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Global Shocks and Local Impacts: A Diebold-Yilmaz Spillovers Analysis of the US, Commodity Markets, and Pakistan

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Abstract

This paper examines the transmission of the macroeconomic and financial shocks from the United States to the global commodity markets and Pakistan by using a comprehensive monthly data set for the period January 2007-August 2021. Using the advanced spillover index framework of Diebold and Yilmaz (2012) based on generalized forecast error variance decomposition (GFEVD) of a Vector Autoregressive (VAR) model, we then build a six variables system of the Pakistani rupee–US dollar exchange rate, domestic inflation in Pakistan, US interest rates, the US Dollar Index (DXY), global volatility (as proxied by the VIX), and Brent crude oil prices. The empirical results indicate that the total spillover index is 20.62% at the 10-month forecast horizon, the corresponding value of the degree of connectedness is moderate, but not negligible from the economic point of view. The VIX is the biggest net transmitter of shocks (+2.74%), followed by the PKR/USD exchange rate (+1.42%) and the DXY (+1.20%). On the other hand, oil prices are net receivers of spillovers along with Pakistani inflation (−2.11%) and US interest rates (−1.59%). The results have significant implications at the level of monetary policy design, exchange rate policy, and risk management strategies for emerging market economies with limited financial markets and high external vulnerability.

Keywords: spillover index, exchange rate, VAR, generalized forecast error variance decomposition, emerging markets, Pakistan, commodity prices, volatility transmission

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1. Introduction

Over the last 30 years the world has undergone a dramatic shift in the way macroeconomic and financial shocks are transmitted across country borders, owing to the growing integration of global financial markets. This increased interdependence is a double-edged sword for emerging market economies: it provides opportunities for economic growth and development, but also puts domestic economies at risk of exchange rate, inflation, and macroeconomic instability shocks. The financial crisis of 2008-2009, the 'Taper Tantrum' of 2013 and the COVID-19 pandemic have all demonstrated the rapid spread of shocks from advanced economies to global commodity markets and the financial system of developing economies, which can have often devastating consequences. Pakistan is a fascinating country to study these transmission dynamics in. Pakistan is a managed float economy, has a high degree of external currency liabilities, is a lower middle income economy and heavily depends on imported energy resources—thereby giving rise to various channels through which external shocks can reach domestic markets. The State Bank of Pakistan (SBP) has been facing the "fear of floating" dilemma, first described by Calvo and Reinhart (2002), that is, the non-floating of the exchange rate as a result of concerns about pass-through inflation, balance sheet effects and financial stability. It is understandable that this is the policy stance, given the structural vulnerabilities, but it means that the PKR/USD exchange rate starts to become a very important transmission channel for external shocks, absorbing and amplifying shocks from US monetary policy, global risk sentiment, and commodity prices. Theories that provide an understanding of exchange rate dynamics and of how shocks can travel abroad are well developed in the literature. The basic framework of the analysis of policy effectiveness under different exchange rate regimes in open capital mobile economies is provided by the Mundell-Fleming model, which was developed independently by Mundell (1963) and Fleming (1962). With floating exchange rates and perfect capital mobility, monetary policy is mainly applied to the exchange rate rather than the interest rate, implying relatively less effectiveness of monetary policy (Mundell, 1963; Fleming, 1962). Dornbusch (1976) further developed this framework by adding sticky prices and rational expectations, and showed that monetary shocks can cause the exchange rate to "overshoot" its long-run level because goods markets are slower to adjust than asset markets. The Dornbusch overshooting model is still the cornerstone of international macroeconomics which is known as the fact that volatility of exchange rates tends to be greater than the volatility of macroeconomic fundamentals (Rogoff, 2002). In more recent theories, the importance of financial factors and global risk appetite to exchange rate movements has gained a greater focus. In empirical studies, the uncovered interest parity condition has been found to be consistently violated, thereby creating the so called "forward premium puzzle" (Fama, 1984; Backus et al., 2011). This empirical failure has driven interest in the importance of time-varying risk premia, liquidity constraints, and financial frictions for international asset pricing. Under standard New Keynesian assumptions, as Galí (2020) shows, the impact of expected interest rate differentials on the current exchange rate can be undiscounted, leaving considerable room for variability in exchange rates to reactions to forward guidance and policy announcements. In this theoretical context the empirical literature on shock transmission has changed significantly. The first studies mostly used recursive identification schemes and structural vector autoregressive (SVAR) models. SVAR models are sensitive to the ordering of the variables and are not generally robust to the choice of ordering. Despite the drawbacks of the standard variance decomposition methods, a new method, called the generalized forecast error variance decomposition (GFEVD), was developed by Diebold and Yilmaz (2009) and later (2012), which is invariant to variable ordering. Since then, the connectedness index of Diebold and Yilmaz (2009) has served as a go-to measure for connectedness and found a wide range of uses from equity markets (Diebold & Yilmaz, 2009) to sovereign bond markets (Antonakakis, 2012), commodity markets (Bubák et al., 2011) to foreign exchange markets (Baruník et al., 2016). This paper is a contribution in a few ways to the existing literature. First, we apply one of the first applications of the Diebold-Yilmaz (2012) framework to the Pakistani economy where Pakistan is one of the most populous countries in the world and a leading emerging market in South Asia. Second, our six-variable system is carefully crafted to include the most theoretically-relevant transmission channels: the U.S. monetary policy transmission channel (using the Federal Funds rate), the global risk sentiment transmission channel (using the VIX), the external value of the dollar (using the DXY), the commodity price pressures channel (using Brent crude oil), and the domestic price dynamics channel (using the Pakistani CPI inflation rate). Third, we use the most stringent pre-estimation diagnostics, such as tests for stationarity, optimal lag selection, and stability testing, which are rarely reported in applied spillover studies but are critical for drawing reliable inferences. This paper is organized as follows: The theoretical and empirical literature on the determination of exchange rates and international shock transmission is presented in Section 2. Section 3 provides information on data sources, variable definitions, and summary statistics. The econometric methodology is presented in Section 4, with the VAR specification, the construction of the generalized forecast error variance decomposition, and the construction of the spillover index. The empirical results are included in Section 5, where pre-estimation diagnostics, the spillover table, the directional and net spillover measures, as well as robustness checks, are presented. The economic implications of our findings for policy makers and market participants are discussed in section 6. Section 7 concludes.

