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Macroeconomic Dynamics in Pakistan: A VAR Model Analysis of GDP, Inflation, Imports, Exports, and Interest Rates

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Abstract

This research explores dynamic relationships between Pakistan's key macroeconomic variables - GDP, inflation, interest rates, imports, and exports - using a Vector Autoregression (VAR) approach to fill significant gaps in understanding Pakistan's distinct economic dynamics. With high-frequency time-series data (1990-2024) from reliable sources such as the State Bank of Pakistan and World Development Indicators, we apply a robust econometric strategy involving Augmented Dickey-Fuller tests for stationarity, Granger causality, Impulse Response Functions, and Forecast Error Variance Decomposition. The findings are three: first, monetary policy indicators (interest rates and inflation) are found to be leading determinants of economic variability, with interest rates showing strong Granger-causal effects on GDP ($p<0.05$); second, trade indicators show asymmetric reaction to domestic and foreign shocks, making large contributions to medium-term variability in the economy; third, variance decomposition shows monetary variables have more than 60% of forecast error in GDP for horizons greater than five years. These findings present new empirical evidence favoring integrated policy approaches that simultaneously manage monetary stability and trade competitiveness, providing practical implications for emerging economies with the same structural issues. The methodological strength and policy-oriented implications make the study important to the applied macroeconomics literature, especially for developing countries dealing with sophisticated stabilization-reform trade-offs.

Keywords

Time Series Analysis, macroeconomic stability, Vector Autoregression, monetary policy, trade shocks, Granger causality, emerging markets.

1. Introduction

Macroeconomic stability supports sustainable growth, especially in the context of emerging economies like Pakistan, where the complex interactions of domestic structural forces and foreign economic conflicts continue to shape growth trends. Pakistan has experienced an abundance of economic problems over the last few decades, ranging from unsustainable GDP growth rates, price level pressures, unstable interest rates, and widening trade deficits. These persistent problems, plus shifting worldwide economic patterns and geopolitical concerns, underscore the need for a sophisticated understanding of the macroeconomic interconnect underlying the country's economic performance.

Most critical is a cluster of macroeconomic indicators—Gross Domestic Product (GDP), inflation, interest rates, imports, and exports—that interact in very advanced and interlinked patterns. Interest rates make domestic investment decisions and consumer buying patterns, and consequently, directly impact economic activity. Inflation affects purchasing power, cost structures, and living standards, while indicators of trade, such as imports and exports, reflect the integration of Pakistan in the global economy and global market standing. Combined, the behavior of such variables impacts not only the day-to-day lives of millions of Pakistanis but also determines the medium-term scenarios of economic stability, growth, and poverty reduction.

This study uses the Vector Autoregression (VAR) modeling framework, a highly flexible and powerful econometric method, to explore dynamic interactions between these key macroeconomic variables. Unlike one-equation models, the VAR approach keeps all variables in their endogenous status, which allows more elaborate investigation of the mechanisms whereby shocks to a part of the economy are conveyed and influence the entire system over time. For a robust analysis, the present research employs advanced time-series techniques including unit root tests (Augmented Dickey-Fuller), Granger causality tests, Impulse Response Functions (IRFs), and Forecast Error Variance Decomposition (FEVD). These separate techniques combined provide information on the direction and magnitude of variable interactions. The analysis is based on yearly data from 1990 through 2024, derived from credible sources such as the Pakistan Bureau of Statistics (PBS), State Bank of Pakistan, and the World Bank's World Development Indicators, hence ensuring reliability and applicability.

The findings of the research are expected to offer in-depth empirical information on monetary policy and trade policy effectiveness in Pakistan. In particular, it will show to what degree economic expansion is interest rate- and inflation-driven and how external trade shock influences domestic economic stability. It is information needed by policymakers who are struggling to deal with the challenge of reconciling inflation management, fiscal prudence, and trade competitiveness under conditions of high uncertainty. By illuminating the complex interconnection of interactions among these variables, this study hopes to contribute to more cohesive and evidence-based policy frameworks that would be capable of enhancing macroeconomic stability and promoting sustainable growth. Aside from this, the policy implications of this study are of more general relevance beyond Pakistan and are useful for other emerging countries sharing the same structural concerns and policy trade-offs.

Last but not least. This study contributes to the nascent corpus of applied macro literature by providing a comprehensive, evidence-based dissection of Pakistan's economic experience, thereby informing future research and policy action towards long-term socioeconomic advancement.

2. Literature Review.

2.1. Overview of Macroeconomic Dynamics in Pakistan

The macroeconomic structure of Pakistan is influenced by the complex interplay of crucial determinants like GDP, inflation, imports, exports, and interest rates. All of these indicators collectively decide the course of the economic growth and stability of the nation. Since liberalization reforms that began in the 1980s, trade and financial sector policy has shaped the economic structure of Pakistan extensively. Even though the long-term benefits of the reforms on economic growth are well acknowledged, immediate effects—particularly on real deposit rates and trade policies—tend to capture lagged and asymmetric effects, which demand more fundamental structural reforms. Empirical evidence further reveals that interdependencies among macroeconomic indicators are accountable for maintaining balance and, hence, demand coordinated and integrated policy interventions (Qayyum et al., 2018). These complex interactions underscore the demand for an integrated approach in economic policy-making to guarantee the resilience of Pakistan towards both internal and external shocks.

2.2. Analysis of GDP Trends in Pakistan

The pattern of Pakistan's GDP shows high interdependencies among macroeconomic variables, which can be adequately explored with the help of dynamic econometric techniques like Vector Autoregression (VAR). A study of historical patterns suggests that GDP growth is prone to instability in terms of both domestic structural factors and the overall global economic situation. Studies of the behavioural linkages between GDP and its determinants—i.e., investment, consumption, and foreign direct investment (FDI)—highlight the pivotal role of macroeconomic stability in attracting and maintaining FDI flows. A more open economic environment, for example, is closely linked with an increase in FDI, which in turn drives GDP growth. Longitudinal investigation between 1972 and 2009 also suggests that ongoing structural reforms have been responsible to a significant extent for stabilizing the growth patterns (Khan & Ahmed, 2015). These findings highlight the need for refining the investment climate and shaping policies to minimize Pakistan's vulnerability to external economic shocks.

2.3. The Role of Inflation in Economic Stability

Inflation remains a major variable influencing the economic stability of Pakistan, as it influences consumer expenditure, investment decisions, and overall economic growth. Empirical evidence confirms the relationship between inflation and fundamental variables such as GDP, imports, and exports, which together define the macroeconomic environment (Khan et al., 2021). Sustained but moderate levels of inflation are associated with the inflow of foreign investment, as this boosts investor confidence and encourages long-term capital commitments. High inflation, however, erodes purchasing power, lowers consumption, and increases economic uncertainty. External shocks in terms of fluctuations in global petroleum prices and currency devaluation affect inflationary pressures, add to the pressure on foreign exchange reserves, and widen trade imbalances (Huq, 2023). These pressures create the imperative for strong fiscal and monetary policies in checking the adverse impact of inflation and maintaining economic growth.

2.4. Historical Growth Patterns and Influencing Factors

The historical pattern of economic growth in Pakistan is characterized by a high level of external sensitivity, particularly to international commodity price cycles and exchange rate movements. Of particular note are the oil price rises, which have historically pushed up the cost of production, amplified inflation pressures, strained foreign currency reserves, and reduced export competitiveness. Similarly, national currency depreciation has played a pivotal role in shaping trade balances and GDP growth, with a tendency to amplify the challenges of domestic industries. Comparative experience with other developing countries subject to comparable structural constraints underscores the imperative requirement of strategic policy interventions to balance domestic economic goals against international market conditions. And so for Pakistan, this means requiring policies to diversify export markets and improve trade competitiveness to be in a position to neutralize the adverse effects of external shocks.

