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A Non-Parametric Evaluation of South African Ports

Abstract

A non-parametric evaluation of South African ports is critical due to the current operational and technological issues affecting the South African port. The study framework relies on the Port efficiency theory. The researcher purposively selected the Container Ports of Cape Town, Coega, Durban, East London, and Port Elizabeth. The researcher used secondary data collected from the Transnet Port website to evaluate the port productivity between 2010 and 2023. The Malmquist Productivity Index (MPI) evaluates port efficiency using multiple inputs and outputs over time. The results of the research reveal MPI=1.07 which is a slight improvement in productivity, for the Ports of Cape Town, Coega, and Durban. The Port of East London has a slightly higher Productivity Index of MPI=1.27. Port Elizabeth had MPI=1.09. Based on these results, the researcher recommends that the port management make proper and correct strategic decisions regarding training on the utilization of artificial intelligence and blockchain technology as a tool to facilitate trade.

Keywords: South Africa, Malmquist Productivity Index, Port Productivity, Port Efficiency.

1. Introduction and Background of Study

South African ports and terminals serve as key engines for economic growth for the South African economy [31]. Ports in South Africa are critical to the South African export-led strategy [62] [63]. This research uses data envelopment analysis to evaluate port efficiency and productivity of South African ports from 2010 to 2023. South African ports consist of the Port of Saldanha, Cape Town, Mossel Bay, Port Elizabeth, East London, Durban, and Richards Bay. South African ports are situated on one of the busiest international sea routes, and hence are critical to international maritime transportation [31]. These ports are crucial to the South African economy and the entire Southern African region that imports and exports commodities through South Africa's seven logistics ports. According to Statista [57], in 2022, 67% of South African international trade was done via the sea. [31] Opines that the South African geographical location presents a huge opportunity for investing in a diversified maritime market. Nevertheless, despite these benefits, the ports are overwhelmed with challenges. Over the past few years, the South African ports have been sinking with challenges increasing delays in operations and causing financial losses [66]. In November 2023, more than 60,000 containers were reportedly stuck at sea around the port of Durban due to bad weather conditions and equipment failures, [66]. The Cape Town port experienced backlogs and delays that cost the fruit industry an estimated R2.5 billion in the 2021/2022 season [66].

According to [47], "Port efficiency is a multi-dimensional concept that describes the operational performance, specifically the maximization and optimization of the produced output or the production of a given output with limited possible resources". The efficiency level increases when the port is deliberate about improving its performance relative to that of the other Ports [8]. Efficiency drives port competitiveness.

The focus of this research is to examine the trend and the drivers of port productivity for the selected South African Port. This evaluation serves as an impetus for port management to make proper and correct strategic decisions. Port Evaluation reveals the true state of the Port and enables Port management to make a decisive decision on what can be done to improve port efficiency.

This research aims to examine and evaluate port efficiency and productivity for the following selected South African Ports; to evaluate the container throughput productivity for the selected South African ports from 2010-2023

The following is the sequence of the discussions, Section 2 is the literature review; Section 3 examines the materials and methods and Section 4 focuses on the findings and results. This study concludes with section 5.

2. Review of Literature

This section examines the key concepts of this paper such as evaluation, ports, and efficiency. Seaports have a significant role in global trade by enhancing trade growth [49]. Container ports play a pivotal role in international trade, facilitating the movement of goods and enhancing economic development [17]. There is a direct significant positive effect of seaport efficiency and port throughput on economic growth in Africa [4]. According to [28], "The productivity of a port is a measure that is important to different stakeholders: port administrators (port authority), third-party logistics providers, manufacturers, and consumers, among others". The competitiveness of a container port is dependent on the productivity of its container terminal operations [38]. Port efficiency focuses on terminal operations efficiency and productivity. It relates to the physical quantities of items, the levels of effort expended, the scale or scope of activities, and the efficiency in transforming resources into outputs in the form of products or services [48]. Productivity is commonly defined as a ratio between the output volume and the volume of inputs. In other words, it measures how efficiently production inputs, such as labour and capital, are being used in an economy to produce a given level of output [75].

