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ASSESSMENT OF MARITIME LOGISTICS EFFICIENCY IN COASTAL STATES THROUGH DATA ENVELOPMENT ANALYSIS

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ABSTRACT

Purpose- Coastal countries are in an advantageous position compared with landlocked countries in terms of logistics costs and transit times. However, for both the efficient functioning of global transport systems and the competitiveness of coastal countries, it is also important to consider whether this geographical advantage is being effectively exploited. Accordingly, this study analyses the relative efficiency of coastal countries in translating their logistics infrastructure and their logistics competence and service quality into maritime connectivity.

Methodology- The study employs a constant returns to scale Data Envelopment Analysis (CCR-DEA) model configured for output maximization. The Infrastructure Score and the Logistics Competence and Quality Score, which are components of the Logistics Performance Index (LPI), are used as model inputs. The Liner Shipping Connectivity Index (LSCI), representing maritime connectivity, is used as the model output.

Findings- The findings indicate that, within the sample, China has the highest efficiency and that East and South Asian countries exhibit higher efficiency levels compared with other regions. The relatively low maritime connectivity efficiency of the Nordic and Baltic countries can be explained by the fact that their hinterlands are very well connected to the major Northern European hubs. Moreover, deep-sea liner services avoid additional sea legs and prefer ports in the Le Havre-Hamburg range.

Conclusion- The study evaluates the relative efficiency of 92 coastal countries within the framework of an output-oriented DEA model configured with LSCI as the output. East and South Asian countries exhibit higher efficiency levels compared with other countries. Sri Lanka, in particular, attains a high level of maritime connectivity despite having below-average input levels. The findings indicate that maritime connectivity is influenced by factors such as geographical location, beyond logistics infrastructure and logistics competence and service quality.

Keywords: LPI, LSCI, logistics infrastructure, logistics performance, maritime logistics
JEL Codes: C61, L91, R41

1. INTRODUCTION

Maritime transport constitutes the backbone of international trade (Gu & Liu, 2023), and enables the movement of large volumes of goods at lower costs compared with other modes of transport. Thanks to the advantages provided by containerization and advances in shipbuilding, the cargo capacities of commercial ships have increased, allowing maritime transport to benefit more from economies of scale through reducing transport costs (Haralambides, 2019). By contrast, the logistics costs of the landlocked countries are about 50% higher than those of coastal countries (Kashiha et al., 2016; Limao & Venables, 2001). In this context, maritime logistics performance is of critical importance for countries to be able to connect seamlessly and efficiently to global supply chains and to exploit as fully as possible the geographical advantage provided by access to the sea. In particular, for coastal countries, the extent to which their logistics infrastructure and service capabilities translate into access to overseas markets through effective liner connectivity is crucial for exploiting this potential efficiently.

Maritime connectivity is a concept that refers to the access of firms operating in a port's hinterland to overseas country markets; higher levels of connectivity are generally associated with lower freight rates and higher trade volumes (Mishra et al., 2021). One of the commonly used measures of maritime connectivity, the Liner Shipping Connectivity Index (LSCI), expresses the degree to which a country is integrated into the global maritime system (United Nations Conference on Trade and Development (UNCTAD), 2025). In the global transport system, ports function as an interface between the interdependent foreland and hinterland (Rodrigue & Notteboom, 2010), and it is more appropriate to conceptualize this system as a complex and multidimensional network ratem than as a set of isolated processes. In this complex and interdependent structure, the efficiency of maritime transport depends not only on ship/port elements but also on port–

hinterland linkages. In this context, the following research question arises: to what extent are coastal countries able to transform their existing level of logistics infrastructure and quality into accessibility to overseas markets (i.e., maritime connectivity)?

To measure this multidimensional performance and to answer the research question, this study proposes a model that uses Infrastructure Score (INFRA) and the Logistics Competence and Quality Score (COMP) metrics from the World Bank's Logistics Performance Index (LPI) as model inputs (World Bank Group, 2023). Furthermore, the suggested model considers LSCI as model output (United Nations Conference on Trade and Development (UNCTAD), 2025). In line with the research aim, the model is based on Data Envelopment Analysis (DEA) with constant returns to scale (CCR) assumption and configured for output maximization (Charnes et al., 1978). DEA is a reliable non-parametric quantitative analysis method that is frequently employed in studies on logistics efficiency (Cavaignac et al., 2021; Gan et al., 2022), maritime transport efficiency (Nguyen et al., 2022), and port efficiency (Krmac & Mansouri Kaleibar, 2023).

