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The Impact of Debt Service and Inflation on Economic Growth in Pakistan: Evidence from ARDL Model and Approximate Bayesian Analysis

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Abstract

The economy of Pakistan has been facing instability and downward trends due to several factors, such as rising foreign debt and goods and services prices. The regression and ARDL models are applied by using R software. Adding lag values of variables become necessary to measure the long-run relationship. Using an ARDL model with GDP as response variable, inflation rate and debt service as explanatory variables, it is found that GDP has significant negative relationship with lagged values of GDP at t-2, t-4, inflation rate at t-2, and debt service. The multiple linear regression explains 24.5% of the variation, whereas the ARDL fits well and explains 82.9% of the variation. Utilizing Bayesian analysis with ABC-MCMC provides more precise estimates of model parameters than the ARDL model, as evidence by smaller posterior standard deviations compared to ARDL standard deviations. This approach yields a comprehensive posterior distribution of unknown parameters, encompassing both point estimates and credible intervals. In light of this, it can be inferred that Pakistan's GDP growth from 2000 to 2021 has been impeded by escalating rates of debt service and inflation rate. It is recommended that the government

and policymakers prioritize sustainable economic growth, implement measures to manage inflation, and effectively address the issue of debt burden.

Keywords: Multiple linear regression, Bayesian, economic growth, ARDL model, GDP, inflation rate, debt service.

1. Introduction

Every nation strives for greater economic growth since it increases a nation's ability to compete globally and attract foreign investors and commercial partners. A nation's economic development is greatly influenced by factors connected to the economy, such as the inflation rate, debt service, and Gross Domestic Product (GDP). Investors reluctant to make investments in country with unstable economic conditions due to high inflation rates, which will discourage foreign investment in developing countries. This can further exacerbate economic challenges in these countries. Developing nations are particularly susceptible to the consequences of inflation due to a combination of poor institutional structures, substantial reliance on imports of necessities, higher proportions of workers in the informal sector, and restricted access to international capital markets (Sarwar et al., 2017).Among the primary obstacles is the high inflation rate, which makes it challenging for the government to finance its spending needs via taxes and other domestic revenue sources (Tiwari et al., 2015). According to World Bank report inflation is projected to rise to 29.5 percent in 2023. High inflation can lead to reduced purchasing power and lower living standards, and can negatively impact business operations (Moridu, 2022).

Inflationary pressures, fluctuations in economic growth, and the burden of debt service are critical factors that directly impact the country's financial stability and development. Pakistan has faced high inflation rates in recent years, which have significant implications for the average Pakistani citizen. Pakistan also has undergone significant economic transformation in recent decades, yet it still faces several challenges that hinder its path towards sustainable economic growth (Hussain, 2017). Thus, Pakistan requires financial help from international lenders to stabilize the economy, fund infrastructure projects, repay existing debts, address balance of payment issues, and sustain economic growth (Jadoon et al.,2015; Ul Hassan, 2020). The present study aims to examine the impact of inflation rate and debt service on the economic growth of Pakistan from 2000 to 2021, using national-level data. This research specifically seeks to determine how much the country's total economic development over this time period is impacted by the inflation rate and debt servicing. The motivation behind this endeavor lies in the urgency to provide policymakers, economists, and stakeholders with a deeper understanding of how these factors collectively shape Pakistan's economic trajectory.

Pakistan secures debt from various sources, including international financial institutions like the International Monetary Fund and the Asian Development Bank (Kausar et al., 2022). Pakistan also takes debt from bilateral sources such as China and the United States. By obtaining financial support from these sources, Pakistan can tackle its economic challenges and foster sustainable economic growth (Rehman et al., 2020). Nonetheless, it

is crucial for Pakistan to develop a comprehensive debt management strategy that ensures the country's debt remains sustainable in the long run (Hye and Wizarat, 2011). According to United States Institute of Peace, Pakistan's external debt was $126.3 billion in December 2022. Analyzing the debt service and inflation rate, in the context of Pakistan's economy can offer insightful information on the state of the national economy.

The Pakistani economy has been subjected to fluctuation, specifically in regards to the variance of prices, which poses a substantial issue. To promote economic stability, it is essential that the governing authorities establish efficacious policy strategies. Consequently, policymakers must scrutinize both the short-term and long-term effects of economic variables to fathom the fundamental reasons for economic oscillations (Abid, 2020), and also to develop climate change mitigation strategies. Analyzing these economic variables will enable policymakers, investors, and researchers to gain profound insight into the current status of the Pakistani economy. By vigilantly monitoring and evaluating debt servicing and inflation rates, it is plausible to recognize potential solutions to tackle these predicaments and uphold continuous economic growth in Pakistan (Ahmad et al., 2012).

In the realm of economics, examining the interdependent relationship of time series data is a common practice when studying the variables at hand (Tryfos, 2013). In the analysis of economic variables, traditional statistical tests or models are commonly utilized, each with its own assumptions. Kryeziu and Durguti., 2018 examines how the inflation rate affects GDP growth in the countries of the Eurozone by using panel data from 1997 to 2017. The study investigates whether inflation rate has a substantial impact on economic growth using a multiple linear regression (MLR) model. The model is validated by diagnostic tests like Durbin-Watson and Breusch-Pagan that show no serial correlation or heteroskedasticity. The inflation rate and economic growth in the Eurozone are positively correlated, according to econometric findings from the MLR model. The traditional regression model for time series data assumes stationarity, which means that the mean and variance remain constant over time (Gujarati, 2022). However, real-world data may not meet this assumption, as it may exhibit non-stationarity due to trends that make the mean and variance non-constant over time. When this occurs, simple regression may yield questionable results (Granger and New-bold, 1974). The effectiveness of a model is usually evaluated by R-squared and Durbin Watson tests.

An Autoregressive Distributed Lag (ARDL) model is frequently employed for analysis when time series data contains both stationary and non-stationary components (Li and Wang, 2017). The ARDL model is a valuable tool for analyzing the dynamic connections between variables (Pachiyappan et al., 2021). Using the lag criterion, the lag order with the least value is selected as the best appropriate lag order for the ARDL model. Typically, OLS is employed to estimate ARDL models; however, this method may yield unsatisfactory results when the variables are endogenous. In such cases, OLS estimation may lead to biased and inconsistent parameter estimates (Nkoro, Uko, et al., 2016). An

alternative approach to estimate ARDL model parameters is through maximum likelihood. However, this technique may result in overfitting of the model, as noted by Martin, 2018. A few studies apply Bayesian technique in economic analysis. Akbar, 2021 used the Bayesian technique to analyze the impact of export volatility and inflation uncertainly on money demand in Pakistan. Akbar 2017 looks on economic aspects affecting money demand in Pakistan from 1976 to 2017. Using Bayesian statistical inference, it examines the effects of inflation uncertainty and exchange rate volatility on money demand. Results demonstrate positive impacts of real income and share prices as well as a negative influence of interest rates on money demand, which are in line with theories already in place. Notably, uncertainty about inflation becomes a key factor in determining the demand for money, influencing both transactional and preventative impulses. The Bayesian approach adds new insights into elasticities and effects.

