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Dynamics of Causality between Inflation Volatility and Exchange Rate Volatility in Pakistan: A Time Series Analysis

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Abstract
This study investigates the dynamic relationship between inflation volatility and exchange rate volatility in Pakistan over the period from 1960 to 2023. Utilizing time series data, the study employes the Vector Error Correction Model (VECM) to analyze both short-run and long-run causality between these variables. The study has found bidirectional causality between exchange rate volatility and inflation volatility, indicating that fluctuations in one variable significantly influence fluctuations in the other, both in the short and long term. Based on the results of the study, it is suggested that to stabilize prices, policymakers should implement measures to stabilize the exchange rate and to stabilize the exchange rate, planners should adopt policies that stabilize the prices.
Keywords: Vector Error Correction Model, Volatility, Short-run, Long-run, Johansen Juselius Cointegration

1. Introduction

Inflation is a main and widely discussed economic issue because of the major effect it has on economies worldwide. It is essential to understand the factors that influence inflation in order to develop effective macroeconomic policies (Iqbal et al., (2022). In Pakistan, inflation is a major issue that damages the country's economic stability as well as development prospects. All sectors of society are impacted by the rapid increase in inflation, which causes economic inequalities and diminishes purchasing power. Inflation control is essential for developing economies like Pakistan's to achieve progress and promote sustainable development (Amjad et al,.2021). Therefore, policymakers consider the maintenance of a moderate inflation rate as an important objective, as it is essential for attaining stable economic growth and maintaining the basic needs of the population. Inflation control is a major concern in Pakistani economic policy discussions due to the difficulty of achieving so (Rasheed et al., 2022; Ali et al., 2023).
One of Pakistan's biggest economic problems is its highly volatile and often depreciating exchange rate compared to other major currencies. This instability has a detrimental impact on the economic stability of the country as it leads to a rise in import expenses and a decline in export competitiveness (Amjad, 2020). An unstable and volatile exchange rate generates inconsistency, hampering investment and growth in the economy. Sustaining exchange rate stability is of significance for Pakistan in order to maintain economic well-being and promote sustainable development (Ali, 2018; Lakhan et al., 2023).
The association between inflation and exchange rates is an important aspect of economic investigation, especially when considering Pakistan's circumstances. Fluctuations in exchange rates can directly impact inflation levels through changes in the prices of imported goods and services (Amjad and Asghar, 2021; Khan and Zahra, 2019). Depreciation of the currency rate results in an increase in the cost of imports, which in turn leads to high price levels and contributes to inflation. On the other hand, a more stable exchange rate for currencies may efficiently reduce inflationary forces by decreasing the expenses of imported goods (Shahzad et al,. 2023). The interaction between exchange rates and inflation is of the most significance aspect for policymakers, as ensuring exchange rate stability is vital for managing inflation and attaining economic stability. Gaining a comprehensive understanding of this relationship is essential for creating efficient monetary and fiscal strategies that promote long-term and stable growth in the economy (Qasim et al., 2021; Ali, 2022).
Pakistan's economy continues to face significant challenges, characterized by limited foreign reserves and a rise in inflation. The level of uncertainty over policies is high, and economic activity is low, which is a result of strict fiscal and monetary policies as well as import restrictions. The average year-on-year consumer price inflation in the first half of FY24 increased to a multi-decade high of 28.8%, compared to 25.0% in the first half of FY23. The rise in expenses can be attributed to the increase in domestic energy prices and disruptions in the supply chain, resulting in higher production costs overall. The presence of inflationary pressure, together with the fluctuation of exchange rates, highlights the need to comprehend the correlation between exchange rates and inflation when devising efficient economic strategies (WDI, 2021).
The study is structured into five different sections. Section 1 presents the problem statement and presents the background information for the study. Section 2 provides literature review of the previous research. Section 3 provides a detailed description of the model specification, data sources, and methods used in the study. In Section 4, the findings are presented, and the consequences of those findings are discussed. Section 5 provides a summary of the study's findings and discusses their policy implications.

