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The Nexus between Macroeconomic Factors and Petroleum Prices in Tanzania: Evidence from 1990 to 2023

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Abstract
This study examines the influence of key macroeconomic variables specifically the inflation rate, Gross Domestic Product (GDP), and exchange rate fluctuations on petroleum prices in Tanzania from 1990 to 2023. Using a quantitative approach and the Autoregressive Distributed Lag model, the study assesses both short-run and long-run effects of these variables on petroleum price stability. The results reveal no long-term Cointegration indicating that inflation, GDP, and exchange rates do not significantly influence petroleum prices in the long run. In contrast, the short-run analysis found that exchange rate fluctuations have a statistically significant impact on petroleum prices in the short run resulting in the rejection of the null hypothesis for GDP. Inflation, however, remained statistically insignificant in both the short and long run, supporting the acceptance of the null hypothesis for inflation. The study concludes that while the long-term effects of these macroeconomic variables on petroleum prices are negligible, short-term fluctuations in exchange rates and GDP have a significant impact. Policymakers are advised to focus on stabilizing exchange rates and fostering GDP growth to mitigate short-term petroleum price volatility.

Introduction

The interplay between macroeconomic factors and domestic oil prices is complex in Tanzania, where oil price fluctuations significantly influence the economy (Nyangarika & Mikhaylov, 2018). Understanding the factors determining the macroeconomic environment and domestic fuel prices is essential for policymakers and economists involved in planning and policy formulation.

Tanzania imports most of its oil, making it sensitive to international market forces and domestic economic conditions. Factors such as the exchange rate of the Tanzanian shilling, inflation, and global oil prices have contributed to the country's fuel price volatility (Sabayo, Massito, & Moshi, 2023). There is a gap in understanding the specific causal relationships between macroeconomic factors and fuel prices. This study seeks to address this gap by examining the nexus between macroeconomic variables and domestic fuel prices in Tanzania.

The study anchors on the Linear/Symmetric Relationship Theory developed by Hamilton (1983), Hooker (1986), and Laser (1987). This framework explores the intricate connections between oil price fluctuations and economic growth volatility. This theory identifies oil price fluctuations as a key driver of economic recessions and macroeconomic instability (Sujit & Ray, 2023). The theory provides a robust framework for understanding how fluctuations in a crucial commodity like oil influence broader economic indicators. The theory's emphasis on causality, symmetry, and historical impact guides the investigation into whether changes in inflation rates, GDP, and exchange rates are causally linked to domestic fuel price fluctuations in Tanzania.

Empirical Literature Review

Numerous studies have explored the intricate relationships between these variables. Nwosu (2009) analysed the impact of fuel prices on inflation in Nigeria, revealing that increases in fuel prices contributed to inflation due to their inclusion in the aggregate price index. Ozdemir and Akgul (2015) investigated the effects of crude oil and gasoline price changes on inflation in Turkey, demonstrating a notable pass-through effect on core inflation. In South Africa, Habanabakize and Dickason-Koekemoer (2023) found long-term relationships between fuel prices, electricity supply, and inflation, suggesting that reducing reliance on imported fuel and enhancing renewable energy could mitigate inflationary pressures. These studies underscore the complex interplay between fuel prices, inflation, GDP, and exchange rate fluctuations, providing a foundation for the hereunder hypotheses:

H1: Inflation has a statistical significance on oil prices

H2: Gross Domestic Product has a statistical significance on oil prices

H3: Exchange rate fluctuations have a statistical significance on oil prices

Conceptual Framework

Figure 1 shows the conceptual framework.

