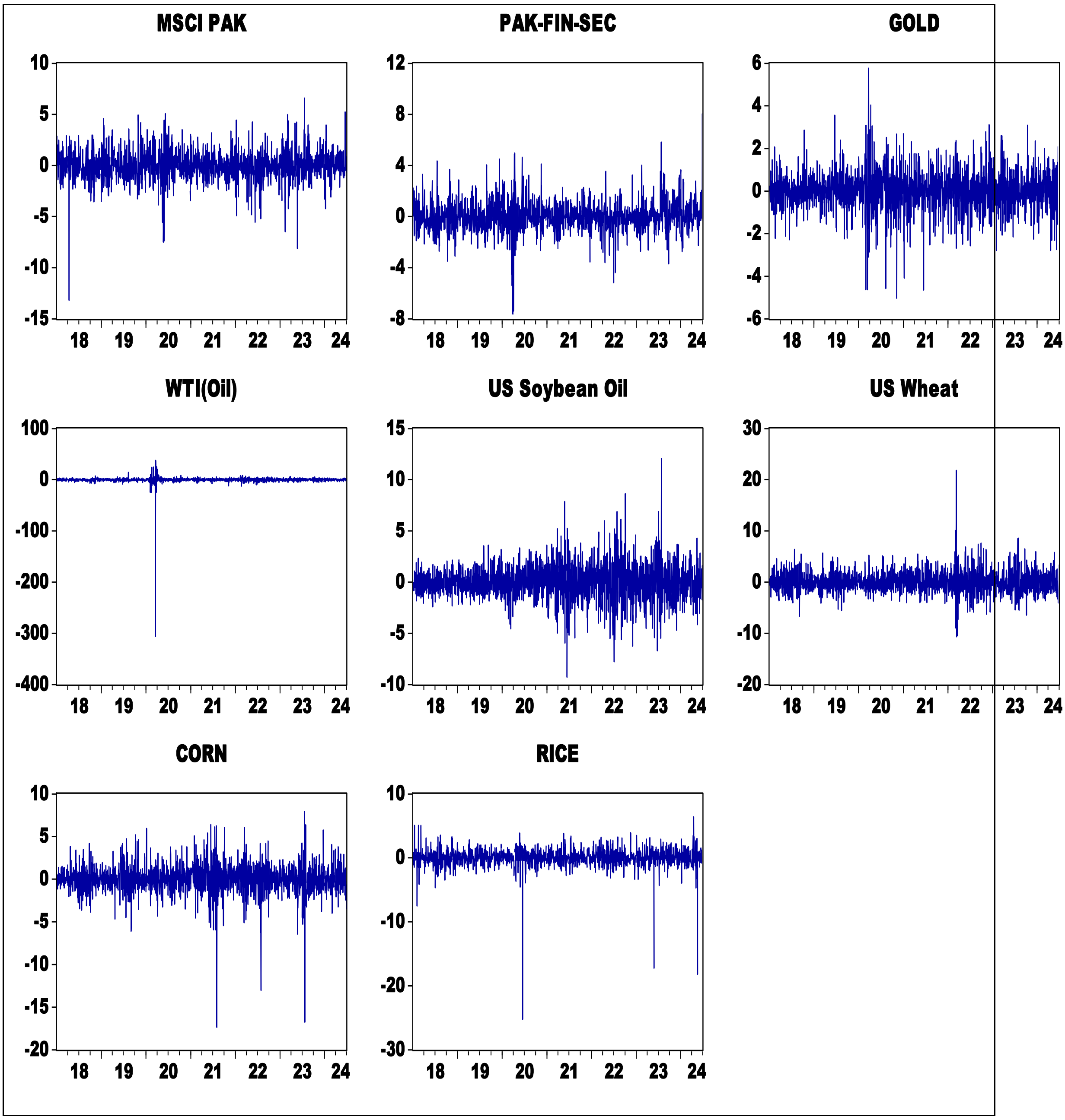

Figure 4.2: Return Series Graphs of the Selected Markets.

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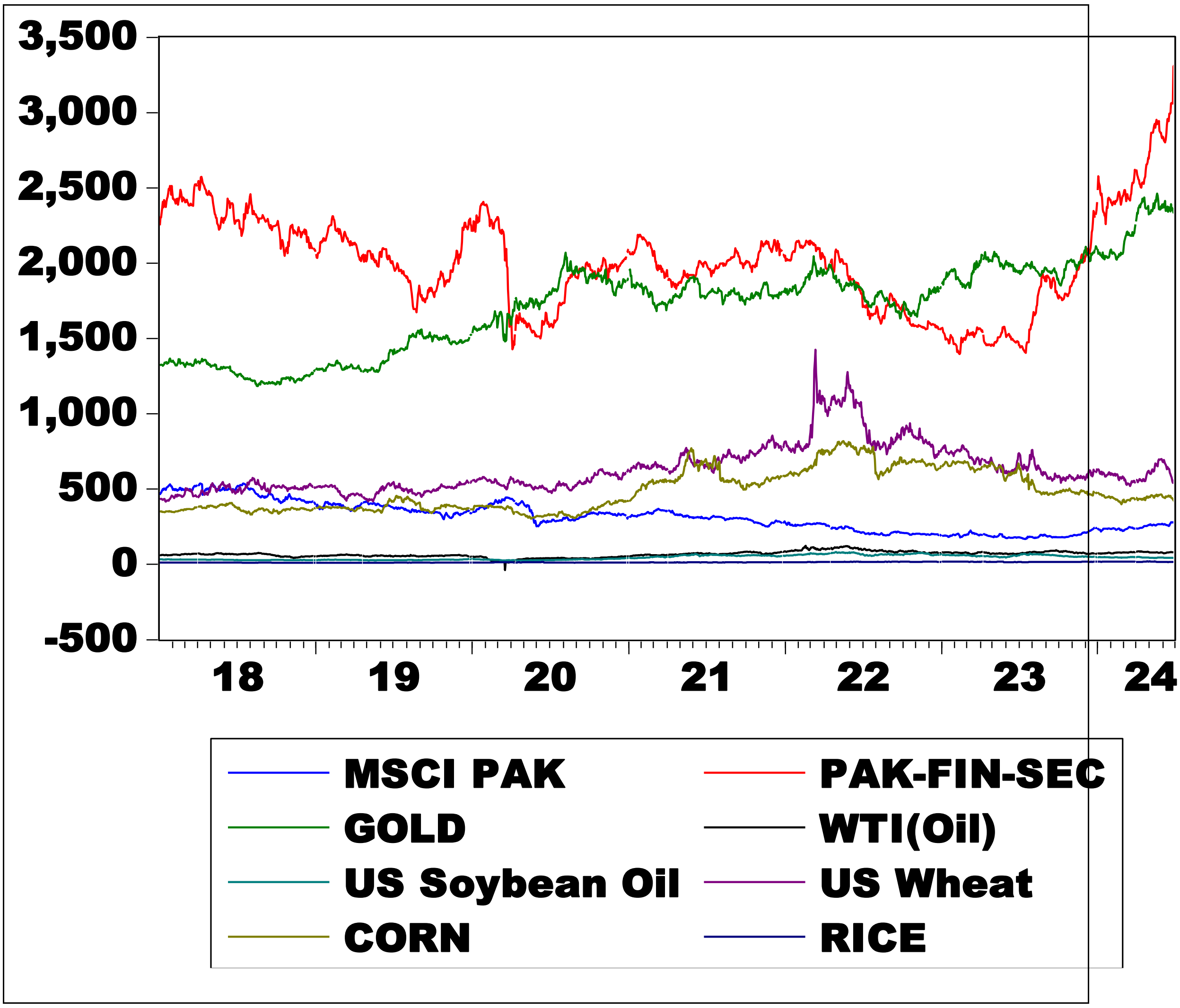