2. Literature Review

This section provides a summary of the previous research. Table 1 presents a brief summary of the literature review. Based on the studies reviewed, several consistent findings emerge regarding the economic relationships examined across various countries and time periods. Inflation tends to have a positive association with oil prices, external debt, and interest rates, while foreign investment shows a negative relationship. Interest rates has a positive association with inflation and a negative association with exports. Real effective exchange rates (RER) are positively influenced by budget deficits and negatively affected by GDP in certain contexts. Additionally, GDP tends to correlate positively with investment and remittances, while negatively impacting money supply and exchange rates. There is scanty literature that explores the causal relationship between exchange rate inflation by employing the VECM model in Pakistan.

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Table 1: Summary of the Literature Review

Author(s)	Time period	Country	Methodology	Main Results
Umoru et al. (2023)	1980-2023	African countries	Vector error correction	Inflation(+), oil prices(+), external debt(+),foreign investment(-), interest rate(+)
Lakhan et al. (2023)	2000-2023	Pakistan	ARDL	Interest rate(+), inflation(+), exports(-)
Bati and Jemal (2023)	1980-2020	Ethiopia	ARDL	RER (+), budget deficit (+), GDP(-)
Neupane (2022)	1980-1920	Nepal	ARDL Bound test	GDP (+), Bond Money Supply (-), Exchange rate (+), Investment (+), Remittance (+), interest rate (+)
Charles et al. (2022)	1981-2017	Nigeria	ARDL Bound test	Output gap (+), BMS (+), total govt expenditure (+), Total imports (+), Unemployment rate (-)
Dung and Okereke (2022)	1981-2019	African countries	PLS	Inflation(-), interest rate(-), terms of trade(-)
Astuty, (2022)	2009-2020	Indonesia	MLR	Trade balance(+), inflation(-), foreign debt(-)
Ugoh et al. (2022)	2001-2020	Nigeria and South Africa	Pooled OLS	Inflation(-), Interest rate(+), GDPPC(+), unemployment(+)
Ali et al. (2022)	1980-2014	Malaysia	ARDL	GDP(-), FDI(-), export(-), interest rate(-), inflation(-)
Sherazi et al. (2022)	1980-2018	Pakistan	Granger Causality	Unemployment (-), imports (+), interest rate (+), money supply (+)
Iqbal et al. (2022)	1989-2019	Pakistan	ARDL	money supply(+), GDP(-), oil prices(-), exchange rate(-)
Qasim et al. (2021)	2004-2019	Pakistan	Cointegration technique	Exchange rate(-), prices of petrol(+)
Čaklovica and Efendic (2020)	2005-2015	28 European countries	dynamic panel	GDP (-), economic openness (-), unemployment (-), real wages(+), exchange rate (-) effects, food and oil prices (+)

3. Model Specification, Data and Methodology

This study relies on time series data from Pakistan which includes the years 1960 to 2023.

Table 2 presents a description of the variables, units of measurement, and data sources. Volatility is calculated using the GARCH method.

Table 2: Description of Variables, Unit of Measurement and Sources of Data

Variables	Descriptions	Unit of Measurements	Sources
EXRV	Official exchange rate volatility	LCU per US$, period average	WDI
INFV	Inflation volatility, GDP deflator	annual %	

This study used the VAR model to determine the long run and short run causality between exchange rate volatility and inflation volatility in Pakistan. In the field of applied econometrics, the application of Vector Error Correction Model (VECM) has gained widespread popularity. A primary advantage of VAR models is their flexibility, as they do not require strict economic dynamic assumptions.

These models can be represented as:

$$EXRV_t = \sum_{i=1}^{n} \alpha_i EXRV_{t-i} + \sum_{j=1}^{n} \beta_j INFV_{t-j} + \varepsilon_{1t} \quad (1)$$

$$INFV_t = \sum_{i=1}^{n} \varphi_i INFV_{t-i} + \sum_{j=1}^{n} \varphi_j EXRV_{t-j} + \varepsilon_{2t} \quad (2)$$

4. Results and Discussions

This section presents the results and discussion of the study.