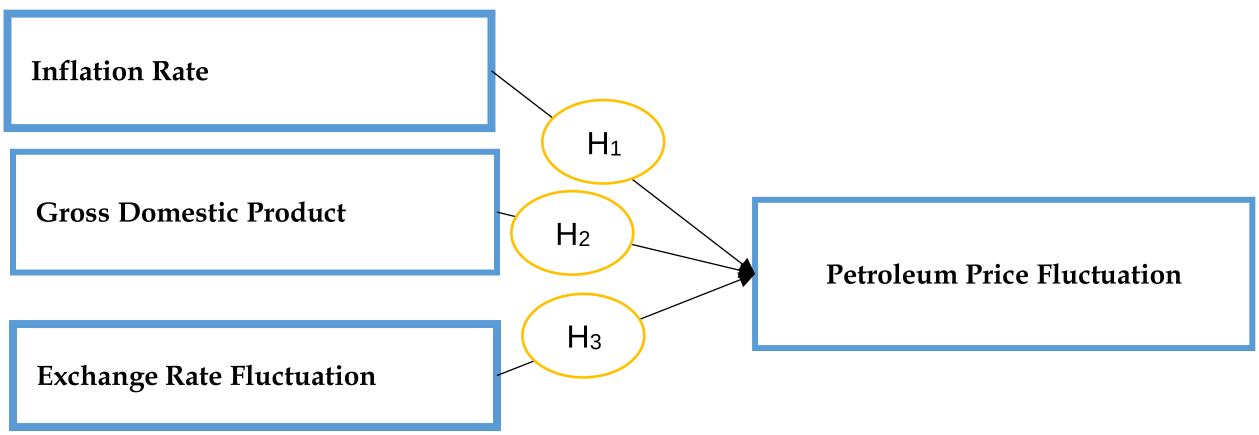

Figure 1: Conceptual Framework

The regressors are Inflation Rate, Gross Domestic Product, and Exchange Rate Fluctuation. The regress is Domestic Petroleum Price Fluctuation.

Methodology

This study is grounded in the positivist research philosophy, which emphasises a quantitative approach. The study explores cause-effect relationships, utilising both descriptive and inferential statistics. The ARDL technique is applied to assess the associations between the variables, aiming to provide precise measurements and verify the research hypotheses through statistical analysis.

Data Source

The study employs a statistical research design utilising annual time series data from the Bank of Tanzania, covering the period from 1990 to 2023 to capture the macroeconomics variables dynamics and their influence on petroleum price fluctuations.

Variables Measurements

The study focuses on three variables: The first is the Inflation Rate, measured by the percentage change in the consumer price index. The second is GDP Growth, measured by the annual percentage change in real GDP, and the third is the Exchange Rate, measured by the average USD exchange rate to TZS (Tanzanian Shilling). Table 1 provides measurements of these variables and their sources of data.

Table 1: Variables measurements and data sources

Variable	Measurement	Source
Inflation Rate	Percentage change in consumer price index	National Bureau of Statistics, Tanzania
GDP Growth	Annual percentage change in real GDP	World Bank, Bank of Tanzania
Exchange Rate	Average exchange rate USD/TZS	Bank of Tanzania
Petroleum Prices	Average Annual prices of oil per litre	Energy and Water Utilities Regulatory Authority

Analytical Modelling

Data analysis was conducted using E-VIEWS software. Johansen Co-integration tests were utilised to explore long-run relationships among the variables. At the same time, short-run dynamics were analysed using Error Correction Models (ECM) to model adjustments to equilibrium in a co-integrated series. Granger Causality tests were applied to examine the direction of causality between oil prices and economic growth. Before these estimations, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were conducted to ensure the stationarity of the time series data. The study used Johansen's Test of Cointegration and Bound Testing to employ the Vector Error Correction Model (VECM) and the Autoregressive Distributed Lag (ARDL) models. Post-estimation diagnostics, including model stability, normality tests, and autocorrelation tests, were conducted to ensure the reliability of the results. The study described various trends through univariate analysis and ensured normality using Jarque-Bera statistics, addressing essential statistical properties before proceeding with the main analysis (Granger & Newbold, 1974; Gujarati, 2004).

Augmented Dickey-Fuller Tests

The augmented Dickey-Fuller (ADF) Test was illustrated as:

$$\Delta \boldsymbol{X_t} = \propto_0 + \propto_1 \boldsymbol{t} + \boldsymbol{\beta_0 X_{t-1}} + \sum_{i=1}^{k} \boldsymbol{\beta_i \Delta X_{t-i}} + \boldsymbol{\eta_t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

Where; Δ = difference operator, t= time trend; k= number of lags used, η= the error term; $\alpha_s$and $\beta_s$are parameters to be estimated.