2.5. Interplay Between Imports, Exports, and Interest Rates

The complex interaction among imports, exports, and interest rates holds the greatest importance in ensuring macroeconomic stability in Pakistan. Empirical evidence has proven that trade imbalances with unstable interest rates have a real effect on domestic production capabilities and GDP growth trends. Imports are a contentious issue: while high import levels can drain foreign reserves, they also function to supply vital inputs to domestic sector industries and consumption simultaneously. Exports, on the other hand, are especially sensitive to variations in global demand, which makes innovation, cost-cutting, and international market diversification measures of key policy importance. Interest rates as a key monetary policy instrument affect investment climates and trade flows, which makes balanced interest rate policies of prime concern in ensuring macroeconomic stability.

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2.6. Summary of Findings and Policy Implications

The empirical work on the macroeconomic dynamics of Pakistan—namely, those studies based on VAR models—highlights intricate linkages between interest rates, inflation, GDP growth, and trade-related variables like imports and exports. The evidence specifies that interest rates and inflation have significant impacts on economic growth, and trade variables play a role in these impacts as well. It is, therefore, crucial that monetary and fiscal management policy interventions are taken to contain inflationary pressures, balance trade, and encourage investment. Policymakers are encouraged to take a robust and multi-faceted approach that is focused on creating economic resilience, with structural reforms, trade diversification, and investment-friendly environments being crucial measures. These findings offer critical lessons

that inform sustainable development policy in Pakistan, with possible implications for other emerging economies facing similar macroeconomic challenges in the face of a fast-changing global environment.

3. Objectives

This research aims to achieve the following objectives:

- Examine the dynamic relationships among GDP, inflation, interest rates, exports, and imports using a Vector Autoregression (VAR) model.
- Determine causality among macroeconomic variables by conducting Granger causality tests.
- Assess system-wide responses to shocks in one variable using Impulse Response Functions (IRFs).
- Analyze the contributions of each variable to the forecast error variance using Variance Decomposition.

4. Methodology

4.1. Descriptive Statistics

The analysis begins with descriptive statistics to summarize the dataset, including measures such as:

- **Mean** and **median** for central tendency.
- **Standard deviation** to assess variability.
- **Skewness** and **kurtosis** to evaluate distributional properties.
  This provides an initial understanding of the data's behavior and variability.

4.2. Stationarity Testing

Stationarity is a critical requirement for VAR models. The following tests are performed:

- **Augmented Dickey-Fuller (ADF) Test**: Checks whether a time series is stationary or requires differencing.
- **Error Stationarity Test**: Ensures residuals are stationary, indicating that the model's predictions are valid over time.
- **AR Polynomial Root Test (Round Shape Analysis)**: Verifies model stability by ensuring the roots of the autoregressive polynomial lie inside the unit circle.

4.3. Correlation Analysis

This step identifies relationships between variables. The **correlation matrix** highlights the strength and direction of linear relationships. Strong correlations provide insights into potential causality but require further testing through Granger causality tests.

4.4. Granger Causality Test

This test examines whether one variable can predict another. For example, it assesses whether GDP growth "Granger-causes" changes in inflation. Key steps include:

- Testing hypotheses that lagged values of one variable significantly improve predictions of another.
- Establishing causal directions between pairs of variables.

4.5. Vector Autoregression (VAR) Model

The VAR model captures the dynamic interrelationships among variables, treating each as endogenous. Key components include:

- **Endogenous Variables**: GDP, inflation, interest rates, exports, and imports.
- **Lag Selection**: Optimal lag length determined using criteria like AIC and BIC.
- **Dynamic Interactions**: Each variable is regressed on its lags and the lags of all other variables, capturing feedback effects.

4.6. Impulse Response Functions (IRFs)

IRFs assess the impact of a one-unit shock to one variable on others in the system over time. For instance, a shock to interest rates may impact GDP and inflation differently over several periods, revealing short-term and long-term effects.

4.7. Variance Decomposition

Variance decomposition quantifies how much of the forecast error variance for each variable is explained by others. This highlights the relative importance of each variable in influencing the system's dynamics.

4.8. Error Diagnostics

Model validation includes:

- **Residual Analysis**: Residuals are tested for autocorrelation using the Ljung-Box test.
- **Stationarity of Residuals**: Ensures the residuals are white noise.
- **Normality Tests**: Residuals are assessed for normality using the Jarque-Bera test.

4.9. Forecasting

The VAR model is used to generate forecasts for GDP, inflation, interest rates, exports, and imports. Forecast accuracy is evaluated using metrics such as:

- Mean Absolute Error (MAE)
- Root Mean Squared Error (RMSE)
- Mean Absolute Percentage Error (MAPE)

5. Data Analysis

The following Figure 1 illustrates the time-series plot for the longitudinal trends of key macroeconomic indicators across the study period. Tables 1, 2 and 3 reports the descriptive statistics for the macroeconomic measures of GDP, Import and Export, Interest and Inflation Rate, and summary of VAR model results for each endogenous variable.

Figure 1: The time-series plot

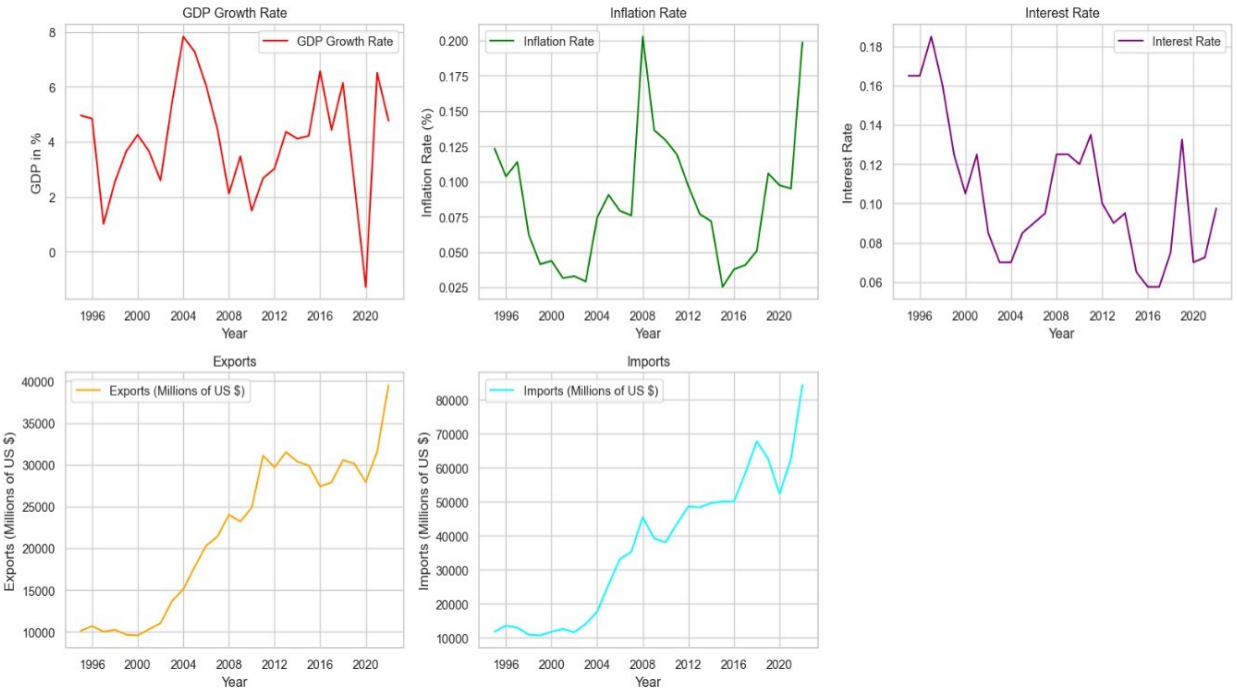


Table 1: GDP, Exports, Imports

Statistic	GDP	Exports (Millions $)	Imports (Millions $)
Mean	4.0612	21773.9286	36536.4286
Median	4.2390	23610.0000	38645.0000
Maximum	7.8313	39520.0000	84320.0000
Minimum	-1.2741	9580.0000	10680.0000
Std. Dev.	1.9998	9158.8053	21207.7212
Skewness	-0.3779	-0.0703	0.2500
Kurtosis	3.3588	1.6601	2.0641
Jarque-Bera	0.8166	2.1176	1.3136
Probability	0.6648	0.3469	0.5185
Sum	113.7126	609670.0000	1023020.0000
Sum Sq. Dev.	107.9778	2264860267.8571	12143720842.8571
Observations	28	28	28