The Bayesian approach provides more comprehensive insights by considering the uncertainty of the model. Bayesian inference considers both the parameters and the uncertainty associated with the model (Van Boekel, 2020). This approach also yields the distribution of forecasts, by combining the posterior distribution of parameters, which is advantageous for prediction purposes. In this study, a novel statistical technique is utilized by employing Subset ABC-MCMC for parameter estimation of ARDL model. Our study reveals an innovative use of the subset ABC-MCMC technique in economic studies, a significant advancement in this discipline. Through the use of this advanced methodology, we hope to add to the expanding body of knowledge in this field and gain fresh insights on economical dynamics.

It is justified due to its potential to improve statistical analysis, provide valuable insights into Pakistan's economy. It also has important policy implications. Furthermore, this research makes a substantial contribution to the existing literature on ARDL modeling by introducing a Bayesian approach. It aims to provide a comprehensive understanding of the strengths of the ABC-MCMC (Bayesian approach) algorithm in ARDL modeling.

1.1 Objectives of the Study

- The impact of inflation rate on GDP growth of Pakistan by using ARDL.
- The impact of debt servicing on GDP growth of Pakistan by using ARDL.
- The probability distributions of parameters by using ABC-MCMC.

2. Literature Review

Numerous studies have looked at the relationship between economic factors like debt service and inflation rate and their effects on economic growth in various nations (Lau et al., 2022; Lopes da Veiga et al., 2016). Yusuf and Mohd, 2023 used the two well-established economic theories which are debt Laffer curve and "endogenous growth theories for the selection of variables. It measured the asymmetric relationship between public debt and economic growth by using Nonlinear ARDL model. The result showed that external debt had a significant positive and symmetric impact on economic growth in the longrun and shortrun. Gómez & Irewole, 2023 used panel ARDL model and pooled mean group estimator to measure the link between some economic factors and unemployment in 29 African countries between 1991 and 2019. It concludes that economic development, debt, labor force, and population had long-term beneficial effects on unemployment. On the other hand, there was a long-term inverse relation between unemployment and inflation, FDI, and gross capital creation. Inflation and economic growth have a complex and dynamic relationship (Uddin and Rahman, 2023). It studied the effects of unemployment, inflation, and corruption on economic development in 79 developing countries between 2002 and 2018. Fully Modified Ordinary Least Square (FMOLS), and Dynamic Least Square (DOLS), are utilized for data analysis and estimation. The results reveal that whereas inflation, good governance, and the rule of law have positive effects on GDP per capita, corruption, unemployment, and political stability have negative effects. Inflation can be particularly severe in developing countries (Karagol, 2012). According to Fatima et al., 2012 inflation also has a considerable negative effect on the economy of Pakistan on the basis of time period from 1978 to 2009. In a prior study by Yusuf and Mohd, 2021, ARDL was used to examine how government debt affected Nigeria's long-term economic growth. There was a considerable and positive relationship between domestic debt and GDP growth. The study conducted by Aloulou et al., 2023 used nonlinear and linear ARDL model to measure the asymmetric relationship between debt and economic growth. The result of nonlinear ARDL model shows that the foreign debt has higher negative relationship with economic growth compared to long run. These negative effects might weaken over time if the anticipated consequences of high debt levels don't actually occur. The research findings are consistent with the debt overhang theory, as they describe the relationship between increased debt, reduced investment incentive, and the anticipation of future tax burdens.

Recent study by Tunc and Kilinc, 2023 investigates the influence of household debt service burden on the economic growth of advanced countries in the short and medium run. By analyzing data from the Bank for International Settlements on debt service ratios, the research reveals that the debt service burden adversely affects economic growth in both time frames. The negative impact of the debt service burden extends to unemployment and household consumption. Ezako, 2023 used the Conditional Least Squares and Two Stage

Least Squares approaches on ARDL model, to examine the effects of inflation on a particular economic indicator while taking into account the existence of an inflation threshold. This method accounts for changes that happen at the given inflation threshold and captures potential nonlinear interactions between inflation and the dependent variable. The research found a threshold level of 13% for inflation. This means that when inflation crosses this threshold, it becomes harmful to economic growth. According to Abate, 2023 the economy suffers if the government is unable to borrow money for whatever reason (such a negative shock). The Nonlinear ARDL and Multivariate Nonlinear ARDL models were used to measure the relationship between public debt and economic growth in Ethiopia. The result was consistent with the "big push" hypothesis, which contends that substantial resources ought to be allocated to fostering long-term economic growth.

A debt service is a crucial economic indicator for Pakistan, which includes interest payments and principal repayments on outstanding debts (Malik et al., 2010). The study conducted by Jadoon et al., 2014 focused on Pakistan's challenge of foreign debt servicing among its macroeconomic issues. It used the ARDL cointegration technique to examine the impact of foreign debt servicing on Pakistan's per capita income growth rate from 1981 to 2010. Results show that foreign debt servicing significantly and negatively affected per capita income growth in both the short and long run. The study conducted by Jilani, Asim, et al., 2010 looks at how Pakistan's GDP has changed from 1980 to 2013, as a result of changes in inflation, real exchange rates, and interest rates. These macroeconomic factors have a considerable impact on GDP, the study finds using multivariate regression analysis. While interest rates and inflation have a negative relation with GDP, exchange rates has positive.