Phillips Perron (PP) test

The Phillips-Perron (PP) tests enhanced the Dickey-Fuller test by adjusting for serial correlation and heteroscedasticity in the error terms. These tests use a heteroscedasticity and autocorrelation consistent covariance matrix estimator, making them more robust to serial correlation. It was specified as follows:

$$y_t = \pi y_{t-1} + (constant, time\ trend) + u_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots 2$$

Lag Selection and Bound Test

The study determined the appropriate lag length using statistical tests: the Schwarz-Bayesian Information Criterion (SBIC), Akaike Information Criterion (AIC), Hannan-Quinn Information Criterion, and the Final Prediction Error test. The study used the ARDL bound test method to examine long-term relationships among the variables.

Autoregressive Distributed Lag (ARDL) Model

The ARDL model was utilised to assess the magnitude of parameters for each variable. The generalised ARDL model was identified as;

$$Y_t = \gamma_{0j} + \sum_{i=1}^{p} \delta_j Y_{t-1} + \sum_{i=0}^{q} \beta_j' X_{t-1} + \varepsilon_{jt} \ldots\ldots\ldots\ldots 3$$

Where Y_t' represents a vector of variables comprised of petroleum prices, GDP, exchange rate and inflation rate. Further, X_t' variables are permitted to be the purest, either I(0), I(1) or co-integrated; β and δ represent coefficients; γ is always constant; $j = 1, \ldots \ldots \ldots . k; p, q$ are optimal lag-orders; ε_{it} represents an error term's vector, non-observable zero (0) mean white noise vector process. Equation 4 was used for the general ARDL model.

$$\Delta lnPetrolPrice_t = \alpha + \sum_{i=1}^{k+d} \beta \Delta lnPetrolPrice_{t-1} + \sum_{i=1}^{k+d} \varphi \Delta lnGDP_{t-1} + \sum_{i=1}^{k+d} \delta \Delta lnExchRat_{t-1} + u_t \ldots\ldots 4$$

Whereas k is the ideal slack request, and d is the most extreme request of incorporation of the factors; u_t is the stochastic mistake term and Δ denotes the first difference operator, whereas PetrolPrice, GDP and ExchRat are changes in Petroleum Prices, Gross Domestic Product and Exchange Rate respectively, all in natural logarithm.

The equation's section which is having coefficients β , φ , δ ,Φ and θ lays-down the short-run model's dynamics while the second section of which is having coefficients λ_1, λ_2, λ_3, $\lambda_4$andλ_5 lays-down the long-run dynamic relationships (Pesaran *et al.*, 2001). The following hypotheses were developed to evaluate the long-run relationship using equations 3 and4:

$$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0$$
$$H_1: \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq 0$$

From two hypotheses, The F-test was used in the ARDL bound testing to determine whether there was cointegration between the specific variables.

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Results

Descriptive Statistics

Table 2 gives the descriptive statistics of the variables.

Table 2: Descriptive Statistics of the variables

Variable	lnINFLATIONRATE	lnEXHANGERATE	lnPETROLLEUMPRIcE	lnGDP
Mean	2.148	6.968	6.794	23.604
Median	1.887061	7.106958	7.178414	23.5864
Minimum	1.191	5.273	4.406	20.446
Maximum	3.579	7.824	8.01	27.283
Std. Dev.	.733	.696	1.038	1.217
Kurtosis	2.041	2.906	2.659	4.519
Skewness	.578	-.797	-.883	.221
Jarque-bera	3.196	3.607	4.588	3.546
Obs	34	34	34	34

