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THE IMPACT OF MACROECONOMIC VARIABLES ON CONTAINER THROUGHPUT IN SRI LANKA: AN ARDL BOUNDS TESTING APPROACH

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ABSTRACT

This study examines the impact of key macroeconomic variables on container throughput in Sri Lanka using annual time-series data from 1994 to 2023. This study focuses on understanding how changes in the exchange rate, GDP per capita growth, inflation, population growth, and trade balance influence the volume of containerised cargo moving in and out of a country. The Autoregressive Distributed Lag (ARDL) model was employed for the analysis. All variables were tested for stationarity using the Augmented Dickey-Fuller and Phillips-Perron unit root tests. The ARDL Bounds Test confirms the existence of a long-run relationship between macroeconomic variables and container throughput. The long-run estimation results indicate that GDP per capita growth, the exchange rate, inflation, and population growth are statistically significant at the 1% level, while the trade balance is significant at the 5% level. Among these, only inflation has a negative long-run effect. The error correction model (ECM) shows that 57% of the disequilibrium is corrected in each period, indicating a stable, long-run relationship. In the short run, GDP per capita growth, population growth, and lagged inflation have positive and significant effects on container throughput. The findings highlight that domestic macroeconomic performance plays a significant role in Sri Lanka's containerised trade.

Keywords: *Container throughput, direct inward and outward movements, macroeconomic variables, time series analysis, ARDL model*

1. INTRODUCTION

Container shipping plays an essential role in international trade, facilitating efficient, secure, and standardised cargo movement between countries. Container throughput, typically measured in Twenty-Foot Equivalent Units (TEU), is the volume of cargo transported in containers through ports, including inward and outward movements, restowing, and transhipments. It is an important indicator of port efficiency and competitiveness [1].

Sri Lanka is located in a geographically strategic position in the Indian Ocean along major East–West maritime routes. This unique position has allowed the country to develop its port infrastructure and become a regional maritime hub. Port of Colombo facilitates both transhipment operations and the handling of direct import and export containers. While transhipment activities are largely influenced by regional shipping trends and external trade flows, the direct inward and outward container movements, which are either originating from or destined for Sri Lanka, are more closely influenced by the country's internal economic conditions. Unlike studies focusing on port efficiency or terminal operations, this study isolates the influence of domestic macroeconomic fundamentals on direct container throughput, thereby contributing new empirical evidence to the Sri Lankan maritime economics literature.

In this study, five macroeconomic variables are considered. The selection of macroeconomic variables in this study was guided by economic theory and empirical evidence from previous studies. Derived Demand Theory and trade-related theories suggest that container throughput is influenced by overall economic activity, trade volumes, and price competitiveness. Accordingly, Gross Domestic Product (GDP) per capita was selected to represent income levels and economic development. Gross Domestic Product (GDP) is the total monetary value of the final goods and services produced within a country over a specific period [2]. GDP per capita measures the average economic output per person in a country over a specific period. It provides insights into the extent to which economic production can be attributed to each individual in a country. Policy-makers use GDP per capita to understand how economies and populations are growing. Rich countries with small populations and more developed industrial countries have the highest GDP per capita. Countries with the highest economic growth may have negative GDP per capita growth if their populations grow faster than GDP. Therefore, since both GDP and population are factors in the per capita equation, countries with a high GDP may or may not have a high GDP per capita [3]. A higher GDP per capita often indicates increased disposable income and consumer spending. This can lead to an increase in the demand for goods, many of which are transported via container.

The exchange rate was included to reflect international price competitiveness and its effect on the trade dynamics. The exchange rate is the value of a currency when exchanged for another currency. In a floating exchange rate system, market forces determine the value of a currency, allowing it to fluctuate freely. Conversely, a fixed exchange rate is pegged to the value of another currency [4]. The dynamics of exchange rates are influenced by several factors, including interest rates, inflation rates, political stability, and economic performance. Higher interest rates attract foreign capital, leading to appreciation of the domestic currency. A higher inflation rate in a domestic country decreases the currency value. High government debt levels and political instability negatively impact the exchange rates. Fluctuations in exchange rates can significantly affect the trade balance [5]. A weaker currency may boost exports by making them cheaper for foreign buyers and reduce imports by increasing the cost of imports for locals [6]. This engagement in international trade may affect the demand for shipping and container throughput in the country.

Inflation was included to identify the impact of domestic prices on container movements. Inflation is defined as a general increase in prices that leads to a loss of purchasing power. Inflation can occur with an increase in the demand for goods and services over production. However, inflation can result from an increase in production costs [7]. People may expect inflation to continue at the same rate as before. Consequently, inflation may increase. Inflation can be measured using different price indices, such as the CPI, WPI, and PPI [8]. Inflation can affect a country's trade balance and influence container throughput. Higher domestic inflation can make imports cheaper and exports more expensive. This situation can lead to increased import container and decreased export container throughputs. However, uncertainty about future inflation can discourage investment and savings, thereby affecting economic activities. As export and import volumes capture trade intensity and containerised cargo flows, the trade balance was also included. The trade balance is defined as the net difference between a country’s exports and imports. It is an important macroeconomic variable that influences container throughput through a direct link to international trade. The population was considered a proxy for the market size and domestic demand. Population refers to the total number of individuals residing in a specific region. It is an important indicator that influences various economic and social dynamics, such as the labour market, consumer demand, and economic growth. A growing population leads to an increased demand for goods and services, which can drive higher import volumes to meet consumer demand. However, with high labour market participation, export volumes can be increased. This often results in increased container throughput at ports. Conversely, a declining population may reduce container throughput. In addition, urbanisation trends associated with population growth can lead to the development of infrastructure that

supports trade, including improved port facilities and logistics networks. However, it is argued that in high-income countries, low population growth creates economic and social problems, while in low-income countries, high population growth slows the development of the country [9]. This systematic selection ensured that the variables used in the model were theoretically and empirically validated.

As an island economy, Sri Lanka depends heavily on its seaports for international trade [10]. This study specifically focuses on understanding the impact of domestic macroeconomic variables on direct container throughputs. In this study, for clarity, container throughput refers to direct inward and outward container movements in Sri Lanka. Transhipment volumes, which involve containers handled in Sri Lanka that are destined for or arriving from other countries, are excluded from the analysis because they are primarily influenced by external regional factors rather than Sri Lanka's macroeconomic indicators. The general objective of this study is to investigate the dynamic relationship between container throughput and macroeconomic variables. The specific objectives include identifying which macroeconomic variables significantly influence container throughput, analysing the long-run effects of these variables, and assessing their short-run impacts.

