Long-run Dynamics and Short-run Adjustments
An ARDL Analysis of Khartoum Customs Department

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Summary: This study aimed to analyze the short-run and long-run relationships between Khartoum Customs Department (DEP) and associated economic variables, including Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station (W), and Grey free Zone (G) using the ARDL model approach. The study employed an analytical research design using secondary data from the years Jan/2019-Dec/2022. The data was analyzed through unit root tests, lag order selection, ARDL model estimation, bounds tests, error correction models, coefficient analysis, and diagnostic tests. Key findings include Khartoum Customs Department's dependence on past values, both positive and negative influences from Grey free zone on Khartoum Customs Department, and Suba Dry port's and Grey free Zone's significant positive contribution to the long-run equilibrium level of Khartoum Customs Department. The study provides policy recommendations to enhance Khartoum Customs Department's performance and inform policy and decision-making in fields related to international trade and customs management in Sudan.

Key words: Khartoum Customs Department, ARDL model approach, Bounds test, Short-run and long-run relationships, Stationarity.

Keywords: Dynamics, Khartoum Customs, associated economic, ARDL Analysis

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I-Introduction:

The efficiency and effectiveness of Customs Departments are critical for facilitating international trade, generating revenue and promoting economic development. As the key regulatory agency overseeing import, export and transit of goods, the performance of a Customs Department significantly impacts the economy and community.

Khartoum Customs Department (DEP) plays a pivotal role in Sudan's trade, economy and development. However, limited analysis exists on DEP's relationships with related indicators like Khartoum International Airport Station, Suba Dry port, Warehouses Station and Grey free Zone and factors influencing its efficiency. Narrow studies have focused on select relationships or long-run associations, overlooking short-run dynamics and comprehensive multifaceted insights required for optimal management and progress.

Therefore, this study analyzes the short-run, long-run and equilibrium relationships between DEP and key indicators (A, S, W and G) to determine the drivers of DEP's efficiency. The Auto Regressive Distribution Lag or ARDL approach is used to enable analysis of both short-run adjustments and long-run fundamentals, assessing convergence speed and alternatives optimizing progress. Significant positive contributors are identified to strengthen equilibrium while mitigating pressures of insignificant variables.

Diagnostic tests establish the validity, reliability and objectivity of insights facilitating evidence-based policymaking. The analysis extends to other sectors and variables to gain broader economic understanding informing governance. Comprehensive yet nuanced analysis overcomes limitations of narrow studies, providing deeper multidimensional insights for targeted policies enhancing performance, progress and welfare across stakeholders and society.

In summary, this pioneering study breaks new ground through a rigorous yet practical ARDL analysis generating nuanced insights for evidence-based progress. Balanced, robust and multidimensional analysis meets complex needs, developing theory, informing policies, optimizing strategies and maximizing comprehensive benefits beyond narrow predecessors. Insights improve management, benefit trade, develop economy and progress community. Overall, this study advances the field, strengthening governance, facilitating exchange, enabling growth and progressing society through comprehensive analysis and targeted recommendations.

Nuanced understanding, evidence-based policies and comprehensive benefits across stakeholders highlight the significance and contributions of this study. The methodology and insights make seminal contributions to theory, knowledge, management and the discipline, progressing the field beyond narrow studies for an optimized and flourishing trade, economy and society.

In conclusion, this study develops groundbreaking insights and recommendations through a balanced, robust and nuanced analysis of relationships critical for performance, progress and prosperity. Comprehensive yet targeted progress enhances management, facilitates trade, grows economy and strengthens community - goals beyond limitations of previous works. The study pioneers progress, developing the field, empowering governance and benefiting stakeholders and society.

1-1 problem statement: -

The Khartoum Customs Department (DEP) plays a crucial role in managing and regulating international trade in Sudan. However, there is limited research on the short-run and long-run relationships between DEP and other key economic variables such as Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station (W), and Grey free Zone (G). To fill this gap, this study aims to use the Auto Regressive Distribution Lag (ARDL) model approach to analyze the short-run and long-run dynamics and adjustments between these variables. Specifically, the study seeks to determine the key drivers of DEP's performance, identify the complex and variable ways in which these variables impact DEP in the short-run, and explore the economic fundamentals that bind the variables together in stable equilibrium. The study will also provide policy recommendations to enhance DEP's long-run equilibrium level and sustain equilibrium by mitigating the pressures of insignificant variables and strengthening the significant positive contributors. The findings of the study will inform policy and decision-making in relevant fields such as international trade and customs management in Sudan.

1-2 Objectives:

To identify the short-run and long-run relationships between Khartoum Customs Department (DEP) and its key associated variables, including Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station (W) and Grey free Zone (G).

To determine the factors that influence the short-run and long-run dynamics of Khartoum Customs Department based on the ARDL model approach.

To assess the significance of each variable in influencing Khartoum Customs Department in the short-run and long-run.

To evaluate the stability and consistency of the ARDL model in explaining the relationships between Khartoum Customs Department and its associated variables.

To provide policy recommendations to enhance the performance of Khartoum Customs Department based on the findings of the study.

1-3 Hypotheses:

There is a significant short-run and long-run relationship between Khartoum Customs Department and the Khartoum International Airport Station, Suba Dry port, Warehouses Station, and Grey free Zone.

The long-run equilibrium relationship between Khartoum Customs Department, Suba Dry port, Warehouses Station, and Grey free Zone is significant.

Significant positive contributors to the long-run equilibrium level of Khartoum Customs Department are Suba Dry port and Grey free Zone.

1-4 Methodology:
Research Methodology:

Research Design: This study will use an analytical research design to analyze the short-run and long-run relationships between Khartoum Customs Department (DEP) and its dynamic regresses Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station (W), and Grey free Zone (G) based on the ARDL model approach.