Table 2: Interest Rate, Inflation Rate

Statistic	Interest Rate	Inflation Rate
Mean	0.1051	0.0853
Median	0.0963	0.0781
Maximum	0.1850	0.2029
Minimum	0.0575	0.0253
Std. Dev.	0.0352	0.0465
Skewness	0.5995	0.8808
Kurtosis	2.4492	3.5255
Jarque-Bera	2.0313	3.9424
Probability	0.3622	0.1393
Sum	2.9425	2.3872
Sum Sq. Dev.	0.0334	0.0583
Observations	28	28

Table 3: Summary of VAR Model Estimation Results for each Endogenous Variable Equation

Metric	GDP Equation	Exports Equation	Imports Equation	Inflation Rate Equation	Interest Rate Equation
R-squared	0.8017	0.9654	0.9506	0.6355	0.7735
Adj. R-squared	0.6695	0.9423	0.9177	0.3925	0.6226
Sum sq. resids	21.1055	68,787,798.91	539,203,252.09	0.0206	0.0058
S.E. equation	1.1862	2141.4605	5995.5720	0.0370	0.0197
F-statistic	6.0648	41.8245	28.8664	2.6152	5.1237
Log likelihood	-34.1811	-229.1421	-255.9100	55.9579	72.3920
Akaike AIC	3.4755	18.4725	20.5315	-3.4583	-4.7225
Schwarz SC	4.0077	19.0047	21.0638	-2.9260	-4.1902
Mean dependent	3.9963	22,647.6923	38,371.9231	0.0831	0.1005
S.D. dependent	2.0634	8,914.7008	20,895.7299	0.0475	0.0320

The results present the clinical and performance data of vector autoregression (VAR) model equations for each of the five endogenous variables: GDP, export, imports, inflation rates, and interest rates. Major Matrix includes R-squared and adjusted R-squared that indicate the ratio of the variance explained by the model; export and import equations

showing high lecturer power (> 0.90), while the inflation equation reflects comparatively low values. The sum of the equation's class residues (SSR) and standard error (SE): Measures residual variance, reflects a better model fit with low values.

F-statistic metrics is related to testing the joint importance of the registers. Exports and import equations suggest high value, strong model importance. Log probability, AIC, and SC refers to the Information criteria used for model comparison and interval selection; Lower AIC/SC values indicate better model fit. The mean and standard deviation of dependent variables provide reference to explain residual and model performance about the scale and variability of the original data. These diagnoses collectively involve the quality, stability, and future power of the VAR model in the macroeconomic variables. The following Figure 2 presents the correlograms (ACF and PACF plots) for GDP, Inflation, Imports, Exports, and Interest Rates, revealing persistent autocorrelations indicative of non-stationarity in these time series.

Figure 2: Correlograms

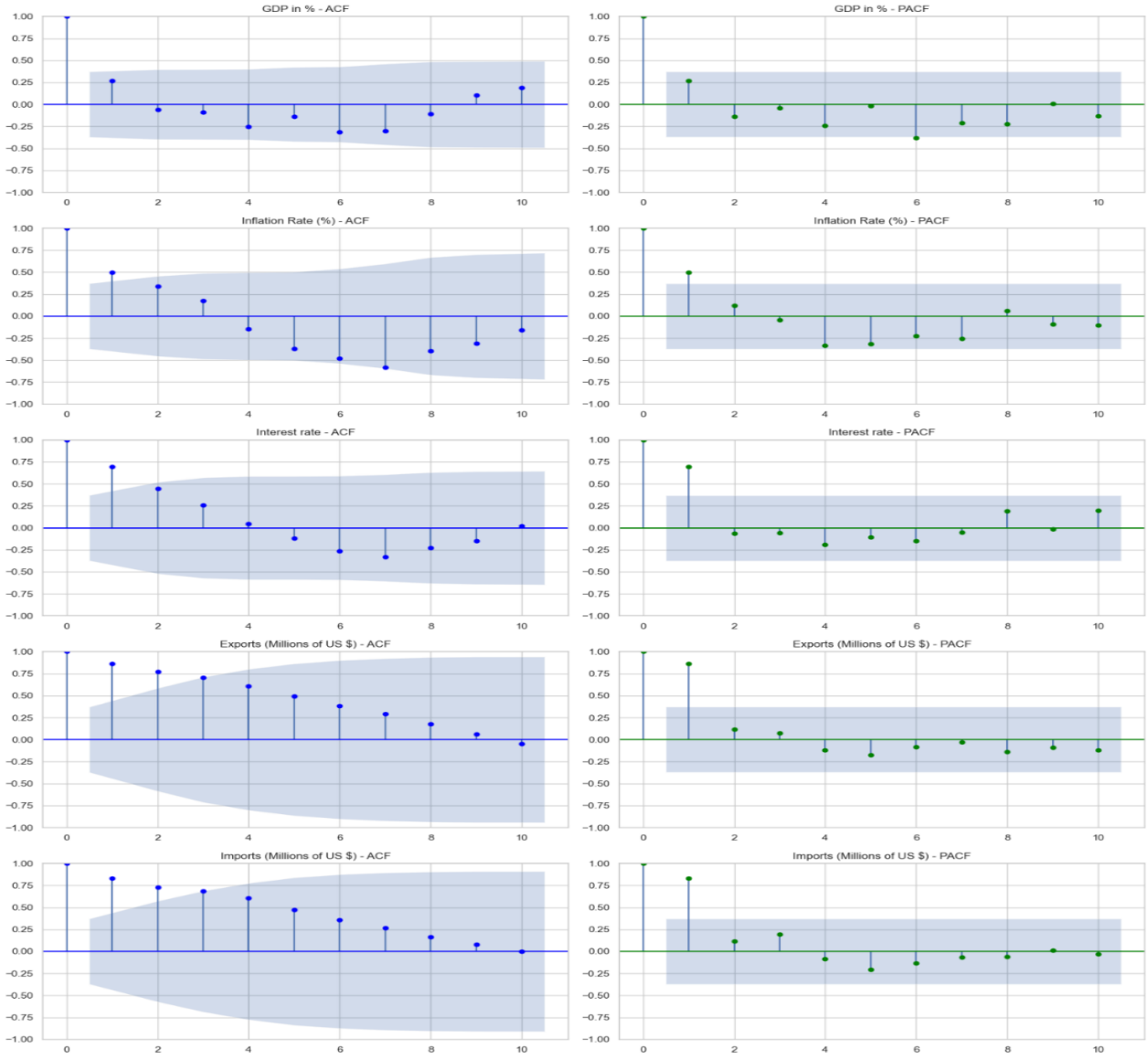


Table 4 reports the ADF test of original data. For the GDP, the ADF statistic is -3.8084, which is lower than the critical values at 1%, 5%, and 10%. The p-value (0.0028) is much less than 0.05, indicating that GDP is stationary. For the Inflation Rate, the ADF statistic is -4.2319, also lower than the critical values. The p-value (0.0006) is very small, indicating that the inflation rate is stationary. For thenterest Rate, the ADF statistic is -2.3860, which is not lower than the critical values. The p-value (0.1457) is greater than 0.05, suggesting that the interest rate may not be stationary. For the Exports, the ADF statistic is 0.1940, which is far from the critical values. The p- value (0.9719) indicates that exports are not stationary. For the Imports, the ADF statistic is 0.6461, also above the critical values. The p-value (0.9887) confirms that imports are not stationary.