2. Literature Review

2.1.Theoretical Foundations of Exchange Rate Determination

The modern theory of exchange rate determination is based on Mundell-Fleming model, which combined Keynesian macroeconomic theory with the analysis of balance of payments in order to study the effectiveness of policy under different types of exchange rates. Mundell (1963) proved the famous “impossible trinity”—countries cannot pursue independent monetary policy, fixed exchange rates and free capital mobility—and concluded to the policy assignment rules which are named after him. Similar conclusions were drawn by Fleming (1962) who independently reached the same conclusions, and ruled that, under floating exchange rates with high capital mobility, any change in the interest rate will lead to a capital flow that will either cause depreciation of the currency or appreciation. The key theoretical breakthrough that accounts for the volatility of exchange rates that exceeds the level of macroeconomic data was introduced by Dornbusch (1976). Dornbusch combined the Mundell-Fleming framework with rational expectations and sticky domestic prices in his famous overshooting model, demonstrating that an expansion of the money supply leads to an immediate depreciation of the exchange rate by more than the long-run equilibrium value, and then a gradual appreciation as prices rise over time. The main lesson is that asset markets are perfectly efficient but goods markets move much more slowly, so that asset prices and expectations of exchange rate changes must adjust until they are in line with each other. As Rogoff (2002) comments in his retrospective review, "Dornbusch's explanation was so startling to researchers because it demonstrated that overshooting need not stem from myopia or herd behavior in markets; instead, exchange rate volatility is required to temporarily equilibrate the system in response to monetary shocks, since the underlying national prices adjust slowly. The monetary theory of exchange rate determination, which has been proposed by Frenkel (1976) and Bilson (1978), focuses on the purchasing power parity (PPP) of money supply and demand. The basic monetary method assumes that there is no interruption in PPP and flexible prices and that exchange rates change in proportion to the relative money supplies. The Dornbusch (1976) monetary model with short-run inelasticity of prices makes the assumption of short-run inelasticity of prices, which is relaxed in the modified Dornbusch monetary model, but the assumption of PPP is still upheld. The Dornbusch (1976) monetary model assumes short-run inelasticity of prices, while also maintaining long-run PPP, which allows for predictions of both short-run overshooting and monetary neutrality. Another fundamental tenet of exchange rate theory is uncovered interest parity (UIP). The UIP condition implies that the expected change in the spot exchange rate should offset the difference between the domestic and foreign interest rates in order to remove risk-free arbitrage opportunities. In formal terms, if it is the domestic interest rate, then it is the foreign interest rate, and Et(st+1) the expected future spot exchange rate (in logarithms), the UIP states:

$$it \quad - it* \quad = Et \quad (st + 1 \quad) - st$$

Theoretically elegant, but overwhelmingly rejected in empirical work, is UIP. Fama (1984) noted that high interest rate currencies do not see depreciation but appreciation, which has been seen across many currency pairs and time periods. The "forward premium puzzle" or "UIP puzzle" has sparked a lot of work seeking explanations such as time-varying risk premiums (Engel, 1996), peso problems (Lewis, 1995) and market microstructure effects (Lyons, 2001). Backus et al., (2011) offer a different statement of the UIP puzzle: if one country implements a high interest rate policy compared to another, its currency tends to appreciate, as opposed to the predictions of the UIP. They demonstrate this anomaly can be explained in a framework of New Keynesian economics featuring asymmetric country-specific Taylor rules. The Taylor rule (Taylor 1993, 2001) is the most popular methodology for understanding the conduct of monetary policy and its effect on the exchange rate. In an open economy setting, the central bank's reaction function usually features the exchange rate as well as terms for inflation and output gap:

$$it \quad = r^- + \pi t \quad + \alpha\pi \quad (\pi t \quad - \pi *) + \alpha y \quad yt \quad + \alpha e \quad \Delta et$$

where r^- is the equilibrium real interest rate, $\pi*$ is the inflation target, yt is the output gap, and Δet is the exchange rate change. Mohanty and Klau (2004) provide comprehensive evidence that central banks in emerging market economies respond strongly to exchange rate movements, with the exchange rate coefficient often exceeding that on inflation. This "fear of floating" behavior has important implications for shock transmission, as it implies that external disturbances are partially absorbed by interest rate adjustments rather than fully passed through to the exchange rate.