4.1 Summary Statistics and Correlation Analysis

Table 3 illustrates the summary statistics of the key variables. The variable EXRV measures the volatility of the official exchange rate, expressed as local currency units (LCU) per US dollar (USD), averaged over the period. The average exchange rate volatility (EXRV) over the period is 3239.809 LCU per USD. This high mean value indicates a significant level of volatility in the exchange rate. The median value is 159.725 LCU per USD, considerably below the mean, indicating that most observations are concentrated towards the lower end of the scale. This substantial difference between the mean and median suggests a distribution that is positively skewed. The maximum observed value for EXRV is 37,576.830 LCU per USD, highlighting periods of extreme volatility. In contrast, the minimum observed value is 0.001 LCU per USD, showing instances of very low or negligible volatility. The standard deviation of 6677.180, reflects substantial variation in exchange rate volatility over the period. With more observations on the lower end and a big tail on the upper end, the distribution is strongly skewed to the right, as indicated by the skewness value of 3.166. The kurtosis value of 14.113 indicates that the distribution is peaked and has heavy tails in comparison to a normal distribution. Based on the Jarque-Bera statistic, data is not normally distributed.

Table 3: Summary Statistics

Variables	Mean	Median	Max	Min	SD	Skewness	Kurtosis	JB	Prob.
EXRV	3239.8	159.72	37576.83	0.001	6677.18	3.16	14.11	436.26	0.00
INFV	54.478	51.93	114.52	0.070	29.10	0.31	2.34	2.19	0.33

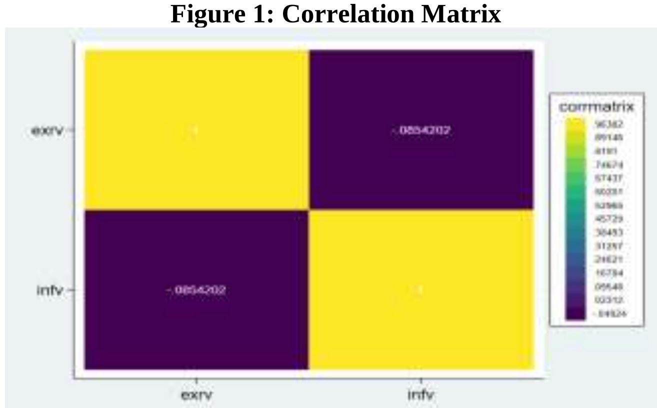
The variable INFV measures the volatility of inflation using the GDP deflator, expressed as an annual percentage. The average inflation volatility (INFV) is 54.478%, with a median of 51.938%. These values are relatively close, suggesting a more symmetric distribution compared to EXRV. The maximum inflation volatility observed is 114.525%, while the minimum is 0.070%. The standard deviation is 29.104%, indicating moderate variability in inflation volatility. The skewness of 0.313 suggests a slight positive skewness in the distribution of inflation volatility. The kurtosis value of 2.343 is close to the normal distribution value of 3, indicating a relatively normal distribution. The Jarque-Bera statistic of 2.199 with a probability of 0.333 suggests that the distribution of inflation volatility does not significantly deviate from normality.

Table 4 and Figure 1 presents the correlation analysis. The result shows that the variables exchange rate volatility has weak negative correlation with inflation volatility.

Table 4: Correlation Matrix

Variables	EXRV	INFV
EXRV	1	-0.085
INFV	-0.085	1

Figure 1: Correlation Matrix



4.2 Unit Root Analysis

This section presents the unit root analysis of the key variables. Table 5 displays the results of the ADF unit root test for the variables EXRV and INFV, revealing that both series are integrated at order one.

Table 5: Unit Roots Tests Results

			ADF Test on Level				
Variables	None	Lags	Intercept	Lags	Intercept and Trend	Lags	Conclusions
EXRV	0.447	0	0.276	0	0.113	0	I(1)
INFV	0.910	0	0.855	1	0.321	1	I(1)

Table 6: Trace and Max Tests for Cointegration

	Unrestricted Cointegration Rank Test (Trace)			
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.116544	12.27363	15.49471	0.1443
At most 1 *	0.080673	4.962697	3.841466	0.0259
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.116544	7.310935	14.26460	0.4530
At most 1 *	0.080673	4.962697	3.841466	0.0259

4.3 Johansen Juselius Cointegration Test

The results of the Trace and Max tests for cointegration are displayed in Table 6. The Trace test results demonstrate the absence of cointegration, as neither of the test statistics above the critical value. However, the hypothesis that there is at most 1 cointegrating equation is rejected (shown by *) because the test statistic is higher than the critical value. This suggests that there is evidence for cointegration.

