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Title: **Volatility Spillovers in Pakistani Financial Markets: Evidence of ARDL-GARCH Modeling**

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Volatility Spillovers in Pakistani Financial Markets: Evidence of ARDL-GARCH Modeling

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Abstract

The research aimed to explore the lead-lag relationships among Pakistan Stock Exchange (PSX), Foreign Exchange (forex), and commodity markets in search of mean spillovers and volatility spillovers using Autoregressive Distributed Lag Model-Generalized Autoregressive Conditional Heteroscedasticity model (ARDL-GARCH) framework. The results highlighted that Pakistani financial markets coexist and there is stronger spillover between KSE-100 Index, PKR/USD exchange rate, and commodities including crude oil and gold prices. The joint system revealed the lead-indicator role of stock returns for currency and capital flow, while exchange rate shocks were found to significantly lag their influence on the stock market. Moreover, it demonstrated that gold price acts as hedge for currency depreciation and both exchange rate and gold exhibit clear linkage. The volatility spillovers are persistent and the asymmetric effects are most pronounced in stock and forex markets, where negative shocks create more volatility than positive shocks. Considerable research in this field in financial economics has been devoted to the effectiveness of stock market diversification. The analysis warned that maintaining an eye on these interconnections is critical in containing systemic risks during times of market stress.

***Keywords*:** autoregressive distributed lag model-generalized autoregressive conditional heteroscedasticity model, financial markets, pakistan, return and volatility transmission, volatility spillovers

Introduction

The underlying globalization, that enables information and shocks to ricochet around global financial markets, has been created by capital flows,

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technological advances, and increasingly allied markets. These interrelations have made the spillovers complicated, multi-faceted, and intertwined to the extent that it has become imperative for academia, policy-makers, and investors alike to understand these interconnected dynamics in a bid to maintain economic stability while reducing financial risk (Khan et al., 2024). One of the central policy and investment questions is how currency movements affect stock market performance. The theoretical debate about this relationship is guided by two models. Flow approach (Dornbusch & Fisher, 1980), or international trade model postulates that the stock market performance and currency value are positively correlated. In other words, stock-based portfolio balance model(s) has a predominantly one-way relationship: capital inflow leads to currency appreciation as stock prices rise (Adjasi et al., 2008).

The financial markets of Pakistan, especially the equity, Foreign Exchange (forex), and commodity markets have witnessed exacerbated volatility in recent years. The KSE-100 Index, a proxy for Pakistan's stock market, soared 84% in 2024 and 55% in 2023, factoring both the growth and risk exposure into its valuation. At the same time, the Pakistani rupee remained under pressure against the US dollar, while global oil and gold prices continued to transmit external shocks into the domestic economy. Despite these developments, existing research has not sufficiently examined the frequency-specific and lagged channels through which returns and volatility are transmitted among Pakistan's stock, foreign exchange and commodity markets. This study addresses that gap by applying an ARDL-GARCH framework to jointly analyze mean spillovers and volatility transmission across these key markets.

It has been shown that exchange rates, commodity prices, and stock markets are interconnected in a significant corpus of literature (Campbell & Hamao, 1992), usually applied by GARCH-type models. However, most studies only focus on instantaneous spillover effects, ignoring the far more important, time-lagged spillovers. The current study filled this gap by using the Autoregressive Distributed Lag Model-Generalized Autoregressive Conditional Heteroscedasticity model (ARDL-GARCH) model. This is an extension of standard GARCH spikes model that considers current and lagged spillover effects across markets. These earlier studies included such new complex networks, for instance Ghouse and Khan (2017) studied global stock market interactions but did not consider the interactions between commodity and forex markets or lagged effects. Unlike previous studies, this study investigated the role of market-specific lagged returns and volatility in determining the dynamic conditional mean and variance equations of an ARDL-GARCH model. This allows for a more global analysis than separate univariate models, for instance ARMA-GARCH (Mir & Bhutta, 2024).

Recent studies exploring the interlinkages of financial markets. Ouyang et al. (2024) and Rodríguez-Ulcuango et al. (2025) highlighted the contagion between commodities and developing of equity markets. This revealed asymmetric volatility impact from forex to stock market in times of global shocks. Zou et al. (2023) examined time-varying volatility spillovers between South Asian markets when it comes to global macroeconomic influences. This suggests that such markets are relatively sensitive to international events. No study has, however, provided a comprehensive analysis of return and volatility transmission between Pakistan' stock, forex, and commodity markets.

The current study attempted to fill this gap in the literature by utilizing a multivariate ARDL-GARCH methodology to investigate short run and long spillovers between these two major markets in Pakistan. The only relevant studies at the country level contributed to our understanding of integration in Pakistan, validating interdependencies among markets and integrating stock, Forex, and commodity markets. In particular, it aimed to evaluate the influence of volatility spillovers on risk management and also financial policy choices within occasions of global economists, such as the 2020 global economic situation that tape-recorded tops in oil costs as well as stock exchange volatility. These results are highly valuable for both investors and policymakers in Pakistan when considering a well-diversified portfolio process with the help of patterns in stock returns, an integral factor to determine the financial stability policies.

Research Objectives

The study aimed to:

- Examine the mean and volatility spillover effects among equity, forex, and commodity markets of Pakistan
- Investigate the dynamic interdependencies among these markets via ARDL-GARCH method with short-run and long-run dynamics
- To evaluate the implications of these spillovers for financial risk

management and policymaking in Pakistan

The current study addressed a void in the existing literature by delving further into how financial markets behave as framed with insight from recent literature, such as Zou et al. (2023). The results may help to gain prudential knowledge about interconnections of markets that are crucial for the management of financial risk and stability of Pakistan's economy.