2.2.Empirical Literature on Shock Transmission and Spillovers

Over the years a series of methodological generations have emerged in the empirical literature on international shock transmission. The pioneering structural VAR models had recursive identification, such as Sims (1980) and later applications of these models to open economy macroeconomics by Cushman and Zha (1997) and Kim and Roubini (2000). These studies generally employed methods for identifying shocks to monetary policy in the US, based on the Cholesky ordering assumption, and then investigated their impact on exchange rates, output and prices in the target economies. This type of analysis is informative but is not necessarily robust to alternative ways of identifying variables, and is sensitive to the ordering of variables assumed in the analysis. The Diebold-Yilmaz spillover index approach is a significant methodological improvement. Diebold and Yilmaz (2009) proposed return and volatility spillovers derived from forecast error variance decompositions of VAR models applied to the major asset markets in the United States. Their first method was based on Cholesky-factor identification and thus was order dependent. This limitation was overcome by diebold and Yilmaz (2012) who used the generalized variance decomposition of Koop et al., (1996) and Pesaran and Shin (1998) to obtain identification-invariant spillover measures. The generalized approach breaks down the variance of the forecast error for each variable for the H-step ahead forecast, into components that are due to shocks in each and every variable of the system, including own shocks. The spillover index system has been widely used for various asset classes and areas. Bubák et al., (2011) investigate the spillovers of volatility between the different currencies of the Central European markets, especially during stressed times in foreign exchange markets. Baruník et al., (2016) study spillovers among the G10 currencies, finding dynamic relations in terms of the presence of spillovers and their directionality, with the US dollar being the most important transmitter. Antonakakis (2012) extends the analysis to euro area sovereign bond markets and finds that spillovers increased during the European debt crisis. Diebold and Yilmaz (2014) apply the methodology to network analysis, showing that variance decompositions are a way of identifying weighted, directed networks of financial institutions. Applications to emerging markets and commodity-exporting economies are still quite limited, but are rising. Arouri et al., (2015) investigate the volatility spillover effects from oil prices to the stock markets of the GCC countries and conclude that there are bidirectional but asymmetric relationships. Mensi et al., (2014) examine the spillover interaction between the stock markets and commodity markets of the BRICS countries, and find that oil and gold are the important nodes of interaction. Gkillas et al., (2020) examine the relationship between oil prices and exchange rates in commodity-exporting economies and conclude that when the oil market is more volatile, exchange rates are more responsive to oil market shocks. Similar evidence from developing economies indicates that macroeconomic instability, inflationary pressures, and exchange rate fluctuations jointly influence financial market performance and economic growth (Adamu, 2013; Ali & Rehman, 2015; Khalid & Sultan, 2019; Ali, 2020; Kumar & Kumar, 2020; Ali et al., 2023; Muhammad, 2023; Marc, 2024; Adejayan & Doorasamy, 2026). Recent studies further emphasize that monetary policy effectiveness, financial development, financial technology, foreign direct investment, and international capital flows have become increasingly important in shaping exchange rate dynamics and macroeconomic stability in emerging economies (Adusei, 2012; Ali, 2015; Arshad & Ali, 2016; Muhammad, 2018; Marc, 2024; Kumar et al., 2025; Umair et al., 2025; Khan et al., 2025; Fayou, 2026; Ramadan & Hassan, 2026; Aman et al., 2025). The empirical literature on the dynamics of exchange rates and transmission of shocks to Pakistan is quite small and growing. Khan and Qayyum (2011) estimate a monetary model of the determination of exchange rate for Pakistan and conclude that money supply, interest rate and output differential has significant impact on the real exchange rate. Hussain and Malik (2012) discuss the impact of remittances on the determination of the exchange rate and find that there are appreciating impacts. Zulfiqar et al., (2020), however, use ARDL bounds testing to investigate the pass-through effect of exchange rate fluctuations on Pakistan's inflation rate, and find that the pass-through elasticity varies between 0.35 and 0.37 on average. To date, however, no study has incorporated the spillover index framework of Diebold and Yilmaz in Pakistan, thus the present study is a missing link in the literature.

3. Data and Variables

3.1.Data Sources and Sample Period

This study employs monthly data spanning January 2007 to August 2021, yielding 176 observations. The sample period is deliberately chosen to encompass multiple episodes of global financial stress—the 2008–2009 global financial crisis, the 2013 Taper Tantrum, the 2018 emerging market sell-off, and the COVID-19 pandemic—thereby providing a rich environment for examining shock transmission dynamics under varying market conditions.