In the analysis of economic variables through classical regression, preliminary insights into the stationarity of time series are obtained using the Durbin-Watson statistic and R-squared coefficient. These metrics have been commonly used by researchers to determine if the model is a good fit or not (Lapinskien˙e et al., 2017; Slavinskait˙e, 2017). However, these preliminary observations are not sufficient to draw a definitive conclusion about the stationarity of the time series. So, formal tests such as unit root tests, which include the Augmented Dickey-Fuller (ADF) test, Phillips-Perron (PP) test, and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test, are employed to confirm whether the economic series is stationary or not (Kreinovich et al., 2018). These tests are designed to examine whether the series has a unit root, which is an indication of non-stationarity (Gujarati, 2022). Therefore, even though a low Durbin-Watson statistic and high R-squared coefficient may suggest non-stationarity (Durlauf and Phillips, 1988). The unit root tests should be used to confirm whether the series is genuinely stationary or not. For non-stationary samples, OLS estimators are biased, and even the FMOLS estimator fails to improve the estimates significantly (Kao and Chiang, 2001). Cointegrated data cannot be accurately estimated using OLS estimators. While DOLS can resolve the issues of endogenous regressors and autocorrelation, it provides different estimates for different lag orders, and its performance is dependent on the number of lags used (Dreger and Reimers, 2005).

In applied economic research and policy analysis, the ARDL model is a popular method for determining how different economic policies and shocks would affect the economy (Chandio et al., 2022). It is important to account the trends, cycles, and structural breaks in economic variables to obtain consistent and robust estimators. The ARDL model is a flexible method suitable for mixed models with both stationary and nonstationary time series variables, and it can be used for both forecasting and policy purposes. The economic growth of Pakistan has been examined by various studies using the ARDL technique (Abbasi et al., 2021; Jalil et al., 2013; Rehman et al., 2020). The ARDL model is a combination of the autoregressive (AR) model and finite distributed lag (DL) models. The AR component of the model is obtained by regressing the response variable on its lagged values, while the DL component is obtained by considering the lagged values of the explanatory variable (Hill et al., 2018). It should be noted that ARDL is not appropriate when the variables are integrated of order I(2), and it is recommended to test for stationarity of the data to ensure compliance with the OLS assumption (Odhiambo, 2009). According to Ngoc and Awan, 2022, the ARDL approach was unable to clearly explain how the rise of the financial sector would affect ecological footprint. However, Bayesian analysis was more enlightening as it demonstrated that both economic growth and financial development have a negative impact on ecological footprint. Bayesian analysis can be applied to various time series statistical methods, such as ARIMA model, state-space models, Markov switching, and mixture models (Steel, 2010). Using MCMC, researchers can obtain the posterior distribution that provides information about the uncertainty in the parameters. It should be recalled that the MCMC algorithm begins with a random parameter combination and generates a new simulation at each step by choosing new parameters that are close to the existing ones. The new parameter combination is allowed if the gap between the simulated and observed data is within the tolerance limit.

The ABC method is a simulation-based approach that does not rely on likelihoods. It uses an "accept-reject" mechanism to calculate the posterior probability distribution. By incorporating the MCMC method, the ABC approach can enhance efficiency and lower the rejection rate compared to traditional methods, while still maintaining numerical accuracy (Hazra et al., 2020). The ABC-sequential and ABC-MCMC schemes are preferable over the ABC-rejection approach due to the faster speed and higher efficiency of the MCMC algorithm (Jabot et al., 2013). Subset ABC-MCMC is an adaptation of the conventional ABC-MCMC algorithm that takes into account only a portion of the parameters of interest. In cases where the parameter space is high-dimensional, the use of ABC-MCMC can be computationally intensive, and the Subset ABC-MCMC technique can be a more efficient alternative. Clyde and George, 2004 suggested a Bayesian approach to subset selection in linear regression, which is focused on identifying the relevant subset of predictors for predicting the response variable. Although their focus is on Bayesian regression, the same approach can be applied to ABC-MCMC. This study reduces the complexity of the

problem and enhances the algorithm's efficiency by concentrating on the significant ARDL coefficients.

3. Methodology

This study is based on GDP, inflation rate, and debt service in Pakistan from 2000 to 2021. There are three economic variables in this study. The GDP is a response variable, while inflation rate and debt service are considered as independent variables. The data utilized in this research was obtained from the official website of the World Development Indicator (WDI), and each variable has 22 observations. Table 1 provides the detail information about variables, along with a brief description of what each variable measures, and where the data for each variable is obtained.

Table 1: Description of Macroeconomic Variables

Variables	Description	Definition	Source
GDP	GDP growth (annual %)	It refers to the annual growth rate (%) of GDP at market prices based on constant local currency.	WDI
Inflation Rate	Inflation, consumer prices (annual %)	It refers to the rate at which prices of goods and services that people buy increase every year.	WDI
Debt Service	Debt service (public and publicly guaranteed and IMF only, % of exports of goods, services and primary income.	The process of regularly making principal and interest payments on a country's outstanding debt is referred to as debt servicing.	WDI

The conventional approach to establish the link between GDP, inflation rate, and debt service is to use a multiple linear regression (MLR) model, as presented below in equation 3.1.

$$GDP = \alpha + \beta_1\, INF + \beta_2\, DS + e_t$$

Where GDP = Gross growth (annual %).
α = intercept term.
β_1= slope coefficient for inflation.
β_2= slope coefficient for debt service.
e_t = Error term.
The ARDL model of (p, q_1, q_2) is given in equation 3.2.

$$\mathrm{GDP_t} = \mathrm{a} + \sum_{\mathrm{i=1}}^{\mathrm{p}} \mathrm{c_i GDP_{t-i}} + \sum_{\mathrm{j=0}}^{\mathrm{q_1}} \beta_2 \mathrm{INF_{t-j}} + \sum_{\mathrm{k=0}}^{\mathrm{q_2}} \mathrm{w_k DS_{t-k}} + \mathrm{e_t}$$

The approximate Bayesian computation method will be used to estimate an ARDL model with lag orders p, q_1 and q_2 for GDP, INF, and DS variables, respectively. The model also incorporates a white noise term denoted by e.