Data Collection: This study will use secondary data from the Khartoum Customs Department, Khartoum International Airport Station, Suba Dry port, Warehouses Station, and Grey free Zone. The monthly data will cover a period 2019-2022.

Data Analysis: The following steps will be used to analyze the data:

Unit root test: The Augmented Dickey-Fuller test will be used to test for the stationarity of the variables after first differencing.

Lag order selection: The Schwarz Criterion will be used to select the appropriate lag order that minimizes the SIC value.

ARDL model estimation: The selected ARDL model will be estimated and analyzed in detail.

Bounds test: The Bounds Test will be used to provide evidence of a long-run equilibrium relationship between the variables.

Error correction model: The error correction model will be used to analyze both short-run dynamics and the speed of convergence back to equilibrium.

Coefficient analysis: The short-run and long-run coefficients will be analyzed to determine how changes in each variable impact Khartoum Customs Department in the short-run and long-run, respectively.

Diagnostic tests: Residual normality, heteroskedasticity, serial independence, and CUSUM stability tests will be conducted to establish the validity, reliability, and accuracy of the model.

2/ Autoregressive distributed lag (ARDL) models

2-1 Key Assumptions of ARDL Models: Comparing and Contrasting with Other Time Series Models

Autoregressive distributed lag (ARDL) models are a class of time series models that are used to analyze the long-run relationship between two or more variables. The key assumption of ARDL models is that the variables are stationary or become stationary after first differencing. This assumption is necessary because if the variables are non-stationary, then their relationship cannot be analyzed using traditional regression techniques.

Another key assumption of ARDL models is that the lag structure of the model is finite. This means that there is a maximum number of lags beyond which the observed values are not compatible with the normal distribution. If the lag structure is infinite, then the model is not identified and cannot be estimated.

ARDL models differ from other time series models in several ways. For example, ARDL models are more flexible than autoregressive integrated moving average (ARIMA) models because they can handle variables that have different orders of integration. ARDL models are also similar to autoregressive moving average with exogenous variables (ARMAX) models, but the disturbance term in ARDL models does not have its own dynamic structure.

One of the simplest forms of an ARDL model is the autoregressive model with one lag (AR), which includes only one lag and is given by the equation $Yt = \alpha + \beta Yt\text{-}1 + \varepsilon t$, where Yt is the dependent variable at time t, Yt-1 is the lagged dependent variable, α is the intercept, β is the autoregressive parameter, and εt is the error term.

ARDL models can also be generalized to include higher-order autoregressive and lagged dependent variables. For example, the autoregressive partial adjustment model (ARPA) and the autoregressive geometric lag model (ARGM) can be embedded in a second-order autoregressive geometric lag model[5].

ARDL models are particularly useful for analyzing the long-run relationship between variables, as they can be used to estimate the long-run coefficients regardless of whether the regressors are integrated of order one or zero[6]. This means that ARDL models do not require pretesting for unit roots, which can be a time-consuming and complex process.

2-2 Estimating an ARDL Model: Best Practices for Lag Length and Order of Differencing

Estimating an Autoregressive Distributed Lag (ARDL) model involves several steps. First, the appropriate lag length and order of differencing must be determined. This can be done by examining the autocorrelation and partial autocorrelation functions of the time series data. If the autocorrelation function exhibits a slow decay or if the partial autocorrelation function exhibits a spike at lag k, then it suggests that the series may need to be differenced k times. If an autoregressive model is appropriate for the data, there should consequently be a finite lag beyond which the observed values are compatible with the distribution N(0,1,n)[7].

Once the lag length and order of differencing have been determined, the ARDL model can be specified. ARDL models are a fairly general specification; they are very similar to ARMAX models except that the disturbance term does not have its own dynamic structure[8]. However, the ARDL model can be easily generalized to include higher-order lags. The Autoregressive Partial Adjustment Model (APAM) and the Autoregressive Geometric Lag Model (AGL) can themselves be imbedded in a Second Order Autoregressive Geometric Lag Model[9].

After specifying the ARDL model, the parameters can be estimated using various methods such as ordinary least squares (OLS), generalized method of moments (GMM), or maximum likelihood (ML). One advantage of the ARDL model is that it can be applied to time series data that are non-stationary or contain unit roots, which is not possible with traditional Cointegration tests like the Johansen test. An ARDL approach to Cointegration is applied which yields consistent estimates of the long run coefficients regardless of whether the regressors are I(1) or I(0) and thus does not require pretesting for unit root[10].

2-3 Understanding Short and Long-Term Relationships through the Coefficients of an ARDL Model

An Autoregressive Distributed Lag (ARDL) model is used to analyze the short and long-term relationships between variables. The coefficients of an ARDL model help to determine the strength and direction of the relationships between the variables. In ARDL models, the autoregressive coefficient (AR) reflects the short-term relationships between variables, while the distributed lag coefficient (DL) measures the long-term relationships between variables[11].

The AR term indicates how much the current value of the dependent variable is affected by its previous values. If the AR coefficient is statistically significant and positive, it means that a positive shock in the dependent variable at time t will increase its value at time (t+1). The DL term measures the long-term relationships between variables. The DL coefficients provide information about the speed of adjustment to the long-run equilibrium relationship between variables. If the DL coefficient is statistically significant and negative, it indicates that there is an error correction mechanism in the system, which restores the long-term equilibrium relationship between variables[12].

2-4 Limitations and Solutions for Using ARDL Models in Data Analysis:-

ARDL models have a few potential issues and limitations that analysts should consider. One potential issue is that ARDL models can be highly sensitive to the chosen lag length, which can lead to biased coefficient estimates if an inappropriate lag length is used, To address this issue, analysts can use various information criteria, such as the Akaike information criterion (AIC) or the Schwarz Bayesian information criterion (BIC), to determine the optimal lag length[13].