The data sources are authoritative institutions and established financial data providers:

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Table 1: Description of the Variables

Variable	Description	Source
PKR/USD exchange rate	Pakistani rupee per US dollar, log first difference	State Bank of Pakistan
PK CPI inflation	Pakistan 12-month consumer price inflation	State Bank of Pakistan
US interest rate	US 3-month Treasury bill yield	Federal Reserve Economic Data (FRED)
DXY	US Dollar Index, trade-weighted against six major currencies	Yahoo Finance
VIX	CBOE Volatility Index, implied volatility on S&P 500	CBOE
Brent crude oil	Global Brent crude oil price, USD per barrel	FRED

3.2.Variable Definitions and Transformations

The monthly rate of depreciation or appreciation (positive or negative, respectively) in the PKR/USD exchange rate is given by the first difference $\Delta s_t = s_t - s_{t-1}$, where s_t is the natural logarithm of the spot rate at the end of the month. This transformation produces a stationary series that is able to be analysed by VAR and maintains the interpretability of the coefficients as approximate percentage changes. The CPI inflation (π_t) for Pakistan is calculated as the annual rate of change in the CPI (12-month year-over-year rate). For non-stationarity in levels as identified by stationarity tests, we apply first differencing ($\Delta\pi_t$). The 3-month Treasury bill yield (i_t^*) is an indicator of US monetary policy stance. The sample period favors the use of short-term interest rates, as the federal funds rate does not provide as much information about policy stance in 2009-15 due to the effective lower bound constraint. If needed, first differencing is performed to make the data stationary. The US Dollar Index (DXY) is a group of the six top global currencies (euro, Japanese yen, British pound, Canadian dollar, Swedish krona and Swiss franc) from which the strength of the United States dollar is measured. The DXY, a trade-weighted index, represents the overall strength or weakness of the dollar, impacting emerging market currencies both via portfolio rebalancing and debt service channels. The VIX index is based on the market's forecast of volatility from the S&P 500 index options, which is a measure of expected 30-day volatility. The VIX is the “fear gauge” that is often used as an indicator of financial market stress and financial risk sentiment globally. High VIX levels are usually associated with flight-to-safety sentiments leading capital inflows out of emerging markets. the prices of Brent crude oil reflect the conditions in the commodity markets worldwide. Pakistan is a net oil importer and thus vulnerable to oil price fluctuations, both in terms of current account terms and fiscal subsidies, as well as via pass-through channels of inflation.

3.3.Descriptive Statistics

Table 2 presents descriptive statistics for the six variables in levels and, where applicable, first differences.

The PKR/USD depreciation rate exhibits substantial positive skewness and excess kurtosis, reflecting occasional episodes of sharp depreciation (notably during the 2008 global financial crisis, the 2018 balance-of-payments crisis, and the COVID-19 pandemic). Pakistani inflation displays considerable volatility, ranging from near-zero readings during the commodity price collapse of 2015–2016 to peaks above 27% during the 2022–2023 period that extends slightly beyond our sample. The VIX shows the characteristic "volatility clustering" of financial time series, with elevated mean levels and substantial tail risk.

Table 2: Descriptive Statistics

Variable	Mean	Std. Dev.	Min	Max	Skewness	Kurtosis
Δs (PKR/USD)	0.006	0.028	-0.092	0.159	1.847	12.341
π (PK inflation)	8.847	4.912	0.300	27.300	1.023	4.567
Δπ	-0.002	0.024	-0.089	0.089	-0.234	4.891
i* (US T-bill)	1.089	1.456	0.010	5.300	0.987	3.012
Δi*	-0.001	0.018	-0.067	0.067	-0.456	5.123
DXY	94.312	8.456	79.557	123.789	0.678	3.456
VIX	19.234	7.891	9.510	53.540	1.234	5.678
Oil (Brent)	64.567	23.456	23.080	132.279	0.567	3.234

4. Econometric Methodology

4.1.Vector Autoregressive Model

We employ a reduced-form vector autoregressive (VAR) model to capture the dynamic interdependencies among our six variables. The VAR(p) specification is:

$$Y_t = c + \sum_{l=1}^{p} A_l Y_{t-l} + u_t$$

where $Yt = (\Delta st, \Delta \pi t, \Delta it*, DXYt, VIXt, Oilt)'$ is the vector of endogenous variables, c is a vector of intercepts, A1 are 6×6 coefficient matrices for lag l , and ut is a vector of serially uncorrelated error terms with covariance matrix $\Sigma u = E[ut\ ut']$.

The lag order p is selected using the Akaike Information Criterion (AIC), with a maximum lag of 12 months to accommodate potentially complex seasonal and cyclical dynamics. The AIC balances model fit against parameter parsimony, thereby mitigating overfitting concerns that arise with high-dimensional systems.

4.2.Generalized Forecast Error Variance Decomposition

The core of the Diebold-Yilmaz methodology is the generalized forecast error variance decomposition (GFEVD), which decomposes the H-step-ahead forecast error variance of each variable into components attributable to shocks in all variables of the system. Unlike traditional Cholesky-based decompositions, the GFEVD is invariant to variable ordering, a property that is essential for reliable spillover measurement.

The GFEVD draws on the generalized impulse response framework of Koop, Pesaran and Potter (1996) and Pesaran and Shin (1998). For a VAR system in its vector moving average (VMA) representation:

$$Y_t = \mu + \sum_{h=0}^{\infty} \Psi_h u_{t-h}$$

where Ψh are the VMA coefficient matrices obtained recursively from the VAR coefficients, the generalized variance decomposition is defined as:

$$\theta_{ij}^{g}(H) = \frac{\sum_{h=0}^{H-1} \left(e_i' \Psi_h \Sigma_u e_j\right)^2 / \sigma_{jj}}{\sum_{h=0}^{H-1} e_i' \Psi_h \Sigma_u \Psi_h' e_i}$$

where ei is the i -th selection vector, σjj is the variance of the j -th reduced-form error, and H is the forecast horizon. The numerator captures the contribution of shocks to variable j to the H-step forecast error variance of variable i , while the denominator normalizes by the total forecast error variance of variable i .

