GREEN ECONOMICS
Vol.2, No.3, 2024, pp.209-214
https://doi.org/10.62476/ge.23209

Jomard Publishing

ASSESSING THE POTENTIAL OF RAILWAYS TO REDUCE CO_2 EMISSIONS: A COINTEGRATION STUDY OF ESTONIA'S TRANSPORT SECTOR

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Abstract. The transportation sector is a major contributor to CO_2 emissions, playing a significant role in exacerbating climate change. Railways, known for their greater energy efficiency compared to other modes of transport, present a viable solution for mitigating emissions, particularly in countries like Estonia. In 2014, transport-related CO_2 emissions in Estonia were recorded at 12.7%, marking an overall upward trend since 1995, despite experiencing some fluctuations over the years. This study aims to explore the long-term equilibrium relationship between CO_2 emissions from transport and railway passenger kilometers in Estonia through the application of cointegration analysis. Utilizing Johansen cointegration tests, the analysis reveals a stable, long-term equilibrium relationship between the two variables. The findings suggest that an increase in railway passenger kilometers could potentially lead to a reduction in CO_2 emissions from transport. These results underscore the importance of enhancing railway infrastructure and usage as a strategic measure to curb transportation-related emissions and contribute to environmental sustainability.

Keywords: *Transport, CO_2 emissions, railways, cointegration analysis, Estonia, green economics.*

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Received: *13 May 2024;* ***Accepted:*** *3 August 2024;* ***Published:*** *30 September 2024.*

1. Introduction

The transportation sector significantly contributes to CO_2 emissions, making it a key focus in efforts to combat climate change. Railways, as a more energy-efficient mode of transport, offer potential for reducing these emissions, particularly in countries like Estonia. Understanding the relationship between transport-related CO_2 emissions and railway passenger usage is crucial for developing effective environmental policies. This study examines whether a long-run equilibrium relationship exists between CO_2 emissions from transport and railway passenger kilometers in Estonia using cointegration analysis. The findings will inform strategies aimed at enhancing the role of railways in reducing the nation's carbon footprint.

In 2014, the share of CO_2 emissions from the transport sector in Estonia was 12.7%. Although there were significant fluctuations in this percentage in recent years, it generally exhibited an upward trajectory throughout the period from 1995 to 2014, ending at 12.7% in 2014 (Knomena, 2015). This suggests a persistent increase in the proportion of transport-related CO_2 emissions over the two-decade span, despite the

How to cite (APA):
Abbasov, Z. (2024). Assessing the potential of railways to reduce CO_2 emissions: A cointegration study of Estonia's transport sector. *Green Economics*, *2*(3), 209-214. https://doi.org/10.62476/ge.23209

variability observed in the data. The overall trend highlights the growing impact of the transport sector on Estonia's carbon emissions during this time frame.

Figure 1 illustrates a consistent rise in CO_2 emissions from the transport sector in Estonia throughout the study period, alongside a gradual increase in railway passenger usage. The data suggests a potential positive correlation between these two variables, indicating that while railway usage has expanded, it may concurrently contribute to an increase in CO_2 emissions. This observation points to the need for further investigation into the relationship between railway transport and emissions to understand the underlying dynamics.

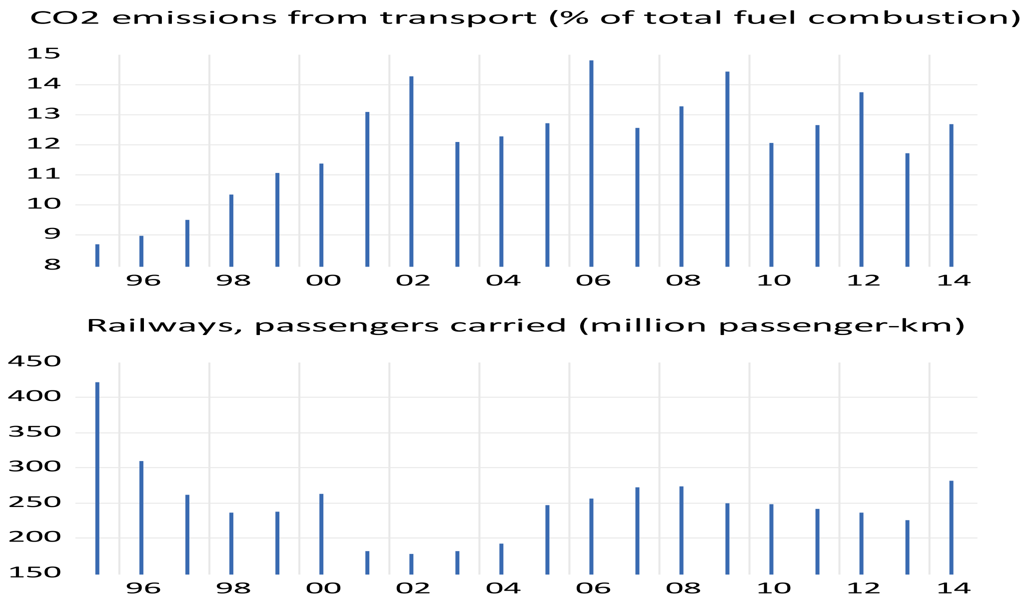

Figure 1. Trends in CO_2 Emissions from Transport and Railway Passenger Usage in Estonia (1995-2014)
Source: https://data.worldbank.org/country/estonia