The research question and model aim to contribute to the scholarly literature by moving beyond the traditional focus on operational performance and cost efficiency, and instead investigating the extent to which existing logistics infrastructure and service quality can be transformed into maritime connectivity. Furthermore, despite their importance and potential in world trade, South Asian ports have received limited attention in the academic literature (Vinod & Prakash, 2024). However, the decision-making units (DMUs) of the current study comprise all coastal countries included in the LPI dataset provided by the World Bank, except for the exclusions specified in the methodology section. The remainder of this paper is structured as follows: Section 2 presents the research methodology. Section 3 reports the empirical findings. Section 4 is devoted to the discussion, and Section 5 presents the conclusions

2. METHODOLOGY

This research employs DEA as a non-parametric approach that is frequently used in efficiency measurement (Charnes et al., 1978). A DEA model can be designed under assumptions of constant or variable returns to scale (Banker et al., 2004). In line with the purpose of the current research, DEA is considered with an assumption of constant returns to scale, and the formulation is adopted from Ragsdale (2007) to ensure clarity and ease of application for business managers. The model aims to calculate the relative efficiency of decision-making units (DMUs) in translating their INFRA and COMP into the LSCI. The analysis is based solely on secondary data obtained from publicly available sources (United Nations Conference on Trade and Development (UNCTAD), 2025; World Bank Group, 2023). The research protocol is shown in Table 1.

Table 1: Research Protocol

Metric	Source/Detail
Input 1: LPI infrastructure score (INFRA)	World Bank Group (2023)
Input 2: LPI logistics competence & quality score (COMP)	World Bank Group (2023)
Output: LSCI	United Nations Conference on Trade and Development (UNCTAD) (2025)
DMU	92 coastal countries
Exclusion criteria	Micro island states, Caribbean Island states, very small coastal or riverine countries, landlocked countries, and war-affected economies. In addition, countries for which 2023 LSCI data were not available were also excluded from the sample.

As shown in Table 1, the output-oriented DEA model is configured for two inputs (INFRA, COMP) and one output (LSCI) to assess the relative efficiency of 92 DMUs (see Eq. 1) and is solved using linear programming. Microsoft Excel's solver module is used for this purpose, and the formulation is based on Ragsdale (2007). The configuration aims to maximize output (see Eq. 2) considering model constraints as shown in Eqs. (3) and (4). In formulation:

i indexes DMUs (i.e., coastal countries) in the model
j indexes the input and output variables in the model
w_j = weight coefficient for output j; where $w_j \geq 0$
v_j = weight coefficient for input j; where $v_j \geq 0$
n_O = total number of outputs
n_I = total number of inputs
O_{ij} = value of output j for DMU i
I_{ij} = value of input j for DMU i

$$Efficiency\ of\ DMU\ "i"=\frac{\sum_{j=1}^{n_O} O_{ij}w_j}{\sum_{j=1}^{n_I} I_{ij}v_j} \quad (1)$$

$$MAX: \sum_{j=1}^{n_O} O_{ij}w_j \quad (2)$$

$$\sum_{j=1}^{n_o} O_{kj}w_j \le \sum_{j=1}^{n_I} I_{kj}v_j\,, \qquad \forall\, k = 1, \dots, 92 \quad (3)$$

$$\sum_{j=1}^{n_I} I_{ij}v_j = 1 \quad (4)$$

3. FINDINGS

In this study, an output-oriented DEA efficiency assessment was carried out for 92 coastal countries based on the evaluation of the output (LSCI) and the inputs (INFRA, COMP) specified in the methodology section. The results of the analysis are presented in Appendix 1. Among the five most efficient countries, four are located in East and South Asia. Accordingly, the five most efficient countries are China (DEA_CN = 1), Korea, Rep. (DEA_KR = 0.521), Malaysia (DEA_MY = 0.458), United States (DEA_US = 0.435), and Singapore (DEA_SG = 0.431). Furthermore, Estonia (DEA_EE = 0.033), Bulgaria (DEA_BG = 0.031), ICELAND (DEA_IS = 0.024), Liberia (DEA_LR = 0.023), and Albania (DEA_AL = 0.017) are the countries with the lowest efficiency scores.