Figure 4.3: Time Series Stake Single Graphs of the Selected Markets

Spillovers Risk Volatility DCC-GARCH COVID-19 Period
Pakistan MSCI Stock with International Commodities Markets
Table 4.4 shows ARMA-GARCH model results examining dynamic relationships between MSCI Pakistan Index (MSCI_PAK), Gold, Oil (WTI), and agricultural commodities. The MSCI_PAK-Gold correlation is negative and statistically significant (rho = -0.0886, t-value = -2.216, p-value = 0.0271). GARCH parameters for MSCI_PAK show ARCH(Alpha1) = 0.172566 and GARCH(Beta1) = 0.739426, both highly significant. Gold exhibits AR(1) = -0.923581 and MA(1) = 0.951661, with ARCH(Alpha1) = 0.116006 and GARCH(Beta1) = 0.78177, indicating strong mean reversion and volatility persistence. WTI Oil shows significant AR(1) and MA(1) terms (p-value < 0.0001), but lower volatility persistence with GARCH(Beta1) = 0.042041; its log-likelihood = -1542.429, indicating good model fit. For Soybean Oil, volatility persistence is strong with GARCH(Beta1) = 0.878057; MSCI_PAK variance equation shows ARCH = 0.176244 and GARCH = 0.73503. The MSCI_PAK-Soybean Oil correlation is weak (rho = -0.087005, p-value = 0.1458). Wheat shows GARCH(Beta1) = 0.913556 and MSCI_PAK-Wheat correlation is weakly positive (rho = 0.014976, p-value = 0.7483). Corn has ARCH = 0.173949, GARCH = 0.741083, and Rice shows ARCH

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= 0.168256, GARCH = 0.698544. MSCI_PAK-Rice correlation is rho = -0.020053 (insignificant). In summary, strong volatility persistence exists across all commodities, with only Gold showing a significant negative correlation with MSCI_PAK (rho = -0.087526).

Table 4.4: DCC-GARCH [COVID PERIOD (MSCI PAK)]

The estimation sample period is: 02-12-2019 to 31-01-2022				
Mean Equation: ARMA (1, 1) model and Variance Equation: GARCH (1,1) model.				
#1: MSCI PAK and #2: GOLD				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.093069	0.13777	0.6755	0.4996
MA(1)	0.024156	0.13111	0.1842	0.8539
ARCH(Alpha1)	0.172566	0.054000	3.1960	0.0015
GARCH(Beta1)	0.739426	0.087495	8.4510	0.0000
Part: GOLD				
AR(1)	-0.923581	0.026232	-35.210	0.0000
MA(1)	0.951661	0.020534	46.340	0.0000
ARCH(Alpha1)	0.116006	0.056342	2.0590	0.0400
GARCH(Beta1) rho_21	0.78177 -0.0886	0.072165 0.039988	10.830 -2.2160	0.0000 0.0271
No. Observations: 559 Kurtosis (Y): 7.75155	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.04159 -825.501	Variance (Y): 1.2809 Alpha[1]+Beta[1]:	Skewness (Y): -0.30707 0.89954
#1: MSCI PAK and #2: WTI(Oil)				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.098111	0.13811	0.7104	0.4778
MA(1)	0.014575	0.13196	0.1104	0.9121
ARCH(Alpha1)	0.173012	0.051786	3.3410	0.0009
GARCH(Beta1)	0.74124	0.081569	9.0870	0.0000
Part: WTI(Oil)				
AR(1)	0.277551	0.054976	5.0490	0.0000
MA(1)	-0.69119	0.023928	-28.890	0.0000
ARCH(Alpha1)	3.562676	1.9169	1.8590	0.0636
GARCH(Beta1)	0.042041	0.036369	1.1560	0.2482
rho_21	-0.033723	0.043918	-0.7679	0.4429
No. Observations: 559 Kurtosis (Y):8.58803	No. Parameters: 9 Log Likelihood:	Mean (Y): -0.51056 -1542.429	Variance (Y):4.47313 Alpha[1]+Beta):	Skewness (Y): -17.32162 3.61167
#1: MSCI PAK and #2: US SOYBEAN OIL				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.087613	0.139	0.6303	0.5288

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MA(1)	0.015147	0.13339	0.1136	0.9096
ARCH(Alpha1)	0.176244	0.054288	3.2460	0.0012
GARCH(Beta1)	0.73503	0.08499	8.6480	0.0000
Part: US SOYBEAN OIL				
AR(1)	0.277835	0.22655	1.2260	0.2206
MA(1)	-0.237543	0.24694	-0.9619	0.3365
ARCH(Alpha1)	0.085115	0.047037	1.8100	0.0709
GARCH(Beta1) rho_21	0.878057 -0.087005	0.084871 0.059724	10.350 -1.4570	0.0000 0.1458
No. Observations: 559 Kurtosis (Y): 0.96098	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.1493 -1086.402	Variance (Y): 3.20989 Alpha[1]+Beta[1]:	Skewness (Y): -0.42807 5.07077
#1: MSCI PAK and #2: US WHEAT				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.101263	0.13862	0.7305	0.4654
MA(1)	0.013315	0.13333	0.0999	0.9205
ARCH(Alpha1)	0.171768	0.051948	3.3070	0.0010
GARCH(Beta1)	0.745615	0.081909	9.1030	0.0000
Part: US Wheat				
AR(1)	-0.103731	0.066458	-1.5610	0.1191
MA(1)	0.078182	0.065642	1.1910	0.2342
ARCH(Alpha1)	0.040091	0.020902	1.9180	0.0556
GARCH(Beta1) rho_21	0.913556 0.014976	0.042974 0.046654	21.260 0.3210	0.0000 0.7483
No. Observations: 559 Kurtosis (Y): 3.34311	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.08947 -1083.3	Variance (Y): 2.88788 Alpha[1]+Beta[1]	Skewness (Y): 0.41552 0.95358
#1: MSCI PAK and #2: CORN				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.103645	0.14077	0.7363	0.4619
MA(1)	0.01054	0.13431	0.0785	0.9375
ARCH(Alpha1)	0.173949	0.052304	3.3260	0.0009
GARCH(Beta1)	0.741083	0.08198	9.0400	0.0000
Part: CORN				
AR(1)	-0.481507	0.26073	-1.8470	0.0653
MA(1)	0.470112	0.28075	1.6740	0.0946
ARCH(Alpha1)	0.126851	0.060031	2.1130	0.0350
GARCH(Beta1) rho_21	0.840953 -0.014977	0.069359 0.03763	12.120 -0.3980	0.0000 0.6908
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.1016	Variance (Y): 3.32263	Skewness (Y): -1.45469