Before modeling ARDL, generate plots of the time series data to discern their stationarity. Additionally, Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF) plots can offer valuable insights into variable stationarity. Unit root tests such as DF, ADF, PP, and KPSS can be employed to evaluate the stationarity of a single time series. ADF test is preferable to the DF test because it can manage the autocorrelation in errors by including various lags on the dependent variable (Palm et al., 2008). If the p-value of the ADF and PP tests is less than 0.05, it indicates a unit root, whereas the KPSS test shows non-stationarity when the p-value is greater than 0.05. Therefore, it is essential to apply unit root tests (ADF and PP) to identify the stationary or non-stationary nature of the dataset. Moreover, for the ARDL model, it is crucial to ensure that all variables are stationary at either I(0) or I(1), and hence unit root tests should be conducted at both levels. There is no universally accepted method for selecting the optimal lag in a model. Various lag criteria, such as AIC(Akaike, 1974), SIC (Schwarz, 1978), BC (Akaike, 1979), and HQ (Hannan and Quinn, 1979) can be employed to determine the best lag. The Akaike Information Criterion (AIC) is a widely used method for model selection in the fields of econometrics and statistics (Montiel Olea et al., 2022). The lag with the lowest value according to the lag criteria is considered the optimal one. The Johansen cointegration test is used to check for cointegration in the data. If a cointegration relationship exists, an Error Correction Model (ECM) is estimated to calculate the long-run and short-run relationship coefficients. In contrast, if no cointegration is detected, the results of the ARDL model are interpreted without the need to compute the ECM. A unified framework for evaluating and verifying cointegration relations inside a single equation is provided by the ARDL approach. The ARDL approach is preferable over the Johansen and Juselius approach when the variables have only one long-run relationship (Nkoro, Uko, et al., 2016). The R-squared and Durbin Watson (DW) statistics are employed to measure the model's appropriateness and accuracy within the ARDL framework.

In Bayesian analysis, the use of weak informative priors can be achieved by employing coefficient estimates obtained from the OLS method, as suggested by Lemoine, 2019. In a similar vein, Ngoc and Awan, 2022 utilized the OLS estimator as a weakly informative prior and modeled it as a normal distribution for their Bayesian analysis. In the present study, we adopted the same technique by utilizing the parameter estimator obtained from OLS estimation to set the prior for ABC-MCMC algorithm, the normal distribution will be used for the coefficient of parameters, and an exponential distribution will be used for the residual standard error. The tolerance limits will be set at 0.0005, and the samples will be simulated 15,000 times. To summarize the Bayesian analysis of posterior distribution, the posterior mean, standard deviation and confidence interval will be employed.

If the posterior credible interval includes zero, then we can say that the effect of explanatory variable on outcome variable is not statistically significant (Sobel, 1982). However, this does not necessarily mean that the variable has no effect, as there may be other factors or interactions that are not captured in the model. Trace plots will be used to diagnose the behavior of the statistical model and the coverage of ABC-MCMC. The shape of the posterior distribution will be plotted to obtain crucial information about the estimated parameters, such as the central tendency and the uncertainty around the estimates.

4. Results

The MLR model exhibits an R-squared value of 0.245, indicating that 24.5% of the variation in the GDP is explained by debt service and inflation rate.

Table 2 Estimators of MLR Model

Coefficients	Estimate	Std. Error	t value	P-value
Intercept	7.12905	1.43935	4.953	0000<0.05
Inflation	-0.22985	0.09588	-2.397	0.027<0.05
Debt Service	-0.06935	0.05907	-1.174	0.255>0.05

Table 2 shows that the p-value of model is less than 0.05 suggest that debt service and inflation rate have a significant impact on GDP growth and should be incorporated into the model. The intercept represents the expected economic growth rate when both inflation and debt service are zero. In practical terms, this is minimum level of economic growth that is achieved regardless of inflation and debt service. The model predicts a decline in the economic growth rate of roughly 0.23 units for every unit increase in inflation. This implies that slower rates of economic growth are linked to greater inflation rates. This negative association may be explained by elements like diminished consumer purchasing power, uncertainty in investment choices, and potential resource allocation distortions. The current model does not statistically adequately describe how debt service affects economic development. However, the DW test score of 1.71 reveals positive autocorrelation in the residuals of the regression model, which implies that the model's assumption of independent errors is violated. Furthermore, Figure 1 reveals that the graphs of GDP, inflation rate and debt service show some patterns in the time series data, indicating that the mean and variance are changing with time.