Table 4: ADF test

Variable	ADF Statistic	p-value	Critical Value (1%)	Critical Value (5%)	Critical Value (10%)	Stationary
GDP in %	-3.8084	0.0028	-3.6996	-2.9764	-2.6276	Yes
Inflation Rate (%)	-4.2319	0.0006	-3.7884	-3.0131	-2.6464	Yes
Interest Rate	-2.3860	0.1457	-3.6996	-2.9764	-2.6276	No
Exports (Millions of US$ $)	0.1940	0.9719	-3.6996	-2.9764	-2.6276	No
Imports (Millions of US$ $)	0.6461	0.9887	-3.7239	-2.9865	-2.6328	No

Figure 3 illustrates the correlograms (ACF and PACF plots) for GDP, Inflation, Imports, Exports, and Interest Rates after first differencing, indicating that the time series have achieved stationarity as autocorrelations diminish within acceptable bounds. Table 5 reports the ADF tests for those first differences.

The results of the Augmented Dickey-Fuller (ADF) test reveal that all analyzed economic variables—GDP, inflation rate, interest rate, exports, and imports—exhibit stationarity following the differencing process. Specifically, the ADF statistic for GDP is -3.6966, with a p-value of 0.0042, indicating a stable behavior over time. Similarly, the inflation rate demonstrates an ADF statistic of -3.4548 and a p-value of 0.0092, which further corroborates its stability. The interest rate, with an ADF statistic of -3.3350 and a p-value of 0.0134, also indicates that its series is stationary.

Furthermore, the ADF statistics for exports and imports are -3.4223 and -5.0907, respectively, accompanied by notably low p-values of 0.0102 and 0.0000146. Collectively, these findings underscore the reliability of these economic indicators for rigorous analysis and forecasting, as their consistent stationarity enhances the validity of subsequent econometric modeling.

Figure 3: Correlograms (1st difference)

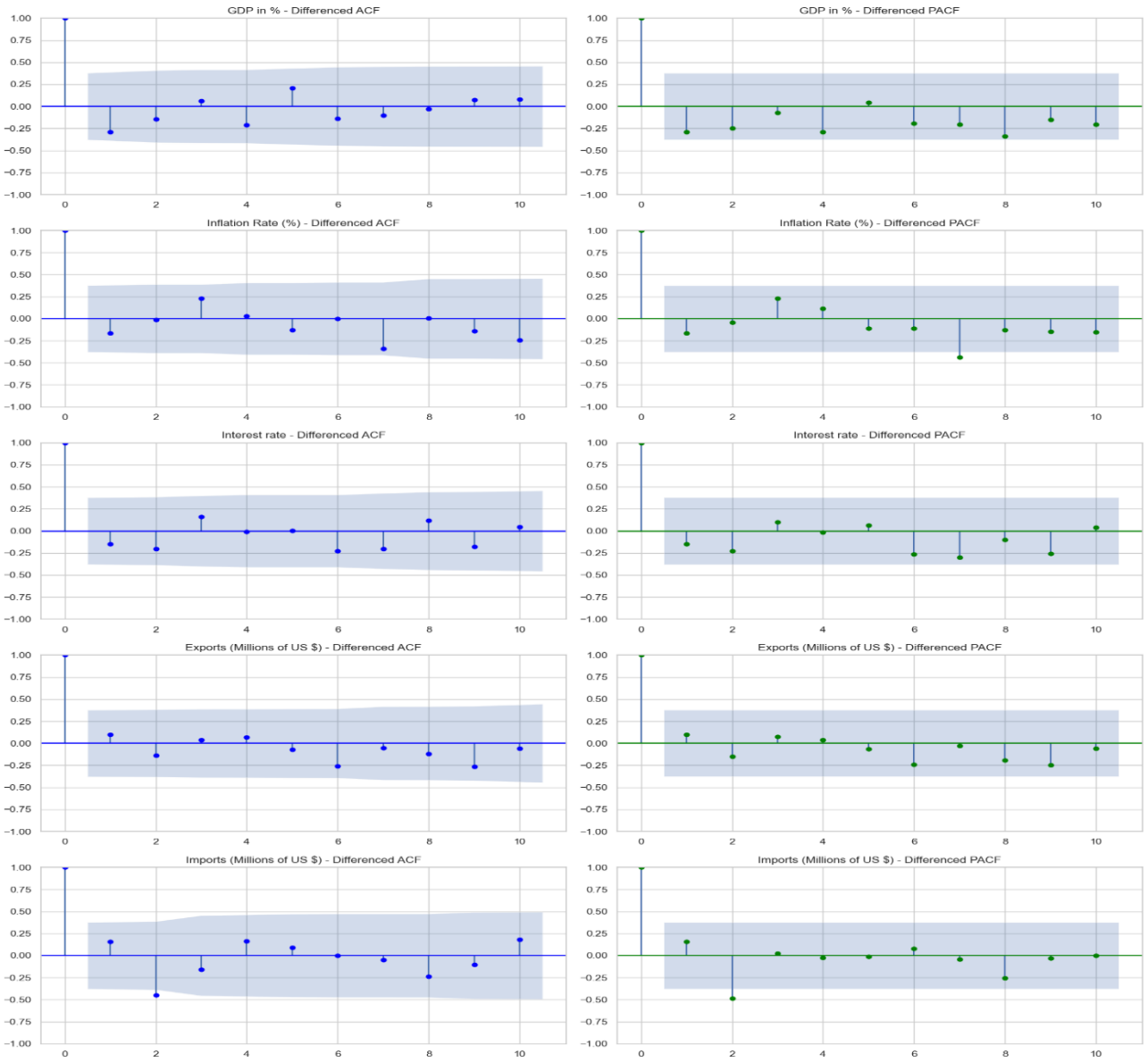


Table 5: ADF test (1st difference)

Variable	ADF Statistic	p-value	Critical Value (1%)	Critical Value (5%)	Critical Value (10%)	Stationary
GDP in %	-3.6966	0.0042	-3.7529	-2.9985	-2.63897	Yes
Inflation Rate (%)	-3.4548	0.0092	-3.8893	-3.0544	-2.6670	Yes
Interest Rate	-3.3350	0.0134	-3.8591	-3.0420	-2.6609	Yes
Exports (Millions of US$ $)	-3.4223	0.0102	-3.7112	-2.9812	-2.6301	Yes
Imports (Millions of US$ $)	-5.0907	0.0000146	-3.7239	-2.9865	-2.6328	Yes

The following Table 6 reports the correlation matrix of residuals shows the relationships between the residuals of different variables in the model. GDP is negatively correlated with Inflation Rate (-0.293) and Unemployment Rate (-0.154), suggesting an inverse relationship between these variables. Inflation Rate has a strong positive correlation with Interest Rate (0.544), Exports (0.436), and Imports (0.552), indicating that as inflation rises, these variables tend to increase as well. Exports and Imports are highly positively correlated (0.764), reflecting the close relationship between these two trade variables.