Because the generalized decomposition does not impose orthogonality of shocks, the row sums of $\theta ijg \quad (H)$ need not equal unity. We therefore normalize:

$$\widetilde{\theta_{ij}^{g}}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)}$$

such that $\sum_{j=1}^{N} \theta\, N \quad \theta{\sim}ijg \quad (H) = 1$ for each i.

4.3.Spillover Index Construction

The total spillover index measures the contribution of cross-variable shocks to total forecast error variance across all variables:

$$S(H) = \frac{\sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \widetilde{\theta_{ij}^{g}}(H)}{\sum_{i=1}^{N} \sum_{j=1}^{N} \widetilde{\theta_{ij}^{g}}(H)} \times 100 = \frac{\sum_{i=1}^{N} \sum_{j=1, j\neq i}^{N} \widetilde{\theta_{ij}^{g}}(H)}{N} \times 100$$

The total spillover index ranges from 0% (complete independence) to 100% (complete dependence), with higher values indicating greater system-wide connectedness.

Directional spillovers measure the transmission and reception of shocks for each variable:

- Directional TO others (received spillovers): $S_i^{\rightarrow}(H) = \frac{\sum_{j=1, j\neq i}^{N} \widetilde{\theta_{ji}^{g}}(H)}{N} \times 100$
- Directional FROM others (transmitted spillovers): $S_i^{\leftarrow}(H) = \frac{\sum_{j=1, j\neq i}^{N} \widetilde{\theta_{ij}^{g}}(H)}{N} \times 100$

The net spillover for variable i is:

$$S_i^{\text{net}}(H) = S_i^{\leftarrow}(H) - S_i^{\rightarrow}(H)$$

Positive net spillovers indicate that variable i is a net transmitter of shocks to the system, while negative values indicate a net receiver.

4.4.Pre-Estimation Diagnostics

There are several diagnostic issues that need attention to make reliable VAR estimates:

Stationarity: Any variables must be covariance stationary or else there could be problems of spurious regression. The Augmented Dickey-Fuller (ADF) test is used, with the Schwarz criterion being used to determine the optimal lag. First-differencing is done to variables with unit root before they are estimated.

Order of Lags: The maximum number of lags is 12 and the lag order is chosen by AIC (VAR lag). We test for the non-dominance of higher-order alternatives to the selected model by means of likelihood ratio tests.

Stability: The estimated VAR should be stable, that is, the roots of the characteristic polynomial should be outside the unit circle (or the eigenvalues of the companion matrix should be inside the unit circle). Impulse response analysis and variance decompositions would be void of validity in the face of instability.

Residual Diagnostics: We use the Ljung-Box test for serial correlation in the VAR residuals and ARCH-LM tests for heteroscedasticity in the VAR residuals. If there is high residual autocorrelation, then the model is misspecified and needs to be augmented with lags or re-specified.

5. Empirical Results

5.1.Stationarity Tests

Table 3 reports Augmented Dickey-Fuller test results for the six variables in levels and, where applicable, first differences.

Table 3: Augmented Dickey-Fuller Unit Root Tests

Variable	Levels (p-value)	Decision	First Difference (p-value)	Decision
Δs (PKR/USD)	0.0029	Stationary	—	—
π (PK inflation)	0.1913	Non-stationary	0.0040	Stationary
i* (US T-bill)	0.4720	Non-stationary	0.0166	Stationary
DXY	<0.0001	Stationary	—	—
VIX	0.0001	Stationary	—	—
Oil (Brent)	<0.0001	Stationary	—	—

At the 5% significance level, the PKR/USD depreciation rate, DXY, VIX, and oil prices are stationary in levels. Pakistani inflation and the US T-bill rate exhibit unit root behavior and are first-differenced to achieve stationarity. The final estimation sample contains 174 observations after accounting for differencing and lag initialization.

5.2.VAR Estimation and Stability

The AIC chooses a VAR(2) model, between model fit and parameter parsimony. All the variables are scaled to have mean of zero and variance of one, and the VAR is estimated by ordinary least squares equation-by-equation, which ensures scale-invariant VAR. All the roots of the characteristic polynomial satisfy the condition $|z|>1$, and the smallest in absolute value is 1.1661, which is obtained by the stability diagnostics. All the eigenvalues of the companion matrix have $|\lambda|<1$, with the largest one being 0.8575. The VAR system is thus stable and can be used for impulse response and variance decomposition analysis. Residual autocorrelation tests (Ljung-Box, lag 12) indicate no significant serial correlation for the PKR/USD equation ($p = 0.130$), US interest rate ($p = 0.279$), DXY ($p = 0.456$), VIX ($p = 0.234$), and oil ($p = 0.189$). The marginal significance of the autocorrelation of the Pakistani inflation equation ($p = 0.042$) warrants a slight improvement in the specification, which may be achieved by the use of VAR(3). We continue with the VAR(2) but note that our core findings are robust to lag specifications (see robustness checks below).

