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Analysis of the influential factors affecting rail freight demand: Evidence from Sri Lanka

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1 Introduction

Rail transport in Sri Lanka is a state monopoly owned and operated by Sri Lanka Railways (SLR), which functions as a government department. In its early years, the railway was the primary mode of freight transport, generating substantial revenue and profits. However, following the introduction of the liberalised economy, the rail freight transport modal share, which accounted for 23% of total motorised freight transport in 1977, has declined to just 1% (Sri Lanka Railways, 1977–2022). Sri Lanka's rail freight sector remains underperforming despite its lower rates compared to road transport (Danthanarayana and Dunusinghe, 2023). Freight earnings, which accounted for 27% of total earnings in 1977, fell to 6% in 2018, reflecting significant drawbacks in rail freight transport, as evidenced by a marked decline in tonne-kilometres with an average annual growth rate of -0.54% (Danthanarayana & Kumarage, 2024). Thus, it is imperative for policymakers and planners to understand the factors contributing to the declining rail freight in Sri Lanka. Empirical studies have shown that rail freight demand is largely influenced by economic activity, prices, and trade performance. Early cross-country work by Bennathan et al. (1992) and FitzRoy and Smith (1995) established GDP, geography, and service quality as key determinants. Subsequent econometric analyses using time-series models confirmed long-run relationships between GDP, freight rates, and rail demand in India (Ramanathan, 2001; Kulshreshtha et al., 2001) and highlighted the impact of exchange rates and freight rates in Australia (Wijeweera et al., 2014). Similarly, Khan and Khan (2020) identified economic activity and freight rates as dominant factors in Pakistan, while Andersson and Elger (2012) emphasised GDP and trade volume as strong predictors in Sweden. More recent research indicates that fuel prices, energy costs, and competitive road services continue to shape modal shifts (Przekota & Szczepańska-Przekota, 2024; Zou & Chau, 2019).

In the Sri Lankan context, the existing literature lacks empirical studies that examine the impact of key determinants of rail freight demand through macro-level time series analysis. This presents a significant research gap that requires policy-driven strategies to enhance rail freight demand and mitigate the long-term financial losses of SLR. The primary goal of this research is to investigate the underlying macro-level factors and their impact on demand for rail freight transport in Sri Lanka. The outcome provides guidance to policymakers to formulate strategic policies focusing on a macro framework to enhance rail freight modal share and economic development. This paper is the first analysis of rail freight transport in Sri Lanka, which focuses on the macro determinants using a time series econometric modelling approach.

2 Methodology

This study adopted a quantitative approach based on annual data from 1990 to 2022, analysed through regression techniques using EViews software. The required data for the variables of the econometric model were obtained from various published sources, including the Sri Lanka Railways, the Central Bank of Sri Lanka, and the Ceylon Petroleum Corporation, comprising annual statistical and administrative reports, as well as unpublished data. The first step in the modelling involved transforming rail freight tonne-kilometres (FTK), rail freight rates (FR), and

fuel price (FP) into their logarithmic forms (LFTK, LFR, and LFP) to linearise the relationships, while GDP growth (GDPR) and trade volume share (STV) were kept in their original form. Stationarity was tested using the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The results showed a mix of I(0) and I(1) variables, confirming the suitability of the Autoregressive Distributed Lag (ARDL) approach (Pesaran & Shin, 1999; Pesaran et al., 2001; Wooldridge, 2020). The general ARDL model is expressed as (Equation 1):

$$Y_t = \gamma_0 + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{j=0}^{q} \beta_j X_{t-j} + \varepsilon_t \quad (1)$$

where Y_t is the dependent variable (LFTK), X_{t-j} are the explanatory variables (LFR, LFP, GDPR, STV), δ_i and β_j are coefficients, and ε_t is the error term. Optimal lag lengths were selected using the Akaike Information Criterion to test for long-run relationships, and ARDL bounds test was conducted using the F-statistic, with the null hypothesis of no cointegration:

(H_0: Null Hypothesis; H_1: Alternate Hypothesis)
H_0: $\alpha_1=\alpha_2=\alpha_3=\alpha_4=\alpha_5=0$ (There is no cointegration between the variables)
H_1: At least one $\alpha_i \neq 0$ (Cointegration exists between the variables)

Rejection of H_0 indicates cointegration among variables. The Error Correction Model (ECM) was then estimated to capture short-run dynamics and the speed of adjustment toward long-run equilibrium (Equation 2):

$$\Delta LFTK_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \mathrm{L} LFTK_{t-i} + \sum_{i=1}^{q} \beta_{2i} \Delta \mathrm{L}\, FR_{t-i} + \sum_{i=1}^{q} \beta_{3i} \Delta \mathrm{L}\, FP_{t-i} + \sum_{i=1}^{q} \beta_{4i} \Delta GDPR_{t-i} + \sum_{i=1}^{q} \beta_{5i} \Delta STV_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (2)$$

where ECT_{t-1} is the error correction term, and λ represents the adjustment speed. Model reliability was verified through diagnostic tests for serial correlation, heteroscedasticity, and normality, while CUSUM and CUSUMSQ tests confirmed the stability of the estimated coefficients over time.

3 Results and Discussion

3.1 Unit root test results

The ADF and PP test results indicate that LFR and LFP (financial variables) are non-stationary at the level but become stationary after first differencing, whereas LFTK, GDPR, and STV are stationary at the level. This mix of I(0) and I(1) variables confirms that the ARDL approach is appropriate, as it can effectively capture both short-run and long-run relationships among variables with different integration orders.

3.2 ARDL bound test results

The ARDL bounds test confirmed a long-run cointegration relationship between rail freight demand (LFTK) and its explanatory variables. The calculated F-statistic value of 5.68 exceeds the upper bound critical values at the 10% (3.09), 5% (3.49), and 1% (4.37) significance levels, leading to rejection of the null hypothesis of no cointegration. This result indicates a stable long-run equilibrium relationship between dependent and independent variables of the regression model.

3.3 ARDL cointegrating form

After analysing the bound test results, the study performed the analysis of ARDL long run form to find the long-run relationship between the variables (Table 1). The long-run results show a positive and significant relationship between rail freight rates (LFR) and rail freight demand (LFTK), with a coefficient of 0.49, indicating that a 1% increase in rates leads to a 0.49% rise

in freight volume. Although inconsistent with demand theory, this reflects that both variables move together over time due to government-controlled low pricing, the monopoly nature of Sri Lanka Railways, and the inelastic demand for bulk commodities such as cement and petroleum. The long-run results show that fuel price (LFP) has a positive but insignificant impact on rail freight demand (LFTK), with a coefficient of 0.17, indicating that a 1% increase in fuel price leads to a 0.17% rise in freight volume. Although higher fuel prices theoretically favour rail, they do not significantly influence modal shift, as road transport remains dominant due to its flexibility and lower handling costs for non-bulk and containerised cargo.

Table 1: Estimated long-run coefficients using ARDL model

Variable	Coefficient	t-Statistic	Prob.
LFR	0.49**	2.43	0.03
LFP	0.17	1.21	0.25
GDPR	-2.36	-1.49	0.16
STV	-1.55**	-3.09	0.01
C	19.60**	32.91	0.00

Note: ** indicate significance at 5% level.

$$LFTK_t = 19.60 + 0.49\ LFR_t + 0.17\ LFP_t - 2.36\ GDPR_t - 1.55\ STV_t + \varepsilon_t \quad (6)$$

The long-run results show that GDP growth rate (GDPR) has a negative and insignificant impact on rail freight demand (LFTK), with a coefficient of –2.36, indicating that higher economic growth does not increase freight volume. Similarly, the share of trade volume (STV) shows a negative coefficient of –1.55, meaning that increases in trade as a share of GDP reduce rail freight demand. These results suggest that growth in GDP and trade activity is associated with greater use of road freight, while international trade expansion has not supported the development of rail freight transport.

3.4 Error correction model (ECM)

The Error Correction Model (ECM) results reveal that the error correction term (ECT-1) is **–** 0.91 and statistically significant (p = 0.00)**,** confirming a stable long-run relationship among variables (Table 2).