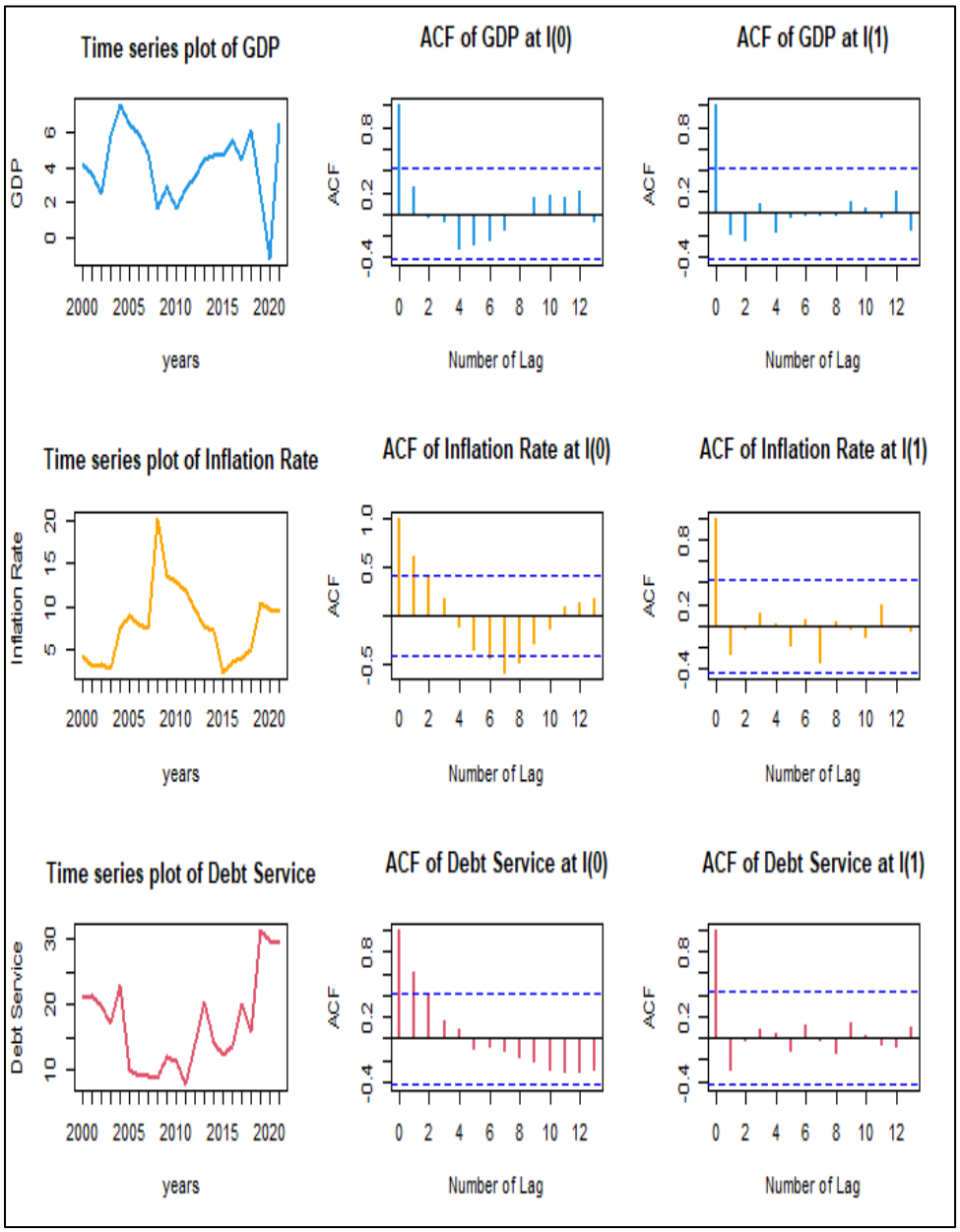

Figure 1 Graph and ACF Plot of Time Series at I(0) and I(1)

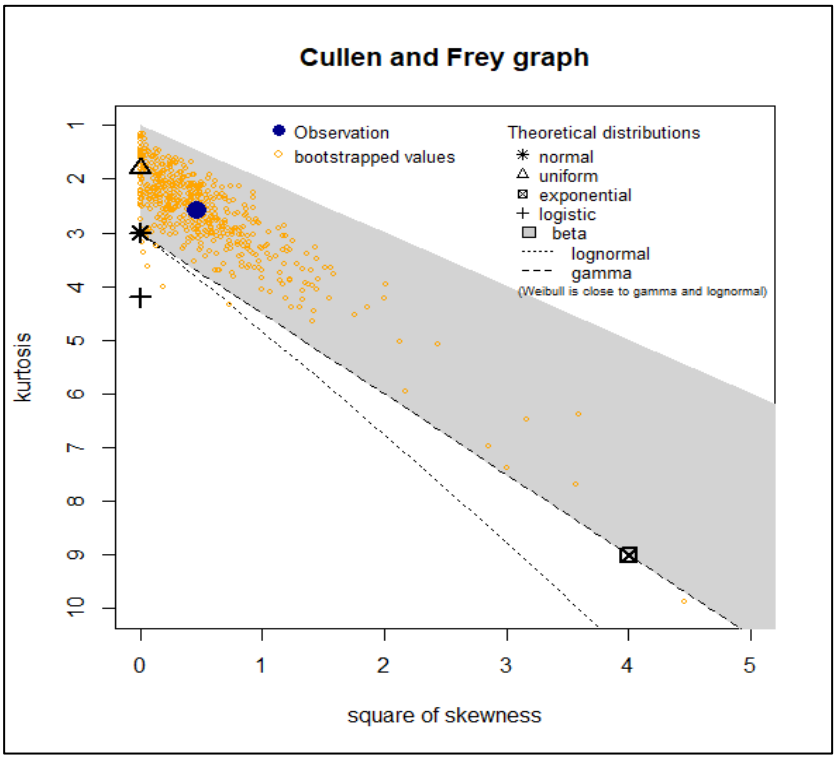

Figure 2 Cullen and Frey Graph of Debt Service

The ACF of the dataset at I(0) shows the non-stationary behavior. In particular, the ACF plot of GDP and debt service reveals a progressive decline as the number of lags rises. A geometric pattern can be seen in the inflation rate's ACF plot. The ACF plot of I(1) reveals that all of the values are close to the center line and that there is no hint of a large autocorrelation, which suggests that the series might be stationary. The distributions of GDP and inflation Rate are roughly normal. Figure 2 depicts a Cullen and Frey graph of debt service, where the observed data is in close proximity to both normal and uniform distributions.

The GDP growth, inflation rate and debt service all exhibit a unit root, which means that these variables are non-stationary at I(0) level as shown in Table 3.

Table 3 Unit Root Test - for each variable at I(0) , I(1)

Variable	Unit Root Test at I(0)			Unit Root Test at I(1)		
	ADF	**PP**	**Decision**	**ADF**	**PP**	**Decision**
GDP	-3.131 (0.127)	-3.644 (0.1254)	Not Stationary	-4.005 (.0272)	-3.846 (.0353)	Stationary
Inflation	-2.1233 (0.5043)	-2.1232 (0.5043)	Not Stationary	-5.390 (.0017)	-5.390 (.0017)	Stationary
Debt Service	-1.9067 (0.6155)	-1.7029 (0.7137)	Not Stationary	-4.679 (.0075)	-6.568 (.0002)	Stationary

After taking the first difference of the dataset, the unit root tests are again applied, which revealed that the dataset became stationary at the I(1) level. To determine the optimal lag order for GDP, inflation rate, and debt service, the AIC criteria were utilized. The fourth lag was discovered to be the best order and was selected as the one with the lowest AIC criterion value. As a result, the ARDL model with lag order is (4, 4, 0), where 4 denotes the number of lags for GDP, 4 denotes the number of lags for inflation rate and 0 denotes the number of lags for debt service.

The ARDL(4,4,0) model is present in equation 4.1.

$$GDP_t = a + c_1 GDP_{t-1} + c_2 GDP_{t-2} + c_3 GDP_{t-3} + c_3 GDP_{t-4} + d_1 INF + d_2\, INF_{t-1} + d_3\, INF_{t-2} + d_4 INF_{t-3} + d_1 INF_{t-4} + w_1 DS + e_t$$

OLS technique is used to estimate ARDL model. Table 4 displays the coefficients of ARDL(4,4,0) model at a significance level of α =0.05 . The intercept value of 24.95184 indicates that the predicted value of GDP growth is about 24.95% when there is no influence of debt service and inflation rate. The GDP_{t-1} estimator is negative but statistically insignificant. The GDP_{t-2} estimator is negative and statistically significant as well. This suggests that the growth rate of GDP is decreasing at an increasing rate over time, which is a more concerning trend. In other words, the growth rate of GDP is decreasing over time, which is not a good sign for a developing economy like Pakistan.