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Kurtosis (Y): 8.82164	Log Likelihood:	-1075.891	Alpha[1]+Beta[1]	0.96754
#1: MSCI PAK and #2: RICE				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.101935	0.13915	0.7251	0.4687
MA(1)	0.012128	0.13263	0.0990	0.8213
ARCH(Alpha1)	0.163679	0.052206	3.3280	0.0009
GARCH(Beta1)	0.751697	0.081766	9.0710	0.0000
Part: RICE				
AR(1)	0.118497	0.137299	0.8630	0.3889
MA(1)	-0.021974	0.128441	-0.1714	0.8635
ARCH(Alpha1)	0.168256	0.051173	3.2850	0.0010
rho_21	-0.01562	-0.3696	-0.0423	0.9669
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.04944	Variance (Y): 2.20049	Skewness (Y): -8.86759
Kurtosis (Y): 152.33695	Log Likelihood:	-838.22	Alpha[1]+Beta[1]	0.93541
Estimated Parameters vector: 0.057532; 0.899780;-1.016463; 0.124106; 0.241353; 0.694058				

Pakistan Financial Sector with International Commodities Markets

Table 4.5 summarizes the ARMA-GARCH results analyzing the PAK-FIN-SEC index with Gold, WTI, and major agricultural commodities. Across all pairs, correlation (rho_21) values are low and statistically insignificant, including PAK-FIN-SEC with Gold, WTI, Soybean Oil, Wheat, Corn, and Rice (e.g., rho_21 = -0.015181 for Rice). Gold shows strong autoregressive dynamics with AR(1) = -0.924903 and MA(1) = 0.952331, alongside significant volatility persistence (ARCH = 0.116384, GARCH = 0.783256). PAK-FIN-SEC also demonstrates persistent volatility across all models (ARCH up to 0.276033, GARCH up to 0.654025). WTI exhibits AR(1) = 0.276258 and MA(1) = -0.690429 with low GARCH = 0.041367 but significant ARCH = 0.257606. Soybean Oil displays high volatility persistence (GARCH = 0.877766) but insignificant AR(1) = 0.250418 and MA(1) = -0.21097. Wheat shows weak mean dynamics (AR(1) = 0.126288, MA(1) = 0.099232), but long-run volatility persistence (GARCH = 0.913643). Corn demonstrates significant AR(1) = -0.480428, low MA(1) = 0.46883, and strong volatility (ARCH = 0.12986, GARCH = 0.838846) with skewness = -1.45469 and kurtosis = 8.82164. Rice shows strong AR(1) = -0.89978, MA(1) = -1.016463, high GARCH = 0.694058, and extreme skewness = -8.86759, kurtosis = 15.23695. Across all models, PAK-FIN-SEC exhibits strong long-run volatility persistence, reinforcing internal market dynamics. Overall, while correlations are weak, all commodities reveal varying degrees of volatility clustering and persistence, with Rice and Corn showing the most extreme fluctuations.

Table 4.5: DCC-GARCH [COVID PERIOD (PAK-FIN-SEC)]

The estimation sample period is: 02-12-2019 to 31-01-2022
Mean Equation: ARMA (1, 1) Model and Variance Equation: GARCH (1,1) Model.

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#1: PAK-FIN-SEC and #2: GOLD				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.266489	0.27127	0.9824	0.3263
MA(1)	-0.140642	0.27069	-0.5196	0.6036
ARCH(Alpha1)	0.280593	0.083505	3.3600	0.0008
GARCH(Beta1)	0.634789	0.087094	7.2890	0.0000
Part: GOLD				
AR(1)	-0.924903	0.026215	-35.280	0.0000
MA(1)	0.952331	0.021429	44.440	0.0000
ARCH(Alpha1)	0.116384	0.056133	2.0730	0.0386
GARCH(Beta1)	0.783256	0.072513	10.800	0.0000
rho_21	0.006019	0.040464	0.1488	0.8818
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.04159	Variance (Y): 1.2809	Skewness (Y): -0.30707
Kurtosis (Y): 7.75155	Log Likelihood:	-1638.646	Alpha[1]+Beta[1]	0.89954
#1: PAK-FIN-SEC and #2: WTI(Oil)				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.222025	0.28511	0.7787	0.4365
MA(1)	-0.112834	0.28088	-0.4017	0.6881
ARCH(Alpha1)	0.257606	0.080905	3.1840	0.0015
GARCH(Beta1)	0.654025	0.086536	7.5580	0.0000
Part: WTI(Oil)				
AR(1)	0.276258	0.055053	5.0180	0.0000
MA(1)	-0.690429	0.024285	-28.430	0.0000
ARCH(Alpha1)	3.579933	1.9305	1.8540	0.0642
GARCH(Beta1)	0.041367	0.035893	1.1530	0.2496
rho_21	0.022141	0.056049	0.3950	0.6930
No. Observations: 559	No. Parameters: 9	Mean (Y): -0.51056	Variance (Y): 4.47313	Skewness (Y): -17.32162
Kurtosis (Y): 8.58803	Log Likelihood:	-1542.429	Alpha[1]+Beta[1]	3.61167
#1: PAK-FIN-SEC and #2: US SOYBEAN OIL				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.258602	0.29008	0.8915	0.3731
MA(1)	-0.137889	0.28873	-0.4776	0.6332
ARCH(Alpha1)	0.281551	0.083611	3.3670	0.0008
GARCH(Beta1)	0.633713	0.087289	7.2600	0.0000
Part: US Soybean Oil				
AR(1)	0.250418	0.18294	1.3690	0.1716
MA(1)	-0.21097	0.20181	-1.0450	0.2963
ARCH(Alpha1)	0.085519	0.046621	1.8340	0.0672
GARCH(Beta1)	0.877766	0.084227	10.420	0.0000