Literature Review

This section critically reviews the previous literature related to financial market integration, focusing on currency, stock, and commodity interlinkages in Pakistan. This literature is jumbled and frequently contradictory, needing more exploration. Early studies predominantly examined long-run associations and directional connections, employing cointegration and causality tests. Roots of such negative extreme stock prices and forex rate stability posited by Muhammad and Rasheed (2002) and Smyth and Nandha (2003) confirmed no interlinkage in short-run/long-run for South Asian countries, such as Pakistan. This indicates that the relationship between security prices and currency depreciation is complex, which is under researched in Pakistan. Thus, as financial markets continue to become more integrated, there have been attempts to analyze the links between stock prices and exchange rates, mainly focusing on Granger causality or cointegration tests. However, these studies (Rahman & Uddin 2009; Zia & Rehman 2011) do not consider volatility nor lagged effects that could potentially play an important role in their output.

Other studies have also reported measurable interactions between exchange rates and stock prices. Farooq et al. (2004) examined the linkage between stock market prices and the exchange rate in Pakistan and found evidence of causal interaction between the two markets. Sohail and Hussain (2009) reported a positive relationship between exchange-rate movements and stock prices in the Lahore Stock Exchange. From a correlation perspective, Qayyum and Kemal (2006) used an EGARCH model, leading to the discovery of two-way volatility spillover between stock and forex markets. However, evidence ceased to be clear-cut after including macroeconomic conditions (Khan & Zahra, 2023). Indeed, other studies, such as Khan et al. (2025) found less significant causal relationships between inflation and Pakistani stock prices and also industrial production and Pakistani stock prices. Conversely, Ahmad et al. (2010) and Jawaid and

Haq (2012) showed a close relationship, especially from rates to stock returns.

Recent studies have broadened the scope to commodity markets by applying GARCH-family models. Thuraisamy et al. (2013) examined linkages between Asian equity and commodity futures markets and showed that these relationships vary across market settings. Mushtaq et al. (2023) analyzed volatility spillovers from crude oil to South Asian stock markets and highlighted the relevance of oil shocks for regional equity markets. Shahzad et al. (2014) found that commodities, particularly gold, can provide diversification and hedging value in a multivariate setting. Hussain et al. (2023) documented asymmetric volatility spillovers among macroeconomic variables and the Pakistan Stock Exchange, while Sahoo and Kumar (2024) showed that volatility transmission differs across emerging and developed market sectors. In Pakistan, however, evidence on the direction and strength of spillovers remains mixed, with some studies reporting insignificant associations and others finding meaningful mean and volatility transmissions. This inconsistency indicates a gap in the literature, which the current study addresses by applying an ARDL-GARCH framework that accounts for both contemporaneous and lagged spillovers among stock, foreign exchange and commodity markets.

New Developments in Financial Spillover Studies

The recent literature has analyzed spillovers, transmission of shocks, as well as volatility across markets. Büyükşahin and Robe (2009), Bouri et al. (2021) and Ouyang et al. (2024) examined the time-varying spillovers of volatility among commodities and stock exchanges in emerging markets. Ouyang et al. (2024) demonstrated that different shocks in the crude oil market jointly influence stock and forex markets. Rodríguez-Ulcuango et al. (2025) found asymmetric effects of exchange rate shocks on equity returns, especially during global economic crises. Sahoo et al. (2023) searched for time-varying mean spillovers from forex to stock markets of BRICS economies and concluded that the linkages could be swayed by policy actions.

Regional market linkages have been explored using multivariate analysis in South Asia. The investigated volatility spillovers focused on mainstream markets. However, both mean and conditional spillover dynamics were not linked enough to explore the structure of the Pakistani markets. In Pakistan, studies conducted by Wagan et al. (2024), Farooq et al. (2021) analyzed bilateral linkages, and only a handful of more recent studies applied multivariate techniques to study cross–market linkages.

Research Gap

The literature on interdependencies in financial markets is well-established. However, most empirical studies conducted in Pakistan remained descriptive or analyzed bilateral information links between stock exchange rate and commodity stock linkages. For instance, Ansari et al. (2026) and Hussain and Rehman (2021) examined spillovers between stock and foreign exchange markets but did not jointly account for volatility dynamics across multiple asset classes. International studies, including Ouyang et al. (2024) and Rodríguez-Ulcuango et al. (2025), identified time-varying volatility spillovers in emerging economies. However, they did not specifically examine Pakistan's financial markets. Similarly, Zou et al. (2023) analyzed South Asian equity markets, but they did not jointly estimate spillovers among Pakistan's equity, foreign exchange, and commodity markets. This leaves an important gap in understanding how shocks originating in one market transmit to other markets over time and under different volatility conditions.

The current study moved towards filling this gap. It followed Ghouse et al. (2021) detailed investigation of return spillovers according to an ARDL-GARCH framework, that allows for the joint study of return and volatility spillovers across various financial markets. This may provide a broader perspective on the interdependencies as well as critical guidance to Pakistani investors and policymakers.

Methods

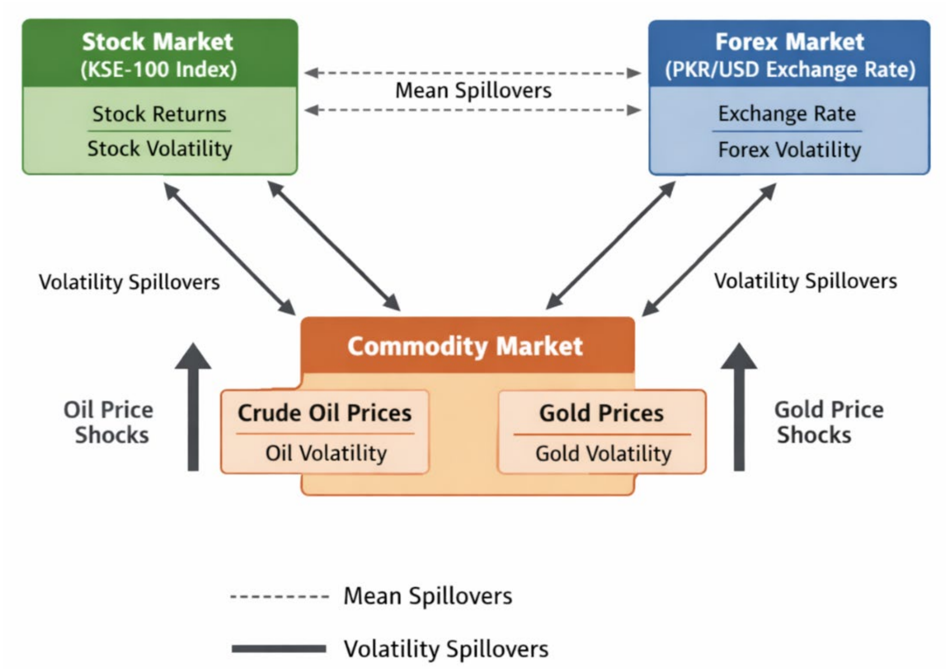
Table 1 shows the main variables of interest in this study, statistics on KSE-100 Index, PKR/USD exchange rate, crude oil prices, as well as gold and their volatilities. These variables represent the equity, forex, and commodity segments of Pakistan's financial system. The table below analyzes the relationships between mean and volatility to understand the distinctions market spillovers of these measures. Moreover, the table also offers a summary of spillover and how transitory price changes in one market can affect other markets, both in the short-run as well as the long-run.