The GDP_{t-3} estimator is positive but statistically insignificant, indicating that the growth rate of GDP is increasing at a slower pace than before. The GDP_{t-4} estimator is negative and statistically significant, indicating that the growth rate of GDP is decreasing at an even faster pace than before. Since Pakistan is a developing nation, it is not surprising that GDP occasionally has a negative impact on GDP. This kind of unexpected outcome was also revealed by a study on the effects of Sri Lankan exports conducted by Sultanuzzaman et al., 2018 demonstrates that exports have a detrimental effect on the country's economy because it is a developing one.

The INF estimator is negative but statistically insignificant, suggesting that inflation does not have a significant long-run impact on GDP. The estimator of INF_{t-1}, INF_{t-2}, INF_{t-3}, INF_{t-4} are all negative, but the estimator of INF_{t-2} is statistically significant. It means that inflation has a negative short-run impact on GDP, and this impact increases with the lag order. The results provide mixed evidence regarding the Inflation Crowding-Out Theory. While there is some support for the theory's predictions in the case of lag 2, the findings for other lagged inflation at lags (t-1, t-3, t-4) do not consistently align with the theory's expectations. The lack of statistically significant relationships for some time periods suggests that factors beyond inflation may also be influencing GDP growth. The DS estimator is negative and statistically significant, indicating that debt servicing has a negative long-run impact on GDP. This result is expected, as a high level of debt servicing can reduce the resources available for investment and growth. It does support the debt overhang theory which implies that high levels of debt discourage investment and economic growth due to the anticipation of future tax increases to service the debt.

Table 4 OLS Estimator of ARDL Model

Coefficient	Estimate	Standard Deviation	Std. Error	t-value	P-value
Intercept	24.95184	22.138	4.71989	5.287	0.00114 < .05
$\boldsymbol{GDP_{t-1}}$	-0.4239	1.399752	0.2984	-1.421	0.19838> .05
$\boldsymbol{GDP_{t-2}}$	-1.14780	1.8338	0.39096	-2.936	0.02184 < .05
$\boldsymbol{GDP_{t-3}}$	0.47883	1.6689	0.35582	1.346	0.22036>.05
$\boldsymbol{GDP_{t-4}}$	-1.00895	1.8212	0.38830	-2.598	0.0355 < .05
$\boldsymbol{INF}$	-0.0381	0.61345	0.13079	-0.292	0.7789> .05
$\boldsymbol{INF_{t-1}}$	-0.1324	0.62172	0.13255	-0.999	0.35094> .05
$\boldsymbol{INF_{t-2}}$	-0.35745	0.6887	0.14684	-2.434	.04514 < .05
$\boldsymbol{INF_{t-3}}$	-0.12297	0.63977	0.13640	-0.902	0.39725> .05
$\boldsymbol{INF_{t-4}}$	-0.2563	0.57218	0.12199	-2.101	0.07375> .05
$\boldsymbol{DS}$	-0.27700	0.3464	0.07386	-3.751	0.00716 < .05

Overall, the results indicate a persistent relationship among GDP, inflation, and debt servicing in Pakistan. The results indicate that GDP has a significant positive relationship with intercept, but a significant negative relationship with $GDP_{t-2}, GDP_{t-4}, INF_{t-2}$ and DS. Therefore, it can be inferred that if GDP decreases, debt service and the inflation rate at lag 2 are likely to increase.

The ARDL(4, 4, 0) model is able to explain 82.9 % of the variation in GDP that is caused by debt service and inflation rate and their respective lag values. Since the model explains a significant amount of variation, it can be concluded that it is a good fit for the data. Furthermore, the Durbin Watson (DW) statistic value of 2.3 suggests that there is no autocorrelation between the residuals and their corresponding lag values in the ARDL model, as the DW value is close to 2.

The Johansen cointegration test results reveal that there is no cointegration among the GDP, inflation rate, and debt service variables. The trace statistics for the no cointegration equation are below the critical values at a 5% significance level, leading to retain the null hypothesis. Therefore, we can conclude that the ARDL model is sufficient, and there is no need to estimate an ECM. It is important to note that the absence of cointegration does not necessarily imply a lack of correlation or causal relationship between the variables. Thus, it may be worthwhile to explore alternative econometric techniques to study the relationship between these variables.

Table 5 shows that point estimators of a posterior distribution for the parameters Intercept, GDP_{t-2}, GDP_{t-4}, INF_{t-2} and DS along with standard deviation (measure of uncertainty). The important thing to note is that Bayesian says that the GDP estimator at lag 2 is positive, the ARDL model's GDP estimator is negative. Due to the fact that the posterior standard deviation is less than the ARDL standard deviation, it is likely that the Bayesian analysis offers more accurate estimates of the model parameters than the ARDL model. The ARDL standard deviation does not take into account any prior knowledge or uncertainty about the coefficients, and therefore it is larger than the posterior standard deviation, which incorporates both prior information and the observed data. So, we can say that higher past GDP (at lag 2) values contribute to present economic growth, while a negative coefficient of GDP (at lag 4) implies a dampening effect. This aligns with economic theories emphasizing the persistence of economic trends. The negative coefficient on inflation suggests that an increase in past inflation may have a dampening effect on current economic activity. This is in line with theories of economics that contend that high inflation can reduce buying power and slow economic progress. A debt service estimator implies that higher debt service payments may have an adverse impact on economic performance. This resonates with the notion that substantial debt service obligations can constrain a country's resources and potentially hinder growth.

Table 5 Summary Statistic of Posterior Distribution

Parameter	Point Estimators of Posterior		Posterior interval	
	Mean	**Standard Deviation**	**2.5%**	**97.5%**
Intercept	4.598463	5.847629	-6.7247103	15.43
$\boldsymbol{GDP_{t-2}}$	1.08103	0.79561	-1.017732	2.55
$\boldsymbol{GDP_{t-4}}$	-0.3156	0.56473	-1.307800	0.79
$\boldsymbol{INF_{t-2}}$	-0.10809	0.20563	-0.527061	0.326
$\boldsymbol{DS}$	-0.2546	0.34937	-0.922403	0.330

The trace plot of all parameters shows values of all the estimated parameters mixing well as all trace plot shows the convergence, it can be observed that the values of the parameter are oscillating around a single value with no discernible trend. The trace plot and posterior distribution of intercept, GDP at lag 2 are shown in Figure 3. Posterior distribution shows the distribution of the estimated parameters after the ABC-MCMC algorithm has converged. Bayesian analysis has estimated that intercept, GDP_{t-2} , GDP_{t-4}, GDP_{t-4}, INF_{t-2} and DS approximately follows normal distribution.