This study contributes to the literature on container throughput in several ways. First, while many previous studies have examined container throughput in developed and major emerging economies, empirical evidence for small, open developing economies such as Sri Lanka is limited. Therefore, this study provides country-specific evidence from Sri Lanka. Second, unlike most previous studies that focus primarily on port-level operational factors, this study focuses on key macroeconomic variables, including GDP per capita growth, inflation, exchange rate, population growth, and trade balance, within a single econometric framework. This allows for a more comprehensive understanding of how macroeconomic conditions influence containerised cargo flows. Third, this study applies the ARDL bounds testing approach using the most recent available data, enabling the simultaneous analysis of both short-run and long-run relationships. Therefore, these findings extend the existing empirical work.

2. LITERATURE REVIEW

2.1. Theoretical Framework

2.1.1. Derived demand theory

Container shipping demand is derived from seaborne trade. International trade is a key factor affecting maritime transportation. In the context of international trade, the demand for services such as container shipping and port operations is derived from

the demand for the movement of goods internationally. The demand for shipping services is a result of customers' demand for products, and the elasticity of demand for sea transport depends on the elasticity of the goods transported by sea. Hence, shipping supply is strongly influenced by freight rates. If freight rates decrease compared to operational costs, the supply of sea transport will be reduced [11]. Therefore, containerisation and container throughput are directly linked to international trade through derived demand.

2.1.2. New trade theory

New Trade Theory (NTT) provides insights beyond classical trade theories by emphasising the roles of economies of scale, network effects, and product differentiation in shaping global trade patterns. The theory suggests that countries can benefit from trade by increasing returns to scale and market size effects, even when they do not differ in terms of factor endowments [12].

Research on South Asian countries indicates that macroeconomic factors such as physical and human capital investment, GDP per capita, labour force size, and exchange rates have substantial impacts on trade openness [13]. These findings align with NTT's predictions that economies of scale and development influence a country's ability to compete in global markets. NTT indicates that large-scale production reduces average costs, thereby encouraging firms to export goods [14]. Furthermore, shipping goods in containers lowers costs, increases efficiency, and facilitates trade. The cost of shipping a container by sea is lower than that of other modes because of the economies of scale associated with increasing the vessel capacity. This reduces the transport cost per TEU. With the inverse relationship between fixed costs and the quantity produced, a cost advantage occurs. Since the induction of container shipping in the 1950s, vessel sizes and capacities have increased, taking advantage of economies of scale [15].

2.1.3. Intra-industry trade theory

Intra-Industry Trade (IIT) refers to the simultaneous export and import of similar types of goods, typically within the same industry. Regional economic integration among countries with similar income levels, such as South Asian countries, supports this development model. One of the strongest determinants of intra-industry trade is the size of the domestic economy. In Italy, a study on intra-industry trade in intermediate goods revealed that market size is a significant determinant of both horizontal and vertical IIT. Larger economies can support a greater range of differentiated products and industrial specialisations [16]. As GDP increases, both exports and imports of similar products tend to grow, especially in the consumer and

industrial goods sectors. As most of these goods are typically containerised, container throughput can increase.

2.2. Empirical Evidence

Several studies have been conducted to identify the relationship between container throughput and macroeconomic variables in various countries and regions worldwide. The literature highlights the complex relationship between container throughput and GDP. Most researchers have used GDP as an independent variable in their analyses. By employing the GDP expenditure approach to decompose GDP into its components, such as consumption, investment, government spending, exports, and imports, and analysing their individual correlations with container throughput, we prove that aggregate GDP is not a suitable independent variable for container throughput analysis. Instead, they showed that the container throughput is best explained by analysing real trade volumes and domestic demand, not GDP as a whole. Their methodology involved qualitative and quantitative correlation analyses using data from Japan, China, and Korea. They established a new framework for analysing container throughput using macroeconomic data, while treating transhipment volumes separately for the first time. It has been indicated that domestic demand is correlated with domestic throughput, and international trade volume is correlated with international throughput [17].

However, a simplified forecasting model was presented by calculating containerisation indices, such as TEU per trade volume, TEU per GDP, and TEU per population. Using Pearson correlation analysis, it has been proven that there is a very strong correlation between container turnover in Polish ports and GDP, GDP per capita, and foreign trade, indicating that macroeconomic growth is a key driver of container demand [18].

Intihar et al. [19] conducted a study to identify the relationship between container throughput in the port of Koper and several macroeconomic indicators, including GDP, purchasing power parity, exports, imports, trade balance, and unemployment rate in Slovenia, neighbouring countries, developed Asian countries, the European Union, and the entire world. To address the high dimensionality and multicollinearity among exogenous variables, two data reduction approaches were employed: principal component analysis (PCA) combined with multiple linear regression (MLR) to select the most significant indicators, and dynamic factor analysis (DFA) to generate dynamic factors as model inputs. Both sets of reduced variables were then used as exogenous inputs in the ARIMAX model to forecast the container throughput. The results show that including macroeconomic indicators as exogenous variables significantly improves forecasting accuracy, confirming their strong influence on port

throughput. It has been proven that GDP per capita, imports, and exports play important roles in the impact of container throughput [19].

Hence, Iwu and Uchendu compare the forecasting performance of Multiple Linear Regression (MLR) and Artificial Neural Network (ANN) models for container throughput at APM Terminals Apapa Port, Lagos, Nigeria. Using annual data, this study examines the relationship between container throughput (TEUs) and macroeconomic variables, including the GDP, inflation rate, exchange rate, and number of container goods. The model performance was evaluated using the coefficient of determination (R^2) and the root mean squared error (RMSE). The results indicate that the ANN model outperforms the MLR model, achieving a higher R^2 and a lower RMSE. The findings suggest that all variables have significant relationships with throughput, with GDP being a particularly strong predictor [20].

A study analyses the short- and long-run effects of macroeconomic variables, specifically real income, bilateral exchange rate, and exchange rate volatility, on Australia's maritime export volumes to its major Asian trading partners. It has been identified that real income and exchange rate volatility are important factors that influence the volume of maritime exports [21].