Performance can be described as the execution of port activities in a manner that meets the goals set by the owners and service providers and fulfills the expectations of the port stakeholders [48]. Port performance and trade facilitation are integral to ensuring the efficiency of maritime transport [65]. Facilitation of maritime trade is pivotal for the seamless and efficient maritime supply chains, including in ports and their hinterland connections [65].

2.1. Taxonomy of the Application of DEA in Port Evaluation

Roll and Hayuth [53] pioneered the application of DEA in a hypothetical port study. Subsequent studies indicate that DEA studies are more contemporary and relevant for port evaluation. Over the years, Data Envelopment Analysis has been used to evaluate port productivity. This section examines the various applications of the Data Envelopment Analysis Malmquist Productivity Index on ports. Table 1 captures fifty such articles in peer-reviewed journals. It reveals the author and year of publication in journals, methods used, inputs, outputs, the DMUs, and the period examined. The review of literature in DEA indicated its application numerously in Asia, America, Latin America, Europe and North America, but few studies in Africa. This paper contributes to the growing body of knowledge on sub-Saharan African port evaluation.

Table 1: Taxonomy of Application of DEA in the Ports Industry

Author/ Year	Title of Journal Article	Methods	Number of DMUs Observed	Period	DMU
[73]	Measuring the contribution of logistics service delivery performance outcomes and deep-sea container liner connectivity on port efficiency	Data Envelopment Analysis	26	2010-2014	Container ports in Denmark, Finland, Iceland, Norway, Sweden and the UK

[1]	Analysis of Sustainable Efficiency of Freight Transport in Major European Economies: An Integrated Multi-Region Input-Output and DEA Approach”,	Multi-region input-output model (MRIO) and Data Envelopment Analysis (DEA)	12	2000-2018	Freight Transport modes in the European Union
[46]	The Drivers of Port Productivity for Selected Indian Ocean Ports Using the Malmquist Productivity Index.	Malmquist Productivity Index	2	2008-2018	Port of Mauritius and Seychelles
[68]	The efficiency analysis of main coastal ports in China	DEA Malmquist Productivity Index Tobit Regression	12	2017-2020	Major Ports is China
[3]	Measuring Saudi ports efficiency using the DEA-MPI method	DEA Malmquist Productivity Index	7	2015-2019	Major Ports in Saudi Arabia
[58]	Multi-element integrated design of marine landscape in sustainable smart ports	DEA Malmquist Productivity Index	9	2012-2020	Smart Ports
[11]	Evaluation and Analysis of Sustainable Development Efficiency of Port Cities in China Using the Super-Efficiency SBM-DEA Model	DEA Malmquist Productivity Index	10	2018-2021	Ports in China

[52]	Nonparametric estimation of allocative efficiency using indirect production theory: Application to container ports in Norway	DEA	8	2010-2016	Norway Ports
[32]	Frontier Analysis of the Container Ports in Taiwan during the COVID Pandemic	Malmquist Productivity Index	4	2018-2022	Ports in Taiwan
[19]	The Impact of Port Total Factor Productivity on Carbon Dioxide Emissions in Port Cities: Evidence from the Yangtze River Ports.	Malmquist Productivity Index	16	2009-2019	Major Ports along the Yangtze River
[42]	Productivity Analysis of Container Port In Malaysia: A DEA Approach	DEA	6	2000-2005	Malaysia Ports
[56]	Assessing the Middle East Top Container Ports Relative Technical Efficiency	DEA	10	2019	Middle East Ports
[2]	An Extended DEA Windows Analysis: The Middle East and East African Seaports	DEA	22	2000-2005	The Middle East and East Africa
[50]	Port Performance in Brazil: A Case Study using Data Envelopment Analysis	DEA	24	2010-2017	Brazilian Ports