The table indicates that the mean value of the logarithm of the inflation rate is approximately 2.148, with a minimum value of 1.191 and a maximum value of 3.579. When logged, these statistics suggest that the inflation rates have been moderately stable, with no significant outliers as the minimum and maximum values are close to the mean. The distribution of the inflation rates is positively skewed (Skewness = 0.578), indicating a longer tail on the right side of the distribution. The mean value of the logarithm of the exchange rate is 6.968, with the observed minimum and maximum values being 5.273 and 7.824, respectively. The negative skewness value (-0.797) suggests that the distribution is left-tailed, meaning there were instances where exchange rates were lower than the average but not significantly so, as the range around the mean is balanced. The logarithm of petroleum prices has a mean value of 6.794, with the minimum and maximum values being 4.406 and 8.010, respectively. This indicates years when petroleum prices varied significantly, with fluctuations reaching the maximum value of 8.010. The data shows a negative skewness (-0.883), which suggests occasional periods of lower petroleum prices compared to the mean.

The Jarque-Bera statistics for all variables suggest that the data distributions are close to normal. The values are low, indicating no strong deviation from normality, supporting the null hypothesis that the data is normally distributed.

Empirical Findings

Univariate test

The time series data exhibit characteristics suggestive of a unit root stochastic process. To investigate this, the trends of the time series data for petroleum prices, GDP, Inflation rate, and exchange rate were examined for stationarity. Figures 2 and 3 indicate that the petroleum price and exchange rate show upward trends with fluctuations, interpreting potential non-stationarity. Similarly, GDP presents a steady upward trend, suggesting that it might also be non-stationary. The inflation rate displays more volatility, with frequent peaks and troughs, but lacks a clear stationary pattern.

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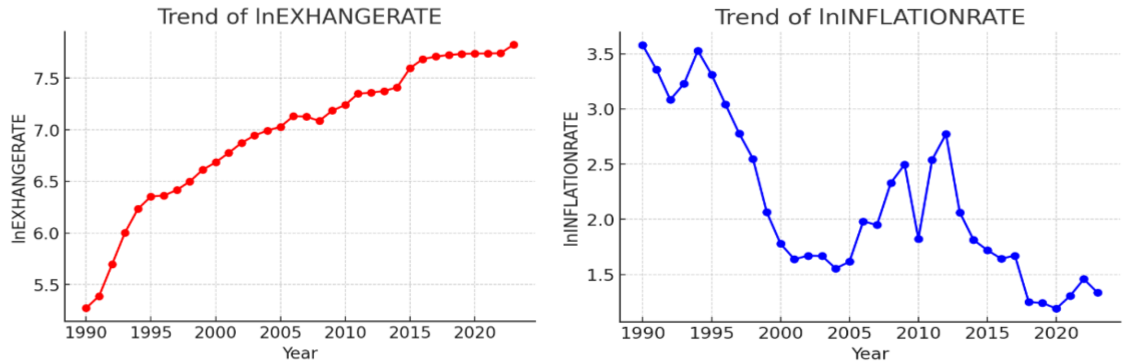