A long-term forecasting study of container throughput at Chittagong Port, Bangladesh, was presented using annual data from 1991 to 2019 [22]. The proposed methodology employs a time-series analysis. The stationarity of the variables was tested using the Augmented Dickey-Fuller (ADF) test. Cointegration is assessed via the Johansen approach, and a Vector Error Correction Model (VECM) is used to capture both short- and long-term dynamics among variables. Impulse Response Functions (IRF) are applied to analyse the effect of shocks in one variable on the others. Hence, the model accuracy was evaluated using RMSE, MAPE, and Theil's U. The results show that GDP, population, and imports significantly and positively influence the container throughput. The VECM forecasts suggest that throughput will grow from 2.95 million TEU in 2020 to 8.73 million TEU by 2040, with an average annual growth rate of 8.9%.

An analysis of Northeast Asian economies (Japan, China, and Korea) from 1990 to 2014 revealed that exports and imports, the primary components of the current account, have the strongest correlations with container throughput, whereas domestic demand components have weaker relationships [17].

The effect of exchange rates (USD/Turkish Lira and Euro/Turkish Lira) on container handling at Turkish ports between 2004 and 2018 was investigated. Using monthly data, the authors identified nonlinear dynamics and found intermittent causal relationships between the variables. Their results showed that the relationship

between exchange rates and port activity was not steady but changed during different periods. In particular, strong effects were observed after 2016, when the Turkish Lira became unstable [23].

Previous research has analysed the impact of Sri Lanka's macroeconomic performance on container throughput at the Port of Colombo, using data from 2000 to 2019. This study examines several macroeconomic variables, including GDP, GDP per capita, national income, exchange rate, number of exports, number of imports, population, unemployment rate, and inflation rate, to identify the factors that most significantly influence container throughput. The methodology involves stationarity tests (ADF and Phillips-Perron tests), Johansen cointegration testing, Vector Error Correction Model (VECM), Granger Causality test, and OLS regression. The Granger Causality test indicated that the number of imports and exports has a more significant relationship with container throughput in the short run, while an Ordinary Least Squares (OLS) model revealed that only the number of exports had a greater influence on container throughput. Other variables, such as GDP, exchange rates, and inflation, do not show significant short-term effects [24].

Table 1: Summary of empirical literature on variable selection

Study	Country(s)	Methodology	Variables	Results
Yang et al. (2017)	Japan, China, Korea	Correlation Analysis	GDP	Disaggregated macroeconomic indicators provide more meaningful insights than aggregate data.
Matczak (2020)	Poland	Pearson Correlation Analysis	GDP GDP per Capita Foreign Trade	A very strong correlation was found between container turnover, GDP, GDP per capita, and trade.
Intihar et al. (2015)	Slovenia, key Asian countries, the EU and global	Principal Component Analysis Multiple Linear Regression Dynamic Factor Analysis ARIMAX Model	GDP per capita Purchasing Power Parity Imports Exports Trade Balance Unemployment Rate	Including macroeconomic indicators as exogenous variables significantly improved the forecasting accuracy and revealed a strong influence of throughput dynamics.
Iwu (2021)	Nigeria	Multiple Linear Regression Artificial Neural Network	GDP Inflation rate Exchange rate	All variables had significant relationships with throughput, with GDP being a particularly strong predictor.

Study	Country(s)	Methodology	Variables	Results
Rashid (2021)	Bangladesh	VECM	GDP Population Imports Exports	GDP, population, and imports are key drivers.
Açık et al.	Turkey	Time-varying causality analysis	Exchange Rate	Exchange rate effects are nonlinear and period-specific
Jayashani & Mudunkotuwa (2021)	Sri Lanka	VECM OLS regression	Exports Imports GDP GDP per Capita National Income Exchange Rate Population Unemployment Inflation	The number of imports and exports has a stronger relationship with container throughput in the short term. Other variables, such as GDP, the exchange rate, and inflation, do not show any significant short-term effects.

Table 1 presents the key empirical studies that support the selection of macroeconomic variables used in this study.

Although numerous studies have analysed the impact of macroeconomic variables on port performance and container throughput, the focus on the Sri Lankan context remains limited. Moreover, the existing literature treats container throughput as a single aggregate variable without distinguishing between transhipment activities and direct inward/outward container movements. This study is important because it specifically examines how domestic macroeconomic variables affect container movements that are directly linked to Sri Lanka's internal trade activities.

3. METHODOLOGY

3.1. Research Approach

This study employs a quantitative research approach that utilises econometric modelling to identify the impact of macroeconomic indicators on container throughput in Sri Lanka. This study relied on secondary annual data from 1994 to 2023. Although higher-frequency data may capture short-term dynamics more effectively, annual data are appropriate for analysing long-run macroeconomic relationships.

In this study, for clarity, container throughput refers to direct inward and outward container movements which either originate from or are destined for Sri Lanka. Transhipment volumes, which involve containers handled in Sri Lanka that are

destined for or arriving from other countries, are excluded from the analysis, as they are primarily influenced by external regional factors rather than Sri Lanka's macroeconomic indicators.

A time-series analysis was conducted to address the objective of identifying the impact of macroeconomic indicators on container throughput in Sri Lanka. This methodology allows for an in-depth examination of both long-run and short-run dynamics using appropriate econometric techniques.

Figure 1 illustrates the study's conceptual framework.