Table 1
Description of Variables

Variables	Measurement
Stock Market (KSE-100 Index)	Daily closing index values of the KSE-100.
Exchange Rate (PKR/USD)	Daily exchange rate between PKR and USD.
Crude Oil Prices	Daily closing price of crude oil (USD per barrel).
Gold Prices	Daily closing price of gold (USD per ounce).
Stock Market Volatility	Standard deviation of daily returns (annualized).
Exchange Rate Volatility	Standard deviation of daily exchange rate returns.
Crude Oil Volatility	Standard deviation of daily crude oil returns.
Gold Price Volatility	Standard deviation of daily gold returns.

Figure 1

Conceptual Framework



The conceptual framework in Figure 1 displays four interconnections that exist (in case of Pakistan), where financial markets (namely stock, forex, commodity: crude oil and gold) are linked mutually through three channels. It captures spillover effects over mean returns and volatility of these markets. This point has been shown very clearly through a diagram. The diagram explains that KSE-100 Index is a representative asset for stock market and PKR/USD exchange rate is a representative asset for forex market. Moreover, they are also affected by each other as indicated by mean spillovers and volatility spillovers. Similarly, commodity markets (e.g., crude oil, gold prices) influence stock markets directly due to oil price shocks/gold price fluctuations. These relationships are emblematic of the complex, dynamic interplay that shapes market stability and investor behavior in Pakistan.

Financial econometrics typically focuses on volatility clustering, shock persistence, and leverage effects, all of which are common features of financial return series (Abro et al., 2024). To model these features, this study first converted raw price series into log returns so that the series would be more stable and suitable for time-series estimation. The ARDL-GARCH framework was then used to capture both short-run and lagged spillover effects in returns and conditional volatility across the selected markets. This approach is appropriate because financial markets often react not only to current shocks but also to earlier movements in related markets.

$$\mathrm{R_t} = \log\left(\frac{k_t}{k_{t-1}}\right) \tag{1}$$

Where k_t represents the current level of the series (e.g., exchange rates and stock indices), and k_{t-1} is the first lag of the raw series.

Autoregressive Conditional Heteroscedasticity (ARCH) Model

Engle (1982) developed the ARCH model, which was a major advancement in modelling time-varying volatility. The model uses two main equations: a conditional mean equation and a conditional variance equation. A typical (x) is itself the mean of the return series, either its own past values or other factors. The variance equation therefore, represents the conditional volatility (or variance of the disturbance term) as a function of past squared innovations, and captures volatility clustering.

The general form of the ARCH(p) model is specified as follows:

Equation of mean

$$\mathrm{R_t} = \omega_0 + \omega_1 \mathrm{X_t} + \varepsilon_t \tag{2}$$

Where $\varepsilon_t = z_t\sigma_t, z_t \sim N\ (0,1)$

Equation of variance

$$\sigma_t^2 = \delta_0 + \sum_{i=1}^{p} \theta_i \varepsilon_{t-1}^2 + u_t \tag{3}$$

Where R_t denotes return the series and ω_1 indicates the direction of ARMA process. The ARCH approach has several constraints: it only takes into account symmetric effects, enforces non-negativity on volatility variables, and requires that the return-on-investment series be represented as a linear derivative of the explanation variable X_t.

Generalized Autoregressive Conditional Heteroscedasticity (GARCH) Model

Bollerslev (1986) developed the GARCH model, which extends ARCH by including lagged conditional variance terms related to the past squared innovations. This small extension allows the model to be more flexible and is much better at capturing the persistent feature of volatility. It frequently allows a GARCH (1, 1) to describe the volatility process when one would require an ARCH of higher order.

The general expression of a model GARCH (p, q) appears in the equations:

Equation of mean

$$R_t = \omega_0 + \omega_1 X_t + \varepsilon_t \tag{4}$$

Whereas, $\varepsilon_t = z_t \sigma_t, z_t \sim N(0,1)$

Equation of variance

$$\sigma_t^2 = \delta_0 + \sum_{i=1}^{p} \theta_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \delta_j \sigma_{t-j}^2 + u_t \tag{5}$$

Despite its advantages, the standard GARCH model shares two key limitations with its ARCH predecessor. Firstly, it imposes a symmetric response to shocks, meaning that positive and negative innovations of the same magnitude are assumed to have an identical impact on future volatility. This fails to capture the "leverage effect" often observed in financial markets, where negative shocks tend to increase volatility more than positive shocks. Secondly, the model requires non-negativity constraints on all parameters (δ_o, θ_i, $\delta_j \geq 0$) to ensure that the conditional variance remains positive, which can sometimes be restrictive for estimation.

GJR-GARCH Model

The traditional ARCH and GARCH families do not capture the so-called leverage effect, where the volatility response to negative shocks is larger than to positive ones. The GJR-GARCH was proposed by Glosten et al. (1993), which includes a dummy variable to differentiate between "good" and "bad":

Equation of mean

$$R_t = \omega_0 + \omega_1 X_t + \varepsilon_t \tag{6}$$

Whereas $\varepsilon_t = z_t \sigma_t, z_t \sim N(0,1)$

Equation of variance

$$\sigma_t^2 = \delta_0 + \sum_{i=1}^{p} \theta_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \delta_j \sigma_{t-j}^2 + \sum_{i=1}^{p} \psi_i D_i \varepsilon_{t-i}^2 + u_t \tag{7}$$

In this specification, the dummy variable D_{t-i} is central to capturing asymmetric effects. It activates specifically for past negative shocks ($\varepsilon_{t-i} < 0$), allowing the model to quantify how negative news (price declines) exerts a different and typically larger influence on future volatility compared to positive news of an equal magnitude.