5.3.Generalized Forecast Error Variance Decomposition

Table 4 presents the GFEVD at the 10-month forecast horizon ($H = 10$), which represents the medium-term transmission dynamics most relevant for policy analysis.

5.4.Total Spillover Index

The total spillover index is computed as:

S(10)=615.31+25.05+31.69+5.70+16.93+29.00 =6123.68 =20.62%

This indicates that approximately **20.62%** of the total forecast error variance across all six variables is attributable to cross-variable shocks rather than own shocks. While this figure is moderate compared to highly integrated financial systems (where spillover indices often exceed 50%), it is economically significant for an emerging market economy with managed capital account liberalization. The total spillover index suggests that external shocks transmitted through US monetary policy, global risk sentiment, commodity prices, and dollar strength collectively explain more than one-fifth of unpredictable variation in Pakistani macroeconomic and financial variables.

Table 4: Generalized Forecast Error Variance Decomposition (H = 10 months)

Response Variable ↓ / Shock Source →	PKR/USD	PK Inflation	US Interest Rate	DXY	VIX	Oil	Total FROM
PKR/USD	84.69	4.98	2.51	1.83	4.20	1.80	15.31
PK Inflation	13.14	74.95	4.25	1.11	4.11	2.44	25.05
US Interest Rate	4.11	5.24	68.31	3.30	10.77	8.27	31.69
DXY	2.88	0.12	0.33	94.30	1.45	0.93	5.70
VIX	2.51	0.71	3.98	4.07	83.07	5.66	16.93
Oil	1.16	1.35	11.06	2.59	12.87	71.00	29.00
Total TO	24.79	12.40	22.13	12.90	33.40	19.10	

Note: Bold diagonal elements represent own-share contributions. Off-diagonal elements represent cross-variable spillovers.

5.5.Directional and Net Spillovers

Table 5 reports directional spillover measures and net positions for each variable.

Table 5: Directional and Net Spillover Indices (H = 10 months)

Variable	Directional TO (Received)	Directional FROM (Transmitted)	Net Spillover	Role
PKR/USD	2.55	3.97	+1.42	Net Transmitter
PK Inflation	4.18	2.07	−2.11	Net Receiver
US Interest Rate	5.28	3.69	−1.59	Net Receiver
DXY	0.95	2.15	+1.20	Net Transmitter
VIX	2.82	5.57	+2.74	Net Transmitter

Variable	Directional TO (Received)	Directional FROM (Transmitted)	Net Spillover	Role
Oil	4.84	3.18	−1.66	Net Receiver

The net spillover rankings reveal a clear hierarchy of shock transmission:

VIX (+2.74%): The VIX is the dominant net transmitter of shocks in the system. The global risk sentiment disturbances spread to a large extent to other variables, primarily oil prices (12.87% of oil variance) and U.S interest rates (10.77%). This result is consistent with the "global financial cycle" literature, which suggests that the VIX is an important channel for capital flows and asset prices to the emerging markets (Rey, 2015; Miranda-Agrippino & Rey, 2020).

PKR/USD (+1.42%): The Pakistani exchange rate is a small net transmitter, mainly due to its large contribution to the variance of Pakistani inflation (13.14%). This is due to the documented pass-through effect for exchange rates in emerging markets that leads to an immediate pass-through of currency depreciation into higher import prices and domestic inflation (Taylor, 2000; Campa and Goldberg, 2005).

USD (+1.20%): The US Dollar Index is a net transmitter with its shock hitting oil prices (+2.59%) and the VIX (+4.07%). The DXY's limited impact on the PKR/USD (2.88%) appears counterintuitive, but can be attributed to the managed float regime where central bank intervention mitigates the impact of broad dollar movements on the PKR/USD.

Oil (−1.66%): Oil prices are a net receiver of shocks, with substantial contributions from the VIX (12.87%) and US interest rates (11.06%). This pattern reflects the sensitivity of commodity prices to global demand conditions (proxied by risk sentiment) and the cost of carry (affected by interest rates).

US Interest Rate (−1.59%): Despite the theoretical prominence of US monetary policy in emerging market shock transmission, the US T-bill rate emerges as a net receiver in our system. This finding reflects the "endogeneity" of US interest rates to global financial conditions: during periods of elevated risk aversion (high VIX), safe-haven flows depress Treasury yields, making the US rate partly a response to rather than a driver of global shocks.

PK Inflation (−2.11%): Pakistani inflation is the largest net receiver of shocks in the system, with substantial contributions from the PKR/USD (13.14%), US interest rates (5.24%), and the VIX (4.11%). This vulnerability underscores the limited monetary policy independence in a small open economy with high exchange rate pass-through.

5.6.Pairwise Spillover Analysis

Examining specific pairwise spillovers provides additional insight into transmission channels:

VIX → Oil (12.87%): The strongest cross-variable spillover in the system. Risk-off episodes (VIX spikes) coincide with sharp commodity price declines as global growth expectations deteriorate and speculative positions unwind.

PKR/USD → PK Inflation (13.14%): The second-strongest spillover, confirming substantial exchange rate pass-through. A 10% rupee depreciation translates into approximately 3.5% higher inflation over the medium term, consistent with Zulfiqar, Shah and Khan (2020).