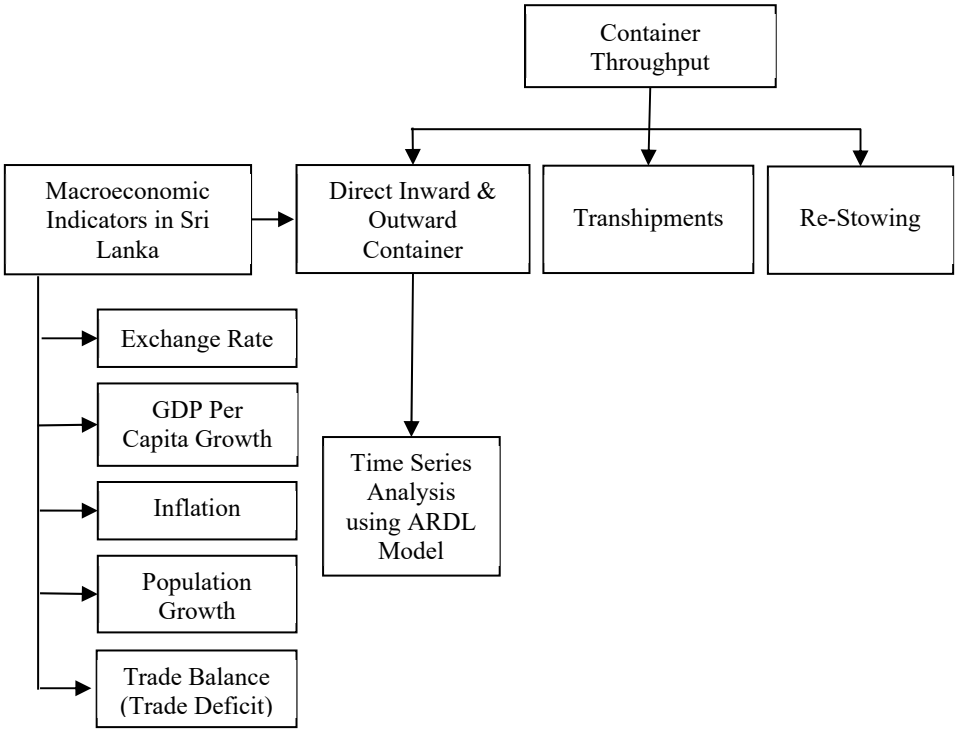

Figure 1: Conceptual framework

3.2. Data Collection

3.2.1. Container throughput data

Container throughput, which refers to the volume of containers handled at a port over a specific period, is a key indicator of port activity and trade performance. For this study, container throughput data were collected with a clear distinction between transshipments and direct inward/outward container movements. According to the purpose of this study, only direct inward and outward container movements were considered as the container throughput. This focus aligns with the study objectives. The data used in this study were collected in twenty-foot equivalent units (TEUs) and

represented annual data from 1994 to 2023. These were sourced from the Central Bank of Sri Lanka [25]. It should be noted that restowing containers, which involve the temporary shifting of containers within a vessel, are not separately reported in the Central Bank's statistics. Given that restowing accounts for a very minor portion of container activity in Sri Lanka, and due to its operational nature, it is assumed to be negligible for this study.

3.2.2. Macroeconomic indicators

The following indicators were included in the time series analysis. The data for these indicators were sourced from the Central Bank of Sri Lanka and World Bank Open Data. All data represent annual observations from 1994 to 2023 [25] & [26].

- Exchange Rate
- Population Growth
- Inflation Rate
- GDP per Capita Growth
- Trade Balance (expressed as a trade deficit)

Macroeconomic indicators were selected based on empirical evidence from previous research and related economic theories. While the literature typically discusses the absolute levels of GDP per capita and population as key macroeconomic drivers of trade activity, this study employs their respective growth rates in the empirical analysis. This transformation is intended to reduce multicollinearity in the explanatory variables.

3.3. Data Analysis

A time-series analysis was conducted to investigate the relationship between container throughput and macroeconomic indicators. All statistical analyses, including unit root testing, ARDL model estimation, bounds testing for cointegration, error correction modelling, and diagnostic testing, were performed using the EViews 10 software [27].

3.3.1. Log transformation

All real-valued macroeconomic indicators and inward/outward container movements were log-transformed to normalise the original data, stabilise the variance, and improve the accuracy of the model. It has been empirically proven that log transformation stabilises the variance in economic time series, improving forecast accuracy [28].

3.3.2. Unit root test

To assess the stationarity of each variable, the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied. The results indicate that some variables were stationary at the level form (I(0)), while others became stationary after first differencing (I(1)), satisfying the precondition for the ARDL model.

3.3.3. Model specification – ARDL approach

To identify the long-run relationships and short-run interactions between macroeconomic variables and container throughput, an Autoregressive Distributed Lag (ARDL) model was developed.

The ARDL bounds testing approach was selected for several reasons. The sample size of this study is relatively small, and the ARDL model is well known for providing reliable estimates in small samples compared to traditional cointegration techniques such as the Johansen Vector Error Correction Model. In addition, the ARDL approach allows the inclusion of variables that are integrated of different orders, I(0) and I(1), which is consistent with the unit root test results of this study. Hence, this is suitable for this study as the objective is to analyse both the long-term and short-term effects of macroeconomic variables on container throughput in Sri Lanka, and the ARDL framework allows simultaneous estimation of both long-run and short-run relationships. Therefore, the ARDL bounds testing approach is considered the most appropriate model for addressing the research objectives of this study.

The functional form of the ARDL (p,q) model is as follows:

$$Y_t = \gamma_0 + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta_i X_{t-i} + \varepsilon_{it} \quad \text{---------- (1)}$$

In this study, inward and outward container throughput in Sri Lanka is modelled as a dependent variable using the ARDL (2,2) framework. The ARDL model includes two lagged values of container throughput and two lagged values of each of the explanatory variables: the exchange rate, GDP per capita growth, inflation, population growth, and trade balance. The augmented ARDL (p, q1, q2, q3, q4, q5) model can be specified as follows:

$$\begin{aligned} \ln\text{INWARD\_\_OUTWARD\_THROUGHPUT}_t = {} & \beta_0 + \\ & \sum_{i=1}^{p} \beta_{1i} \ln\text{INWARD\_\_OUTWARD\_THROUGHPUT}_{t-i} + \\ & \sum_{i=1}^{q1} \beta_{2i} \ln \text{EXCHANGE\_RATE}_{t-i} + \sum_{i=1}^{q2} \beta_{3i} \text{GDP\_PER\_CAPITA\_GROWTH}_{t-i} + \\ & \sum_{i=1}^{q3} \beta_{4i} \text{INFLATION}_{t-i} + \sum_{i=1}^{q4} \beta_{5i} \text{POPULATION\_GROWTH} + \\ & \sum_{i=1}^{q5} \beta_{6i} \ln \text{TRADE\_BALANCE}_{t-i} + \varepsilon_t \end{aligned} \quad \text{---------- (2)}$$

3.3.4. Bounds test for cointegration

The ARDL Bounds Test was conducted to test for the existence of a long-run equilibrium relationship among the variables. Null Hypothesis (H_0) states that there's no long-run relationship (no cointegration) among the variables. The alternative Hypothesis (H_1) states that a long-run relationship exists. If the calculated F-statistic exceeds the upper critical bound, the null hypothesis is rejected, indicating cointegration exists.

3.3.5. Error correction model

Once cointegration was established, the error correction model (ECM) was estimated to quantify the short-run adjustments and long-run equilibrium dynamics. The error correction term (ECT) measures the speed of adjustment to the long-run equilibrium after a short-run shock.