The highest LSCI value in the dataset is 1.2k (China), while the lowest is 12.3 (Albania), and the mean LSCI value is 159.4. Singapore has the highest INFRA score of 4.6, whereas Libya ranks last with a score of 1.7. Singapore also has the highest COMP score of 4.4, while Somalia ranks last with 1.8. The mean INFRA score is 3.09, and the mean COMP score is 3.16. The findings indicate that China is the only country operating at full efficiency with a DEA score of 1. As discussed in detail in the Discussion section, East and South Asian countries are generally efficient, whereas the Baltic and Nordic regions display low efficiency levels.

4. DISCUSSION

4.1. The High-Quality, Small-Market Paradox: The Case of Northern Europe

The research findings indicate that the Nordic and Baltic countries have relatively low DEA efficiency scores compared to their comparatively high levels of INFRA and COMP values. It can be argued that this is related to their relatively small populations, limited domestic market size, and the fact that these countries do not assume the role of a mega hub on the scale of Rotterdam, Antwerp or Hamburg in the context of maritime transport, but rather function as regional gateways. The Baltic region access overseas markets through ports located in the geographic area between Hamburg and Le Havre (Notteboom, 2010). The Nordic mainland, on the other hand, has been integrated into Europe via the Øresund and Storebælt (Great Belt) bridges.

The Øresund crossing connects Denmark and Sweden by both road and rail (Ejermo et al., 2022), thus integrating Sweden into the European mainland. This system consists of a bridge and a tunnel and is 15.9 km long (Knowles, 2025). The 18-kilometre-long Storebælt (Great Belt), on the other hand, is a system comprising two bridges and one tunnel, connecting the Danish islands of Zealand and Funen to the Danish mainland. In this way, Øresund and Storebælt ensure Sweden–Denmark–Germany road and rail logistics integration. The Fehmarn tunnel, planned to be 18 kilometres in length, is currently under construction and, once completed, will connect Germany and Denmark via the islands of Fehmarn and Lolland (European Commission, 2024).

Although ports in the Kattegat region such as Gothenburg and Aarhus are of high importance at the regional scale, they are not located on the main trade route of liner services operating between Europe and the Far East. The need to sail an additional maritime leg to access this region leads these ports in the Kattegat area accommodating a limited number of large-sized liner vessels compared to hub ports on the main trade lanes (Notteboom, 2010). These geographical findings may help explain the relative DEA inefficiency of Baltic and Nordic countries in our model, and this result can be interpreted not as a failure of maritime logistics, but rather as a successful outcome of a high degree of integration and capacity sharing.

4.2. Emerging Maritime Transport Centres: The Relative Advantage of India, Malaysia and Sri Lanka

The research findings indicate that East and South Asian countries are prominently represented among the most DEA-efficient countries. Among these countries, Sri Lanka stands out as an interesting case. Although Sri Lanka's INFRA (2.4) and COMP

(2.7) scores are below the dataset average, container liner operators make regular calls at the Port of Colombo due to its hub position in the Indian Ocean, which positively affects the country's LSCI score (243.1). According to the DEA model, Sri Lanka appears to achieve a relatively high level of maritime connectivity despite having below-average levels of LPI inputs. As a major transshipment hub port, the Port of Colombo handled 6.9 million TEU of cargo in 2023 (Sri Lanka Ports Authority, 2025). The port competes with important Southeast Asian ports such as Singapore and Tanjung Pelepas for transshipment cargo (Kavirathna et al., 2018).

Due to its strategic position between East and West, another important maritime hub is Malaysia (Othman et al., 2016). Malaysia's role in international maritime transport can also be explained by the fact that it is one of the coastal states hosting the Strait of Malacca, which reduces the sailing distance between the Indian and Pacific Oceans (Qu & Meng, 2012). In addition, Malaysia is among the Asian coastal states with the longest coastline (Othman et al., 2016). Malaysia is able to transform its above-average input values (INFRA= 3.6, COMP= 3.7) into a relatively high level of maritime connectivity (LSCI = 494.6), and its DEA efficiency score places the country in 3rd position among the DMUs included in the model (DEA_MY = 0.458). One factor that very likely contributes to the relative efficiency of Malaysia is the business capacity of the Port of Tanjung Pelepas, which handled approximately 12.3 million TEU in 2024 (Port of Tanjung Pelepas, 2025).