Table 2: Error correction representation

Variable	Coefficient	t-Statistic	Prob.
D(LFR)	-0.09	-0.62	0.54
D(LN_FR(-1))	-0.40**	-3.00	0.01
D(LN_FR(-2))	-0.39**	-2.27	0.04
D(LN_FP)	-0.11	-1.31	0.21
D(LN_FP(-1))	0.31**	2.65	0.02
D(GDP)	1.84***	3.30	0.00
D(GDP(-1))	2.80**	3.22	0.01
D(GDP(-2))	2.65***	3.41	0.00
D(STV)	-0.65**	-2.39	0.03
CointEq(-1)*	-0.91***	-6.74	0.00
R-squared			0.84
Adjusted R-squared			0.77
Durbin-Watson stat			2.11

Note: *, **, and *** indicate significance at 10%, 5%, and 1% respectively.

The negative sign of ECM indicates convergence toward equilibrium, with about 91% of short-run disequilibrium in rail freight volume corrected each year. This suggests a strong and rapid

adjustment speed of the system toward its long-run equilibrium after short-term shocks. The short-run ECM results show that current changes in rail freight rates (D(LFR)) have no immediate effect on freight volume (p=0.54), but the first and second lags are negative and significant (–0.40 and –0.39), indicating a delayed, inelastic response where higher rates reduce demand. Fuel price (D(LFP)) has an insignificant contemporaneous effect (–0.11; p=0.21), while its first lag is positive and significant (0.31; p=0.02), suggesting that rising trucking costs encourage limited short-term shifts toward rail. GDP growth (GDPR) shows a positive and significant short-run effect, indicating that economic activity increases freight demand. In contrast, trade volume share (STV) has a negative and significant coefficient (–0.65; p=0.03), implying that trade expansion benefits road rather than rail freight. The model fits well (R^2 = 0.84, Adj. R^2 = 0.77) with no autocorrelation (Durbin–Watson = 2.11), confirming robustness.

3.5 Diagnostic tests

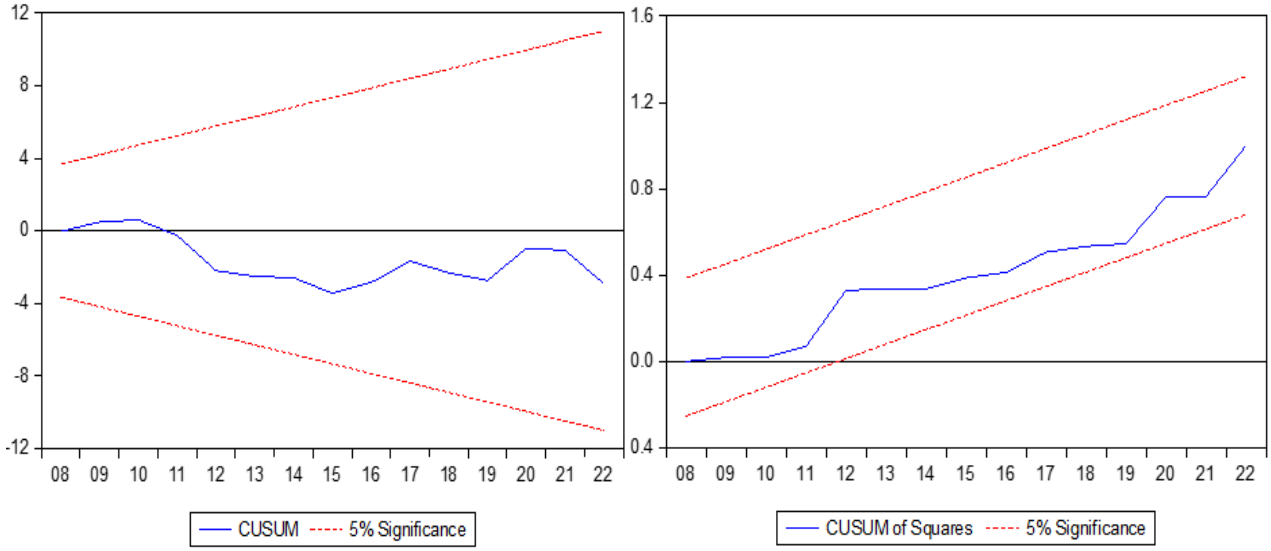
The results of the diagnostic tests provide important insights into the robustness of the estimated model (Table 3).