ECM is simply defined as:

$$\Delta yt = \lambda + \alpha\varepsilon t - 1 + \gamma\Delta xt + ut \quad \text{---------- (3)}$$

3.3.6. Diagnostic tests

To ensure the model's validity and robustness, the following diagnostic tests were performed. The Breusch-Godfrey LM test was used to detect autocorrelation in the residuals of a regression model. It regresses residuals against the original predictors and lagged residuals using a Lagrange Multiplier (LM) statistic. The Breusch-Pagan-Godfrey Test was used to test for heteroskedasticity, where the residual variance depends on the predictors. The test regresses squared residuals on independent variables and uses an F-statistic or $\chi 2$-test to evaluate significance. The Jarque-Bera test was used to test whether the residuals followed a normal distribution by comparing the skewness (S) and kurtosis (K). If the p-value is less than 0.05, we reject the null hypothesis, implying that the residuals are non-normal. The CUSUM and CUSUMSQ Tests were used to examine the stability of the model over time. CUSUM Test tracks cumulative residuals, and crossing 5% bounds signals the instability. The CUSUMSQ test uses squared residuals to detect variance shifts. The variance inflation factor (VIF) test was used to detect multicollinearity. Multicollinearity occurs when two or more independent variables are highly correlated with each other. In this study, the VIF values were calculated for each macroeconomic variable included in the ARDL model. A commonly accepted threshold is that a VIF value exceeding 5 indicates a serious multicollinearity problem.

4. RESULTS AND DISCUSSION

4.1. Unit Root Test

The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests were applied to find the unit root for the variables. GDP per capita growth, inflation, population growth, and log-transformed values of direct inward/outward container throughput, exchange rate, and trade balance were tested.

Table 2 presents the results of the Augmented Dickey-Fuller unit root test conducted to examine the stationarity of the variables used in the study.

Table 2: ADF test results

Variable	Level		1st Difference	
	Intercept	Trend Intercept	Intercept	Trend Intercept
Inward/Outward Throughput	0.0830	0.9598	0.0002**	0.0001**
GDP per Capita Growth	0.8043	0.9226	0.0000**	0.0214*
Inflation	0.0032**	0.0158*	0.0000**	0.0000**
Population Growth	0.0211*	0.0082**	0.0000**	0.0000**
Exchange Rate	0.9892	0.9297	0.0002**	0.0008**
Trade Balance	0.5801	0.9584	0.0003**	0.0010**

Note: P-values are represented in the table. * denotes statistical significance at 5% level and ** denotes statistical significance at 1% level.

Table 3 reports the results of the Phillips-Perron unit root test, which are used to confirm the findings obtained from the ADF test.

Table 3: Phillips-Perron test results

Variable	Level		1st Difference	
	Intercept	Trend Intercept	Intercept	Trend Intercept
Inward/Outward Throughput	0.0618	0.9773	0.0002**	0.0001**
GDP per Capita Growth	0.0504	0.1061	0.0000**	0.0000**
Inflation	0.0033**	0.0155*	0.0000**	0.0000**
Population Growth	0.0231*	0.0083**	0.0000**	0.0000**
Exchange Rate	0.9908	0.9162	0.0002**	0.0008**
Trade Balance	0.5801	0.9584	0.0003**	0.001**

Note: P-values are represented in the table. * denotes statistical significance at 5% level and ** denotes statistical significance at 1% level.

The ADF unit root test results show a mixture of orders for the series. Inflation and population growth are stationary at level I(0), as indicated by their significant p-

values under both the intercept and trend specifications, while variables such as inward/outward throughput, GDP growth, GDP per capita growth, exchange rate, purchasing power parity, and trade balance are non-stationary at levels. However, they become stationary after first differencing, confirming that they are integrated of order I(1). Importantly, none of the variables is stationary at the second difference level. According to the Phillips-Perron Test, in addition to inflation and population growth, GDP growth is also stationary at level I(0). All variables are stationary with the first difference at the 1% significance level. The results of both the ADF and the Phillips–Perron tests show that the null hypothesis of the time series having a unit root was rejected. The combination of I(0) and I(1) variables justifies the application of the ARDL model.

4.2. ARDL Model Estimation

Table 4 presents the ARDL model results.

Table 4: ARDL model results

Dependent Variable: **INWARD_OUTWARD_THROUGHPUT**			
Variable	**Coefficient**	**t-Statistic**	**Probability**
INWARD__OUTWARD_THROUGHPUT(-1)	0.4305	2.2459	0.0414
EXCHANGE_RATE	-0.0751	-0.2930	0.7738
EXCHANGE_RATE(-1)	0.5660	1.9926	0.0662
GDP_PER_CAPITA_GROWTH	0.0272	3.1572	0.0070
GDP_PER_CAPITA_GROWTH(-1)	0.0173	2.2288	0.0427
INFLATION	-0.0008	-0.3024	0.7668
INFLATION(-1)	-0.0048	-2.2857	0.0384
INFLATION(-2)	-0.0043	-1.5893	0.1343
POPULATION_GROWTH	0.0581	3.0364	0.0089
POPULATION_GROWTH(-1)	0.0324	1.7618	0.0999
TRADE_BALANCE	0.0312	0.5020	0.6234
TRADE_BALANCE(-1)	-0.1068	-1.6514	0.1209
TRADE_BALANCE(-2)	0.1543	3.6231	0.0028
C	3.6529	3.2036	0.0064
R-squared	0.990782		
Adjusted R-squared	0.982222		
F-statistic	115.7496		
Prob(F-statistic)	0		
Durbin-Watson stat	2.66807		

The ARDL model was estimated with a maximum of two lags. Population growth and GDP per capita emerged as influential factors, being statistically significant at the 1% level with positive coefficients. It shows how strongly the increase in economic prosperity and population size is associated with container throughput. The second lag of the trade balance is also highly significant at the 1% level, with a positive coefficient of 0.1543. With a continuing trade deficit in Sri Lanka, this suggests that a growing trade deficit caused by increased imports is associated with an increasing container throughput. The first lag of the inward-outwards throughput is positive and significant at the 5% level. In addition, at the 5% significance level, the first lag of GDP per capita growth is significant with a positive influence, whereas inflation is significant with a negative coefficient. The variables significant at the 10% level include the first lag of the exchange rate and the first lag of population growth, which have positive values.