In modern scientific research, the topic of green transport is of significant importance because of its implications for both environmental sustainability and public health. As the urgency of addressing climate change and improving urban air quality increases, the shift toward more sustainable transportation options has become a primary area of scholarly focus. As a result, a comprehensive body of literature has developed, examining various aspects of green transport, such as the emissions impact of different transport modes, advancements in technology, policy interventions and changes in behavior (Shah *et al*., 2019; Hasanov, 2023; Shouket *et al*., 2019). This expanding research highlights the essential need for effective strategies to minimize the environmental impact of transportation systems. This study conducted an econometric analysis of the Estonian transport system from the perspective of green economics.

2. Literature Review

The concept of green supply chain management, which gained prominence through scientific literature in the late twentieth century, has become crucial for the planet's future due to growing concerns about the global environmental crisis from an anthropological perspective (Tseng *et al*., 2019; Hasanov & Safarli, 2023; Safarov & Hasanov, 2024).

The transportation system, as part of this broad framework and the evaluation of CO_2 emissions from it, are extensively examined on a global scale. Lin et al. (2021) explain that reducing carbon emissions in the transportation sector is essential and high-speed rail (HSR) systems can significantly contribute to this effort. In China, the introduction of new HSR routes has resulted in a 20.5% reduction in passenger vehicles and a 15.7% reduction in freight vehicles on parallel highways, leading to an annual decrease of 11.183 million tons of CO_2 equivalent emissions, although the full environmental benefits are constrained by the reliance on thermal electricity. Dimoula et al. (2016) reveal that environmental concerns are vital in the transport sector, which is the second largest emitter of greenhouse gases in the EU. It finds that while highway construction has a lower environmental impact than railway construction, the operation of railway systems is more environmentally friendly compared to highways, emphasizing the need to optimize route design for long-term greenhouse gas reductions. Alonso et al. (2014) analyze air traffic patterns within the European Union and internationally, using data on flights, passengers, cargo, fuel consumption and CO_2 emissions from Eurostat and EUROCONTROL. It finds that traffic is heavily concentrated in five major countries, with the 500-1000 km distance segment generating the most flights and emissions and provides projections for future CO_2 emissions based on various growth and biofuel scenarios. The forecast for the ten Central and Eastern European countries poised to join the EU predicts that transportation energy demand will double and CO_2 emissions will increase by 70% by 2030 compared to 2000, based on 'business as usual' assumptions (Zachariadis & Kouvaritakis, 2003). The study considers factors such as transport mode evolution, rising fuel prices and technological improvements, comparing the results with other forecasts and discussing their potential energy and environmental impacts along with major policy implications. Transportation is a major driver of economic development in Estonia and affects various sectors, with road transport being a significant contributor to greenhouse gas (GHG) emissions. Valdas et al. (2016) employ an econometric simultaneous equations model to forecast the environmental impact of road freight under different GDP per capita growth scenarios, revealing that GDP per capita and population size are crucial factors influencing both freight volumes and GHG emissions.

3. Data and Methodology

In this study, we analyze the relationship between CO_2 emissions from transport and railway passenger usage in Estonia. The variables utilized in this analysis are:

- LN_CO2T: The logarithm of CO_2 emissions from transport as a percentage of total fuel combustion in Estonia.
- LN_RPC: The logarithm of railways, passengers carried in million passenger-kilometers.

The data was sourced from the World Bank (2024) and covers the period from 1995 to 2014. The logarithmic transformation of the variables helps to normalize the distribution and mitigate heteroscedasticity, while the first differencing of LN_CO2T1 addresses potential non-stationarity in the time series. To assess the long-run equilibrium relationship between CO_2 emissions from transport and railway passenger usage in Estonia, we employ Johansen cointegration (1991) test and its formula as following:

$$\Delta \mathbf{x}_t = \boldsymbol{\alpha}(\boldsymbol{\beta}' \mathbf{x}_{t-1}) + \sum_{i=1}^{k-1} \Gamma_i \Delta \mathbf{x}_{t-i} + \boldsymbol{\epsilon}_t \quad (1)$$

The statistical summary (Table 1) provides crucial insights into the data's central tendency, variability and distribution characteristics. The mean and median values help assess the central tendency, while the range (maximum and minimum) indicates the extent of variability. Standard deviation measures dispersion around the mean and skewness reveals the asymmetry of the distribution, with negative skewness indicating a leftward tail and positive skewness a rightward tail. Kurtosis highlights the presence of outliers or extreme values, with higher kurtosis indicating heavier tails. These metrics are essential for understanding the data's distribution and guiding further analysis and model assumptions.