The ARDL-GARCH Method

To fully explore the immediate and lagged transmission mechanism, this study used ARDL-GARCH (Junejo et al., 2025). This joint approach is an attractive extension to capture contemporaneous and lag spillover effects in the mean specification as well as conditionally. This study, to the best of our knowledge, is among the first to employ such a model in reference to Pakistan's integrated capital markets.

The ARDL-GARCH model is given by the following equations:

Equation of mean

$$R_t = \omega_0 + \omega_1 X_t + \sum_{i=0}^{p} \theta_i X_{t-i} + \sum_{i=0}^{p} \theta_i K_{t-i} + \varepsilon_t \tag{8}$$

Whereas $\varepsilon_t = z_t \sigma_t, z_t \sim N(0,1)$

Equation of variance

$$\sigma_t^2 = \delta_0 + \sum_{i=1}^{p} \theta_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \delta_j \sigma_{t-j}^2 + \sum_{i=0}^{p} \theta_i K^2{}_{t-i} + u_t \tag{9}$$

In this specification, R_t represents the return series of the dependent market, while K_{t-i} signifies the contemporaneous and lagged values of the return series from an external, independent market. The discovery of statistically significant coefficients for the lagged external variable (θ_i) in the mean equation (Eq. 8) indicates the presence of mean spillover effects. Similarly, significant coefficients for the external variable's squared returns (K_{t-i}^2) in the variance equation (Eq. 9) provide evidence of volatility spillover effects, demonstrating how risk transmits across markets.

Multivariate GARCH Methods

MGARCH (Multivariate GARCH) models build on univariate volatility by modeling conditional variances and covariances across multiple time series, which is important for examining market interactions and spillovers. The VEC and BEKK specification is well-known, where past squared errors and cross-products affect the variance-covariance matrix. Although the VEC model is flexible, it is computationally expensive. On the other hand, the BEKK model (Engle & Kroner, 1995) guarantees positive definiteness and has a simpler structure. Therefore, it is preferable for applied econometric studies. The multivariate TARCH model is popular for its simplicity and effectiveness in modeling multivariate volatility.

$$vech(H_t) = c + A\, vech(\varepsilon_{t-1} - \varepsilon_{t-1}) + G\, vech(H_{t-1}) \quad (10)$$

Where:

- $vech(.)$ denotes the half-vectorization operator that stacks the lower triangular elements of a matrix.
- $\boldsymbol{\varepsilon}_t$ represents the vector of residuals.
- **c** is a vector of constants, while A and G are parameter matrices capturing the effects of past shocks and volatility persistence, respectively.

Results and Discussion

Data Visualization

The daily closing prices of KSE-100 Index, PKR/USD exchange rate, crude oil, and gold were collected from January 3rd, 2007 to November 29th, 2019. The authors started with raw price series to look for any trends and non-stationary behaviors before moving to transformed return series utilized through a volatility clustering, non-normality, as well as stationarity.

Figure 2 shows the raw price series for the KSE-100\index, PKR/USD exchange rate, crude oil, and gold. Overall, series show broad upward trends but also provide a considerable volatility, particularly during the global credit crisis of 2008. Performance results based on log-differences convert these non-stationary series into stationary cumulative return series.

Figure 2

Raw Data Series from 2007-2019

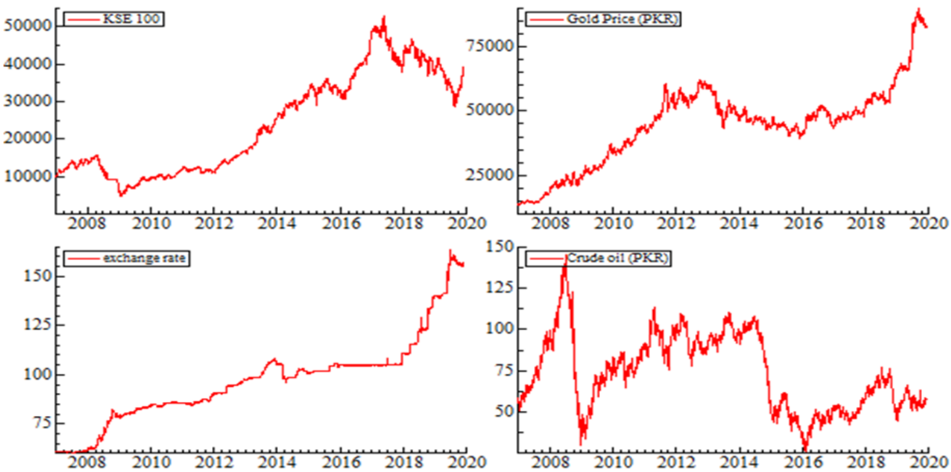
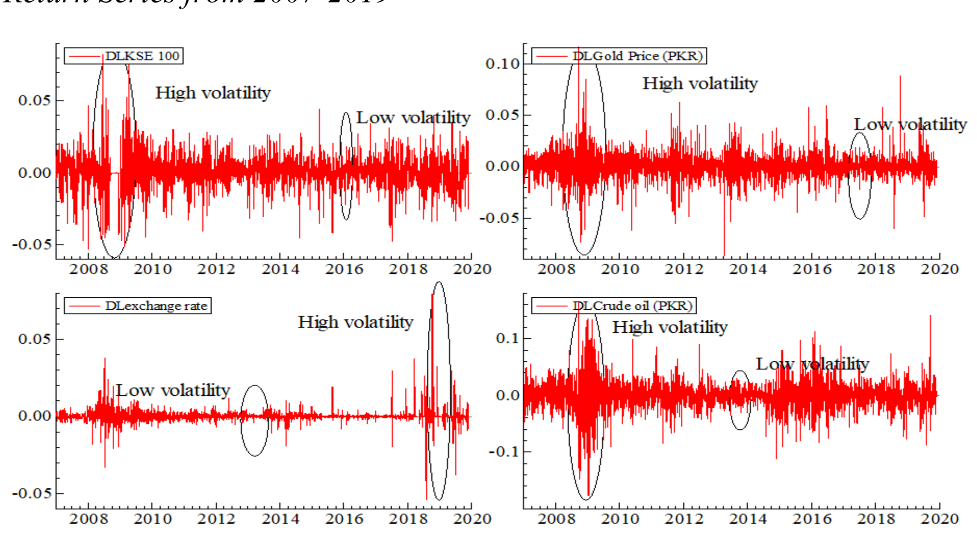