The very high F statistic of 115.75 and its associated p-value indicate that the independent variables collectively have a statistically significant effect on the dependent variable. The model shows a very high explanatory power, as evidenced by the R-squared value of 0.99 and the adjusted R-squared value of 0.98. The model explains approximately 98% of the variation in container throughput. While such high values might raise concerns about overfitting, in this case, the strong explanatory power appears valid because the most macroeconomic variables move together over time, and these variables have a clear rationale for influencing container throughput. In addition, all key diagnostic tests confirmed the robustness of the model. The Durbin-Watson statistic of 2.668 suggests there's no severe autocorrelation since it's still relatively close to the ideal value of 2. The Wald test conducted proved that the independent variables in the model collectively had a significant impact on the dependent variable. Overall, these statistics provide strong evidence that the ARDL model is well-specified and reliable for explaining the long- and short-run determinants of container throughput in Sri Lanka.

4.3. ARDL Bounds Test

Table 5 presents the ARDL bounds test results used to examine the existence of a long-run relationship between the variables.

Table 5: Bounds test results

F- Statistic	Critical Value Bounds		Significance Level
	I (0)	I (1)	
6.0037	2.407	3.517	10%
	2.910	4.193	5%
	4.134	5.761	1%

The ARDL bounds test confirms whether there is a long-term relationship between the variables. If the F statistic is higher than the upper bound I(1), it confirms that there is a long-term relationship. If the F statistic is lower than the lower bound I(0), there is no long-term relationship between the variables. If the F statistic is between the bounds, the result is inclusive [29]. This bounds test shows an F-statistic of 6.0037, which exceeds the upper-bound critical value at the 1% significance level. This result provides strong statistical evidence to reject the null hypothesis of no level relationship between the variables.

4.4. ARDL Cointegration Form

Table 6 shows the long-run estimated coefficients derived from the ARDL model, indicating the direction of the impact of each macroeconomic variable on container throughput.

Table 6: Cointegration results

***Dependent Variable*: INWARD_OUTWARD_THROUGHPUT**			
Variable	**Coefficient**	**t-Statistic**	**Probability**
C	6.41	6.56	0.00
EXCHANGE_RATE	0.86	6.60	0.00
GDP_PER_CAPITA_GROWTH	0.06	3.22	0.01
INFLATION	-0.02	-2.89	0.01
POPULATION_GROWTH	0.16	3.16	0.01
TRADE_BALANCE	0.14	2.22	0.04

The long-run estimation of the ARDL model provides valuable insights into how macroeconomic variables influence container throughput in Sri Lanka over time. The results show that the exchange rate, GDP per capita growth, inflation, and population growth are statistically significant at the 1% level for all countries. The trade balance is significant at the 5% level.

4.4.1. Exchange rate

The positive and significant coefficient implies that a unit increase in the exchange rate is associated with a 0.8-unit increase in container throughput in the long run. The depreciation of the Sri Lankan Rupee tends to make exports more competitive because Sri Lankan goods become less expensive for foreign buyers. This encourages exports and boosts outbound container volumes. Supporting this finding, a study conducted in Sri Lanka proved that there is a positive relationship between exchange rate volatility and export earnings [30].

4.4.2. GDP per capita

A one-unit increase in GDP per capita growth corresponds to a 0.06-unit increase in the container throughput. Rising income levels typically signal economic expansion, increased consumption, and global market integration. These trends often lead to increased trade and expansion of shipping activities, which can directly affect container throughput. This relationship aligns with the Keynesian demand theory, which states that rising income stimulates consumption, production, and trade involvement. Keynesian demand theory states that aggregate demand (AD), comprising consumption, investment, government spending, and net exports, drives economic output. As a measure of average income, GDP per capita directly influences consumption, which is a core component of AD [31]. This leads to an increase in container volumes. A study using Pearson Correlation Analysis found a very strong correlation between container turnover and GDP per Capita in Poland [18].

4.4.3. Inflation

Inflation has a negative and significant long-run effect on container throughput. Empirical results show that a unit increase in inflation leads to a 0.02 decrease in the throughput. This outcome is logical because rising domestic prices cause higher production and operational costs, which discourage exports, making domestically produced goods less competitive in the international markets. In contrast, high inflation usually weakens the currency, discouraging imports of goods. Hence, high inflation increases the costs of shipping and port services, which may discourage container movement. Since higher domestic inflation reduces both exports and imports and increases the cost of shipping services, it negatively affects container throughput in the long run. Evidence from global trade trends supports this. In 2022, global container throughput growth decreased to 0.4%, the lowest in 40 years, because of high inflation in consumer markets, which reduced the demand for goods [32]. The container throughput of the Port of Rotterdam declined by 5.5% in H1 2023 due to inflationary pressure [33].

4.4.4. Population growth

Population growth has a positive and significant long-term effect. A one-unit increase in population growth leads to a 0.16-unit increase in the container throughput. This is reasonable because a growing population typically causes higher consumption and demand for goods, leading to higher imports, which are transported in containers. In contrast, increased population growth may increase the labour force, companies, and entrepreneurship, which can lead to higher exports, affecting container throughput. Over time, these factors can lead to increased trade volumes and throughput at ports. Supporting this finding, research conducted in Bangladesh has proven that the population is one of the key drivers of container throughput [22].

4.4.5. Trade balance

The trade balance variable is interpreted in the context of Sri Lanka's continuous trade deficit. This shows that a one-unit increase in the trade deficit causes a 0.14-unit increase in container throughput. This makes economic sense because larger deficits often reflect rising import volumes in the trade balance. As most imported goods, including consumer goods, machinery, and raw materials, are transported in containers, higher imports directly increase containerised cargo traffic.

4.5. Error Correction Model and Short-Run Dynamics

Table 7 presents the Error Correction Model results, showing the short-run dynamics and speed of adjustment towards the long-run equilibrium.

Table 7: Error correction model results

Dependent Variable: INWARD_OUTWARD_THROUGHPUT			
Variable	**Coefficient**	**t-Statistic**	**Probability**
D(EXCHANGE_RATE)	-0.07510	-0.63	0.54
D(GDP_PER_CAPITA_GROWTH)	0.01720	4.96	0.00
D(INFLATION)	-0.00080	-0.65	0.53
D(INFLATION(-1))	0.00430	3.06	0.01
D(POPULATION_GROWTH)	0.05810	5.55	0.00
D(TRADE_BALANCE)	0.03120	0.85	0.41
D(TRADE_BALANCE(-1))	-0.15430	-5.23	0.00
CointEq(-1)*	-0.56950	-7.75	0.00
R-squared	0.86574		
Adjusted R-squared	0.81875		
Durbin-Watson stat	2.66807		
Akaike info criterion	-3.28626		
Schwarz criterion	-2.90563		
Hannan-Quinn criterion.	-3.16990		

The error correction term [CoinEq(-1)] has a coefficient of -0.5695, which is highly significant ($p = 0.00$). This significant negative coefficient confirms a stable long-term relationship. This value implies that approximately 56.95% of the disequilibrium from the previous period is corrected in the current period, indicating a relatively fast speed of adjustment towards the long-run equilibrium.