Figure 2: Stochastic Movement for Exchange Rate and Inflation Rate

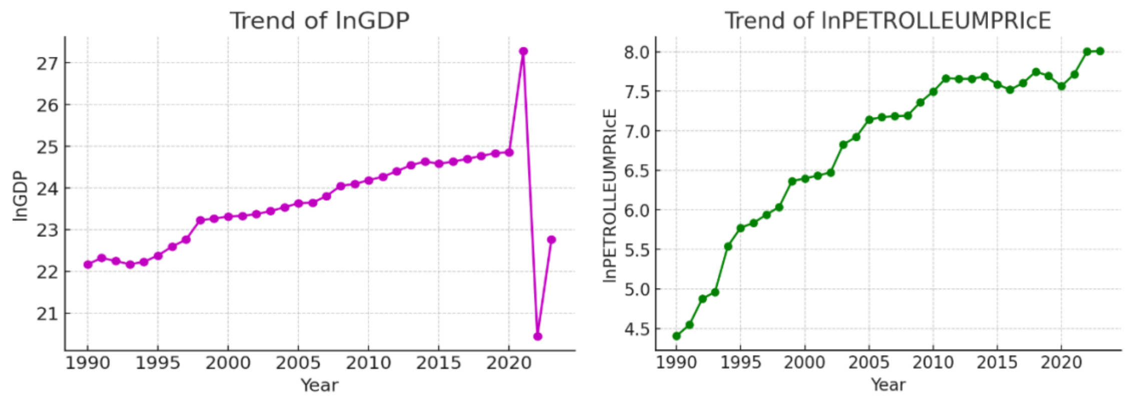

Figure 3: Stochastic Movement for GDP and Petroleum Prices

Diagnosis Test of Pre-Estimation

Stationarity Tests Results

Stationarity tests were conducted using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The ADF test results in Table 3 revealed that the inflation rate was not stationary at level, as the test statistic (-1.791) was less than the 5% critical value (-2.978), but it became stationary after first differencing, with a test statistic (-3.162) exceeding the critical value (-2.992). The exchange rate was stationary at level, with a test statistic (-4.997) greater than the 5% critical value (-2.978), confirming stationarity without differencing. The Petroleum price and GDP were both stationary at level, with test statistics of -3.373 and -3.805, respectively, both exceeding the critical values, leading to the rejection of the null hypothesis of a unit root and confirming that these series were stationary.

Table 3: Unit Root Test Results for ADF

Variables	At level		1st Difference		Conclusion
	Test statistics	5% Critical value	Test statistics	5% Critical value	
Inflation rate	-1.791	-2.978	-3.162	-2.992	I(1)
Exchange rate	-4.997	-2.978			I(0)
Petroleum price	-3.373	-3.696			I(0)
GDP	-3.805	-2.978			I(0)

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The Phillips-Perron test was conducted to assess the stationarity of the variables, revealing that most series are stationary at the level as indicated in Table 4.

Table 4: Unit Root Test, Phillips-Peron test

Variables	At level		1st Difference		Conclusion
	Test statistics	5% Critical value	Test statistics	5% Critical value	
Inflation rate	-3.568	-1.808			I(0)
Exchange rate	-4.475	-2.978			I(0)
Petroleum price	-2.121	-3.568	-3.513	-2.978	I(0) & I(1)
GDP	-4.881	-3.568			I(0)

The inflation rate is stationary with a test statistic of -3.568, exceeding the 5% critical value of -1.808, indicating it is integrated of order zero, I(0). The exchange rate and GDP are also stationary at the level, with test statistics of -4.475 and -4.881, respectively. However, petroleum prices are not stationary at this level, with a test statistic of -2.121 falling below the critical value. However, they become stationary after first differencing, achieving a test statistic of -3.513. This suggests that the Petroleum price is integrated of order one, I (1). Overall, the stationarity conditions required for the ARDL model are met, confirming that most variables are I (0), while the Petroleum price is I(1).

Bound Test for Cointegration

The bound testing approach was used to assess the presence of a long-term relationship between inflation rate, GDP, exchange rate, and petroleum prices in Tanzania. Table 5 gives the bound testing results for cointegration.

Table 5: Bound Testing for Cointegration

Test Statistics	Value	Significance	Bound Critical Values		P_value	
			I(0)	I(1)	I(0)	I(1)
vcF-test	4.710	10%	2.72	3.77		
		5%	3.23	4.35	0.017	0.064
		1%	3.69	4.29		
T test	2.652	10%	1.57	2.46		
		5%	2.13	2.05	0.006	0.051
		1%	2.43	2.37		

The table indicates that the computed F statistic of 4.710 and t-test value of 2.652 exceed the critical values at a 10% significance level but fall short at 5%. Therefore, we fail to reject the null hypothesis, indicating no long-run Cointegration between the variables at the 5% significance level. According to Kripfganz and Schneider (2020), rejecting the null hypothesis at the 1% significance level requires both F and t statistics to exceed the critical values for I (1) variables, which was not observed in this study. Consequently, the results suggest no significant long-run relationship between inflation, GDP, exchange rate, and petroleum prices, implying that these variables do not substantially impact petroleum prices in Tanzania.

Autocorrelation

The Durbin-Watson d-statistic is a test for the presence of autocorrelation in the residuals of regression analysis, as displayed in Table 6.