Figure 3

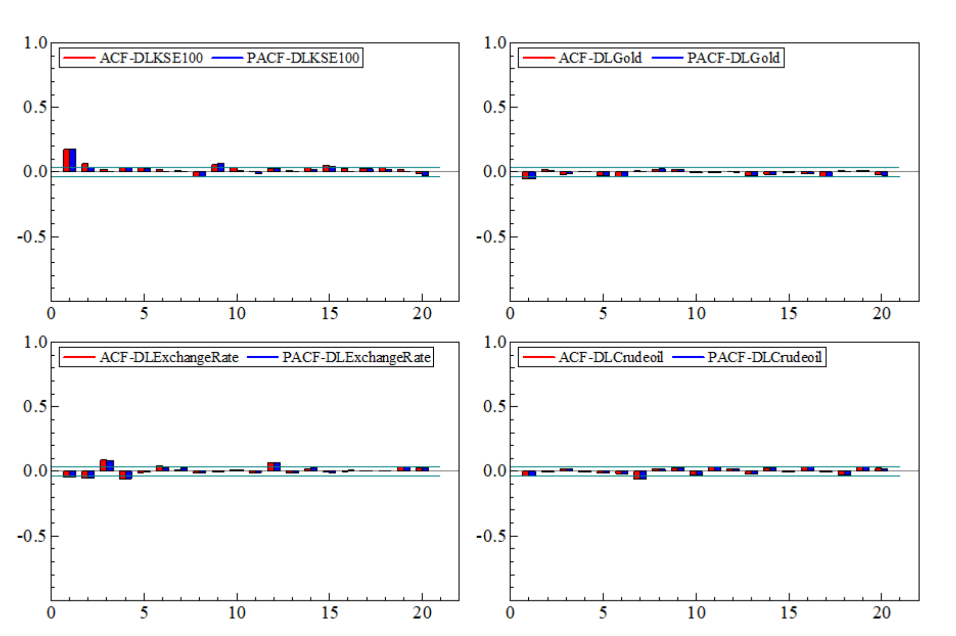
Return Series from 2007-2019



The converted return series are shown in Figure 3. The past times of volatility clusters are obvious from the graph, as high levels of volatility (or large changes in volatility) are followed by periods of low volatility (or small changes in volatility). Hence, GARCH-type models can be justified empirically for this dataset. Further, the return series appear to fluctuate around a constant average value with no so clear trend (which implies now you are working on stationary data). This is required to avoid artifacts in time domain analysis.

Figure 4

CF and PACF of the Return Series

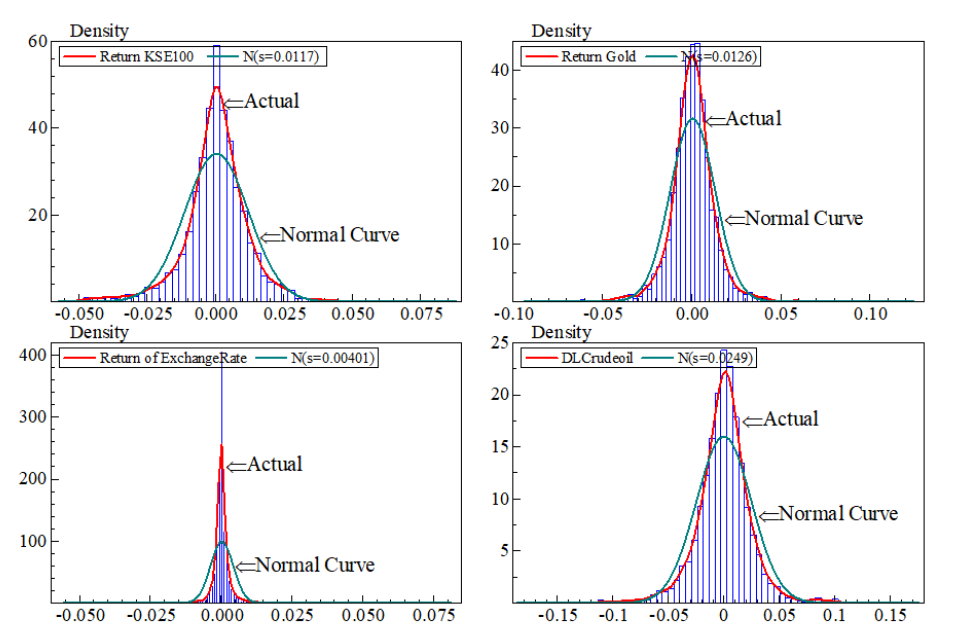


The figures below (Figure 4) show the ACF and PACF plots of the return series, ensuring that the series is stationary. ACF (red bars) shows un-adjusted correlations for different lags, PACF (blue line) factors short lags, and the green confidence bounds help notice serial correlations that are statistically significant. This would also assist with the selection of lag orders (p and q) for the ARMA model.

The return series in histogram format, compared to normal distribution (blue line), is presented in Figure 5. The visual inspection shows that all the return series have a mild leptokurtic distribution. This shows more peaks in the series and flatter tails than one might expect of a normal distribution. Fat tails are the characteristics of financial returns: higher likelihood of extreme values compared to normal.

Figure 4

Distribution of Return Series from 2007-2019



Summary of Data Statistics

Summary statistics for the logarithmic return series of all variables are reported in Table 2. Table displays central tendency, dispersion, and shape of distribution along with the test results.