Similarly, the Max-Eigenvalue test also indicates no cointegration. The rejection of the at most 1 cointegrating equation hypothesis (indicated by *) supports the presence of cointegration.

4.4 Lag Length Selection Results

This section provides the results of lag selection. The outcomes of the lag selection criterion are displayed in Table 7. Based on a variety of information criteria, including the Akaike Information Criterion (AIC), Schwarz Criterion (SC), Final Prediction Error (FPE), and Hannan-Quinn Criterion (HQ), the optimal lag order, denoted by asterisks (*), is determined. Lag order 4 is selected in this table because it is the optimal choice for the majority of criteria, as shown by asterisks.

Table 7: Optimal Lag Selection

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-901.0088	NA	4.05e+10	30.10029	30.17011	30.12760
1	-774.4279	240.5038	6.81e+08	26.01426	26.22370	26.09618
2	-770.5349	7.137115	6.84e+08	26.01783	26.36689	26.15437
3	-759.1584	20.09852	5.35e+08	25.77195	26.26063	25.96310
4	-734.8712	41.28827*	2.73e+08*	25.09571*	25.72401*	25.34147*

* indicates lag order selected by the criterion

4.5 Granger Causality Tests

This section uses Granger causality tests augmented with a suitable error correction term obtained from the long-term cointegration relationship. The analysis use a Residual Vector Autoregression (VAR), more precisely a Vector Error Correction Model (VECM), to evaluate the causal effects in both the short-term and long-term. The decision to use VECM follows the confirmation of stationarity at the first difference level for the exchange rate volatility and inflation volatility models, as identified in Unit Root tests presented in Table 5.

Table 8: Long run Causality between Exchange Rate Volatility and Inflation Volatility

Parameter	Variable	Coefficient	Std. Error	t-Stat.	Prob.
		EXRV-INFV Model DV=D(EXRV)			
C(1)	ECT	-0.201	0.080	-2.509	0.015
C(2)	D(EXRV(-1)	0.980	0.228	4.293	0.000
C(3)	D(EXRV(-2)	-2.205	0.257	-8.580	0.000
C(4)	D(EXRV(-3)	2.606	0.307	8.479	0.000
C(5)	D(EXRV(-4)	-0.863	0.416	-2.076	0.043
C(6)	D(INFV(-1)	-7.464	0.595	-12.541	0.000
C(7)	D(INFV(-2)	8.996	3.622	2.484	0.001
C(8)	D(INFV(-3)	-10.405	4.669	-2.229	0.016
C(9)	D(INFV(-4)	19.113	7.563	2.527	0.015
C(10)	C	418.679	220.812	1.896	0.064
	R^2 = 0.473			DW stat = 1.978	
		INFV-EXRV Model DV=D(INFV)			
C(11)	ECT	-0.030	0.002	-19.011	0.000
C(12)	D(INFV(-1)	0.045	0.004	10.169	0.000
C(13)	D(INFV(-2)	0.011	0.005	2.287	0.017
C(14)	D(INFV(-3)	-0.003	0.006	-0.469	0.963
C(15)	D(INFV(-4)	0.125	0.008	15.487	0.000
C(16)	D(EXRV(-1)	-0.178	0.047	-3.758	0.004
C(17)	D(EXRV(-2)	-0.238	0.048	-4.952	0.000
C(18)	D(EXRV(-3)	-0.103	0.049	-2.105	0.103
C(19)	D(EXRV(-4)	-0.354	0.147	-2.409	0.108
C(20)	C	-0.213	0.029	-7.401	0.000
	R^2 = 0.401			DW stat = 2.004	

Table 8 presents the long-run causality relationship between exchange rate volatility (EXRV) and inflation volatility (INFV) using a Vector Error Correction Model (VECM). It includes two models. The first model examines the relationship where the dependent variable is the exchange rate volatility. The presence of a considerable Error Correction Term (ECT) in this model suggests the existence of a long-term equilibrium relationship between the variables. Several lagged differences of EXRV and INFV are also included, showing significant impacts on the current value of EXRV. In the second model, the dependent variable is inflation volatility. The ECT is also significant, reinforcing the existence of a long-run equilibrium relationship between exchange rate volatility and inflation volatility. Various lagged differences of INFV and EXRV are significant, indicating that past values of these variables affect current inflation volatility. This suggests a bidirectional relationship where changes in exchange rate volatility and inflation volatility influence each other over time. Both models show relatively good explanatory power, indicated by their R-squared values. Additionally, the Durbin-Watson statistics indicate that there is no significant autocorrelation present in the residuals.