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rho_21	0.009249	0.046503	0.1989	0.8424
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.1493	Variance (Y): 3.20989	Skewness (Y): -0.42807
Kurtosis (Y): 5.07077	Log Likelihood:	-1086.402	Alpha[1]+Beta[1]	0.96098
Estimated Parameters vector: 0.161012; 0.241079;-0.202770; 0.123473; 0.086682; 0.874298				
#1: PAK-FIN-SEC and #2: US WHEAT				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.266125	0.29172	0.9122	0.3620
MA(1)	-0.144041	0.29157	-0.4940	0.6215
ARCH(Alpha1)	0.276033	0.083705	3.2980	0.0010
GARCH(Beta1)	0.639536	0.088416	7.2330	0.0000
Part: US Wheat				
AR(1)	-0.126288	0.06273	-2.0130	0.0446
MA(1)	0.099232	0.059904	1.6570	0.0982
ARCH(Alpha1)	0.039437	0.020714	1.9040	0.0575
GARCH(Beta1) rho_21	0.913643 -0.016067	0.042447 0.045434	21.520 -0.3536	0.0000 0.7238
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.08947	Variance (Y): 2.88788	Skewness (Y): 0.41552
Kurtosis (Y): 3.34311	Log Likelihood	-1083.3	Alpha[1]+Beta[1]	0.95358
#1: PAK-FIN-SEC and #2: CORN				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.266996	0.27352	0.9762	0.3294
MA(1)	-0.140354	0.27229	-0.5155	0.6064
ARCH(Alpha1)	0.277051	0.082902	3.342	0.0009
GARCH(Beta1)	0.638058	0.086654	7.363	0.0000
Part: CORN				
AR(1)	-0.480428	0.2295	-2.093	0.0368
MA(1)	0.46883	0.24856	1.886	0.0598
ARCH(Alpha1)	0.12986	0.06032	2.153	0.0318
GARCH(Beta1) rho_21	0.837422 -0.010475	0.06893 0.043315	12.15 -0.2418	0.0000 0.8090
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.1016	Variance (Y): 3.32263	Skewness (Y): -1.45469
Kurtosis (Y): 8.82164	Log Likelihood:	-1075.891	Alpha[1]+Beta[1]	0.96754
PAK-FIN-SEC and RICE				
Parameter	Coefficient	Std.Error	t-value	t-prob
Cst(M)	0.057532	0.899	0.0000	0.0000
AR(1)	0.89978	6.715	0.0000	0.0000

MA(1)	-1.016463	-8.365	0.0000	0.0000
Cst(V)	0.124106	3.258	0.0010	0.0010
ARCH(Alpha1)	0.241353	1.895	0.0580	0.0580
GARCH(Beta1)	0.694058	4.946	0.0000	0.0000
rho_21	-0.02005	-0.44310	-0.6578	0.6578
No. Observations: 559	No. Parameters: 9	Mean (Y): 0.04944	Variance (Y): 2.20049	Skewness (Y): -8.86759
Kurtosis (Y): 15.23695	Log Likelihood:	-838.223	Alpha[1]+Beta[1]	0.93541
Estimated Parameters vector: 0.057532; 0.899780; -1.016463; 0.124106; 0.241353; 0.694058				

Spillovers Risk Volatility DCC-GARCH Russia-Ukraine War Period Pakistan MSCI Stock with International Commodities Markets

Table 4.6 reports results from a dynamic ARMA-GARCH model exploring relationships between MSCI Pakistan (MSCI_PAK) and key commodities like Gold, WTI Oil, Soybean Oil, Wheat, Corn, and Rice. The correlation between MSCI_PAK and Gold is weak and statistically insignificant (rho = -0.005633, p = 0.8928). However, volatility persistence is evident, especially in MSCI_PAK (ARCH = 0.084538, GARCH = 0.868662) and Gold (GARCH = 0.934093). WTI Oil also shows strong volatility persistence (GARCH = 0.934093) with weak ARMA dynamics. Soybean Oil demonstrates dominant autoregressive and moving average effects (AR(1) = -0.969115, MA(1) = 0.983168, both $p < 0.01$), with high volatility persistence (Alpha1 + Beta1 = 0.96355). MSCI_PAK consistently shows significant AR(1) coefficients, suggesting strong time dependence in returns. The correlation with Soybean Oil (rho = -0.070718) is weak and insignificant (p = 0.1052), indicating minimal spillover effects.

Table 4.6 further indicates strong ARMA-GARCH behavior in Wheat and Corn. US Wheat has significant AR(1) = -0.507878 and MA(1) = 0.570067, showing strong return dependence and high GARCH-based volatility persistence. The correlation between MSCI_PAK and Wheat is weak and insignificant (rho = -0.066272, p = 0.1873). Corn also shows persistent volatility (ARCH = 0.232723, GARCH = 0.682569), with insignificant correlation to MSCI_PAK (rho = 0.031696). For Rice, AR(1) is insignificant, MA(1) significant, and GARCH terms weak, suggesting low volatility persistence. Finally, across all models, MSCI_PAK consistently exhibits strong volatility clustering (GARCH > 0.86), indicating self-driven market dynamics. Overall, while volatility persistence is high in most markets, return interdependencies between MSCI_PAK and international commodities remain weak and statistically insignificant.

Table 4.6: DCC-GARCH [RUSSIA-UKRAINE WAR PERIOD (MSCI PAK)]

The estimation sample period is: 21-02-2022 to 28-06-2024				
Mean Equation: ARMA (1, 1) model and Variance Equation: GARCH (1,1) model				
#1: MSCI PAK and #2: GOLD				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.353707	0.13435	2.6330	0.0087

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MA(1)	-0.233548	0.12915	-1.8080	0.0710
ARCH(Alpha1)	0.084538	0.040785	2.0730	0.0386
GARCH(Beta1)	0.868662	0.067144	12.940	0.0000
Part: GOLD				
AR(1)	-0.243592	0.17952	-1.3570	0.1753
MA(1)	0.1368	0.18219	0.7509	0.4530
ARCH(Alpha1)	0.022131	0.016017	1.3820	0.1675
GARCH(Beta1)	0.934093	0.05364	17.410	0.0000
rho_21	-0.006022	0.041457	-0.1453	0.8846
No. Observations: 622 Kurtosis (Y): 3.7274	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.04805 -826.566	Variance (Y): 0.85085 Alpha[1]+Beta[1]:	Skewness (Y): -0.06237 0.95618
#1: MSCI PAK and #2: WTI(Oil)				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.356862	0.13259	2.6910	0.0073
MA(1)	-0.235748	0.12687	-1.8580	0.0636
ARCH(Alpha1)	0.08488	0.040582	2.0920	0.0369
GARCH(Beta1)	0.867746	0.066694	13.010	0.0000
Part: WTI(Oil)				
AR(1)	-0.159731	0.13519	-1.1820	0.2379
MA(1)	0.214245	0.12822	1.6710	0.0953
ARCH(Alpha1)	0.06069	0.031055	1.9540	0.0511
GARCH(Beta1) rho_21	0.928096 -0.038128	0.037022 0.043125	25.070 -0.8841	0.0000 0.3770
No. Observations: 622 Kurtosis (Y): 4.79689	No. Parameters: 9 Log Likelihood: '	Mean (Y): 0.01189 -1384.558	Variance (Y); 5.89075 Alpha[1]+Beta[1]:	Skewness (Y): '-0.35788 0.98861
#1: MSCI PAK and #2: US SOYBEAN OIL				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.335824	0.13739	2.4440	0.0148
MA(1)	-0.21311	0.13207	-1.6140	0.1071
ARCH(Alpha1)	0.085367	0.04103	2.0810	0.0379
GARCH(Beta1)	0.86762	0.067653	12.820	0.0000
Part: US Soybean Oil				
AR(1)	-0.9691	0.0240	-40.380	0.0000
MA(1)	0.9832	0.0180	54.620	0.0000
ARCH(Alpha1)	0.0971	0.0638	1.5220	0.1284
GARCH(Beta1) rho_21	0.8675 -0.07072	0.1066 0.04358	8.1420 -1.6230	0.0000 0.1052
No.	No.	Mean (Y): '-	Variance (Y):	Skewness (Y):