Table 2

Statistics Summary

Variables	*SD*	Skewness	Kurtosis	Jarque-Bera	ARCH 1-2	Q Stat (5)	Q Square (5)	KPSS
KSE 100	0.011	-0.2240	3.9120	1989.6 (0.00)	180.560 (0.00)	116.50 1(0.00)	730.164 (0.00)	0.1790
Gold Price	0.012	0.2090	7.7510	7731.1 (0.00)	19.6190 (0.00)	14.191 (0.014)	126.710 (0.00)	0.2760
Exchange Rate	0.004	2.8010	78.547	795540 (0.00)	14.5340 (0.00)	51.913 (0.00)	41.9700 (0.00)	0.2410
Crude Oil Price	0.024	-0.0440	5.4610	3827.8 (0.00)	133.77 (0.00)	6.5770 (0.25)	962.8700 (0.00)	0.0770

These findings confirm the existence of stylized facts in financial time series from the preliminary analysis (visualization and summary statistics) perspective. The most prominent are the presence of volatility clustering and clear deviation from a normal distribution captured by kurtosis, leptokurtosis, and skewness. Such empirical regularities confirm the requirement of more advanced econometric techniques which can capture time varying volatility. Consequently, the outcomes endorse the fact that such GARCH-type models are appropriate to properly capture these financial variables' dynamic changes in the forthcoming sections.

Volatility Modeling of Return Series

This section presents the fit of GARCH-type models for the return series of KSE-100 Index, gold, exchange rate, and crude oil. Results presented in Table 3 describe the dynamics of conditional mean and conditional variance for each asset.

Table 3

Volatility Return Series Modeling

Series	Equation	Term	Coefficient	Prob
KSE 100 Return	Mean Equation	Constant (M)	0.000	0.005
		AR(1)	0.957	0.000
		AR(2)	-0.100	0.000
		MA(1)	-0.793	0.000
	Variance Equation	Constant (V)	0.048	0.001
		ARCH (Alpha1)	0.066	0.000
		GARCH (Beta1)	0.793	0.000
		GJR (Gamma)	0.259	0.000
		Degrees of Freedom	5.227	0.000
Gold Prices Return	Mean Equation	Constant (M)	0.000	0.001
		AR(1)	0.564	0.000
		MA(1)	-0.627	0.000
		MA(2)	0.048	0.005
	Variance Equation	Constant (V)	0.014	0.001
		ARCH (Alpha1)	0.042	0.000
		GARCH (Beta1)	0.949	0.000
		Degrees of Freedom	4.134	0.000
Exchange Rate Return	Mean Equation	Constant (M)	-0.003	0.000
		AR(1)	0.125	0.000

Series	Equation	Term	Coefficient	Prob
		AR(2)	0.133	0.000
		AR(3)	0.135	0.000
		MA(1)	0.092	0.001
	Variance Equation	Constant (V)	0.016	0.526
		ARCH (Alpha1)	0.098	0.000
		GARCH (Beta1)	0.874	0.000
		Degrees of Freedom	6.002	0.000
Crude Oil Return	Mean Equation	Constant (M)	0.000	0.002
		AR(1)	-0.795	0.000
		MA(1)	0.777	0.000
	Variance Equation	Constant (V)	0.030	0.005
		ARCH (Alpha1)	0.012	0.240
		GARCH (Beta1)	0.942	0.000
		GJR (Gamma1)	0.088	0.000
		Degrees of Freedom	6.789	0.000

The GARCH-type model results inform about the return and volatility dynamics in Pakistan's financial markets. The AR(1) coefficient (0.957) for the KSE-100 Index is quite high and positive, confirming that past returns have a significant influence over its current returns. The negative MA(1) coefficient (-0.793) captures the persistence of past shocks. The variance equation exhibits volatility clustering, and the GARCH term is highly significant showing that volatility is persistent. The big GJR part signals asymmetric volatility where adverse news has a larger impact, which represents leverage effect. It indicates high chances of extreme price actions. The autoregressive equation for gold prices displays a relationship similar to KSE-100, where up to 1 lag is negatively proportional. However, it was observed that this effect was not strong. The highly significant GARCH term (0.949) indicates high volatility persistence. Once again, the leptokurtic distribution was seen. The exchange rate (PKR/USD) has a complex autoregressive structure, suggesting that previous behavior tends to persist. The large GARCH term shows volatility clustering. The positive and significant GJR term indicates asymmetric volatility that the shocks have different effects on volatility. Exchange rate returns are also leptokurtic distributed. From the results, it was interpreted that crude oil returns follow mean-reverting behavior and a strong GARCH term. The GJR term captures asymmetries in volatility, such that negative shocks have a greater impact than positive ones. All markets are characterized by volatility persistence, asymmetric effects, and leptokurtic returns.

Analyzing Simultaneous and Lagged Mean Spillover Effects

This section examines whether return movements in one market affect returns in another market either contemporaneously or with a time lag. By using Campbell and Hamao (1992) methodology, the study found meaningful contemporaneous and lagged effects that expose the direction of information and price shocks between Pakistan's forex, stock, and commodity markets.

Table 4

Simultaneous and Lag Mean Spillover Effect

Relationship	Coefficient	Prob	Conditional Mean Equation	Conditional Variance Equation	Residual Analysis
Exchange Rate to Gold Price	0.5530	0.0000	Mean Spillover	ARCH (Alpha1): 0.2870 (0.0000)	Jarque-Bera: 1650.8000, Skewness: -0.6180
Gold Price to Exchange Rate	0.0230	0.0000	Lag Mean Spillover: -0.0030 (0.3150)	GARCH (Beta1): 0.9830 (0.0000)	Q Stat (5): 3.5310, Q Square Stat (5): 14.0180
KSE 100 to Exchange Rate	-0.0210	0.0340	Lag Mean Spillover: -0.0210 (0.0340)	ARCH (Alpha1): 0.1660 (0.0000)	Jarque-Bera: 6.0670, Skewness: -0.2690
Exchange Rate to KSE 100	0.0010	0.0000	AR (1): 1.0390 (0.0000)	GARCH (Beta1): 0.9010 (0.0000)	Q Stat (5): 18.2100, Q Square Stat (5): 5.6240
Crude Oil to KSE 100	0.0170	0.0160	Lag Mean Spillover: 0.0170 (0.0160)	ARCH (Alpha1): 0.3710 (0.0000)	Jarque-Bera: 1167.7000, Skewness: -0.4510
KSE 100 to	-0.0160	0.6570	AR (1): -	GARCH	Q Stat (5):