The posterior distribution for the intercept follows a normal distribution, then the posterior confidence interval for the intercept is -6.7247103 to 15.43, which means that we are 95% confident that the true population mean of the intercept lies within this range. It is important to note that this interval contains both negative and positive values, which suggests that the intercept may not be significantly different from zero. However, since the interval is relatively wide, it also indicates that there is a considerable amount of uncertainty in the estimate of the true population mean of the intercept.

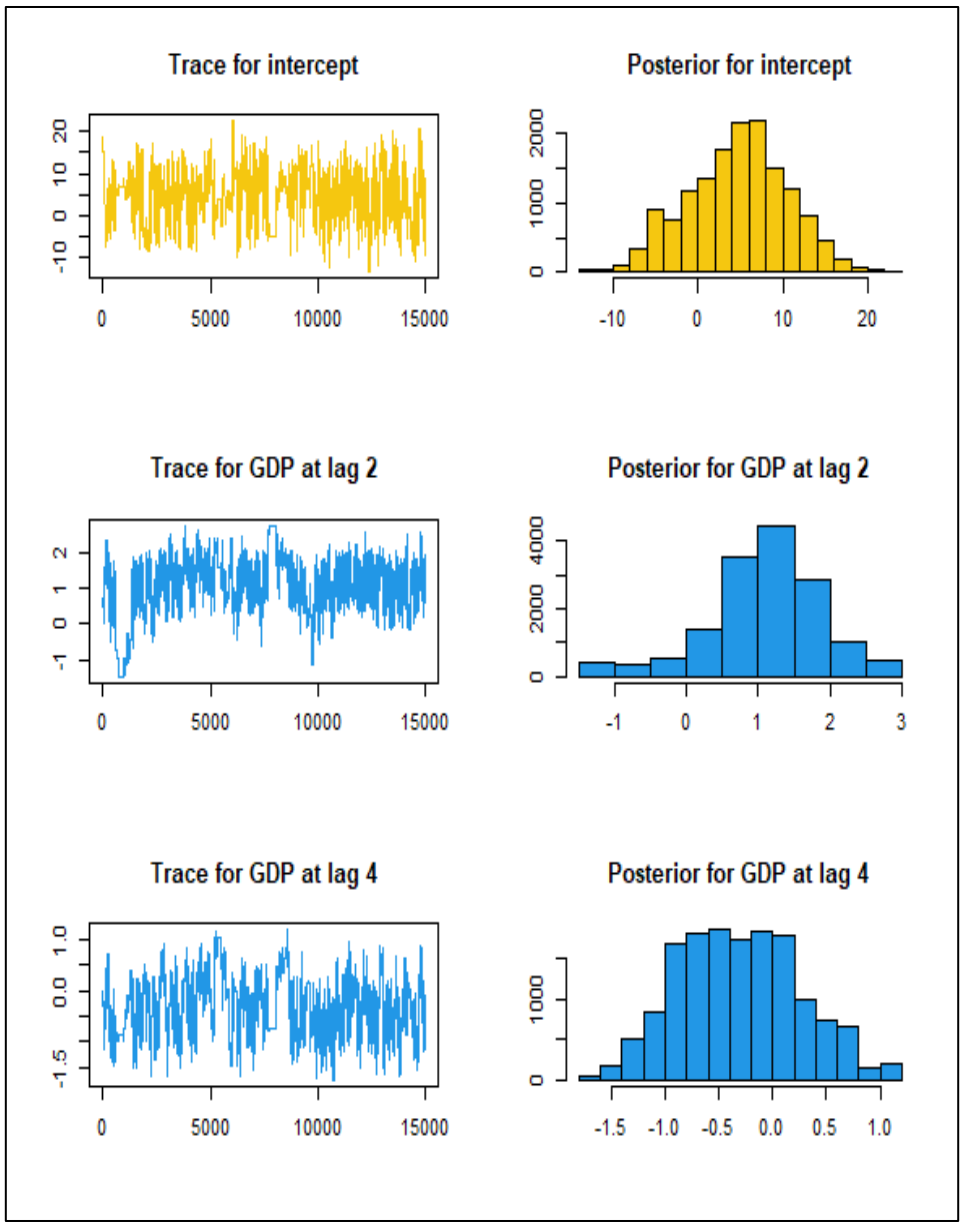

Figure 3 Trace plot and Posterior Distribution of Intercept, GDP(t-2) and GDP(t-4)

The range of the credible interval for GDP at lag 2 is -1.017732 to 2.55, with normal posterior distribution. The small interval size, suggests that there is a degree of uncertainty in the calculation of the interval true population mean. The distribution of GDP at lag 4 is platykurtic means that extreme swings in GDP, whether exceptionally high or low, may be less common. The fluctuations in GDP are often driven by business cycles, which are periods of alternating expansion and contraction. This finding aligns with the idea that economies tend to experience relatively stable periods (moderate deviations from the mean) more frequently than they encounter extreme boom or bust cycles.

The trace plot and posterior distribution of INF_{t-2} and DS are shown in Figure 4 (below). The distribution of INF_{t-2} is normal, then it has symmetrical shape with a peak at the mean value. It indicates that it would be an equal probability of observing inflation rates above and below the mean. On the other hand, distribution of INF_{t-2} is leptokurtic, it means that there is a greater probability of observing inflation rates that are closer to the mean value, but there is also a non-negligible risk of experiencing extreme values, both high and low inflation rates. The leptokurtic inflation distribution aligns with both cost-push and demand-pull inflation theories. Cost-push inflation as supply-side factors lead to price increases, often associated with external shocks like rising oil prices. Demand-pull inflation results from excessive aggregate demand. A leptokurtic distribution suggests that both supply and demand factors may contribute to varying levels of inflation, requiring nuanced policy responses This could be due to factors such as external shocks or unexpected changes in economic policies that is leading to sudden spikes in inflation. Although there is some indication that the inflation rate at lag 2 may have a negative impact on the GDP.