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Observations: 622	Parameters: 9	0.03891	4.61719	0.26603
#1: MSCI PAK and #2: US WHEAT				
	Coefficient	Std.Error	t-value	t-prob
Part: MSCI PAK				
AR(1)	0.35381	0.13849	2.5550	0.0109
MA(1)	-0.23351	0.13278	-1.7590	0.0791
ARCH(Alpha1)	0.084658	0.039888	2.1220	0.0342
GARCH(Beta1)	0.868921	0.066308	13.100	0.0000
Part: US Wheat				
AR(1)	-0.507878	0.12919	-3.9310	0.0001
MA(1)	0.570067	0.14955	3.8120	0.0002
ARCH(Alpha1)	0.143505	0.04022	3.5680	0.0004
GARCH(Beta1) rho_21	0.756462 -0.066272	0.057367 0.050205	13.1900 -1.320	0.0000 0.1873
No. Observations: 622	No. Parameters: 9	Mean (Y): '-0.02392	Variance (Y): 7.17831	Skewness (Y): 0.9981
Kurtosis (Y): 10.88257	Log Likelihood:	-1425.077	Alpha[1]+Beta[1]	0.89962
#1: MSCI PAK AND #2: CORN				
Part: MSCI PAK				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.360023	0.13439	2.6790	0.0076
MA(1)	-0.244515	0.12934	-1.8900	0.0592
ARCH(Alpha1)	0.083225	0.040326	2.0640	0.0395
GARCH(Beta1)	0.870226	0.066736	13.040	0.0000
Part: CORN				
AR(1)	-0.545986	0.26181	-2.0850	0.0374
MA(1)	0.531892	0.31217	1.7040	0.0889
ARCH(Alpha1)	0.232723	0.074483	3.1250	0.0019
GARCH(Beta1)	0.682569	0.075221	9.0740	0.0000
rho_21	0.031696	0.046853	0.6765	0.499
No. Observations: 622	No. Parameters: 9	Mean (Y): '-0.04390	Variance (Y): 3.52364	Skewness (Y): '-1.48534
Kurtosis (Y): 17.25497	Log Likelihood:	-1181.777	Alpha[1]+Beta[1]:	0.91581
#1: MSCI PAK and #2: RICE				
Part: MSCI PAK				
AR(1)	0.347227	0.13778	2.5200	0.0120
MA(1)	-0.229798	0.13208	-1.7400	0.0824
ARCH(Alpha1)	0.084017	0.040648	2.0670	0.0392
GARCH(Beta1)	0.869112	0.06691	12.990	0.0000
Part: RICE				
AR(1)	-0.032858	0.13448	-0.2443	0.8070
MA(1)	0.354214	0.05916	5.9870	0.0000
ARCH(Alpha1)	1.077473	0.67273	1.6020	0.1098

GARCH(Beta1) rho_21	-0.028006 0.027457	0.054822 0.035607	-0.5108 0.7711	0.6096 0.4409
No. Observations: 622 Kurtosis (Y): 54.73513	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.01963 -1116.193	Variance (Y): 2.45883 Alpha[1]+Beta[1]:	Skewness (Y): '-4.48231 1.04992

Pakistan Financial Sector with International Commodities Markets
The ARMA-GARCH model results across various pairings of the PAK-FIN-SEC index with commodities such as Gold, WTI Oil, US Soybean Oil, US Wheat, Corn, and Rice reveal weak and statistically insignificant correlations (e.g., rho_21 = -0.000437 for PAK-FIN-SEC and Gold, and rho_21 = -0.006282 for PAK-FIN-SEC and WTI Oil), indicating limited co-movement between Pakistan's financial sector and international commodities. However, PAK-FIN-SEC consistently shows high volatility persistence, with GARCH (Beta1) values such as 0.877926 (vs. Gold), 0.878102 (vs. WTI), 0.878035 (vs. Corn), and 0.87809 (vs. Wheat), all highly significant, highlighting lasting effects of market shocks. WTI Oil also exhibits strong volatility clustering with GARCH(Beta1) = 0.926737 and a low ARCH(Alpha1) = 0.061885. Gold shows similar behavior, with GARCH(Beta1) = 0.933773, while both series have insignificant AR(1) and MA(1) terms (e.g., WTI AR(1) = -0.153664, MA(1) = 0.21064). US Soybean Oil presents distinct dynamics with a highly significant AR(1) = -0.967476 and MA(1) = 0.981725, indicating strong mean reversion. Its GARCH(Beta1) = 0.865377 confirms high volatility persistence.
US Wheat demonstrates significant mean equation coefficients (AR(1) = -0.507856, MA(1) = 0.569919) and volatility persistence with GARCH(Beta1) = 0.756489 and ARCH(Alpha1) = 0.14325. Corn also shows high volatility persistence (GARCH(Beta1) = 0.684103) and strong short-term shock responsiveness (ARCH(Alpha1) = 0.231744), with mean dynamics AR(1) = -0.539364 and MA(1) = 0.525101 being statistically insignificant. Its skewness = -1.48534 and kurtosis = 17.25 reflect extreme price behavior. Rice shows weak time-series dependence (AR(1) = -0.032427), moderate mean reversion (MA(1) = 0.352168), but insignificant volatility parameters (ARCH(Alpha1) = 1.089514, GARCH(Beta1) = -0.027905). Meanwhile, PAK-FIN-SEC paired with Rice maintains high volatility persistence (GARCH(Beta1) = 0.87809) and strong short-term memory (AR(1) = 0.851319, MA(1) = -0.738246). Overall, these findings highlight the internal market memory and volatility clustering in the PAK-FIN-SEC index and commodities like WTI and Soybean Oil, despite weak direct spillovers between financial and commodity markets.

Table 4.7: DCC-GARCH [RUSSIA-UKRAINE WAR PERIOD(PAK-FIN-SEC)]

The estimation sample period is: 21-02-2022 to 28-06-2024				
Mean Equation: ARMA (1, 1) model and Variance Equation: GARCH (1,1) model				
#1: PAK-FIN-SEC and #2: GOLD				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.853228	0.17751	4.8070	0.0000