Table 9: Short-run Causality based on Wald Test Results Between Exchange Rate Volatility and Inflation Volatility

Null Hypothesis		F-Stat.	Prob.
D(EXRV(-1) = D(EXRV(-2) =D(EXRV(-3) = D(EXRV(-4) = 0	C(2)=C(3)=C(4)=C(5)=0	41.352	0.000
D(INFV(-1) = D(INFV(-2) =D(INFV(-3) = D(INFV(-4) = 0	C(6)=C(7)=C(8)=C(9)=0	2.640	0.044
D(EXRV(-1) = D(EXRV(-2) =D(EXRV(-3) = D(EXRV(-4) = 0	C(12)=C(13)=C(14)=C(15)=0	12.812	0.000
D(INFV(-1) = D(INFV(-2) =D(INFV(-3) = D(INFV(-4) = 0	C(16)=C(17)=C(18)=C(19)=0	16.023	0.000

Table 9 presents the short-run causality between exchange rate volatility (EXRV) and inflation volatility (INFV) based on Wald test results. The Wald test evaluates the null hypothesis that the lagged differences of EXRV and INFV are jointly zero. For the first hypothesis, the test strongly rejects the null, indicating that the lagged values of EXRV significantly affect the current value of EXRV. The second hypothesis also rejects the null, suggesting that the lagged values of INFV have a significant impact on the current value of EXRV, but with a lower level of significance compared to EXRV's own lagged values.

For the third hypothesis, the test rejects the null, demonstrating that the lagged values of INFV significantly influence the current value of INFV. Similarly, the fourth hypothesis rejects the null, indicating that the lagged values of EXRV significantly impact the current value of INFV. These results imply that in the short run, both EXRV and INFV have significant bidirectional causality.

Bidirectional causality between inflation volatility and exchange rate volatility in both the long run and short run due to several reasons. In the long run, the relationship is largely explained by theories such as Purchasing Power Parity (PPP) and the role of monetary policy. According to PPP, exchange rates adjust to reflect differences in inflation rates between countries, so higher inflation in one country will lead to a depreciation of its currency. Additionally, central banks' efforts to control inflation through monetary policy influence long-term exchange rate movements. Persistent exchange rate volatility impacts import and export prices, which in turn affects inflation volatility (Lado, 2015). In the short run, this bidirectional causality is influenced by immediate responses to economic changes. Central banks often adjust interest rates in response to short-term inflation volatility, which affects capital flows and consequently exchange rates. These exchange rate fluctuations can then impact inflation by altering the prices of imported goods and services. This creates a feedback loop where short-term exchange rate movements influence inflation volatility, and vice versa, maintaining a dynamic interaction between the two variables in both timeframes (Monfared and Akin, 2017).

5. Conclusions and Policy Recommendations

This study explores the causal relationship between inflation volatility and exchange rate volatility in Pakistan over both the long run and short run, using time series data from 1960 to 2023. The Vector Error Correction Model (VECM) is applied to estimate this relationship. Initially, the study calculates summary statistics and conducts a correlation analysis. Next, it checks for stationarity and non-stationarity in the data using unit root tests, finding that both variables are integrated at order one. The study then examines cointegration using the Johansen-Juselius cointegration test. Following this, the optimal lag selection is determined. Finally, the study calculates long-run causality based on the VECM model and short-run causality using the Wald Test. The findings reveal bidirectional causality between exchange rate volatility and inflation volatility in both the short run and long run. The study recommends that to stabilize prices, policymakers should implement measures to stabilize the exchange rate and to stabilize the exchange rate, planners should adopt policies that stabilize the prices.

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