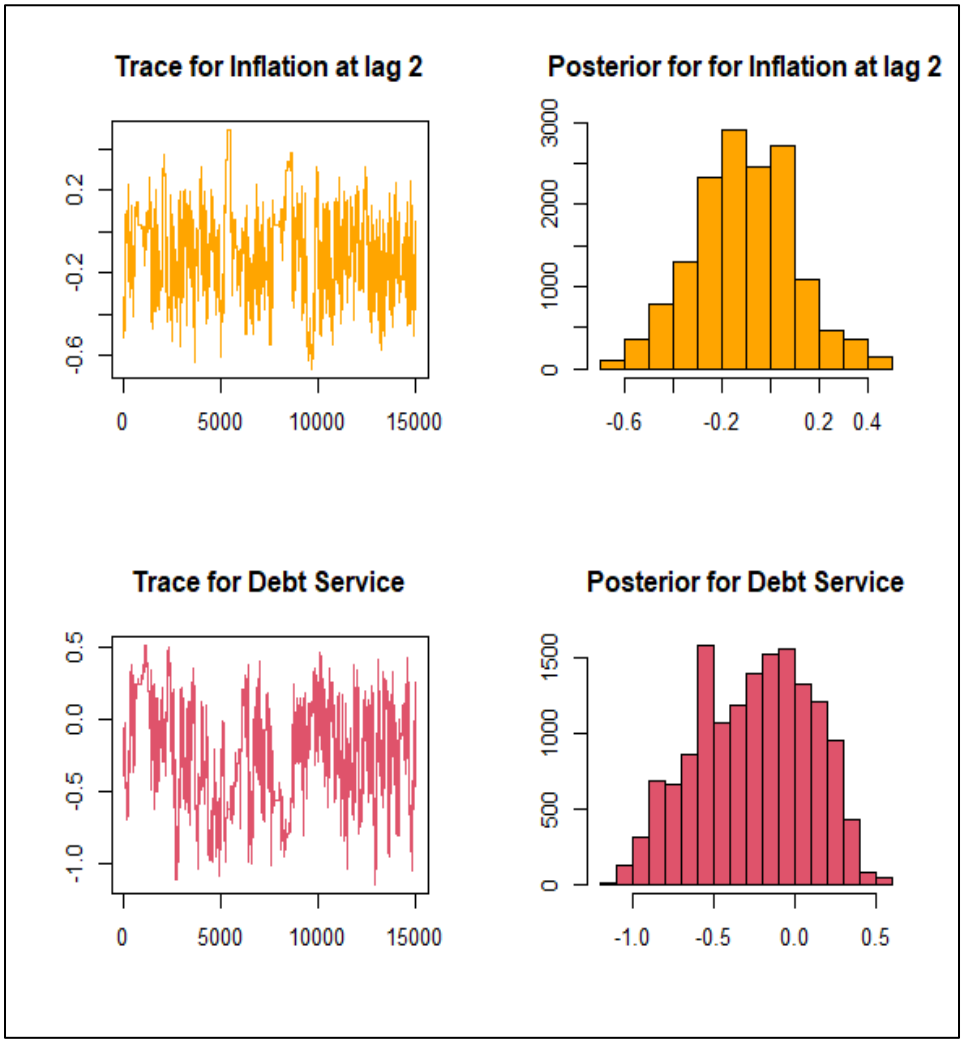

Figure 4 Trace Plot and Posterior Distribution of INF(t-2) and DS

Debt service has leptokurtic posterior distribution, it means that there is a lower likelihood of observing extreme values for debt service. A leptokurtic distribution of debt service aligns with the concept of debt sustainability. The narrow range of credible intervals implies that debt service tends to remain relatively stable around its average level. This stability can be essential for managing debt burdens and ensuring that a country's fiscal obligations are sustainable over time. Additionally, the fact that the posterior credible

interval includes zero and is slightly negatively skewed means that there is some probability of observing very low or negative values for debt service, but this probability is relatively small compared to the probability of observing values close to the mean. This range of credible interval is due to various factors, such as changes in interest rates, changes in economic conditions, or unexpected events that impact the ability of Pakistan to service their debts.

4.1 Theoretical Implications

The findings of this study are consistent with the Debt Overhang Theory, which holds that high amounts of debt can hinder economic development. The strong inverse link between GDP and delayed debt service emphasizes the theory's claim that high debt obligations might stifle a country's economic growth. The Inflation Crowding-Out Theory, which contends that high inflation rates might obstruct economic growth, is consistent with our findings. The idea behind the hypothesis is that rising prices reduce consumers' buying power and stifle economic activity, which is reflected in the negative relation between GDP and inflation rate at lag t-2. Our understanding of Pakistan's economic environment is improved by the integration of our empirical findings with recognized economic theories. While corroborating certain theories, our study illuminates the intricate interplay of factors that shape economic performance.

5. Conclusion

The non-stationarity observed in the economic variables of GDP, inflation rate, and debt service in Pakistan suggests that the MLR model may not be the best fit for the data as evidenced by the low R-squared value of 0.2455 and a DW statistic of 1.71. While the ARDL model which incorporates the lagged values of variables, performs better with an R-squared value of 0.829 and DW statistic of 2.3 indicating no autocorrelation.

The ARDL model's long-run coefficients of lagged GDP, inflation rate, and debt service are significant at a significance level of $\alpha = 0.05$. The significant coefficients were estimated using the Subset ABC-MCMC method, a likelihood-free method better suited for high-dimensional data or complex parameters. The Bayesian approach employed in this method reduces uncertainty in the parameter estimates and provides a full posterior distribution, which is not possible with the OLS estimation method.

Overall, the results suggest that increasing debt service and inflation rate have slowed down the growth of GDP in Pakistan between 2000 and 2021. The government of Pakistan should concentrate on implementing policies to regulate inflation and maintain price stability. These policies could include fiscal and monetary measures such as cutting down government spending, increasing taxes, and implementing appropriate monetary policy tools to control the money supply. To ensure sustainable debt levels, policymakers should adopt effective debt management policies such as rescheduling, restructuring or renegotiation. The estimated posterior distributions offer valuable insights into the current state of the Pakistani economy, thereby guiding policymakers in making informed

decisions to foster sustainable economic growth, manage inflation, and handle the debt burden.

The study specifically focuses on the context of Pakistan, and the findings may not be readily applicable to other countries or regions with different economic, political, or social conditions. The study only covers a certain time period. Due to this, economic conditions and government regulations may have changed throughout time, limiting the applicability of the results to hypothetical futures. By applying a stochastic process, the ABC-MCMC technique estimates model parameters. The choice of priors and tuning parameters in the ABC-MCMC approach can significantly influence the results by shaping how the algorithm explores the parameter space and estimates the posterior distribution. So, noninformative prior can be used to check out it does it make the ABC-MCMC algorithm better or not. Furthermore, this study can be extended by examining the dynamics between debt service, inflation, and economic growth across various time horizons. External shocks, world economic conditions, and geopolitical developments that affect Pakistan's economy can be taken into account for further study.

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