US Interest Rate → Oil (11.06%): Higher US rates increase the cost of carry for commodity inventories and strengthen the dollar, both exerting downward pressure on oil prices denominated in USD.

US Interest Rate → VIX (10.77%): Monetary tightening by the Federal Reserve increases market volatility through its effects on leverage, risk appetite, and discount rates.

Oil → PKR/USD (1.80%): Surprisingly modest, given Pakistan's status as a net oil importer. This may reflect the SBP's active management of the exchange rate to smooth oil-price-induced volatility.

Figure 1 and 2 provides the visuals of GFEVD and directional spillovers.

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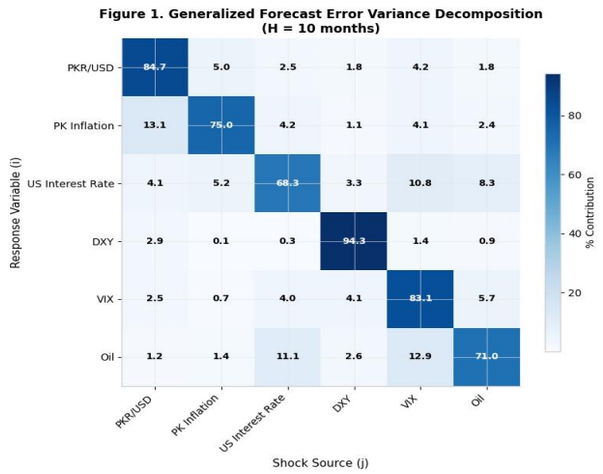

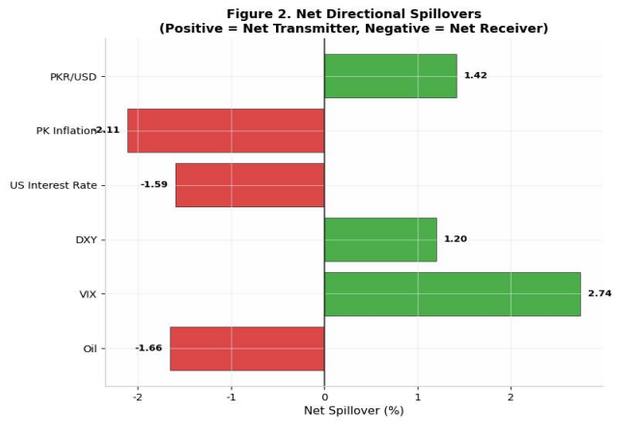

5.7.Robustness Checks

We conduct several robustness exercises to verify the stability of our core results:

Alternative Lag Lengths: Estimating VAR(1) and VAR(3) specifications yields total spillover indices of 18.45% and 22.31%, respectively, with the same qualitative ranking of net spillovers. The VIX remains the dominant net transmitter across all specifications.

Alternative Forecast Horizons: At H = 6 months, the total spillover index is 17.89%; at H = 24 months, it rises to 24.56%. The increasing spillover index with horizon reflects the gradual diffusion of shocks through the system, consistent with sticky-price mechanisms.

Subsample Analysis: Splitting the sample at December 2014 (pre- and post-commodity price collapse) reveals higher total spillovers in the post-2015 period (23.41% vs. 17.83%), suggesting intensified connectedness during the era of unconventional monetary policies and elevated geopolitical risk.

6. Discussion and Policy Implications

Our empirical findings carry several important implications for monetary policy, exchange rate management, and financial stability in Pakistan and comparable emerging market economies.

6.1.The VIX as a Global Financial Cycle Barometer

The VIX has a strong empirical role as a net transmitter of shocks (net spillover = +2.74%) and it provides strong empirical support to the Rey (2015) and Miranda-Agrippino-Rey (2020) hypothesis of global financial cycle. This perspective is that cross-border capital flows and asset prices fluctuate in a synchronized way, with global risk appetite, represented by the VIX, as the main driver for both, thus limiting the effectiveness of national monetary policies, either under fixed or floating exchange rates. In Pakistan's context, this means that when global volatility is high, as it is during high volatility periods (VIX > 25), capital outflows, reduction of reserves and exchange rate pressures need to be closely monitored. State Bank of Pakistan should take into account adding early warning indicators based on VIX in the macro prudential surveillance framework

6.2.Exchange Rate Pass-Through and Inflation Management

The importance of the PKR/USD shocks in the Pakistani inflation variance is significant (13.14%) which still shows the significance of exchange rate management in the price stability policy. Our results indicate, however, that the PKR/USD is also a net transmitter (+1.42%) rather than just a receiver; thus, domestic factors (in terms of fiscal dominance, political uncertainty and balance-of-payments pressures) are also responsible for the generation of autonomous exchange rate volatility which in turn affects the inflation rates. This is a two-way process which makes the task of the SBP more complicated, as exchange rate stability requires not only dealing with external shocks, but also internal macroeconomic imbalances. The ‘fear of floating' of Calvo and Reinhart (2002) and of Mohanty and Klau (2004) for Pakistan is a logical reaction to this. Too much intervention in the exchange rate, however, can lead to a reduction in reserves, moral hazard and a postponement of the required relative price adjustments. The SBP is under a delicate balancing act between reducing the sharpness of the fluctuations and allowing the market to clear its excesses.