Table 1. Descriptive Statistics

Parametres	**LN_CO2T**	**LN_RPC**
Mean	2.484	5.500
Median	2.519	5.511
Maximum	2.695	6.042
Minimum	2.164	5.181
Std. Dev.	0.150	0.199
Skewness	-0.755	0.529
Kurtosis	2.775	4.214

The logarithmic trends in Figure 2 show that "LN_CO2T" fluctuates steadily around a value of 3, indicating proportional stability, while "LN_RPC" starts near 7 and gradually declines, reflecting a decreasing multiplicative effect over time.

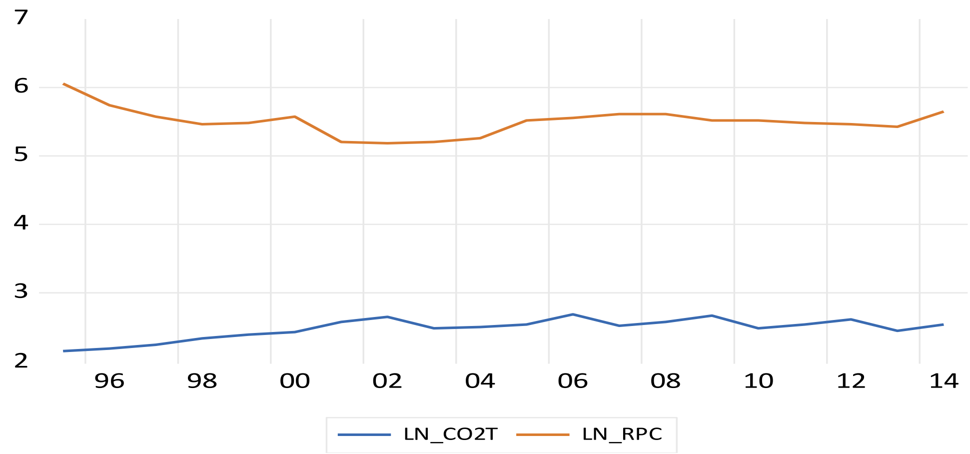

Figure 2. Logarithmic Trends of variables

4. Empirical Results

Table 2 reveals the results of the Unrestricted Cointegration Rank Test (Maximum Eigenvalue), which tests for the number of cointegrating equations based on the maximum eigenvalue statistic. The test compares the maximum eigenvalue statistic with a critical value at the 5% significance level. Similar to the trace test, the results indicate two statistically significant cointegrating relationships, as the null hypotheses for "None" and “At most 1” are both rejected at the 0.05 level, suggesting the presence of long-term equilibrium relationships between the variables.

Table 2. Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.595043	19.83515	15.49471	0.0104
At most 1 *	0.231104	4.467595	3.841465	0.0345

Trace test indicates 2 cointegrating eqn(s) at the 0.05 level
- denotes rejection of the hypothesis at the 0.05 level

** MacKinnon-Haug-Michelis (1999) p-values

Table 3 presents the results of the Unrestricted Cointegration Rank Test (Maximum Eigenvalue), which evaluates the number of cointegrating relationships within a time series dataset. For the null hypothesis of no cointegration, the Max-Eigen Statistic of 15.36755 exceeds the corresponding critical value of 14.26460, with a p-value of 0.0333, leading to rejection of the null hypothesis at the 5% significance level. Similarly, for the hypothesis of at most one cointegrating equation, the Max-Eigen Statistic of 4.467595 surpasses the critical value of 3.841465, with a p-value of 0.0345, also rejecting the null hypothesis. These findings indicate the presence of two cointegrating equations at the 5% significance level, suggesting that the variables exhibit long-term equilibrium relationships, which are vital for econometric analysis.

Table 3. Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.595043	15.36755	14.26460	0.0333
At most 1 *	0.231104	4.467595	3.841465	0.0345

Max-eigenvalue test indicates 2 cointegrating eqn(s) at the 0.05 level
- denotes rejection of the hypothesis at the 0.05 level

** MacKinnon-Haug-Michelis (1999) p-values

5. Conclusion

This study underscores the potential of railways to reduce emissions in Estonia due to their higher energy efficiency. By employing cointegration techniques, the analysis reveals a stable long-term equilibrium relationship between CO_2 emissions from transport and railway passenger kilometers. Significant cointegration is evidenced by the Johansen cointegration tests, all of which have p-values below 0.05. These results suggest a consistent, long-term association, indicating that increased railway utilization could effectively lower CO_2 emissions. To fully understand this relationship and develop effective strategies for utilizing railways to reduce Estonia's carbon footprint.

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