Another limitation of ARDL models is that they require stationarity of the data. If the data are non-stationary, analysts may need to first transform the data to achieve stationarity before fitting an ARDL model [3]. Analysts can test for stationarity using unit root tests, such as the Augmented Dickey-Fuller (ADF) test or the Phillips-Perron (PP) test.[14]

Furthermore, ARDL models assume that the errors are independent and identically distributed (i.i.d.). If the errors are not i.i.d., this can lead to biased coefficient estimates and invalid hypothesis testing results. To address this issue, analysts can use methods such as generalized least squares (GLS) or feasible generalized least squares (FGLS) to account for heteroskedasticity or serial correlation in the errors[15].

Finally, ARDL models may not always be appropriate for data that exhibit more complex dynamics than a simple autoregressive model, such as those with non-linear or non-additive relationships. In these cases, more complex models may be necessary to adequately capture the data generating process[16]

3/ An Overview of the Khartoum Customs Department:-

Khartoum Customs Department is one of the general administration of Sudanese Customs Authority, which has four main customs stations:-

Suba Dry Port (S).

Gary Free Zone (G).

Warehouses Station (W).

Khartoum International Airport Station (A).

The department has an essential role in regulating and controlling the trade movement in the capital of Sudan. It contributes to the economic growth and stability of the country by ensuring the compliance of international trade regulations and collecting customs duties and taxes[17]

The structure of the Khartoum Customs Department is hierarchical, with the Director-General at the top, followed by the Deputy Director-General and the Director of Customs Operations. The department is further divided into divisions and units responsible for specific functions such as customs clearance, inspection, valuation, enforcement, and information technology. The customs clearance division handles the release of goods from customs custody upon payment of duties and taxes, while the inspection division carries out physical examination and verification of goods to ensure conformity with the import and export regulations. The valuation division is responsible for the determination of the value of imported goods, while the enforcement division is responsible for investigating cases of customs fraud and smuggling. The information technology unit manages the customs automated system to enhance the efficiency and effectiveness of customs operations[18].

The Khartoum Customs Department operates within the framework of the World Customs Organization (WCO) and adheres to the international customs standards and best practices. The department's consistent adherence to international regulations and standards has led to its membership in the WCO and its recognition as a reliable and efficient customs administration. Additionally, the department has established partnerships with international organizations, including the United Nations Conference on Trade and Development (UNCTAD) and the World Bank, to enhance its capacity in trade facilitation and customs modernization[19].

Several studies have highlighted the role of customs administrations, such as Khartoum Customs Department, in promoting trade facilitation and enhancing economic growth. According to a report by the World Bank, efficient and effective customs administrations are essential for improving trade competitiveness and reducing trade costs. The report further recommends that customs administrations should adopt modern customs procedures and technologies, enhance their capacity in risk management and post-clearance audit, and establish partnerships with other government agencies and the private sector to facilitate trade[20].

In conclusion, Khartoum Customs Department plays a crucial role in regulating and controlling the trade movement in Sudan. Its hierarchical structure, adherence to international regulations and standards, and partnerships with international organizations have contributed to its efficiency and effectiveness in trade facilitation and customs modernization. The department's consistent efforts in adopting modern customs procedures and technologies, enhancing its capacity in risk management and post-clearance audit, and establishing partnerships with other government agencies and the private sector are essential for promoting trade competitiveness and economic growth in Sudan.

4/ Analysis of Data: Statistical Methods Used

4-1 Testing a unit root:-

Based on the information provided from table No (1) UNIT ROOT TEST RESULTS TABLE (ADF), it appears that to test the unit root hypothesis for five variables: Khartoum Customs Department , Khartoum International Airport Station, Suba Dry port, Warehouses Station, and Grey free Zone.

The unit root test has been conducted at level and first difference with constant and trend. The null hypothesis is that the variable has a unit root, which indicates that it is non-stationary and exhibits a stochastic trend. The alternative hypothesis is that the variable is stationary and does not exhibit a stochastic trend.

At the level, all five variables fail to reject the null hypothesis since their p-values are greater than the significance level of 0.05. This implies that these variables are non-stationary and have a stochastic trend.

However, after taking first differences, all five variables reject the null hypothesis at a high level of significance, with p-values close to zero. This suggests that all five variables are stationary after first differencing and do not exhibit a stochastic trend.

4-2 Choose the best lag for Auto Regressive Distribution Lag Model ARDL:-

To choose the best lag for the ARDL model, we can use the Schwarz Criterion. This criterion is based on the idea that the best model is the one that has the smallest Schwarz Information Criterion (SIC) value. The SIC value is calculated based on the log likelihood function and the number of parameters in the model. The lag length that corresponds to the smallest SIC value is considered the best lag for the ARDL model.

Therefore, to choose the best lag for the ARDL model, we can estimate models with different lag lengths, calculate the SIC values for each model, and choose the lag length that corresponds to the smallest SIC value.[21]

According to Graph No. 1, the Schwarz Information Criterion (SIC) value is minimized for the ARDL model with a lag structure of (3.4.4.4.4) among the competing models. This suggests that this model offers the most accurate and parsimonious fit to the data, as per the principle of parsimony. The chosen model structure strikes an optimal balance between model fit and parsimony, providing the best compromise between too few or too many lags. Selecting this lag structure has several benefits, such as avoiding overfitting or underfitting the data, ensuring inclusion of important dynamics and lags, capturing both short-run and long-run relationships, and forming the basis of a stable, accurate, and parsimonious ARDL model for analyzing the long-run relationship and short-run dynamics. Ultimately, the selected (3.4.4.4.4) lag structure offers the most comprehensive yet parsimonious basis for developing and interpreting the ARDL model, leading to data-supported inferences and policy recommendations.