[10]	Analysing the Operational Efficiency of Container Ports in Sub-Saharan Africa	DEA	16	2012	Sub Saharan Africa
[39]	Ranking Selected Container Terminals in Africa Using Data Envelopment Analysis	DEA MPI	15	2013-2014	African Ports
[35]	Efficiency and Productivity of Container Terminals in Brazilian Ports (2008-2017)	DEA	20 Container Ports	2019	Container Ports
[61]	Are larger and more complex port more productive? An analysis of Spanish Port Authorities	DEA MPI	26	2019	Spanish Ports
[41]	The Evaluation of The Operational Efficiency of the World's Leading Container Seaports	DEA	20	2012	World Leading container ports
[70]	Analysis of the Efficiency of Port Container Terminals with the use of DEA Method or Relative Productivity Evaluation	DEA	9	2014	European Port
[7]	Productivity Assessment of African Sea Ports	DEA MPI	23	2004-2010	Nigeria, Mozambique and Angola

[12]	Evaluating Impacts of Institutional Reforms on Port Efficiency Changes: Ownership, Corporate Structure, and Total Factor Productivity Changes Of World Container Ports	DEAMPI	98	1991-2004	World Container Ports
[14]	A DEA Model to evaluate Brazilian Container Terminals	DEA	9	2010-2014	Brazilian Ports
[15]	An Application of DEA Windows Analysis to Container Port Production Efficiency	DEA	30	1992-2000	Top 30 Container Port
[51]	DEA Window Analysis for Measuring Port Efficiencies in Serbia	DEA Window Analysis	5	2001-2008	Serbian
[23]	Sources of Efficiency Gains in Port Reform: A DEA Decomposition of a Malmquist TFP Index For Mexico.	DEA MPI	11	1996-1999	Mexican ports
[24]	Assessment of Transit Transport Corridor Efficiency of Landlocked African Countries Using DEA	DEA	15	2008-2013	Landlocked African countries

[44]	Productivity Change in Nigerian Seaports After Reform: A Malmquist Production Index Decomposition Approach	MPI DEA	6	2000-2011	Nigerian
[9]	DEA-Based Malmquist Productivity Index Measure of Operating Efficiencies: New Insights With an Application to Container Ports	MPI DEA	10	2001-2006	China
[67]	Assessment of Port Efficiency in West Africa Using Data Envelopment Analysis	DEA	6	2006-2012	West Africa
[54]	Bootstrapped operating efficiency in container ports: a case study in Spain and Portugal	DEA	35	2008-2014	Spanish and Portuguese Ports
[55]	The Technical Efficiency of Norwegian Container Ports: A Comparison to Some Nordic and UK Container Ports Using DEA	DEA	24	2002-2008	Nordic Ports and the United Kingdom

[22]	Efficiency Assessment of Jazan Port Based on Data Envelopment Analysis	DEA	9	2000-2014	King Saudi Arabia Port
[26]	Efficiency Measurement of Shenzhen Port Using Data Envelopment Analysis	DEA	1	2003-2008	Shenzhen Port
[6]	Seaport Efficiency and Productivity	MPI DEA	18	2012	18th world leading container port 2012
[18]	Productivity in Cargo Handling in Spanish Ports During a Period of Regulatory Reforms	MPI DEA	21	1994-1998	Spanish
[13]	Measuring Efficiency of Indian Ports: An Application Of DEA	DEA	12	2000-2006	India
[40]	Efficiency of Operations in Container Terminals: A frontier method	DEA	6	2003-2010	Malaysia Ports
[15]	The Efficiency Analysis of Container Ports Production Using DEA Panel Data Approaches	DEA Window Analysis	25	2010	Leading container ports
[29]	Impact of Famagusta Port Efficiency on North Cyprus	DEA	1	2010-2015	Port of Famagusta