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MA(1)	-0.744361	0.22398	-3.3230	0.0009
ARCH(Alpha1)	0.042774	0.022249	1.9230	0.0550
GARCH(Beta1)	0.877926	0.030203	29.070	0.0000
Part: GOLD				
AR(1)	-0.25077	0.18524	-1.3540	0.1763
MA(1)	0.143982	0.1882	0.7650	0.4445
ARCH(Alpha1)	0.021991	0.016164	1.3610	0.1742
GARCH(Beta1)	0.933773	0.055383	16.860	0.0000
rho_21	-0.034028	0.035458	-0.9597	0.3376
No. Observations: 622	No. Parameters: 9	Mean (Y): 0.04805	Variance (Y): 0.85085	Skewness (Y): '-0.06237
Kurtosis (Y): 3.7274	Log Likelihood:	-826.566	Alpha[1]+Beta[1]	0.95618
#1: PAK-FIN-SEC and #2: WTI(Oil)				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.851303	0.19069	4.4640	0.0000
MA(1)	-0.743384	0.24035	-3.0930	0.0021
ARCH(Alpha1)	0.043305	0.022453	1.9290	0.0542
GARCH(Beta1)	0.878061	0.029859	29.410	0.0000
Part: WTI(Oil)				
AR(1)	-0.153664	0.13298	-1.1560	0.2483
MA(1)	0.21064	0.12665	1.6630	0.0968
ARCH(Alpha1)	0.061885	0.031728	1.9500	0.0516
GARCH(Beta1) rho_21	0.926737 -0.002708	0.03771 0.037288	24.580 -0.0726	0.0000 0.9421
No. Observations: 622	No. Parameters: 9	Mean (Y): 0.01189	Variance (Y): 5.89075	Skewness (Y): -0.35788
Kurtosis (Y): 4.79689	Log Likelihood:	-1384.558	Alpha[1]+Beta[1]:	0.98861
#1: PAK-FIN-SEC and #2: US Soybean Oil				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.851312	0.19155	4.4440	0.0000
MA(1)	-0.74338	0.24125	-3.0810	0.0022
ARCH(Alpha1)	0.043344	0.022493	1.9270	0.0545
GARCH(Beta1)	0.878102	0.029914	29.350	0.0000
Part: US Soybean Oil				
AR(1)	-0.967476	0.022226	-43.530	0.0000
MA(1)	0.981725	0.016699	58.790	0.0000
ARCH(Alpha1)	0.09823	0.065334	1.5040	0.1332
GARCH(Beta1) rho_21	0.865377 0.003721	0.110000 0.038937	7.8670 0.0956	0.0000 0.9239
No. Observations: 622	No. Parameters: 9	Mean (Y): -0.03891	Variance (Y): 4.61719	Skewness (Y): 0.26603

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Kurtosis (Y): 5.15322	Log Likelihood:	-1332.085	Alpha[1]+Beta[1]:	0.96355
#1: PAK-FIN-SEC and #2: US Wheat				
Part: PAK-FIN-SEC				
Parameter	Coefficient	Std. Error	t-value	t-prob
AR(1)	0.850631	0.19325	4.4020	0.0000
MA(1)	-0.742336	0.24385	-3.0440	0.0024
ARCH(Alpha1)	0.043325	0.022471	1.9280	0.0543
GARCH(Beta1)	0.87809	0.029932	29.340	0.0000
Part: US Wheat				
AR(1)	-0.507856	0.13554	-3.7470	0.0002
MA(1)	0.569919	0.15779	3.6120	0.0003
ARCH(Alpha1)	0.14325	0.041371	3.4630	0.0006
GARCH(Beta1)	0.756489	0.060597	12.480	0.0000
rho_21	-0.002435	0.038624	-0.0631	0.9497
No. Observations: 622	No. Parameters: 9	Mean (Y): '-0.02392	Variance (Y): 7.17831	Skewness (Y): 0.9981
Kurtosis (Y): 10.88257	Log Likelihood:	-1425.077	Alpha[1] + Beta[1]:	0.89962
#1: PAK-FIN-SEC and #2: CORN				
Part: PAK-FIN-SEC				
AR(1)	0.853494	0.19065	4.4770	0.0000
MA(1)	-0.745913	0.24117	-3.0930	0.0021
ARCH(Alpha1)	0.043291	0.022365	1.9360	0.0534
GARCH(Beta1)	0.878035	0.029857	29.410	0.0000
Part: CORN				
AR(1)	-0.539364	0.33788	-1.5960	0.1109
MA(1)	0.525101	0.39995	1.3130	0.1897
ARCH(Alpha1)	0.231744	0.074652	3.1040	0.0020
GARCH(Beta1)	0.684103	0.075601	9.0490	0.0000
rho_21	0.00716	0.047333	0.1513	0.8798
No. Observations: 622	No. Parameters: 9	Mean (Y): -0.0439	Variance (Y): 3.52364	Skewness (Y): -1.48534
Kurtosis (Y): 17.25497	Log Likelihood:	-1181.777	Alpha[1]+Beta[1]	0.91581
#1: PAK-FIN-SEC and #2: RICE				
Part: PAK-FIN-SEC				
	Coefficient	Std.Error	t-value	t-prob
AR(1)	0.851319	0.21344	3.9890	0.0001
MA(1)	-0.738246	0.27195	-2.7150	0.0068
ARCH(Alpha1)	0.042841	0.022138	1.9350	0.0534
GARCH(Beta1)	0.876898	0.029514	29.710	0.0000
Part: RICE				
AR(1)	-0.032427	0.13539	-0.2395	0.8108

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MA(1)	0.352168	0.059826	5.8870	0.0000
ARCH(Alpha1)	1.089514	0.67894	1.6050	0.1091
GARCH(Beta1) rho_21	-0.027905 -0.046048	0.054367 0.045769	-0.5133 -1.0060	0.6080 0.3148
No. Observations: 622 Kurtosis (Y): 4.73513	No. Parameters: 9 Log Likelihood:	Mean (Y): 0.01963 -1116.193	Variance (Y): 2.45883 Alpha[1]+Beta[1]:	Skewness (Y): -4.48231 1.04992

Empirical Discussion

At large results of the study show volatility spillovers from international commodities markets to Pakistan stock exchange and financial sector of Pakistan that get intensifies during the crises as seen during COVID-19 and Russia Ukraine war period. Output produced in 4.4, 4.5, 4.6, 4.7, provide key insights regarding Pakistan Financial Sector and Pakistan Stock Exchange and its connectedness with international commodities markets GOLD, WTI Oil, and Agricultural Products (US Soybean Oil, US Wheat, Corn and Rice) as discussed below.

Table 4.4 and 4.5 reveals significant spillover effects from international commodities to both MSCI Pakistan and the Pakistan financial sector (PAK-FIN-SEC) during the COVID-19 period. Flight-to-safety theory explains how heightened global uncertainty led to capital shifting from riskier assets like MSCI Pakistan to safe-haven assets like Gold, amplifying Gold's volatility and its spillover to both MSCI Pakistan and PAK-FIN-SEC. Sadiq et al. (2022) study results indicated similar significant connections between Gold and Pakistan Stock market during COIVD-19. Commodities Futures and Safe Haven Theory supports Gold's role as a key transmitter of risk in crisis period (Khan, 2024). In contrast, the results show weak spillover from WTI Oil, as oil's volatility lacked persistence, limiting its effect on both markets aligning Modern Portfolio Theory (MPT) and Tiwari et al. (2020) study arguing that crude oil can be a better choice to diversify the risks of stock markets due to their weak connections.