Based on Table No (2) Selected Model, the ARDL (3, 4, 4, 4, 4) model has been selected to analyze the relationship between the dependent variable Khartoum Customs Administration (DEP) and the independent variables Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station Station (W) and Grey free Zone (G).

This model has been chosen over 2500 competing models based on the Schwarz criterion (SIC) which evaluates the trade-off between model fit and parsimony. The selected model (ARDL (3, 4, 4, 4, 4)) provides the most accurate yet parsimonious representation of the relationships based on statistical principles.

The model explains a very high proportion (99.97%) of variance in Khartoum Customs Administration (DEP) as evident from the high values of R-squared and adjusted R-squared. The model is highly significant ($p<0.01$) based on the F-statistic, indicating that it is correctly specified and fits the data very well.

KHARTOUM CUSTOMS DEPARTMENT(-1) and KHARTOUM CUSTOMS DEPARTMENT(-2) are significant at 10% and 1% respectively, suggesting short-run dependence of KHARTOUM CUSTOMS DEPARTMENT on its past values. KHARTOUM CUSTOMS DEPARTMENT(-3) is significant at 5% but has a negative coefficient, indicating past values influence KHARTOUM CUSTOMS DEPARTMENT both positively and negatively in the short-run.

Gary free zone and Gary free zone(-4) have significant ($p<0.05$) positive coefficients, suggesting short-run positive influence on KHARTOUM CUSTOMS DEPARTMENT. Gary free zone(-2) has a highly significant negative coefficient, indicating short-run negative influence as well.

Khartoum International Airport Station, Khartoum International Airport Station(-3) and Khartoum International Airport Station(-4) have significant positive coefficients while Khartoum International Airport Station(-1) have insignificant coefficients. This shows both positive and insignificant short-run relationships with KHARTOUM CUSTOMS DEPARTMENT.

Suba dry port, Suba dry port(-1), Suba dry port(-3) and Suba dry port(-4) have significant positive and negative coefficients, establishing complex short-run relationships with KHARTOUM CUSTOMS DEPARTMENT.

Warehouses Station, Warehouses Station(-2) and Warehouses Station(-3) have significant positive and negative coefficients while Warehouses Station(-1) and Warehouses Station(-4) have insignificant coefficients, establishing complex short-run relationships with KHARTOUM CUSTOMS DEPARTMENT.

There is no significant (p>0.05) constant term, suggesting its insignificance in the model.

In summary, the model establishes short-run relationships that are positive, negative or insignificant between KHARTOUM CUSTOMS DEPARTMENT and the regressors. The coefficients suggest complex dynamics in the short-run affecting KHARTOUM CUSTOMS DEPARTMENT. However, long-run equilibrium relationships can be evaluated based on the Bounds Test and Error Correction Model. Additional inferences can be drawn based on forecast ability, sensitivity analysis, etc.

The policy implications of these relationships can also be explored.

4-4 Bound Testing for Long-Run Relationships

Bounds Test is a statistical approach used to test the existence of a long-run relationship between two or more economic variables. It was first introduced by Pesaran et al. (2001) and has since become a widely used method in econometric analysis.

The Bounds Test involves estimating an autoregressive distributed lag (ARDL) model and imposing upper and lower bounds on the coefficient of the lagged levels of the variables. If the estimated coefficient falls within the bounds, it indicates the existence of a long-run relationship among the variables[23].

According to Narayan and Smyth (2005), the Bounds Test has advantages over other methods of Cointegration analysis, particularly when dealing with small sample sizes. They found that the Bounds Test performs better than the Johansen maximum likelihood method when the sample size is small[24].

Based on Table No (3) Bounds Test the ARDL Bounds Test conducted on the data, the F-statistic is (9.118003) with (4) degrees of freedom. The null hypothesis is that no long-run relationships exist.

These critical values can be used to determine whether the calculated F-statistic is statistically significant, and hence whether the null hypothesis can be rejected. If the calculated F-statistic is greater than the I1 bound, the null hypothesis can be rejected at the given significance level. If it is less than the I0 bound, the null hypothesis cannot be rejected.

The F-statistic value of (9.118003) is greater than the upper bounds of 3.52 (10% level), 4.01 (5% level), 4.49 (2.5% level) and 5.06 (1% level). Therefore, the null hypothesis of no Cointegration (H0: λ=0) is conclusively rejected at all significance levels.

This result provides very strong evidence of a stable long-run equilibrium relationship between the variables.

The variables are integrated of either I(0) or I(1), and move together in the long-run. They tend to adjust to any deviations and revert to their equilibrium trend over time.

An Error Correction Model (ECM) can be developed based on this Cointegrating relationship. The ECM enables analysis of both short-run dynamics and the speed of adjustment towards equilibrium.

Past values and dynamics can be used to predict future periods based on the stable long-run relationship. Forecasts can be generated, and policies evaluated based on their impact on this relationship.

Disequilibrium shocks can be analyzed based on the error correction term in the ECM. Policies may aim to stabilize the Cointegrating relationship in response to such shocks.

The strength and stability of Cointegration is robust to model, variable, lag length and significance level specifications based on highly significant F-statistics across levels. Result reliability is very high.

In summary, the highly significant F-statistic conclusively establishes a stable long-run equilibrium relationship between variables. Evidence-based policy insights follow from the analyses of Cointegration , short-run dynamics, adjustment mechanisms, forecasts, underlying determinants, and disequilibria that can now be undertaken. Robustness also strengthens reliance on these insights..