Relationship	Coefficient	Prob	Conditional Mean Equation	Conditional Variance Equation	Residual Analysis
Crude Oil			1.8510 (0.0000)	(Beta1): 0.9610 (0.0000)	4.7160, Q Square Stat (5): 6.8750
Gold to Crude Oil	0.3560	0.0000	Lag Mean Spillover: 0.0320 (0.2700)	ARCH (Alpha1): 0.2620 (0.0000)	Jarque-Bera: 905.3900, Skewness: -0.2412
Crude Oil to Gold	0.0960	0.0000	AR (1): -0.0720 (0.0010)	GARCH (Beta1): 0.9600 (0.0000)	Q Stat (5): 1.0165, Q Square Stat (5): 7.1274
KSE 100 to Gold	-0.0330	0.0950	Lag Mean Spillover: -0.0330 (0.0950)	ARCH (Alpha1): 0.2270 (0.0000)	Jarque-Bera: 5409.0000, Skewness: -0.3115
Gold to KSE 100	-0.0100	0.5120	AR (1): 1.0470 (0.0000)	GARCH (Beta1): 0.9010 (0.0000)	Q Stat (5): 4.7719, Q Square Stat (5): 3.1079
Crude Oil to Exchange Rate	-0.0020	0.3240	AR (1): -0.7480 (0.0200)	GARCH (Beta1): 0.9610 (0.0000)	Jarque-Bera: 6.2880, Skewness: -0.2110
Exchange Rate to Crude Oil	0.0360	0.7410	Lag Mean Spillover: 0.0160 (0.8960)	ARCH (Alpha1): 0.2620 (0.0000)	Q Stat (5): 0.4920, Q Square Stat (5): 5.5780

Table 4 presents the overall spillover analysis of Pakistan's financial markets, showing key relationships between exchange rates, gold prices, KSE-100 stock index, and crude oil prices. It provides evidence of these markets' interconnections through static mean spillover effects, rolling mean spillover effects over a horizon as well as lagged and short-run dynamics, volatility clustering's, and residuals. There is a robust positive correlation between the adjusted cross merchandise coefficient of 0.5530 between the exchange rate and gold price, that is to say currency depreciation has a significant effect on international gold prices. It is consistent with gold's role over the years as a hedge against a declining currency. The significant ARCH effect validates the presence of volatility clustering in this relationship. This indicates that fluctuations in exchange rates lead towards persistent changes in gold prices. However, there is no significant spillover effect from gold to exchange rates. This suggests that while exchange rates drive gold, the reverse causal relationship does not hold in the short run.

There is a negative significant lagged spillover from the KSE-100 Index to exchange rates (-0.0210). This indicates that the relationship between the KSE-100 Index and exchange rates appears to be playing more than one position among themselves. This indicates that the induced stock price changes, through capital inflows, affect the exchange rate with lags. Finally, the crude oil price has a positive and statistically significant impact of 0.017 on the KSE-100 Index. This indicates that, due to energy-dependent firms listed on the stock market in Pakistan, fluctuations in oil prices have battle scars on the market performance (Shahbaz & Malik, 2025). Nevertheless, there is no strong spillover between the KSE-100 significant index and crude oil prices, though this reinforces Pakistan's position as a price-taker in international oil market. The contemporaneous spillover between gold and crude oil prices is 0.3560. This implies that both commodities are driven by the same macroeconomic factors, including inflation and global risk sentiment. However, the pass-through from crude oil prices to gold prices is negligible, indicating that while gold responds to changes in oil price, the reverse does not apply for short-run.

The study also investigated the spillover affecting KSE-100 Index and gold prices. The coefficient of -0.0330 (t = -2.2090, p = 0.0950) for the KSE-100 Index captures a weak negative spillover: positive changes in the KSE-100 Index negatively influence gold prices to a negligible extent. This hints towards the fact that there is a flight of investors towards gold stocks during years when the stock market underperforms. Noticeably, the spillover between crude oil prices and exchange rates is feeble and not significant. This is probably because Pakistan's exchange rates are determined by forces apart from oil prices, but also trade balance and remittance flows.

Moreover, the persistence volatility analysis shows that it was subjected to significant GARCH effects (Beta1 = 1), which indicates that shocks in one market would persist forever in time in other markets. It underscores how no market exists in a vacuum, where volatility in one market can seep into others and increase uncertainty. Residual analysis also indicated the skewness and non-normal distribution of data points. This led towards the conclusion that already-existing linear approximation methods may not be enough to describe market dynamics.

Based on the study dataset, the results showed that shocks can move from one market to another and may create persistent volatility in related markets. This has important policy implications, as financial stability measures should consider cross-market linkages rather than treating the equity, foreign exchange and commodity markets as isolated segments.

Examining the Simultaneous and Delayed Volatility Spillover Effect

In this section, the relationship between current and past-period volatility variations was examined. This study used the method developed by Campbell and Hamao (1992). This method recognizes both immediate and delayed financial market spillover effects. Furthermore, it is also helpful in assessing the relationship between one of the stock market's volatility or lagged volatility with that of another one. However, statistically significant data shows that such spillover effects do exist.