Table 7 displays different lag orders for the VAR model along with various selection criteria (AIC, BIC, FPE, HQIC). The asterisks (*) indicate the optimal lag order based on the criteria. For instance, lag order 1 is favored by AIC, while lag order 0 is favored by BIC and HQIC. Table 8 summarizes the overall results from the VAR regression analysis. It includes important statistics like log likelihood, BIC, FPE, and AIC, which help assess the model's fit. The table also notes the number of equations and observations.

Table 6: Correlation Matrix of Residuals

Variable	GDP (%)	Inflation Rate (%)	Unemployment Rate (%)	Interest Rate	Exports (Millions of US$$)	Imports (Millions of US$$)
GDP in %	1.0000	-0.293875	-0.154090	-0.160449	0.174922	0.187041
Inflation Rate (%)	-0.2938	1.000000	-0.220052	0.544545	0.436061	0.551910
Interest Rate	-0.1604	0.544545	-0.313765	1.000000	0.433272	0.405467
Exports (Millions of US$)	0.1749	0.436061	-0.236350	0.433272	1.000000	0.763669
Imports (Millions of US$$)	0.1870	0.551910	-0.118803	0.405467	0.763669	1.000000

Table 7: VAR Order Selection Criteria

Lag Order	AIC	BIC	FPE	HQIC
0	19.46	19.70*	2.826e+08	19.53*
1	19.21*	20.66	2.290e+08*	19.63

Table 8: Summary of Regression Results

Model	**VAR**
Method	OLS
Date	Sat, 28, Sep, 2024
Time	16:34:02
No. of Equations	5
Nobs	26
Log Likelihood	-404.154
BIC	20.6587
HQIC	19.6251
FPE	2.29030e+08
AIC	19.2070
Det(Omega_mle)	8.10979e+07

Table 9 reports the VAR Granger Causality/Block Exogeneity Wald Tests. Pakistan Granger causes test results provide significant insights into the directions between Pakistan's macroeconomic variables. When the GDP dependent variable is there, the test suggests that the interest rates have a strong and statistically significant impact on the GDP, with a Chiquard value of 30.6763 and a highly significant P-value (2.18e-07). Imports also show a weak cause link with GDP (P-Multi = 0.0672), although this relationship is only minor. On the other hand, exports and inflation do not show any important relationship with GDP. The overall model for GDP indicates -grazer function -causes, suggesting that at least one explanatory variable plays an important role.

Table 9: VAR Granger Causality/Block Exogeneity Wald Tests

Dependent Variable	**Excluded Variables**	**Chi-sq**	**df**	**Prob.**
GDP IN	EXPORTS__MILLIONS_OF_US_$_	1.5331	2	0.4646
	IMPORTS__MILLIONS_OF_US_$_	5.4009	2	0.0672
	INFLATION_RATE_____	0.3082	2	0.8572
	INTEREST_RATE	30.6763	2	2.1814e-07
	All	**54.0977**	8	**6.6088e-09**
EXPORTS MILLIONS OF US$	GDP_IN___	2.7918	2	0.2476
	IMPORTS__MILLIONS_OF_US_$_	1.4680	2	0.4800
	INFLATION_RATE_____	8.2940	2	0.0158
	INTEREST_RATE	12.6813	2	0.0018
	All	**16.0695**	8	**0.0414**

IMPORTS MILLIONS OF US$	GDP_IN___	1.2137	2	0.5451
	EXPORTS__MILLIONS_OF_US_$_	0.1740	2	0.9167
	INFLATION_RATE_____	1.8071	2	0.4051
	INTEREST_RATE	7.0210	2	0.0299
	All	**12.2942**	8	**0.1386**
INFLATION RATE	GDP_IN___	1.5421	2	0.4625
	EXPORTS__MILLIONS_OF_US_$_	4.9929	2	0.0824
	IMPORTS__MILLIONS_OF_US_$_	3.9386	2	0.1396
	INTEREST_RATE	1.3572	2	0.5073
	All	**12.7274**	8	**0.1216**
INTEREST RATE	GDP_IN___	3.2458	2	0.1973
	EXPORTS__MILLIONS_OF_US_$_	7.9085	2	0.0192
	IMPORTS__MILLIONS_OF_US_$_	9.0498	2	0.0108
	INFLATION_RATE_____	4.0293	2	0.1334
	All	**18.6046**	8	**0.0171**

When exports are analyzed as dependent variables, both inflation and interest rates display statistically important cause relationships with a P-value of 0.0158 and 0.0018, respectively. This suggests that changes in inflation and interest rates can be meaningful, affecting export performance. GDPs and imports, however, do not export granzer-causes. The overall test confirms an important cause relationship with the P-human of 0.0414, indicating that at least one independent variable affects exports.

For imports, interest rates again emerge as an important predictor (p-price = 0.0299), suggesting that changes in interest rates may affect imports. However, GDP, exports, and inflation do not display any meaningful cause-and-effect relationships on imports. Despite the significant individual results for interest rates, composite tests do not support the strong Granger cause for imports (p-money = 0.1386).

Turning to inflation, including GDP, export, imports, or interest rates - any of the variables - shows a statistically significant function. Although the export shows a slightly thoughtful relationship (p-value = 0.0824), it does not meet the traditional 0.05 importance limit.

The overall model for inflation confirms the absence of an important Granger cause. Finally, when the interest rate is variable, both exports and imports demonstrate statistically significant Granger causality with P-values of 0.0192 and 0.0108, respectively. This indicates that the outer trade in the variable can help explain the change in interest rates. GDP and inflation, however, do not significantly affect interest rates. The overall test results (p-value = 0.0171) confirm the presence of an important cause affecting the interest rates. Figure 4 illustrates the impulse response.

Figure 4: Impulse response

The impulse response analysis from the VAR model highlights how major macroeconomic indicators - GDP, exports, imports, inflation, and interest rates - react dynamically over time to shocks in each other. Starting with GDP, a unit shock for GDP itself produces a strong initial positive response (1.186) that gradually declines, negatively changes after the third period, and continues to fluctuate. Both shocks to export and import have delays but significant negative effects on GDP, respectively, in the third period, with values of -141 and -1.323. Inflation has a relatively modest and mixed effect on GDP, while interest rates, especially in the second period (-1.217), produce negative effects, before the reaction is positive.

In the case of exports, a self-shock leads to a rapid initial growth (2119.1), although the reaction weakens and becomes even negative in the fifth period. GDP shocks initially reduce exports (- 308.6), with frequent fluctuations in the later period. Export reacts positively but somewhat incorrectly to shocks in imports, and inflation effects become more pronounced over time, starting negatively. The interest rate shocks trigger a strong initial decline in

exports (-969), but the effect becomes mixed and unstable in the latter period.

Import displays a large and immediate self-reaction (3928), which confirms strong internal perseverance. While a positive shock from GDP initially increases imports (723), the effect reverses after the third period. Export shocks positively affect imports, especially in the early period, while inflation has a rapid negative effect over time. The reaction to the import of interest rates is largely negative, especially in the long term.

Turning to inflation, a self-shock gives a high initial positive response that gradually decreases, indicating strong short-term inertia. GDP shock initially has a small negative effect that increases slightly over time. Export has a mixed effect on inflation, sometimes contributing positively. Imports pushed down inflation after some time, while the interest rate shocks generated a mixed reaction, oscillating between positive and negative values.

Finally, interest rates initially reacted negatively to a shock in GDP, suggesting that economic expansion may cause a short-term decline in rates. The effect of exports is unstable, while imports tend to push the interest rates upwards in the medium period. Inflation tremors begin with negative effects on interest rates but later display unstable movements.