Intensified spillovers from US soybean oil are observed, where its volatility persistence and clustering amplified spillovers to MSCI Pakistan and PAK-FIN-SEC conforming Spillover Theory. Results show, heightened COVID-induced supply chain disruptions increased volatility in US wheat, Corn and rice markets impacting both MSCI PAK and Pakistan financial sector, reflects Spillover Theory and Market Contagion Theory evident from similar empirical study of Younis et al. (2024), All these results highlights increased transmission of shocks from global commodities markets to both MSCI Pakistan and PAK-FIN-SEC causing increased volatility during COVID-19.

Table 4.6 and 4.7 reveals moderate to significant spillover effects from international commodities to both MSCI Pakistan and PAK-FIN-SEC during the Russia-Ukraine war. The results explain Gold's persistent spillovers, though less intense than COVID-19, as Gold acted as a stabilizing asset amid global uncertainty in line with Flight-to-safety theory. Buszko et al. (2021) in their study described the role of gold as contributing to market stability or volatility. Further the results highlight significant spillovers from WTI Oil to both markets, as the high persistence of oil volatility amplified volatility transmission, as Jiang and Chen (2024) study reports that in Russia-Ukraine war, the energy commodity always has the position of transmitter, reflecting sustained global instability supported by Spillover Theory stating that volatilities transmit between markets during period of crisis and instability due to greater integration (Alam et al., 2022; Ha, 2023). For US soybean oil, explains moderate spillovers, with long-term persistence influencing MSCI Pakistan and PAK-FIN-SEC, though short-term clustering was less impactful. Further, heightened spillover effects from US wheat are also evident from the results outcomes, where short-term volatility clustering increased due to global supply chain disruptions conforming to Spillover Theory. Corn's volatility spillovers intensified significantly, aligning with Market Contagion Theory, as the war's disruption in agricultural markets amplified transmission to both MSCI Pakistan and PAK-FIN-SEC. Conversely, Results show minimal spillovers from the rice market, as rice was less impacted by the crisis, and due to less dependence of Pakistan for rice on global markets elaborated by Ahmad et al. (2024), reflecting its relative insulation compared to wheat and corn. Overall results show that global agricultural markets have substantial spillovers effect on both PAK MSCI and Pakistan financial sector in line with study of Malhotra et al. (2024) arguing that there is dynamic linkage of agricultural commodities with stock markets during Russian-Ukraine war and conforms Spillover Theory. In summary, the Russia-Ukraine war heightened spillover effects, particularly for oil, wheat, and corn, while Gold and rice exhibited moderated transmission dynamics as revealed by Wang et al. (2022), that increased volatility spillovers often coincide with elevated geopolitical risks.

Pairwise Granger Causality Tests: Robustness

The results of the pairwise Granger causality tests between various commodities, including PAK_FIN_SEC, MSCI_PAK, GOLD, WTI_OIL_, US_SOYBEAN_OIL, US_WHEAT, CORN, and RICE, provide important insights into the causal relationships and potential spillovers among these markets. In terms of the relationship between PAK_FIN_SEC and MSCI_PAK, there is a significant causal effect running from PAK_FIN_SEC to MSCI_PAK, as evidenced by the F-statistic of 3.77806 (p-value = 0.0231), while the reverse causality is not significant (p-value = 0.7761). This suggests that the PAK_FIN_SEC index is a leading indicator for the MSCI_PAK stock index, but not vice versa. Similar causal links were found between WTI_OIL_ and PAK_FIN_SEC, with WTI_OIL_ Granger causing PAK_FIN_SEC (p-value = 0.0011), while the reverse relationship is weak (p-value = 0.1202). Furthermore, other commodities such as GOLD, CORN, and RICE do not exhibit significant causality in either direction with respect to the PAK_FIN_SEC index, indicating that these markets may be more independent in their dynamics.

The analysis also highlights some significant bidirectional causalities, particularly between GOLD and WTI_OIL_. The results show that WTI_OIL_ Granger causes GOLD (p-value = 0.01), and GOLD also Granger causes WTI_OIL_ (p-value = 0.1997), indicating a strong interconnection between the two in terms of price movements. A similar bidirectional causality is observed between US_WHEAT and US_SOYBEAN_OIL, with US_SOYBEAN_OIL Granger causing US_WHEAT (p-value = 0.0101) but not the other way around (p-value = 0.3223). On the other hand, the relationship between US_WHEAT and CORN is weak, with no significant Granger causality in either direction, suggesting that these two agricultural commodities may not share a strong dynamic connection over the

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sample period.
In terms of robustness, the pairwise Granger causality results are consistent with the findings from the DCC-GARCH model, which highlighted the presence of volatility spillovers and cross-market interdependence, especially in terms of the commodities that show causal relationships. For example, the significant causality from WTI_OIL_ to PAK_FIN_SEC and from PAK_FIN_SEC to MSCI_PAK aligns with the volatility spillovers found in the DCC-GARCH model, confirming the dynamic correlation and risk transmission mechanisms. The lack of causality between some pairs, such as RICE and most other commodities, further validates the robustness of the DCC-GARCH model, which did not detect strong interactions or volatility spillovers between these markets. Additionally, the lack of significant causality between many agricultural commodities, including CORN, RICE, and US_WHEAT, supports the idea that these markets may operate somewhat independently, with limited interconnections in terms of risk transmission during the observed period.

Table 4.8: Pairwise Granger Causality Tests

Pairwise Granger Causality Tests			
Null Hypothesis:	Obs	F-Statistic	Prob.
PAK_FIN_SEC does not Granger Cause MSCI_PAK	1674	3.77806	0.0231
MSCI_PAK does not Granger Cause PAK_FIN_SEC		0.25356	0.7761
GOLD does not Granger Cause MSCI_PAK	1674	1.00948	0.3646
MSCI_PAK does not Granger Cause GOLD		0.76358	0.4662
WTI_OIL_ does not Granger Cause MSCI_PAK	1674	1.23371	0.2915
MSCI_PAK does not Granger Cause WTI_OIL_		0.21718	0.8048
US_SOYBEAN_OIL does not Granger Cause MSCI_PAK	1674	0.13904	0.8702
MSCI_PAK does not Granger Cause US_SOYBEAN_OIL		1.48957	0.2258
US_WHEAT does not Granger Cause MSCI_PAK	1674	0.50051	0.6063
MSCI_PAK does not Granger Cause US_WHEAT		1.35136	0.2592
CORN does not Granger Cause MSCI_PAK	1674	1.2889	0.2758
MSCI_PAK does not Granger Cause CORN		1.74847	0.1744
RICE does not Granger Cause MSCI_PAK	1674	0.04999	0.9512
MSCI_PAK does not Granger Cause RICE		4.12674	0.0163