Table 3: Diagnostic testing results

Test Type	Test Name	Test Statistic	P-value	Conclusion
Serial Correlation	Breusch-Godfrey LM Test	F = 3.68	0.054	No serial correlation (p > 0.05)
Heteroscedasticity	Breusch-Pagan-Godfrey Test	F = 0.25	0.99	No heteroskedasticity (p > 0.05)
Normality	Jarque-Bera Normality Test	Jarque-Bera =9.27	0.01	Residuals are not normally distributed
Ramsey RESET Test (Functional Form)			0.18	Model functional form is correctly specified.

The Breusch-Godfrey LM test (p=0.054) indicates no serial correlation, and the Breusch-Pagan-Godfrey test (p=0.99) confirms homoscedasticity. Although the Jarque-Bera test (p=0.01) suggests non-normal residuals, the Ramsey RESET test (p=0.18) verifies the correct model specification. Consistent with Pesaran and Shin (1999), the ARDL model remains valid despite mild non-normality, as other diagnostics support model reliability. The CUSUM and CUSUMSQ stability tests (Figure 1) further confirm that the model's coefficients are structurally stable over time.

Figure 1: CUSUM test and CUSUM of squares test results



The CUSUM graph shows that the blue line stays within the 5% critical bounds, confirming no significant coefficient instability and a stable long-run relationship among variables. Similarly, the CUSUMSQ graph remains within the bounds, indicating constant residual variance and overall model stability throughout the sample period.

4 Conclusion

This study examined the key factors influencing the demand for rail freight transport in Sri Lanka with the objective of improving the rail modal share and supporting economic growth. The results show that all four factors: rail freight rates (LFR), fuel price (LFP), GDP growth (GDPR), and share of trade volume (STV) influence rail freight demand in different ways across time horizons. In the short run, changes in freight rates and fuel prices affect demand, though the response is relatively inelastic. Over the long run, the positive association between rail freight rates and demand reflects the effect of regulated low pricing, government control, and the dominance of bulk commodities such as cement and petroleum, which are less sensitive to price changes. Since rail rates are maintained at socially acceptable levels rather than market-based levels, moderate rate adjustments supported by improved service quality could help the government minimise financial losses while maintaining competitiveness. The findings also show that fluctuations in fuel prices have limited long-term influence on rail freight demand, as road transport remains more flexible and efficient for most types of freight. Similarly, economic growth does not automatically translate into greater use of rail freight because the road sector continues to dominate due to better infrastructure, higher reliability, and customer-oriented services. The impact of trade volume reinforces this imbalance, as the increasing movement of imports and exports is mainly absorbed by road freight, which offers faster and more adaptable services. The lack of integration between rail and the broader supply chain has limited the sector's capacity to capture growing trade-related freight. Overall, the results indicate that rail freight demand in Sri Lanka is influenced primarily by institutional, infrastructural, and competitive challenges rather than purely by market forces. Policymakers should prioritise investment in rail infrastructure, technological modernisation, and service reliability, while promoting multimodal integration to strengthen rail's position in the logistics network. Adjusting freight rates in line with service improvements could enhance the sector's financial sustainability. These findings may be useful for future empirical studies in countries where rail freight is under pressure due to strong competition from road transport, geographic constraints, or government-regulated pricing structures. While Sri Lanka is a geographically small country with shorter rail corridors, the findings may still offer relevant implications for geographically large countries such as Australia, particularly in addressing the declining modal share of non-bulk rail freight, especially over short-haul corridors. Future studies should explore micro-level factors, including reliability, frequency, flexibility, transit time, and customer satisfaction, to better understand how service improvements could attract more freight to rail.

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