Table 6: Durbin-Watson

Durbin-Watson	0.5441605
Prob > chi2 (4, 34)	
Conclusion	no serial correlation

The d-statistic ranges from 0 to 4 and specifies no autocorrelation. The calculated d-statistic is 0.5441605, which lies between the decision range. This suggests that there is no autocorrelation present in the residuals.

Heteroscedasticity

The outcome of White's test for homoskedasticity reveals a chi-squared statistic of 11.51 with 9 degrees of freedom and an associated p-value of 0.2425, as indicated in Table 7.

Table 7: White's Test

chi2(9)	11.51
Prob > chi2	0.2425

Ho: homoscedasticity

Ha: unrestricted heteroscedasticity

The null hypothesis of this test postulates that the errors in the model possess a constant variance, indicating homoscedasticity. Given the high p-value of 0.2425, we cannot reject the null hypothesis of homoscedasticity at conventional levels of significance.

The study employed Cameron & Trivedi's decomposition of the IM-test alongside White's test to examine heteroscedasticity, skewness, and kurtosis. Table 8 gives results for Cameron and Trivedi's decomposition of the IM-test.

Table 8: Cameron and Trivedi's decomposition of IM-test

Source	chi2	df	p
Heteroskedasticity	11.51	9	0.2425
Skewness	2.23	3	0.5269
Kurtosis	2.93	1	0.0870
Total	16.66	13	0.2151

The table shows that the overall chi-squared statistic for White's test was 16.6 with a p-value of 0.2151, indicating no significant evidence of heteroscedasticity. The decomposition revealed that the heteroscedasticity component had the highest chi-squared statistic (11.51), but its p-value of 0.2425 suggested no substantial heteroscedasticity. The skewness and kurtosis components showed no significant contributions, with high p-values confirming homoscedasticity.

The study employed the Breusch-Pagan/Cook-Weisberg test to assess heteroscedasticity, with the null hypothesis asserting constant variance of errors. Table 9 gives the Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

Table 9: Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

chi2(1)	0.57
Prob > chi2	0.4515

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Ho: Constant variance

Variables: fitted values of change in petroleum prices

The table shows that the test yielded a chi-squared statistic of 0.57 with a p-value of 0.4515, indicating no significant evidence against the null hypothesis. This suggests that the assumption of homoskedasticity is satisfied for the change in GDP within the ARDL model.

Multicollinearity
Table 10 gives the multicollinearity test results.

Table 10: Multicollinearity

Multicollinearity	VIF	1/VIF
Petroleum price	9.705	0.008
Exchange rate	5.156	0.015
GDP	2.093	0.031
Inflation rate	1.689	0.086
Mean VIF	4.660	0.035.

The multicollinearity analysis reveals that the Petroleum price has a high VIF of 9.705 and a very low tolerance of 0.008, indicating significant multicollinearity. At the same time, the Exchange rate shows moderate multicollinearity with a VIF of 5.156 and a tolerance of 0.015. The **GDP** and Inflation rate exhibit low multicollinearity, with VIFs of 2.093 and 1.689, respectively, and corresponding tolerances of 0.031 and 0.086. The overall mean VIF of 4.660 suggests that multicollinearity does not heavily affect the model.

Model Stability
The ARDL model's stability was assessed using the CUSUM squared test. Figure 3 shows that the CUSUM squared statistic exceeds the boundaries, suggesting a significant structural change in the time series and indicating that the model may not be stable.