The current GDP per capita growth has a significantly positive effect on container throughput. This result is economically reliable, as increased income levels often

drive both consumer demand and production activities, which can affect containerised imports and exports. Hence, the current period of population growth has a positive and significant coefficient, indicating that the growing population boosts imports and exports. Lagged inflation is positively significant, suggesting that past periods of high inflation may lead to an increase in container throughput in the short term. This may occur because past domestic inflation levels encourage people to import more goods to avoid higher future costs as they expect prices to continue rising. For example, in Sri Lanka, in early 2022, businesses importing goods such as electronics and consumer goods increased their imports because of expected price hikes. However, in the short run, when domestic prices rise faster than international prices, imported goods may seem cheaper. Therefore, people tend to import substitutes during inflation. Hence, the first lag in the trade balance is highly significant and negative, indicating that a higher trade deficit in the previous period is associated with a reduction in container throughput in the current period, possibly due to adjustments in imports and exports, or constraints on foreign exchange. The exchange rate, current inflation, and trade balance are not significant, indicating that their movements do not have an immediate impact on container throughput.

This model has a high R-squared and adjusted R-squared. This indicates that over 81% of the short-run variation in container throughput is explained by the model. Durban Watson statistic is close to 2, suggesting that there is no serious autocorrelation in the residuals. The model selection criteria, including the Akaike Info Criterion (AIC), Schwarz Criterion (SC), and Hannan-Quinn Criterion (HQ), show low and negative values, confirming that the model is well-fitted and the chosen lag structure is appropriate.

4.6. Diagnostic Tests

Table 8 summarises the diagnostic test results used to verify the validity and robustness of the ARDL model.

Table 8: Diagnostic test results

Test Type	Test Name	Test Statistic	Probability
Normality	Jarque-Bera	0.172126	0.918
Serial Correlation	Breusch-Godfrey	F=2.3655	0.136
		Obs*R^2=7.9175	0.019
Heteroskedasticity	Breusch-Pagan-Godfrey	F=1.2901	0.321
		Obs*R^2=15.2607	0.291

The Jarque-Bera test was conducted to identify whether the residuals of the model were normally distributed. As the p-value (0.918) is greater than 0.05, the null

hypothesis of normally distributed residuals cannot be rejected. This indicates that the residuals are approximately normally distributed, satisfying one of the key assumptions of regression. Serial correlation was tested using the Breusch-Godfrey test. The p-value of the F-statistic is higher than 0.05, while the p-value of $ObsR^2$ is lower than 0.05. These results provide mixed signals as the $ObsR^2$ statistic indicates the presence of autocorrelation, while the F statistic provides evidence against serial correlation. Because this study involved a small sample size, the F statistic was considered more reliable. Therefore, it can be concluded that there is no strong evidence of serial correlation among the residuals. The Breusch-Pagan-Godfrey test was conducted to examine the presence of heteroskedasticity. As both the p-values of the F-statistic and $ObsR^2$ are higher than 0.05, the null hypothesis of homoskedasticity cannot be rejected.

Figures 2 and 3 present the CUSUM and CUSUM of Squares test results used to examine the stability of the ARDL model over time.

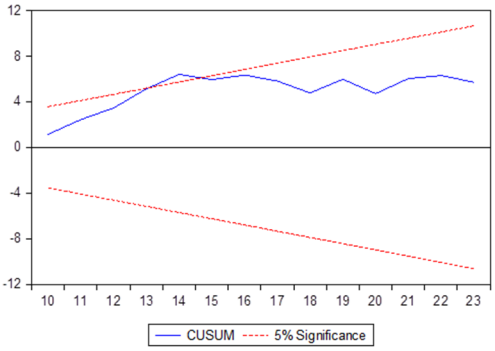

Figure 3: CUSUM test results

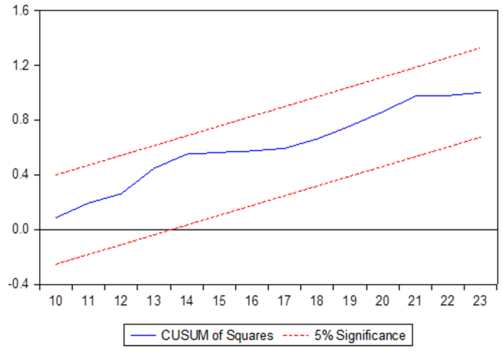

Figure 2: CUSUM of squares test results

Both the CUSUM and CUSUM of Squares tests were conducted to test the stability of the ARDL model. The CUSUM test results confirm that the cumulative sum of recursive residuals remains within the 5% significance boundaries, while the test statistic approaches the upper bound once. The CUSUM of squares test provides stronger evidence of stability at the 5% significance level.

Table 9: VIF test

Variable	VIF Value
GDP_PER_CAPITA_GROWTH	2.40
INFLATION	1.41
POPULATION_GROWTH	1.72
EXCHANGE_RATE	4.13
TRADE_BALANCE	2.69

Table 9 shows the VIF values used to assess the presence of multicollinearity among the explanatory variables.

All VIF values were below the accepted threshold of 5, indicating that multicollinearity was within acceptable limits. Initially, all relevant macroeconomic variables were included in the models. This transformation helped to minimise multicollinearity among the macroeconomic indicators. Growth rates of GDP, population, and GDP per capita were used instead of their absolute values for the analysis. However, extremely high multicollinearity was detected between GDP growth and GDP per capita growth because these variables are mathematically related. Only GDP per capita growth was retained in this model. In addition, purchasing power parity was excluded because of its high multicollinearity with the exchange rate, as they are theoretically linked. The exchange rate was retained because it is the most comprehensive and commonly used macroeconomic indicator in international trade. Moreover, the exchange rate was statistically significant in the final model, further justifying its inclusion.