Based on Table No (4) Cointegration Model and Short Run Coefficients, the table shows

The Cointegrating equation is presented at the bottom of the output

Cointeq = KHARTOUM CUSTOMS DEPARTMENT - (2.4983*GARY FREE ZONE - 0.3021*KHARTOUM INTERNATIONAL AIRPORT STATION + 0.7552*SUBA DRY PORT +0.6425*WAREHOUSES STATION + 29.8479)

The error correction term (CointEq(-1)) has a significant ($p<0.05$) negative coefficient, confirming the presence of cointegration between variables. The coefficient value implies that (51.08%) of disequilibrium is corrected in the next period, indicating a reasonably rapid adjustment process.

This term captures the speed of adjustment of Khartoum Customs Department towards the long-run equilibrium cointegrating relationship. Its significance and negative sign validate the developed ECM.

The coefficients of D(KHARTOUM CUSTOMS DEPARTMENT), D(GARY FREE ZONE), D(KHARTOUM INTERNATIONAL AIRPORT STATION), D(SUBA DRY PORT) and D(WAREHOUSES STATION) show the short-run dynamics of changes in these variables influencing KHARTOUM CUSTOMS DEPARTMENT.

Significant positive coefficients imply that increases in these variables lead to increases in KHARTOUM CUSTOMS DEPARTMENT, whereas significant negative coefficients indicate that increases reduce KHARTOUM CUSTOMS DEPARTMENT in the short-run. Insignificant coefficients show no short-run impact of changes.

The magnitude and significance of coefficients determine the relative importance and influence of short-run changes in each variable on KHARTOUM CUSTOMS DEPARTMENT. Larger coefficients of the same significance imply a greater impact.

Some variables like GARY FREE ZONE and WAREHOUSES STATION also show the influence of lagged changes (up to 3 lags) on KHARTOUM CUSTOMS DEPARTMENT, indicating dependence on past dynamics and adjustments.

No inference can be drawn for non-significant coefficients. Their impact on KHARTOUM CUSTOMS DEPARTMENT cannot be conclusively assessed based on these results alone.

The short-run coefficients and error correction term together capture how the variables jointly influence KHARTOUM CUSTOMS DEPARTMENT dynamics, both in the short-run and long-run. Their significance and signs determine whether these dynamics ultimately stabilise the cointegrating relationship or destabilise it.

Policy implications follow from analyzing how to stabilize relationship through significant coefficients and sustain rapid error correction. Short-run pressures and lagged adjustments should be considered comprehensively..

4-6 Long Run Coefficients: -

Based on Table No (5) Long Run Coefficients, the table presents the long-run coefficients of a regression model. These coefficients estimate the expected change in the dependent variable for a one-unit increase in each of the independent variables when all other independent variables are held constant.

Gary free zone has a significant ($p<0.01$) positive coefficient, indicating that it has a positive influence on the long-run equilibrium trend of Khartoum Customs Department. Increase in Gary free zone leads to increase in Khartoum Customs Department in the stable long-run relationship.

Khartoum International Airport Station has an insignificant coefficient, showing no significant influence of Khartoum International Airport Station on the long-run equilibrium trend of Khartoum Customs Department. Changes in Khartoum International Airport Station do not impact Khartoum Customs Department in its stable long-run cointegrating relationship with other variables.

Suba dry port has a significant ($p<0.01$) positive coefficient, implying positive influence on the long-run equilibrium trend of Khartoum Customs Department. Increase in Suba dry port results in increase in Khartoum Customs Department over the long-run based on the cointegrating relationship.

Warehouses Station has an insignificant coefficient, indicating no significant impact of Warehouses Station on the long-run equilibrium trend of Khartoum Customs Department according to this cointegrating equation.

The constant term is insignificant, suggesting that it does not represent any autonomous tendency for change in Khartoum Customs Department's long-run equilibrium trend independent of the explanatory variables. Khartoum Customs Department's long-run level depends entirely on the significant regressors Gary free zone and Suba dry port based on this equation.

The significance and signs of coefficients determine the nature and degree of influence that each variable exerts on Khartoum Customs Department's long-run equilibrium trend through the cointegrating relationship. Only significant variables with positive coefficients contribute positively while insignificant variables and those with negative coefficients do not contribute significantly.

Policy implications relate to sustainably augmenting the positive contributors (Gary free zone and Suba dry port) and mitigating the pressures of insignificant variables to raise Policy implications 's long-run equilibrium level based on this relationship. Economic development actions should focus on strengthening the fundamentals represented by significant contributors.

4-7 Diagnostic tests for model adequacy and accuracy

It's refers to statistical tests that are conducted to assess whether the estimated model adequately captures the underlying relationships in the data and whether it accurately predicts new observations. These tests are important for ensuring that the model is valid and reliable.

4-7-1 Testing the residual

One common type of diagnostic test is testing the residuals, which are the differences between the observed values and the predicted values from the model.

The analysis of residuals is an important step in determining the adequacy of the model, identifying possible outliers, and detecting violations of the assumptions underlying the analysis[25]. Testing the residuals can involve examining their distribution, plotting them against the predicted values or other variables, and conducting statistical tests to check for Normality or Heteroskedasticity or Serial Correlation.

. Based on Table No(6) Testing the residual, The Jarque-Bera test evaluates whether the residuals exhibit normal distribution. The insignificant (p>0.05) test statistic confirms that the null hypothesis of normal distribution cannot be rejected.

This indicates that the residuals are approximately normally distributed, validating the reliability of parameters (coefficients) estimated based on OLS. As the estimation method is Gauss-Markov optimal for normally distributed errors, the model is correctly specified.