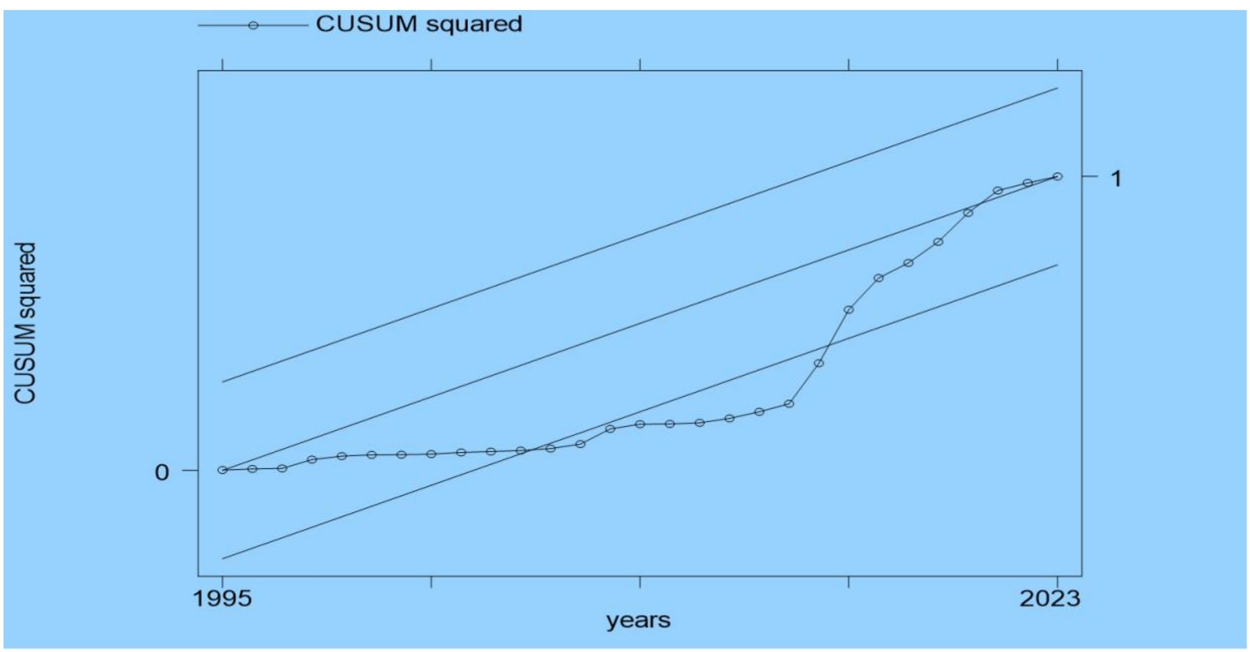

Figure 4: CUSUM Squared Test

Autoregressive Distributed Lag Model Estimates

Table 11 presents the results from an ARDL (1, 1, 1,1) regression analysis.

Table 11: Autoregressive Distributed Lag Model Estimates

	Variable	Coeff	Std. err.	t	P>|t|	95% conf. interval	
ADJ	lnPETROLLEUMPRIcE L1.	0.8454	0.1083	7.81	0.000	0.6223724	1.068563
	lnGDP	0.8465	0.1577	5.37	0.000	0.5216742	1.17132
LR	lnINFLATIONRATE	-0.252	0.0496	-5.08	0.000	-0.3542159	-0.1498
	lnEXHANGERATE	1.249	0.2206	5.66	0.000	0.7948989	1.70376
	lnGDP L1.	-0.824	0.1573	-5.24	0.000	-1.148884	-0.5007
SR	lnINFLATIONRATE L1.	-0.180	0.0548	3.3	0.003	0.0678521	0.29395
	lnEXHANGERATE L1.	-1.079	0.2517	-4.29	0.000	-1.598361	-0.5598
	_cons	-0.340	0.9761	-0.35	0.730	-2.350788	1.6701
ARDL(1,1,1,1) regression							
Number of observation		33					
R-squared		0.8643					
Adj R-squared		0.8564					
Root MSE		0.0729					
Sample: 1990 - 2023							

The analysis reveals various statistical measures, including the R-squared value. The R-squared value of 0.8643 indicates that approximately 86.43% of the variation in the petroleum price can be explained by GDP, Exchange rate, and Inflation rate.

The impact of the inflation rate on Petroleum prices

The study examined the impact of inflation on petroleum prices, revealing a statistically significant negative relationship in both the long and short run. In the long run, the coefficient for the inflation rate was negative and significant (p=0.003), indicating that as inflation increases, petroleum prices decrease, likely due to factors such as the erosion of purchasing power or government interventions to control fuel prices. In the short run, the analysis showed a consistent negative and significant relationship (p=0.003), suggesting that rising inflation exerts downward pressure on petroleum prices.