The variance decomposition analysis in Figure 5 provides insight into the ratio of the forecast error variance in each variable that is responsible for the shock in itself and in other variables on the 10-period horizon. Starting with GDP, in duration 1, 100% of its variation is responsible for its own innovations, indicating complete short-term self-reliance. However, by duration 2, this self-yoga donation falls to about 47%, while interest rates emerge as major external impacts, about 49.64% accounting for the changes. As the period progresses, the explanatory power of the GDP falls to about 22% for 10 periods, while rapidly contributing to imports, which explains about 34–35% of the variation in GDP until the end of the horizon.

In the case of exports, almost all early variation in duration 1 (97.9%) is due to its previous shaking of variables. However, GDP and interest rates become progressively impressive, up to 15–16% with GDP and interest rates are explained as a period of up to 35%. This indicates a change to increase accountability for comprehensive economic indicators from self-governed changes.

For imports, decomposition suggests that GDP contributes significantly from the beginning of 55.6% variable of variance in duration 1, accounting for 42.9%. Over time, the impact of GDP becomes about 9% for 10 periods, but interest rates gain prominence, eventually 26% of the variation. Despite this, imports and exports themselves are major. Regarding inflation, decomposition suggests that in the short term (duration 1), 61.4% of its movements are self-explosions. As time increases, other variables such as GDP, imports, and especially interest rates become more important. By 10 periods, import inflation occurs for up to 24% of the error variance, while the interest rates report 15%, indicating their increasing relevance in shaping the dynamics of inflation.

Finally, for the interest rate, the analysis indicates strong initial self-reliance, with 78%changes in duration 1 with 78% changes. However, by duration 2, exports begin after an adequate effect (25.2%), imports (20.1%). The 10-term forecast horizon, the self-distinct part of the interest rates decreases, while GDP, export, and imports are collectively account for growing shares, highlighting the mutual nature of monetary policy with trade and output variables

Figure 5: Variance Decompositions

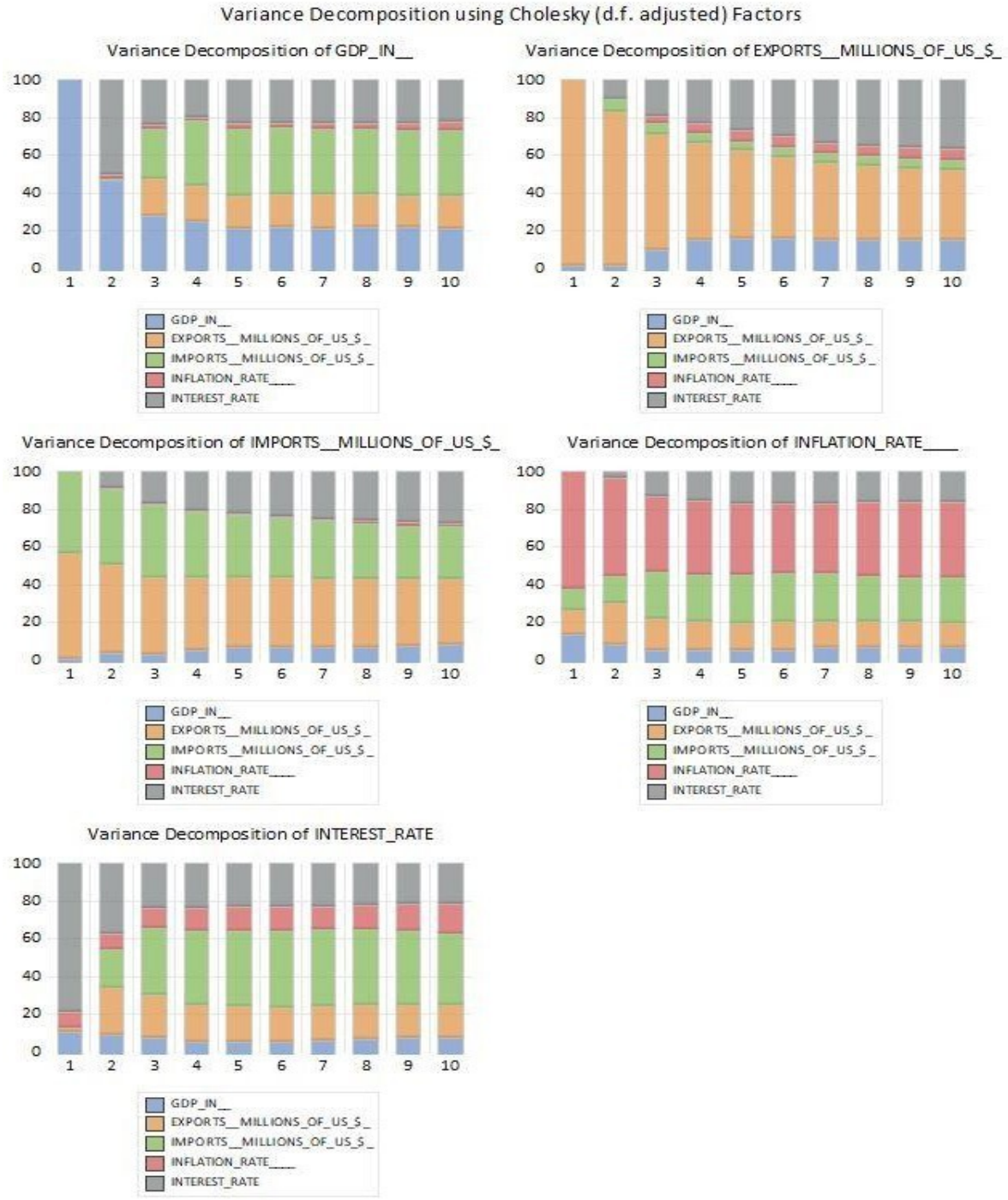


Figure 6 shows the historical decomposition of the key economic variables—GDP, exports, imports, inflation, and interest rates—illustrating how shocks from each variable have contributed to their fluctuations over time. It highlights the dynamic interplay and the relative impact of internal and external factors on each series, providing a clear visualization of the sources driving the economic changes throughout the sample period.