India is an important maritime logistics hub that connects the South Asian hinterland to the Persian Gulf, East Africa and the Far East shipping corridors. In this context, Jawaharlal Nehru Port is among the most important ports in India in terms of throughput (Vinod & Prakash, 2024). The port is located in Navi Mumbai and handles a substantial share of the country's total TEU throughput (Jawaharlal Nehru Port Authority, 2025). According to the structure of the DEA model with LSCI as the output, India transforms its above-average level input values (INFRA= 3.2, COMP= 3.5) into a relatively high level of maritime connectivity output, which allows the country to rank as the seventh most efficient country among 92 countries in the dataset.

4.3. Relative Position of Türkiye in the Mediterranean Basin

The DEA findings indicate that Türkiye holds an advantageous position in terms of maritime connectivity compared with other countries in the Mediterranean region. The LPI values show that Türkiye has above-average input levels in terms of infrastructure (INFRA = 3.4) and logistics competence and quality (COMP= 3.5). The country is able to transform these inputs into a relatively high level of maritime connectivity (LSCI_TR = 279). Within the DEA model, Türkiye achieves an efficiency score of 0.274 and is ranked 16th among 92 coastal countries.

To put Türkiye's input/output values and DEA score into context, it is useful to compare them with countries in the Mediterranean basin. In Southern Europe, even though Italy, Greece and France have higher INFRA and COMP values than Türkiye, DEA efficiency of Türkiye is higher than DEA scores of these countries. In this region, the only country whose DEA efficiency score is higher than that of Türkiye is, understandably, Spain, which is a gateway between the Mediterranean and the Atlantic Ocean. For the Mediterranean basin as a whole, Spain ranks first, Egypt immediately ahead of Türkiye, while Italy and France rank below Türkiye.

Türkiye has the third-highest level of maritime connectivity (LSCI) among the Mediterranean countries, following Spain and Italy. The fact that Türkiye's relative DEA efficiency is below 1 (DEA_TR = 0.274) indicates that, given its current level of infrastructure and service quality, the country has the potential to achieve a greater LSCI value. Although Türkiye is not a country with insufficient connectivity, it would also not be accurate to say that it is fully exploiting its existing potential.

5. CONCLUSION

Research findings indicate that the relationship between INFRA, COMP and LSCI is neither straightforward nor one-dimensional, and that factors such as geographical location may also play a decisive role in maritime connectivity. The fact that Baltic countries have relatively low DEA efficiency despite their high levels of INFRA and COMP can be given as an example of this. This finding can be explained by these countries being strongly integrated into continental Europe, with feeder services (Notteboom, 2010), as well as extensive road and railway access to the main hub ports along the Hamburg–Le Havre range.

By contrast, Sri Lanka is able to generate a relatively high level of maritime connectivity with below-average INFRA and COMP values. In this particular case, it appears that the geographical advantage in attracting liner services outweighs the logistics infrastructure and service quality. Similarly, Türkiye stands out as the country with the third-highest DEA efficiency after Spain and Egypt among the Mediterranean basin countries; however, this efficiency level could be raised considerably further through logistics investments.

This study has several limitations. First, the proposed model is designed to assess countries' relative efficiency in transforming their logistics infrastructure and service quality into liner connectivity. It is possible to redesign the model using different criteria, which may in turn lead to different empirical findings. The annual TEU throughputs of countries were not considered as an output and could be incorporated into the model in future studies. The output-oriented research model evaluates the DEA efficiency within specific context of given inputs and output; therefore, efficiency/inefficiency scores reported here should not be interpreted as overall logistics performance of the countries. Finally, the dataset does not include Pakistan, Tunisia and Morocco, for which LPI data were unavailable. In addition, data for Vietnam were not incorporated into the model, which may introduce bias in the DEA results; therefore, it is recommended that Vietnam be included in the sample in future studies.

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Appendix 1: DEA Inputs, Output, and Efficiency Scores by Economy