The nexus between the Gross Domestic Product and Petroleum prices

The study investigated the relationship between Tanzania's GDP and petroleum prices, finding a positive and statistically significant relationship in both the long run and short run. In the long run, the coefficient for GDP is positive and highly significant (p=0.000), indicating that as Tanzania's economy grows, petroleum prices increase, likely due to higher demand for energy and transportation. Short-run analysis also shows a positive and significant relationship (p=0.000), suggesting that GDP growth leads to immediate increases in petroleum prices.

The effect of exchange rate fluctuation on Petroleum prices

The study further examined the effect of exchange rate fluctuations on petroleum prices, revealing a positive and statistically significant relationship in both the long run and short run. In the long run, the coefficient for the exchange rate is positive and highly significant (p=0.000), indicating that as the Tanzanian Shilling depreciates, petroleum prices increase due to the higher cost of importing petroleum. The short-run analysis shows a positive and significant relationship (p=0.000), suggesting that exchange rate fluctuations immediately impact petroleum prices.

Discussions

The study found that both long-run and short-run inflation rates significantly and negatively impact petroleum prices. As inflation increases, petroleum prices decrease in the long run, likely due to government interventions and market adjustments. This finding aligns with studies from various countries, such as Bhattacharya and Mukherjee (2017) in India, Adeniyi et al. (2018) in Nigeria, and Mokoena and Phiri (2020) in South Africa. In the short run, the study found a negative and statistically significant relationship between inflation and petroleum prices, suggesting that inflation leads to decreased fuel prices, possibly through short-term government actions like price controls or subsidies. This short-run dynamic is consistent with findings from studies in countries such as Turkey (Yildirim & Akinci, 2016), Ghana (Amoah & Boateng, 2017), and Egypt (El-Sayed & Mahmoud, 2021), where inflationary pressures are mitigated by rapid government interventions to stabilise petroleum prices.

The study also found that GDP growth has a positive and statistically significant impact on petroleum prices in the long run and short run. In the long run, as Tanzania's economy expands, the increased demand for energy and transportation fuels drives up petroleum prices, a relationship supported by studies in other countries such as India (Sahoo & Dash, 2017), China (Zhang & Liu, 2018), and Brazil (Silva & Santos, 2019). In the short run, the analysis revealed a positive and significant relationship between GDP and petroleum prices, indicating that immediate economic activity increases fuel demand and prices. This short-term dynamic aligns with findings from Turkey (Yilmaz & Gungor, 2016), Nigeria (Okoye & Eze, 2017), and Egypt (Hassan & El-Masry, 2019).

Furthermore, the study found that long-run and short-run exchange rate fluctuations significantly and positively impact petroleum prices. In the long run, a depreciation of the Shilling increases petroleum prices as the cost of importing fuel rises—an effect consistent with findings from Nigeria (Adeniyi et al., 2018) and Uganda (Kasekende & Kibikyo, 2019). This relationship underscores the role of exchange rate stability in managing domestic petroleum prices. A short-run analysis revealed that exchange rate fluctuations have an immediate and significant impact on petroleum prices, which aligns with studies from India (Bhattacharya & Mukherjee, 2017) and Kenya (Gachanja & Muriuki, 2020).

Conclusion

This study demonstrated the intricate connections between key economic variables: inflation, GDP, exchange rate fluctuations, and petroleum prices in Tanzania. The findings reveal that while inflation tends to suppress petroleum prices through government interventions and market adjustments, economic growth drives demand and increases petroleum prices. The exchange rate fluctuations raise petroleum costs, underscoring the importance of exchange rate stability in managing energy prices. These insights highlight the need for economic policies that balance growth, inflation control, and exchange rate management. Policymakers should enhance inflation control mechanisms, such as strategic fuel reserves and targeted subsidies, to protect consumer purchasing power.

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