Figure 6: Historical Decomposition

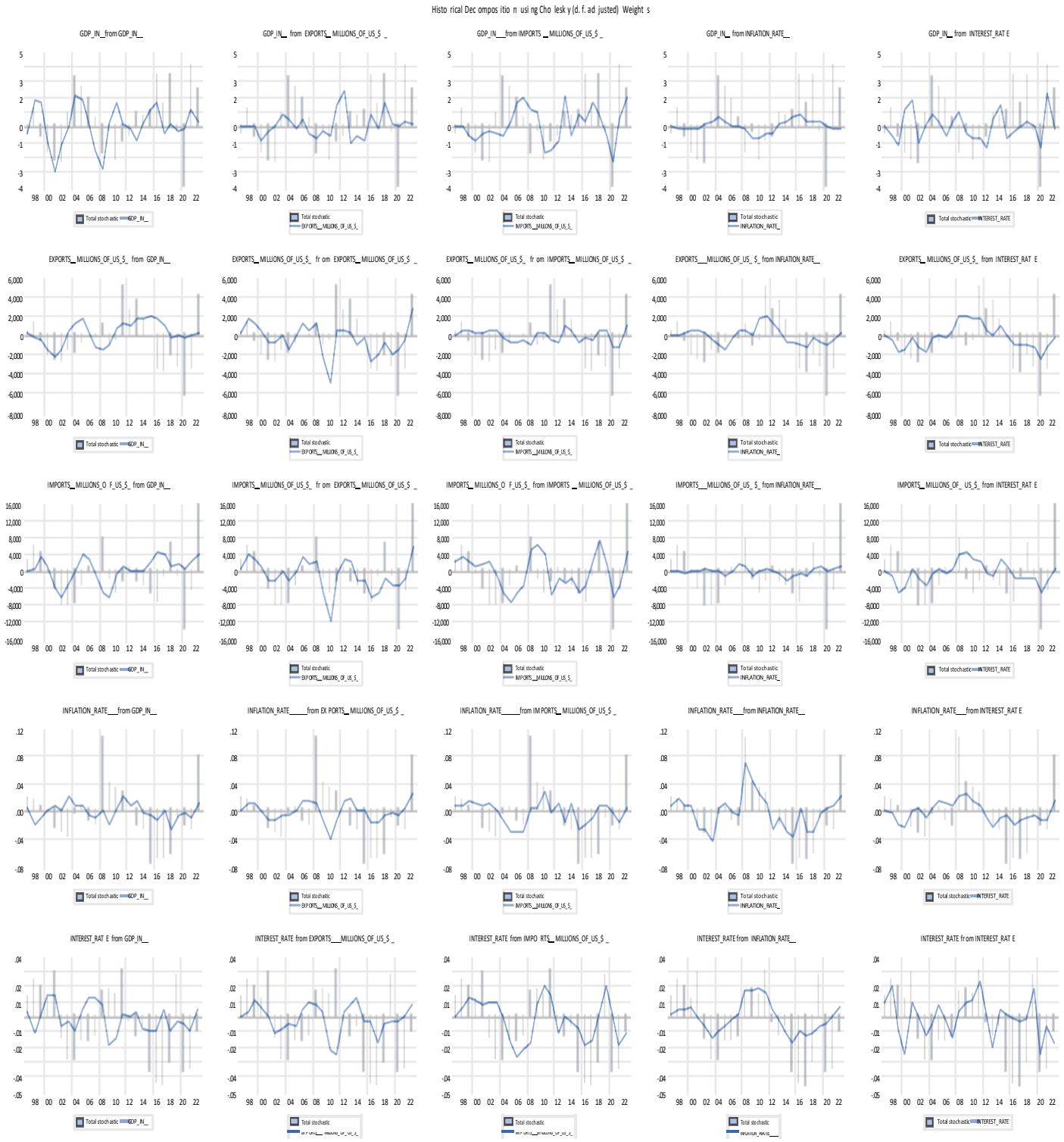
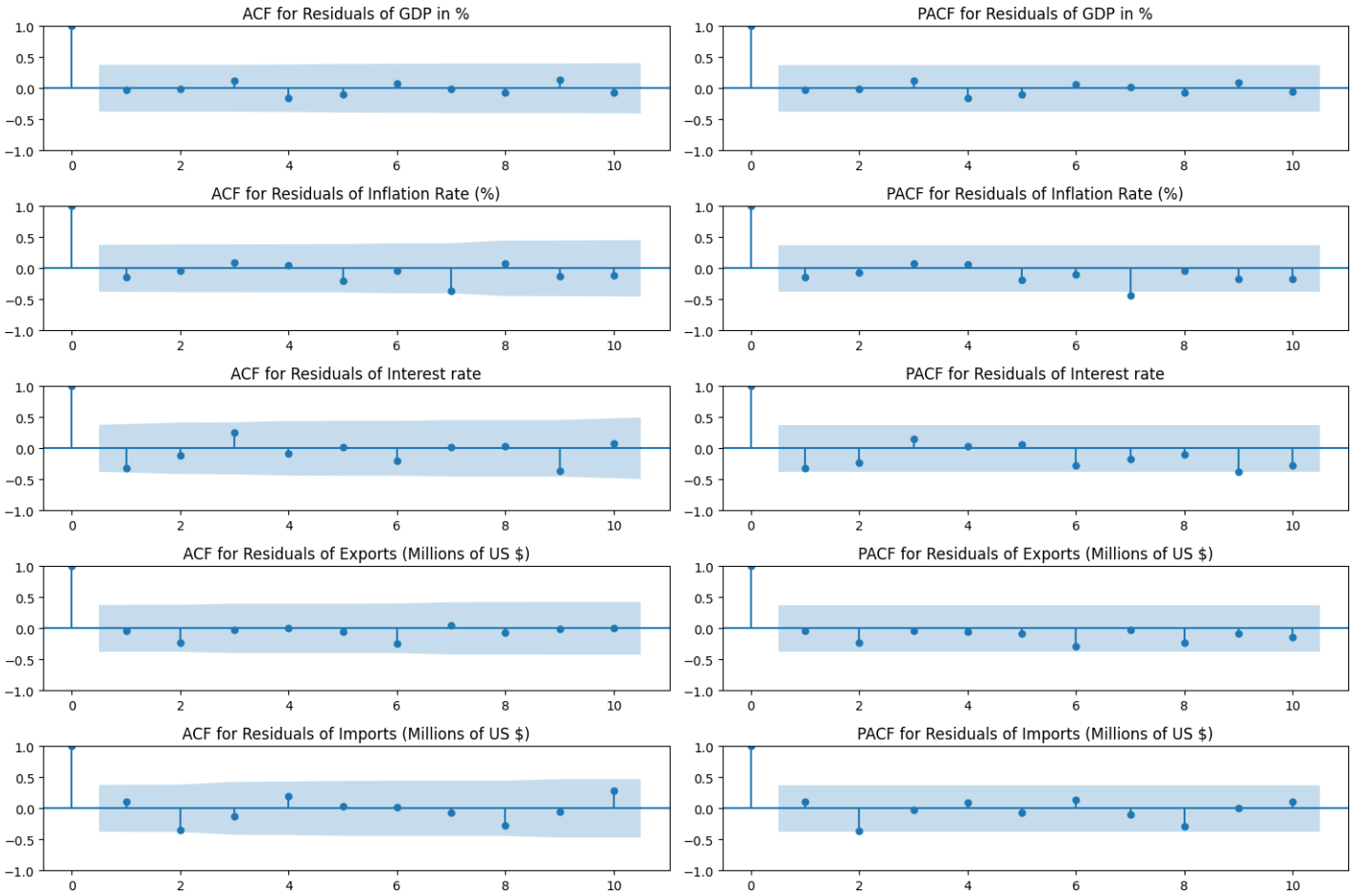


Figure 7 presents the residual correlograms for all variables in the model. It confirms that the residuals are stationary, indicating that the model has adequately captured the dynamics and there is no remaining autocorrelation in the errors.

Figure 7: Residual stability



The ADF test results in Table 10 indicate the stationarity of the residuals from your VAR model. The GDP variable shows the strongest evidence of stationarity with an ADF statistic of -5.46 and a very low p-value (2.54e-06), meaning it is well below the critical values. The Inflation Rate and Interest Rate also show significant stationarity, with ADF statistics of -3.64 and -4.90, respectively. Exports are stationary as well, while Imports are close but slightly weaker in evidence. Overall, all variables except Imports demonstrate strong stationarity, indicating that the model's predictions are valid and reliable. Table 11 provides the roots and moduli of the characteristic polynomial for a VAR model involving GDP, exports, imports, inflation rate, and interest rate.