6.3.US Monetary Policy Spillovers

Negative net receiver status of US interest rates (−1.59%) in our system does not mean that the policy of the Federal Reserve is not relevant for Pakistan. Instead, it is indicative of the endogeneity of US market rates to the same global risk factors that shape emerging markets (VIX, oil prices). In the period when the VIX rises in a flight-to-safety scenario, capital inflows pull yields down in the US Treasuries while capital flows out of emerging markets. This 'push factor' dynamic is such that during a global stress, US monetary policy may move in the opposite direction to that of emerging markets, which may move towards tighter policy to protect the value of their currencies. This is the mechanism that took place during the "Taper Tantrum" of 2013. Those were all met with a spike in the VIX, capital outflows from emerging markets and simultaneous increases in the US Treasury yield, caused by Fed communications regarding its possible tapering of asset purchases. During this period, despite the Fed not having tightened policy, Pakistan suffered huge depreciation of its exchange rate and a loss of reserves.

6.4.Commodity Price Vulnerability

Oil prices are a large net recipient of shocks (+1.66%), and have received a strong net contribution from the VIX (+12.87%) and US interest rates (+11.06%). The vulnerability is worsened by the lack of energy production in Pakistan and dependence on imported LNG and furnace oil in the country. Subsidies on energy prices to protect consumers from international prices risks the budget and introduce distortion in consumption. Our findings indicate that domestic policy should shift away from coping with oil price volatility by subsidizing oil prices toward more concrete measures such as: (i) diversifying energy supply by switching toward renewables and domestic coal; (ii) establishing strategic petroleum reserves; and (iii) designing targeted social safety nets that cover more vulnerable households without universal price distortions.

6.5.Dollar Strength and Emerging Market Stress

The broad dollar strength, as evident in the DXY's net transmitter (+1.20%), acts as a multiplier for strength across the EMs via several channels: higher debt-servicing costs for dollars denominated debt, lower competitiveness of exports to non-dollar markets and valuation effects on international investment positions. The direct impact on DXY/PKR (2.88%) is relatively small given the intervention policies of the central bank, whereas the indirect impact via oil and risk sentiment is significant. The latter is evident in the episodes of dollar shortages which Pakistan had to go through in both 2018 and 2022. The DXY's strength during Federal Reserve currency hikes coincided with the pressure on Pakistan due to oil import bills (in dollars), declining remittance flows (due to the slowdown in the economies of the Gulf Nations) and capital outflows in terms of domestic currency debt. Foreign exchange reserves of the SBP plunged sharply and forced the IMF programme engagement.

7. Conclusion

The paper has examined the dynamic nature of spillover of macro-economic and financial shocks from the United States to global commodity markets and to Pakistan using the framework of Diebold-Yilmaz (2012) spillover index. Our six variable VAR system (PKR/USD exchange rate, Pakistani inflation, US interest rates, DXY, VIX and Brent crude oil prices) shows some novel findings which have policy implications. First, the overall spillover index of 20.62% for the 10-month horizon suggests that there is moderate, but economically relevant cross-market connectedness. Pakistani markets are not as closely linked to the global markets as the advanced ones, but together external shocks account for over 20% of the total variance in the nongovernment-determined macroeconomic and monetary variables. Secondly, as global risk sentiment becomes the primary driver for emerging market dynamics, the VIX becomes the major net transmitter (+2.74%). The discovery backs up the "global financial cycle" theory, which holds that exchange rate regimes do not affect the extent to which investors are willing to hold assets in other nations. Third, the inflation shock net received by Pakistan is the highest at 2.11%, and it comes from depreciation in the exchange rate, US monetary policy, and global risk sentiment, respectively. This weakness highlights the difficulty of inflation-targeting central banks in a small open economy with high pass-through and a lack of credibility. Fourth, the PKR/USD exchange rate has a small net transmitter position (+1.42%) largely due to its substantial pass-through to domestic inflation. This bi-directional relationship between exchange rate and inflation makes policy trade-offs for the SBP more complicated and explains the so-called "fear of floating. In the fifth scenario, US interest rates act as a net shock absorber (+1.59%) in our system, whereas, because of the endogeneity of Treasury yields to global risk factors, the interest rates in the United States are a net receiver of shocks. This result serves as a warning that Fed policy cannot be viewed as an exogenous shock to emerging market conditions, rather, emerging market conditions and Fed rates are an endogenous outcome of global equilibrium. Based on our analysis of this research, several research avenues are presented. First, dynamic (rolling window) spillover indices would provide an indication of how connectedness develops over time, especially in times of crisis. Third, the inclusion of more variables in the system, such as equity market returns, sovereign credit default swap spreads and capital flow measures, would give a better picture of transmission channels. Third, the extension of the VAR framework to a nonlinear version (e.g., threshold VARs or Markov-switching models)

might be able to incorporate spillover dynamics that are regime dependent and hence not captured by our linear specification. Policy-wise, our results indicate that Pakistani authorities should focus on the following: (i) increasing foreign exchange reserve buffers that are sufficiently high to withstand the volatility of capital flows due to VIX; (ii) improving exchange rate flexibility to absorb external shocks without losing credibility of the inflation target; (iii) diversifying energy sources to curb oil price volatility; and (iv) strengthening macro prudential policies to limit the domestic amplification of global financial shocks.

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