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GOLD does not Granger Cause PAK_FIN_SEC	1674	0.01153	0.9885
PAK_FIN_SEC does not Granger Cause GOLD		1.55224	0.2121
WTI_OIL_ does not Granger Cause PAK_FIN_SEC	1674	6.83255	0.0011
PAK_FIN_SEC does not Granger Cause WTI_OIL_		2.12093	0.1202
US_SOYBEAN_OIL does not Granger Cause PAK_FIN_SEC	1674	1.05186	0.3495
PAK_FIN_SEC does not Granger Cause US_SOYBEAN_OIL		0.91099	0.4023
US_WHEAT does not Granger Cause PAK_FIN_SEC	1674	1.5387	0.215
PAK_FIN_SEC does not Granger Cause US_WHEAT		4.65244	0.0097
CORN does not Granger Cause PAK_FIN_SEC	1674	0.01875	0.9814
PAK_FIN_SEC does not Granger Cause CORN		1.95772	0.1415
RICE does not Granger Cause PAK_FIN_SEC	1674	0.03462	0.966
PAK_FIN_SEC does not Granger Cause RICE		0.20881	0.8116
WTI_OIL_ does not Granger Cause GOLD	1674	1.61227	0.1997
GOLD does not Granger Cause WTI_OIL_		4.61656	0.01
US_SOYBEAN_OIL does not Granger Cause GOLD	1674	3.74873	0.0237
GOLD does not Granger Cause US_SOYBEAN_OIL		1.28393	0.2772
US_WHEAT does not Granger Cause GOLD	1674	1.3414	0.2618
GOLD does not Granger Cause US_WHEAT		0.69836	0.4975
CORN does not Granger Cause GOLD	1674	0.0586	0.9431
GOLD does not Granger Cause CORN		0.63016	0.5326
RICE does not Granger Cause GOLD	1674	1.17738	0.3083
GOLD does not Granger Cause RICE		1.82808	0.161
US_SOYBEAN_OIL does not Granger Cause WTI_OIL_	1674	0.80777	0.446
WTI_OIL_ does not Granger Cause US_SOYBEAN_OIL		0.99135	0.3713
US_WHEAT does not Granger Cause WTI_OIL_	1674	0.23175	0.7932
WTI_OIL_ does not Granger Cause US_WHEAT		2.08817	0.1242
CORN does not Granger Cause WTI_OIL_	1674	0.03447	0.9661

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WTI_OIL_ does not Granger Cause CORN		1.67449	0.1877
RICE does not Granger Cause WTI_OIL_	1674	1.01238	0.3636
WTI_OIL_ does not Granger Cause RICE		0.12818	0.8797
US_WHEAT does not Granger Cause US_SOYBEAN_OIL	1674	2.4363	0.0878
US_SOYBEAN_OIL does not Granger Cause US_WHEAT		1.13312	0.3223
CORN does not Granger Cause US_SOYBEAN_OIL	1674	0.18363	0.8323
US_SOYBEAN_OIL does not Granger Cause CORN		4.60766	0.0101
RICE does not Granger Cause US_SOYBEAN_OIL	1674	0.2096	0.8109
US_SOYBEAN_OIL does not Granger Cause RICE		2.59103	0.0752
CORN does not Granger Cause US_WHEAT	1674	0.55686	0.5731
US_WHEAT does not Granger Cause CORN		0.30784	0.7351
RICE does not Granger Cause US_WHEAT	1674	0.3357	0.7149
US_WHEAT does not Granger Cause RICE		0.39329	0.6749
RICE does not Granger Cause CORN	1674	0.32629	0.7216
CORN does not Granger Cause RICE		5.10533	0.0062

Summary of Results

The analysis reveals varying spillover effects and causal relationships between international commodities, MSCI Pakistan (MSCI PAK), and the Pakistan financial sector (PAK-FIN-SEC) across different periods, influenced by global conditions. During, COVID-19 heightened spillovers from Gold, soybean oil, wheat, and corn, aligning with Flight-to-safety, Spillover Theory, and Market Contagion Theory due to global disruptions. The Russia-Ukraine war amplified spillovers, especially from WTI Oil, wheat, and corn, reflecting persistent volatility and supply chain disruptions. In line with results found by Baek et al. (2023), overall results show that period of Russia-Ukraine War exhibits comparatively less spillover effects from international commodities markets to Pakistan stock exchange than the COIVD-19 period. Pairwise Granger causality tests show significant causality from PAK_FIN_SEC to MSCI_PAK and from WTI Oil to PAK_FIN_SEC, while commodities like rice exhibit independence. Bidirectional causality between Gold and WTI Oil, as well as US soybean oil and US wheat, confirms strong interconnections. Overall the results reveals intensified risk transmissions during period of crises between markets, as interconnectivity increases in times of crisis (Naeem et al., 2024; Naeem et al., 2023). These findings, supported by the DCC-GARCH model, underscore the dynamic nature of spillovers driven by crises and global market dynamics.

Conclusion

This study investigates the dynamic interrelationships between the financial sector of Pakistan, represented by MSCI PAK, and international commodity markets, particularly gold, oil, and agricultural commodities (soybean oil, wheat, corn, and rice), during significant global crises, namely the COVID-19 pandemic and the Russia-Ukraine conflict. The analysis employs ARMA-GARCH models to examine volatility dynamics, return relationships, and spillover effects. Key findings indicate that while the co-movements between MSCI PAK and various commodities are weak or insignificant, there is notable volatility persistence within both the financial sector and commodities markets. Specifically, gold and oil show high volatility clustering, with oil prices displaying more significant mean-reversion dynamics. This highlights the complex and varied nature of these markets' interdependence, particularly during periods of global uncertainty.

For agricultural commodities, such as soybean oil, wheat, corn, and rice, while the return correlations with MSCI PAK remain statistically insignificant, substantial volatility persistence is observed. This suggests that although these markets do not exhibit strong return co-movements, volatility shocks in one market can spill over and impact other markets over time. For instance, the GARCH model coefficients indicate that volatility in soybean oil and wheat persists longer than in oil, highlighting the importance of volatility transmission across these markets. The evidence of high volatility persistence in agricultural markets such as rice and corn, coupled with extreme kurtosis, suggests that these markets may be more susceptible to abrupt shocks, especially during crises. Overall, the study suggests that the relationship between Pakistan's stock market and international commodities is complex, with significant volatility clustering but weak return correlations. The economic and geopolitical crises such as the COVID-19 pandemic and the Russia-Ukraine conflict have accentuated these dynamics, increasing the sensitivity of both the financial and commodities markets to past volatility shocks. The findings underscore the importance of understanding market volatility and interconnectedness when making investment and policy decisions, especially in the context of global crises.

The analysis focuses only on the Pakistan Stock Exchange (PSX) and the international commodity markets, which limits the scope of understanding spillover effects to other sectors of the economy. Additionally, the research employs the DCC-GARCH model, which, while useful for capturing time-varying volatility, may not fully account for other complex factors, such as non-linear relationships between markets, geopolitical risks, and other external shocks.

Future research could extend this analysis by incorporating other emerging markets to provide a more comprehensive understanding of how global commodity price fluctuations affect stock markets across different regions. Additionally, future studies could explore the impact of other types of financial instruments, such as exchange-traded funds (ETFs), on spillover dynamics, especially during periods of heightened geopolitical risk. Further investigation using more advanced models, such as nonlinear or multi-factor approaches, could improve the understanding of complex interdependencies between markets. Moreover, future work could investigate the long-term effects of the COVID-19 pandemic and the Russia-Ukraine war on market resilience and recovery, offering more insights into how financial markets can adapt to such global crises.

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