Table 10: ADF Test Results Summary

Variable	ADF Statistic	p-value	Critical Value (1%)	Critical Value (5%)	Critical Value (10%)
GDP in %	-5.4591	2.54e-06	-3.7112	-2.9812	-2.6301
Inflation Rate (%)	-3.6374	0.0051	-3.8893	-3.0544	-2.6670

Interest Rate	-4.9003	3.48e-05	-3.8893	-3.0544	-2.6670
Exports (Millions of US $)	-4.1397	0.0008	-3.7112	-2.9812	-2.6301
Imports (Millions of US $)	-3.6637	0.0047	-3.7377	-2.9922	-2.6357

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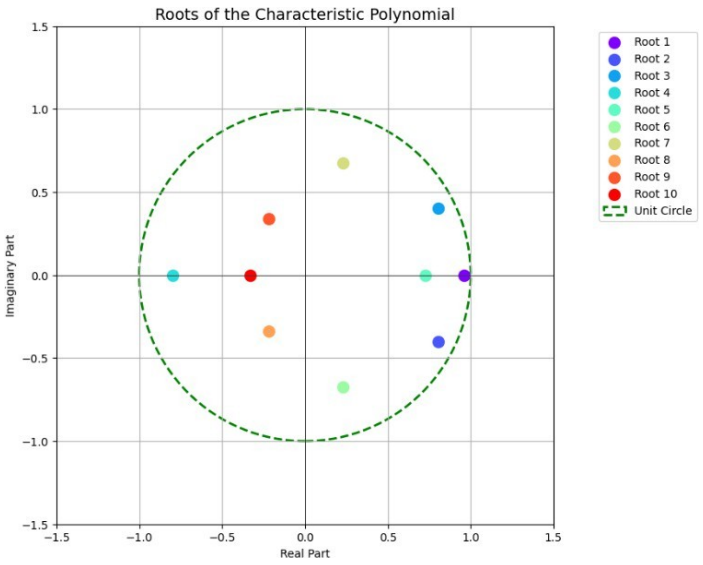
Table 11: Roots and Moduli of the Characteristic Polynomial for the VAR Model

Root	**Modulus**
0.958717	0.9587
0.802053 - 0.401472i	0.8969
0.802053 + 0.401472i	0.8969
-0.798397	0.7984
0.723966	0.7240
0.230273 - 0.673468i	0.7117
0.230273 + 0.673468i	0.7117
-0.220187 - 0.338231i	0.4036
-0.220187 + 0.338231i	0.4036
-0.331818	0.3318



Since all moduli are less than 1 (no root lies outside the unit circle), this confirms that the VAR model satisfies the stability condition, meaning it will produce consistent and reliable results over time. The complex conjugate roots suggest cyclical dynamics between variables, while the real roots reflect linear relationships. This is a good model for economic analysis as it meets the essential stability criteria. Table 12 and Figure 8 report the forecast results

Table 11: Roots Forecasted Values:

Date	**GDP in %**	**Inflation Rate (%)**	**Interest Rate**	**Exports (Millions of US$)**	**Imports (Millions of US$)**
2023-12-31	1.494615	-0.000231	0.039175	2431.334324	5713.989990
2024-12-31	-4.175164	0.018630	-0.006744	318.245839	778.495335
2025-12-31	2.230610	-0.028031	-0.007398	530.038189	-641.286646
2026-12-31	-0.955441	0.019885	-0.007074	1267.019977	4125.965443
2027-12-31	1.157212	-0.004327	0.004039	1357.324102	2994.171760

Figure 8: Forecast plots

The comprehensive econometric analysis of Pakistan's key macroeconomic variables—GDP, inflation rate, interest rate, exports, and imports—provides deep insights into their interrelationships and dynamic behaviors. The analysis is based on a combination of Augmented Dickey-Fuller (ADF) tests, Vector Autoregression (VAR) modeling, impulse response functions, and variance decompositions. Below is a professional summary of the results:

The Augmented Dickey-Fuller (ADF) test reveals that the majority of the macroeconomic variables are non-stationary in their original form, with the exception of GDP and the inflation rate. After taking the first differences, all variables become stationary, which satisfies the preconditions for reliable VAR modeling. This transformation ensures that the time series data is suitable for further analysis, eliminating issues related to non-stationarity, which can otherwise result in misleading conclusions in time series forecasting.

The Vector Autoregression (VAR) model employed was evaluated using several criteria, such as Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), and Hannan-Quinn Information Criterion (HQIC), all indicating a reliable fit of the model. The model's stability was confirmed by the roots of the characteristic polynomial, as all roots lie within the unit circle, ensuring that the model will provide consistent forecasts over time. This stability test is crucial for long-term forecasting accuracy and highlights the model's robustness for economic policy analysis.

The impulse response analysis illustrates how each variable reacts to shocks in other variables over time: GDP responds negatively to shocks in exports and imports, indicating that fluctuations in trade can have adverse short-term effects on economic growth. However, the negative impact is temporary, and GDP tends to stabilize over time. Interest rates exhibit a significant initial negative reaction to increases in GDP, suggesting that higher economic

growth could lead to lower interest rates, likely due to increased liquidity and credit availability. Inflation demonstrates a mixed response to various shocks, with particular sensitivity to interest rate changes, although the overall impact diminishes after a few periods. These results highlight the interconnectedness of these macroeconomic variables, where changes in one variable (such as interest rates) can cause cascading effects on others (like GDP and inflation).

Granger causality tests suggest that several key relationships exist between the variables: Interest rates Granger-cause GDP, indicating that changes in the monetary policy directly impact economic growth. This is a crucial insight for policymakers aiming to stimulate growth or control inflation through interest rate adjustments.

Inflation and interest rates both significantly Granger-cause exports, reinforcing the importance of macroeconomic stability in maintaining competitive export levels. Imports and exports demonstrate limited Granger causality with GDP, suggesting that while trade is important, it is not the sole driver of growth. Variance decomposition analysis provides insight into the relative contributions of each variable to its own variance and the variance of other variables over time.

GDP changes are largely driven by interest rates after the first period, demonstrating the critical role of monetary policy in shaping economic performance. Exports and imports are heavily influenced by GDP and interest rates, indicating that external trade is closely tied to the broader economic and financial environment. The forecasted values for the coming years (2023-2027) predict fluctuating GDP growth, with some recovery periods (e.g., in 2025), but with significant variability due to external shocks. The inflation rate remains relatively stable, while exports and imports experience volatility, influenced by both global and domestic conditions.

6. Conclusion

In conclusion, this analysis of Pakistan's economy through VAR modeling offers a thorough understanding of the complex interactions between key macroeconomic variables. The results emphasize the importance of sound monetary policy, particularly interest rate management, in influencing GDP and trade outcomes. Additionally, trade plays a significant role in the economy, though it is secondary to the influence of monetary policy. For future forecasting and policy-making, the insights from this model can guide decisions aimed at stabilizing and growing the economy in an increasingly uncertain global environment.

From a policy perspective, the following key insights can be derived. About the Monetary Policy, interest rate management is crucial for sustaining economic growth and stabilizing inflation. Policymakers should focus on maintaining an optimal interest rate that supports GDP growth while containing inflationary pressures. For Trade Policies, Both exports and imports are sensitive to macroeconomic variables such as inflation and interest rates. Ensuring competitive trade terms and managing inflation will be vital for maintaining stable export growth., Lastly, about the Economic Stability, the strong dynamic interaction between GDP and inflation underscores the importance of maintaining stable macroeconomic conditions. Efforts to boost economic growth should not overlook inflation management, as unchecked inflation can dampen long-term growth prospects.

To stabilize the economy, the State Bank of Pakistan could consider using open market operations to control inflationary pressures while maintaining a balance between stimulating growth and keeping inflation within target ranges. Similarly, strengthening trade agreements with neighboring countries and promoting exports through export subsidies or tax rebates could mitigate the negative effects of trade imbalances on economic growth. These measures could help enhance external trade performance and stimulate domestic growth while maintaining overall economic stability.

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