Economy	LSCI[1]	LPI_INFRA[2]	LPI_COMP[2]	DEA_Eff.
China	1200.0	4	3.8	1.000
Korea. Rep.	625.2	4.1	3.8	0.521
Malaysia	494.6	3.6	3.7	0.458
United States	509.3	3.9	3.9	0.435
Singapore	594.8	4.6	4.4	0.431
Spain	409.8	3.8	3.9	0.359
India	330.9	3.2	3.5	0.345
Sri Lanka	243.1	2.4	2.7	0.338
United Kingdom	373.8	3.7	3.7	0.337
Hong Kong SAR. China	399.2	4	4	0.333
Japan	411.1	4.2	4.1	0.326
Netherlands	393.4	4.2	4.2	0.312
Taiwan. China	344.2	3.8	3.9	0.302
Belgium	353.6	4.1	4.2	0.288
Egypt, Arab Rep.	247.3	3	2.9	0.275
Turkiye	279.0	3.4	3.5	0.274
Indonesia	233.2	2.9	2.9	0.268
Saudi Arabia	273.7	3.6	3.3	0.263
Italy	287.4	3.8	3.8	0.252
Germany	316.9	4.3	4.2	0.246
United Arab Emirates	300.9	4.1	4	0.245
Thailand	264.3	3.7	3.5	0.239
France	260.8	3.8	3.8	0.229
Mexico	180.3	2.8	3	0.215
Panama	202.5	3.3	3	0.214
Colombia	183.2	2.9	3.1	0.211
Philippines	179.0	3.2	3.3	0.186
Greece	194.8	3.7	3.8	0.175
Jamaica	120.0	2.4	2.5	0.167

Peru	125.0	2.5	2.7	0.167
Portugal	176.3	3.6	3.6	0.163
Dominican Republic	127.2	2.7	2.6	0.157
Oman	140.9	3.2	3.2	0.147
Ghana	101.9	2.4	2.5	0.142
Brazil	132.8	3.2	3.3	0.138
Togo	94.0	2.3	2.4	0.136
Congo, Rep.	83.5	2.1	2.9	0.133
Israel	137.0	3.7	3.8	0.123
Australia	149.9	4.1	3.9	0.122
Canada	155.4	4.3	4.2	0.120
Chile	101.2	2.8	3.1	0.120
Bangladesh	82.4	2.3	2.7	0.119
Argentina	99.8	2.8	2.7	0.119
Costa Rica	96.2	2.7	2.9	0.119
Uruguay	96.1	2.7	3.1	0.119
Poland	123.5	3.5	3.6	0.118
Malta	124.8	3.7	3.4	0.116
Djibouti	80.2	2.3	2.8	0.116
Nigeria	82.3	2.4	2.3	0.114
Iraq	72.3	2.2	2.2	0.110
Libya	54.5	1.7	1.9	0.107
Algeria	65.7	2.1	2.2	0.104
South Africa	110.4	3.6	3.8	0.102
Qatar	111.4	3.8	3.9	0.098
Cameroon	60.1	2.1	2.1	0.095
New Zealand	105.1	3.8	3.7	0.092
Iran. Islamic Rep.	60.7	2.4	2.1	0.092
Angola	56.4	2.1	2.3	0.090
Sweden	112.5	4.2	4.2	0.089
Romania	68.8	2.9	3.3	0.079
Honduras	62.7	2.7	2.7	0.077
Slovenia	74.5	3.6	3.3	0.071
Denmark	87.2	4.1	4.1	0.071
Croatia	61.0	3	3.4	0.068
Cambodia	42.5	2.1	2.4	0.067
Lithuania	66.4	3.5	3.6	0.063
Cyprus	50.4	2.8	3.2	0.060
Somalia	33.5	1.9	1.8	0.059
Haiti	31.5	1.8	2	0.058
Gabon	35.7	2.2	2	0.057
Ireland	57.5	3.5	3.6	0.055
Finland	68.3	4.2	4.2	0.054
Norway	62.9	3.9	3.8	0.054

Namibia	43.4	2.8	2.9	0.052
Nicaragua	26.0	1.9	2.8	0.046
Madagascar	24.5	1.8	2.2	0.045
Kuwait	41.2	3.6	2.9	0.045
Venezuela. RB	31.3	2.4	2.5	0.043
Mauritania	24.8	2	2.5	0.041
Georgia	28.4	2.3	2.6	0.041
Latvia	39.8	3.3	3.7	0.040
Cuba	26.0	2.2	2.2	0.039
Guinea	27.6	2.4	2.7	0.038
Sudan	25.8	2.3	2.4	0.037
Bahrain	37.5	3.6	3.3	0.036
Congo. Dem. Rep.	23.5	2.3	2.4	0.034
El Salvador	22.2	2.2	2.7	0.034
Estonia	34.5	3.5	3.7	0.033
Bulgaria	28.4	3.1	3.3	0.031
Iceland	26.4	3.6	3.5	0.024
Liberia	16.7	2.4	2.4	0.023
Albania	12.3	2.7	2.3	0.017

Source: [1]UNCTAD (2025), [2]World Bank Group (2023)