4.7. Key Findings

The main findings of this study are as follows. GDP per capita and population growth are the strongest positive determinants of container throughput in both the short and long runs, indicating that domestic economic expansion and market size play crucial roles in Sri Lanka's containerised trade. Inflation has a significant negative impact on container throughput in the long run, suggesting that price instability reduces trade competitiveness and container cargo flows. In contrast, the exchange rate shows a positive and statistically significant long-run effect, implying that currency depreciation supports export-oriented container movements. Moreover, the error correction model confirms a stable long-run relationship, with approximately 57% short-run disequilibrium adjustment each year.

Overall, the results confirm that the ARDL bounds testing approach employed in this study is methodologically appropriate for examining the relationship between macroeconomic variables and container throughput. Compared to previous studies that rely on single equations or correlation-based models, the ARDL framework allows for the capture of both short-run and long-run relationships, providing a more comprehensive understanding.

5. POLICY IMPLICATIONS

Based on the findings of this study, the following recommendations are proposed for policymakers, port authorities, and relevant stakeholders in the maritime and trade sectors.

- **Strengthening economic growth policies**

The results show a strong positive relationship between GDP per capita and container throughput. This indicates that higher income levels lead to increased trade activity. Therefore, the government should be involved in employing sustainable development strategies, such as investing in productive sectors and infrastructure development. Economic growth policies facilitate international trade and contribute to improving port efficiency.

- **Monitor and manage inflation impacts**

The study identified that in the short run, inflation has a positive effect on container throughput, while in the long run, it has a negative effect. This suggests that policymakers should closely monitor inflation trends and maintain price stability to ensure a favourable trade environment and minimise uncertainties in import and export behaviour.

- **Development of population-driven trade infrastructure**

As population growth is positively related to container throughput, infrastructure development and urban expansion planning is required. To accommodate the rising import and export activities, expanding logistics and port infrastructure in line with population trends is important.

- **Data-driven port management**

As macroeconomic indicators significantly influence container throughput, port management should monitor macroeconomic changes and gain insights into operational and strategic planning.

6. CONCLUSION

This study analysed the impact of macroeconomic variables on container throughput in Sri Lanka using time-series annual data from 1994 to 2023. Direct inward and outward container movements were considered the container throughput, excluding transhipments, to better reflect the domestic economic activities linked to port performance. The selected macroeconomic indicators were GDP per capita growth, population growth, GDP growth, inflation, exchange rate, purchasing power parity, and trade balance. To address multicollinearity, GDP per capita growth was used instead of GDP growth due to severe multicollinearity, and the exchange rate was retained instead of purchasing power parity due to its theoretical importance and statistical significance.

The stationarity of the variables was tested using the ADF and Phillips-Perron unit root tests. The results showed a combination of I(0) and I(1) variables, making the Autoregressive Distributed Lag (ARDL) model an appropriate estimation method. Confirming the suitability of the ARDL bounds testing approach for cointegration, none of the variables were found to be integrated of order two.

The estimated ARDL model showed that population growth and GDP per capita growth were highly significant at the 1% level with positive coefficients. This indicates that increases in population and GDP per capita growth are strongly associated with higher container throughput. The second lag of the trade balance was also positively significant, suggesting that a growing trade deficit leads to increased container movement. Other notable findings are the positive significance of the first lag of GDP per capita growth and the negative effect of inflation at the five% level. The first lag of the exchange rate and population growth was positively significant at the 10% level. With an R-squared of 0.99 and an adjusted R-squared of 0.98, the overall model exhibited strong explanatory power. The Durbin-Watson statistic has indicated no severe autocorrelation, and the Wald test has confirmed the joint significance of explanatory variables.

The ARDL bounds test was conducted to determine the existence of a long-run relationship between the variables. In this study, the F-statistic exceeded the upper bound at the 1% significance level. Therefore, the null hypothesis of no long-run relationship was rejected. The long-run estimation of the ARDL model provides valuable insights into how macroeconomic variables influence container throughput in Sri Lanka in the long run. The exchange rate, GDP per capita growth, inflation, and population growth are statistically significant at the 1% level, and the trade balance is significant at the 5% level. A one-unit increase in the exchange rate is associated with a 0.86-unit increase in container throughput, whereas a one-unit increase in GDP per capita growth influences a 0.06-unit increase in container throughput. However, inflation negatively impacts container throughput in the long run (coefficient is -0.02). Moreover, a one-unit increase in population growth leads to a 0.16-unit increase in the container throughput. The trade balance was interpreted by considering Sri Lanka's trade deficit. A one-unit increase in the trade deficit results in a 0.14-unit increase in container throughput, reflecting higher imports, which are primarily containerised.

In the error correction model (ECM), the error correction term was negative and statistically significant, indicating the existence of a stable long-run relationship. The coefficient of -0.5695 indicates that approximately 57% of the deviation from the long-run equilibrium was corrected in the previous period.

The short-run dynamics show that current GDP per capita and population growth have positive and significant effects on container throughput. Lagged inflation was also positively significant in the short run, possibly due to increased import activities in response to the expectations of further price increases. However, current inflation, trade balance, and exchange rates did not show immediate effects, suggesting that changes in some macroeconomic indicators may take time to influence port activities.

In addition, all diagnostic tests confirmed the robustness of the model. The normality of the residuals was confirmed using the Jarque-Bera test ($p = 0.918$). Based on the Breusch-Godfrey test, with a preference for the F-statistic due to the small sample size, there is no strong evidence of serial correlation. Homoskedasticity was confirmed by the Breusch-Pagan-Godfrey test, with a p-value higher than 0.05. Model stability was confirmed by the cumulative sum (CUSUM) and CUSUM of squares tests. Multicollinearity was assessed using the Variance Inflation Factor (VIF). All values were below the threshold of 5, indicating acceptable levels of multicollinearity.

6.1. Further Research Direction

An important direction for future research is to analyse the impact of macroeconomic indicators in South Asian countries on container transhipment volume in Sri Lanka. By using panel data from countries such as India, Bangladesh, Pakistan, Maldives, Nepal, Bhutan, and Afghanistan alongside Sri Lanka's transhipment data, researchers can identify how economic trends across the South Asia region contribute to the volume of containers transhipped through Sri Lankan ports. This method enables the study of both cross-country and over-time variations in the data.

Panel data analysis techniques, such as Fixed Effects, Random Effects, or Panel ARDL models, allow for the identification of relationships between regional economic indicators, such as GDP, exchange rates, trade balances, population growth, and transhipment activities. Such a study would help better understand the strategic role of Sri Lanka as a transshipment hub and guide policies to strengthen its position in the South Asian maritime trade network.

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