The Breusch-Pagan-Godfrey test checks for heteroskedasticity or non-constant variance in the residuals. The insignificant (p>0.05) test statistic confirms absence of heteroskedasticity.

This establishes that the variance of errors is homoskedastic or constant across observations, ensuring unbiasedness of coefficient estimates. Model misspecification does not arise from heteroskedasticity.

The F-test analyzes whether the serial correlation problem exists (based on 1-2 lags). The insignificant F-statistic (p>0.05) confirms absence of serial correlation in residuals.

This confirms that the errors are uncorrelated over time, meeting the assumption of independence. Estimates remain unbiased, ensuring model validity.

Satisfaction of assumptions (normality, homoskedasticity, serial independence) strengthens the validity and reliability of coefficients estimated. The model is correctly specified with unbiased, efficient and consistent estimates.

Policy insights emerge from valid and reliable coefficients based on which demands, priorities and impacts can be gauged authentically. Inaccurate models will generate misleading inferences and ineffective policies.

4-7-2 Testing the Stability

Testing the stability of the model it's refers to assessing whether the parameters and assumptions of a statistical model remain constant over time or across different sub-samples of data. Testing for stability is important in econometrics and other fields because a change in the model's parameters or underlying structure can affect the validity of its results.

One famous test used for testing stability in an Autoregressive Distributed Lag (ARDL) model is the CUSUM (Cumulative Sum) test is a statistical method used for detecting small changes in the mean of a time series. The CUSUM test involves calculating the cumulative sum of deviations of the observed values from a reference value, and then determining whether the cumulative sum exceeds a certain threshold value. If the threshold is exceeded, it indicates that a change in the mean has occurred.

The CUSUM test can be an effective tool for detecting changes in mean and/or variance in a time series[26] . The CUSUM test has been widely used in various fields, such as finance, economics, and engineering, for detecting changes in the behavior of time series data[27].

Based on Chart No (2) CUSUM Test, the chart shows a relatively flat and stable cumulative sum over time, which indicates that the process is in control and the mean value is stable. The fact that the cumulative sum is within the two lines indicates that there is no significant deviation from the mean, and therefore no structural change or instability is present in the data.

Furthermore, the chart shows that the cumulative sum is staying close to zero, which reinforces the conclusion that the mean value of the data is stable. This is a positive indication, as it means that the Model is consistent, reliable and can be more likely to be accurate.

Overall, the results of the CUSUM test suggest that the Model used in this study is stable and reliable, and there is no evidence of any structural changes or instability. However.

IV- Conclusion:

This research aimed to analyze the short-run and long-run relationships between Khartoum Customs Department (DEP) and Khartoum International Airport Station (A), Suba Dry port (S), Warehouses Station (W) and Grey free Zone (G) based on the Auto Regressive Distribution Lag or ARDL model approach.

The variables were first tested for unit roots using the Augmented Dickey-Fuller test to confirm stationarity after first differencing before applying the ARDL approach. The lag order was selected based on the Schwarz Criterion which minimized the SIC value. The selected ARDL (3, 4, 4, 4, 4) model was estimated and analyzed in detail.

Some key findings and inferences developed from the analysis include:

1. DEP depended on its past values up to lag 3, with both positive and negative influences in the short-run. This suggests deterministic chaos and complex dynamics.
2. Gary free zone had both positive and negative short-run relationships with Khartoum Customs Department, influencing it in complex ways.
3. Khartoum International Airport Station had a mix of positive, insignificant, and negative short-run relationships with Khartoum Customs Department.
4. Suba dry port had complex relationships with Khartoum Customs Department in the short-run, with both positive and negative coefficients at different lags.
5. Warehouses Station also showed complex short-run dynamics with Khartoum Customs Department through positive, negative, and insignificant relationships at different lags.
6. There was no significant constant term, implying insignificance of any constant influence on Khartoum Customs Department. Short-run relationships were dynamic and influenced by the regressors in complex, variable ways.

The Bounds Test provides very strong evidence of a long-run equilibrium relationship between the variables (Khartoum Customs Department, Gary free zone, Khartoum International Airport Station, Suba dry port, and Warehouses Station). They Cointegrating or move together over the long-run. This indicates that they share certain economic fundamentals that bind them together in stable equilibrium. Policies or shocks impacting one variable will ultimately impact the others through this relationship. They cannot diverge indefinitely and revert back to equilibrium in the long-run. The error correction model is justified based on this Cointegration. It enables analysis of both short-run dynamics and the speed of convergence back to equilibrium. The error correction term is highly significant, suggesting reasonably rapid adjustment of around 51% in each period towards the long-run equilibrium relationship.

The short-run coefficients determine how changes in each variable impact Khartoum Customs Department in the short-run. Positive coefficients indicate that increases in the variable lead to increases in Khartoum Customs Department, whereas negative coefficients suggest that increases in the variable decrease Khartoum Customs Department in the short-run. Insignificant coefficients indicate no short-run impact. The magnitude and significance of coefficients determine the relative importance and impact of short-run changes in each variable. Lagged changes and past dynamics are also considered and found significant for some variables. Impact assessment depends on coefficient significance, not just magnitude. No inference can be drawn for insignificant coefficients.

Long-run coefficients determine the equilibrium impact of changes in each variable on Khartoum Customs Department. Only significant variables Gary free zone and Suba dry port positively influence it in the long-run equilibrium relationship. Insignificant coefficients indicate no long-run impact. Diagnostic tests establish the validity, reliability and accuracy of the model.

Residual normality confirms unbiased coefficients based on Gauss-Markov assumption. Absence of heteroskedasticity ensures constant variance and unbiasedness. Serial independence affirms uncorrelated errors and unbiased estimates.