Table 5

Simultaneous and Delayed Volatility Spillover Effect

Variables	Coefficient	Prob	Coefficient	Prob
	Exchange Rate to KSE 100		KSE 100 to Exchange Rate	
	Conditional Mean Equation			
Cst (M)	0.001	0.000	0.000	0.000
AR (1)	1.045	0.000	-0.679	0.012
AR (2)	-0.131	0.000	-0.101	0.003
MA (1)	-0.883	0.000	0.580	0.041
	Conditional Variance Equation			
Cst (V) x 10^4	0.002	0.000	0.000	0.172
ARCH (Alpha1)	0.383	0.000	0.173	0.000
GARCH (Beta1)	0.885	0.000	0.981	0.000
Volatility Spillover	0.047	0.741	0.003	0.039
Lag Volatility Spillover	0.000	0.013	0.000	0.023

Variables	Coefficient	Prob	Coefficient	Prob
	Exchange Rate to KSE 100		KSE 100 to Exchange Rate	
	Exchange Rate to Gold		Gold to Exchange Rate	
	Conditional Mean Equation			
Cst (M)	0.000	0.002	0.000	0.002
AR (1)	-0.068	0.001	0.847	0.000
AR (2)	-------	-------	0.105	0.004
MA (1)	-------	-------	-0.944	0.000
	Conditional Variance Equation			
Cst (V) x 10^4	0.002	0.012	0.000	0.000
ARCH (Alpha1)	0.297	0.000	0.166	0.000
GARCH (Beta1)	0.922	0.000	0.983	0.000
Volatility Spillover	--------	-------	0.000	0.012
Lag Volatility Spillover	-0.054	0.002	0.000	0.008

The mean spillovers indicate an asymmetric and unique connectivity of Pakistan's financial markets. Ranging from A-Z, one notable contemporaneous spillover involves exchange rates and gold prices (coefficient 0.553). This indicates that gold gets hit by this influence from PKR immediately; as gold retains a hedge function against PKR currency weakness. In contrast, the spillover from gold prices to the exchange rate is weak, indicating a largely unidirectional relationship. A similar pattern is observed between the stock market and the currency market, where KSE-100 returns have a limited but meaningful lagged influence on exchange-rate movements. As the key determinant of stock market, crude oil (0.017) shows a positive lagged spillover to KSE-100 that could be due to a company's profitability and energy endowment in Pakistan. In contrast, KSE-100 has no significant spillovers to crude oil. This confirms that price signals incrementally changing in the global oil market do not likely pass-through to Pakistan. Crude oil and gold show a high synchronous spillover (0.356), indicating that they are affected by common macroeconomic factors, such as inflation or global risk appetite. Some risk relationships are also partially significant at times, while others namely KSE-100 vs gold, crude oil, and exchange rate appear to be insignificant. This points towards these kinds of markets not necessarily being influenced by similar drivers in the underlying markets or being affected more on the basis of complex interaction. Thus, this research established and highlighted the economic stability through markets.

Conclusion

The current study examined the static and dynamic spillovers confined not just to Pakistan's commodity sector but its stock and currency markets as well. For this purpose, the study used a dataset covering crude oil, gold, PKR/USD exchange rate, and KSE-100 Index. Moreover, the study through ARDL-GARCH model provided a deep analysis for both mean and volatility spillovers. This may accommodate discussion with respect to spot and lagged co-movements which might have been missed by other studies in literature. The study concluded that there is an asymmetric relationship between exchange rate and stock market. This confirmed the positive significant lagged mean spillover effect of KSE-100 Index on exchange rate. Additionally, in stock market volatility, the impact of exchange rate is even more direct. Moreover, an external driver having high spillovers to the KSE-100 Index is crude oil prices interplaying with a significant lagged spillover. This suggests that the Pakistani economy tends to be more vulnerable during global energy price shocks. The study also determined significant and time-varying volatility spillovers between the markets of interest. This suggests that if policymakers assume markets are independent then they cannot afford to do so anymore since a shock in one market cascades into other markets, creating permanent volatility. The nature of the stock and forex market also tends to their asymmetric behavior. This is why it most often needs protection for individual investors. The only exception is gold, which is a safe-haven asset. As for other limited spillover effects from the original changes of their kind in forex movements translating into a negative correlation as an opposite to its ripple manifestations, this can lead its sensitivity to exchange rate movements where it explodes. Finally, the study showed both persistence and asymmetry in KSE-100 Index and crude oil markets, as increasing or decreasing (bad like good) news event triggers-up an increasing future volatility.

Policy Recommendations

The empirical results provided valuable insights for pertinent stakeholders mentioned as follows:

- *Investors and Portfolio Managers:* Dynamic hedging exists for the reason of asymmetric volatility. Stock pricing and risk attitude must always inline up with crude oil. Price direction and gold can play a hedge role in all sorts of currency risks within Pakistan.

- *Central Banks and Policymakers:* Directional linkages are crucial for financial stability. In that scenario, a stable stock market would ensure stability of the currency therein; if global commodity prices rise or fall, regulators should track the transmission across markets and take measures to avoid systemic risks.
- *Practitioners in Risk Management:* The variability of crude oil prices should be included in risk management strategies within firms, especially those identified with energy.

Future Research Implications

This study did not only add value for the financial markets of Pakistan but also served as a necessary implication for further studies. The authors may thereafter choose a temporal dimension, fortnightly or monthly data in which there should be clear spillover effects visually, possibly shedding light on equilibrium long-run relationships. Furthermore, the cointegration framework can be further enhanced by incorporating interest rates, inflation expectations, remittance flows, and geopolitical risk indicators. By applying applied techniques, such as TVP-VAR or DY, Spillover Index would help quantify the spillovers in crises. The knowledge about Indices' comparisons of Pakistan with that of other economies can be enhanced by conducting an inter-country comparison study (i.e., comparative study analysis). This can be particularly done to know the relationship between Pakistan's stock market (Karachi Stock Exchange index). Furthermore, it could comparatively provide a wider understanding on impact output as well as with respect to regional and world economies' financial integration.

Author Contribution

Jawad Khan: Conceptualization, Formal analysis, Writing – original draft.. **Fareeda Rehman:** Formal analysis, Data curation, Writing – review & editing. **Nain Tara:** Investigation, Writing – review & editing.

Conflict of Interest

The authors of the manuscript have no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

Data Availability Statement

The data supporting the findings of this study is available from the corresponding author upon reasonable request. Data on the KSE-100 Index; PKR/USD, crude oil, and gold prices was acquired from public sources from January 3, 2007 to November 29, 2019.

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