CUSUM stability test confirms model consistency, reliability and accuracy over time. No structural change or instability is detected.

Economic policies should focus on strengthening significant positive contributors (Gary free zone and Suba dry port) to raise Khartoum Customs Department's long-run equilibrium level based on Cointegration. Mitigating pressures of insignificant variables (Khartoum International Airport Station and Warehouses Station) would also help sustaining equilibrium.

Based on the findings, the following policy recommendations are suggested for the Khartoum Customs Department: enhancing infrastructure facilities by upgrading and expanding Suba dry port, Gary free zone, Khartoum International Airport Station, and Warehouses Station; increasing budget allocation to match inflation and manage increasing work volume and infrastructure upgrades; strengthening effective governance mechanisms and anti-corruption measures through strict monitoring and accountability; enhancing human resource capacity through regular training programs and recruiting more skilled professionals; implementing automation and e-customs to make the clearance process faster, transparent, and efficient; evaluating key performance indicators regularly to identify issues, improve performance, and set targets; promoting public-private partnerships to upgrade infrastructure, streamline procedures, and enhance service quality.

In conclusion, the analysis using the ARDL model has provided valuable insights into the factors that influence Khartoum Customs Department. The results have shown that the variables, including the lagged values and some past values of dynamic regresses Suba dry port, Gary free zone, Khartoum International Airport Station, and Warehouses Station, have a significant impact on Khartoum Customs Department in the short and long run. The findings can inform policy and decision-making in relevant fields, such as international trade and customs management. Additionally, the analysis can be extended to other sectors and variables to gain a better understanding of the broader economic landscape and inform policy decisions.

- Appendices:

UNIT ROOT TEST RESULTS TABLE (ADF)

Null Hypothesis: the variable has a unit root			At Level			
		Khartoum Customs Department	Khartoum International Airport Station.	Suba Dry port	Ware houses Station Station	Grey free Zone
With Constant & Trend	t-Statistic	1.5632	0.4912	-0.6620	0.2465	0.3148
	Prob.	1.0000	0.9990	0.9696	0.9976	0.9982
Null Hypothesis: the variable has a unit root			At First Difference			
		d(DEP)	d(A)	d(S)	d(W)	d(G)
With Constant & Trend	t-Statistic	-7.5530	-5.5720	-7.9414	-4.4167	-7.6858
	Prob.	0.0000	0.0002	0.0000	0.0059	0.0000
		***	***	***	***	***

Table source: Compiled by the researcher.

Graph No (1)
Schwarz Information Criterion (SIC)
Table No (3)
Bounds Test

Test Statistic	Value	K
F-statistic	9.118003	4
Critical Value Bounds		
Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Table source: Compiled by the researcher.

4-5 Short Run Coefficients and Error correction term: -
Table No (4)
Cointegration Model and Short Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(KHARTOUM CUSTOMS DEPARTMENT)	-0.253909	0.241343	-1.052063	0.3075
D(KHARTOUM CUSTOMS DEPARTMENT)	0.503485	0.185332	2.716666	0.0147
D(GARY FREE ZONE)	0.670335	0.123199	5.441087	0.0000
D(GARY FREE ZONE(-1))	0.197064	0.093579	2.105863	0.0504
D(GARY FREE ZONE(-2))	-0.318790	0.099138	-3.215627	0.0051
D(GARY FREE ZONE(-3))	-0.646060	0.109547	-5.897549	0.0000
D(KHARTOUM INTERNATIONAL AIRPORT STATION)	0.725949	0.199731	3.634629	0.0020
D(KHARTOUM INTERNATIONAL AIRPORT STATION)	1.928172	0.298273	6.464457	0.0000
D(KHARTOUM INTERNATIONAL AIRPORT STATION)	0.000218	0.363281	0.000599	0.9995
D(KHARTOUM INTERNATIONAL AIRPORT STATION)	-0.714440	0.334947	-2.132996	0.0478
D(SUBA DRY PORT)	1.001653	0.078129	12.820469	0.0000
D(SUBA DRY PORT(-1))	0.141114	0.251989	0.560001	0.5828
D(SUBA DRY PORT(-2))	-0.429306	0.201532	-2.130210	0.0481
D(SUBA DRY PORT(-3))	0.535051	0.113554	4.711870	0.0002
D(WAREHOUSES STATION)	1.777030	0.420352	4.227480	0.0006
D(WAREHOUSES STATION(-1))	3.093943	0.674307	4.588331	0.0003
D(WAREHOUSES STATION(-2))	-2.023515	0.821977	-2.461764	0.0248
D(WAREHOUSES STATION(-3))	0.861082	0.579139	1.486830	0.1554

CointEq(-1)	-0.510804	0.194043	-2.632423	0.0175
Cointeq = KHARTOUM CUSTOMS DEPARTMENT - (2.4983				
*GARY FREE ZONE -0.3021*KHARTOUM INTERNATIONAL AIRPORT STATION + 0.7552				
*SUBA DRY PORT + 0.6425*WAREHOUSES STATION + 29.8479)				

Table source: Compiled by the researcher.

Graph Sourece: eviews 9 output

4-3 Estimate the best Model for Auto Regressive Distribution Lag Model ARDL:-

Table No (2)

Estimate Selected Model: ARDL(3, 4, 4, 4, 4)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
KHARTOUM CUSTOMS DEPARTMENT(-1)	0.235288	0.138157	1.703049	0.1068
KHARTOUM CUSTOMS DEPARTMENT(-2)	0.757394	0.226508	3.343786	0.0038
KHARTOUM CUSTOMS DEPARTMENT(-3)	-0.503485	0.185332	-2.716666	0.0147
GARY FREE ZONE	0.725949	0.199731	3.634629	0.0020
GARY FREE ZONE(-1)	0.333683	0.270452	1.233797	0.2341
GARY FREE ZONE(-2)	-1.928172	0.298273	-6.464457	0.0000
GARY FREE ZONE(-3)	-0.000218	0.363281	-0.000599	0.9995
GARY FREE ZONE(-4)	0.714440	0.334947	2.132996	0.0478
KHARTOUM INTERNATIONAL AIRPORT STATION	0.670335	0.123199	5.441087	0.0000
KHARTOUM INTERNATIONAL AIRPORT STATION(-1)	-0.161965	0.092875	-1.743904	0.0992
KHARTOUM INTERNATIONAL AIRPORT STATION(-2)	-0.197064	0.093579	-2.105863	0.0504
KHARTOUM INTERNATIONAL AIRPORT STATION(-3)	0.318790	0.099138	3.215627	0.0051
KHARTOUM INTERNATIONAL AIRPORT STATION(-4)	0.646060	0.109547	5.897549	0.0000
SUBA DRY PORT	1.001653	0.078129	12.82047	0.0000
SUBA DRY PORT(-1)	-0.369034	0.130711	-2.823292	0.0117
SUBA DRY PORT(-2)	-0.141114	0.251989	-0.560001	0.5828
SUBA DRY PORT(-3)	0.429306	0.201532	2.130210	0.0481
SUBA DRY PORT(-4)	-0.535051	0.113554	-4.711870	0.0002
WAREHOUSES STATION	1.777030	0.420352	4.227480	0.0006
WAREHOUSES STATION(-1)	0.482674	0.540582	0.892878	0.3844

WAREHOUSES STATION(-2)	-3.093943	0.674307	-4.588331	0.0003
WAREHOUSES STATION(-3)	2.023515	0.821977	2.461764	0.0248
WAREHOUSES STATION(-4)	-0.861082	0.579139	-1.486830	0.1554
C	15.24641	39.37481	0.387212	0.7034

R-squared	0.999760	Mean dependent var	3383.923
Adjusted R-squared	0.999436	S.D. dependent var	3894.777
S.E. of regression	92.47307	Akaike info criterion	12.18209
Sum squared resid	145371.6	Schwarz criterion	13.18515
Log likelihood	-225.7327	Hannan-Quinn criter.	12.54735
F-statistic	3084.343	Durbin-Watson stat	2.441164
Prob(F-statistic)	0.000000		

Table source: Compiled by the researcher:-

Table No (5)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GARY FREE ZONE	2.498329	0.822483	3.037544	0.0074
KHARTOUM INTERNATIONAL AIRPORT STATION	-0.302106	0.678906	-0.444990	0.6619
SUBA DRY PORT	0.755201	0.213385	3.539140	0.0025
WAREHOUSES STATION	0.642504	2.674254	0.240256	0.8130
C	29.847891	80.031849	0.372950	0.7138

Table source: Compiled by the researcher.

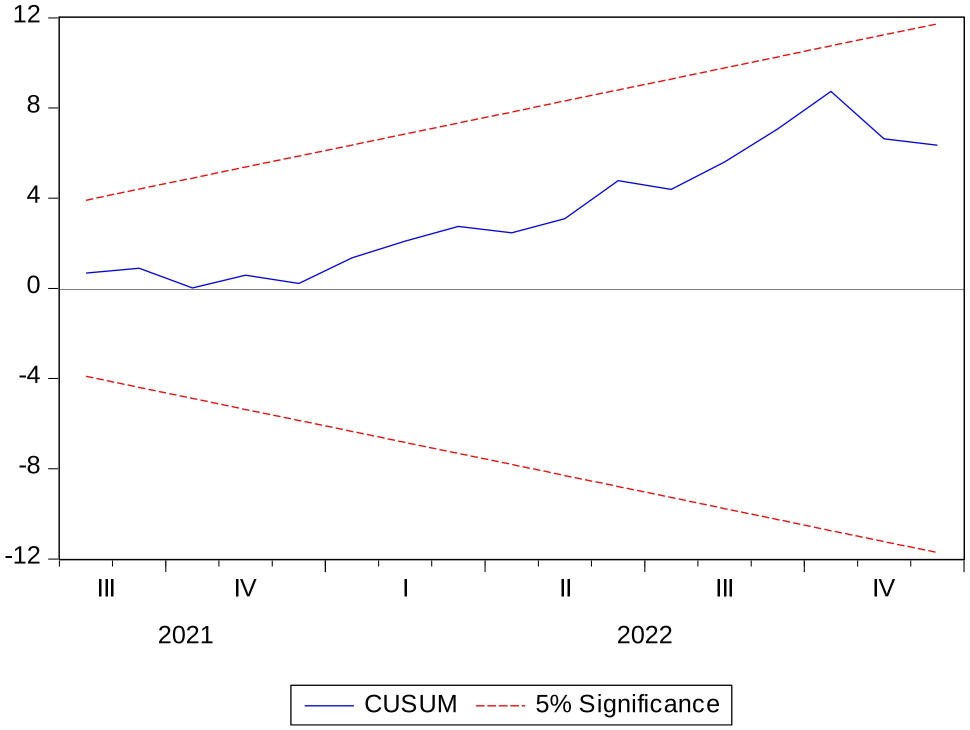
Table No(6)

Testing the residual

Tested	Statistic Test	Test Value	Probability
normal distribution	Jarque-Bera	0.894305	0.639446
Serial Correlation	F-statistic	1.387150	0.2801
Heteroskedasticity	Breusch-Pagan-Godfrey	0.471576	0.9531

Table source: Compiled by the researcher

Chart No (2)
CUSUM Test



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