[33]	Relative Efficiencies of ASEAN Container Ports Based on DEA	DEA	50	2014	Asian Container Port
[45]	Measurement of Efficiency Level in Nigerian Sea Port After Reform Policy Implementation. The Case Study of Onne and Rivers Seaport	DEA	2	2001-2010	Onne and Rivers
[69]	Determinants of Efficiency at Major Brazilian Port Terminals	DEA and SFA	25	2009	Brazilian Ports
[43]	The Impact of Public Reforms on The Productivity of Spanish Ports: A Parametric Distance Function Approach	DEA	27	1986-2005	Spanish
[53]	Port Performance Comparison Applying Data Envelopment Analysis	DEA	Hypothetical 20	1993	Ports
[59]	Container Ports Throughput Analysis: A Comparative Evaluation of China and Five West African Countries	DEA	6	2008-2013	West Africa and China

[60]	Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis	DEA	16	1998	Australian Ports
[27]	Efficiency Analysis of Mediterranean Container Ports	DEA	14	2016	Mediterranean Ports
[71]	Sources of Efficiency changes at Asian container ports	DEA	23	2000-2007	Asian Ports
[72]	The Efficiency of Major Ports Under Logistics Risk In North- East Asia	DEA MPI	13	2005-2007	China, Korea and Taiwan

Source: Author's compilation, 2024

2.2. Port Efficiency Theories

This research relies on two main theoretical frameworks such as the Productivity Evaluation and Efficiency Evaluation theories [6]. This research views productivity in terms of total outputs such as the number of container throughputs that the port handles per day, week, month, and year. Port throughput is the total number of tons loaded and unloaded within a specified period. Throughput is, therefore, the sum of import and export cargoes [59].

Vessel visits are the number of vessels that make use of the port. The Efficiency Evaluation approach deals with the optimal inputs that will give the desired outputs considering limiting resources.

3. Materials and Methods

The South African ports are the material for this research. This research purposively focused on the container Ports in South Africa. Figure 1 displays all the Ports of South Africa.

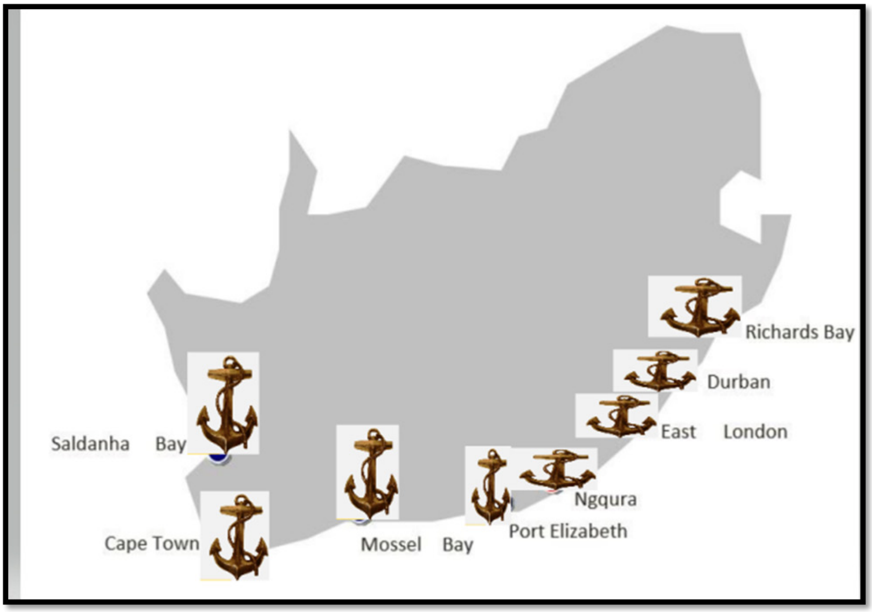

Figure 1: Map of South African Ports
Source: Adapted by the author

3.1. The Port of Cape Town

The Port of Cape Town located in Cape Town, Western Cape is part of Transnet, South Africa [62]. The Port of Cape Town lies in the shadow of Table Mountain approximately 120 nautical miles north-west of Cape Agulhas, strategically positioned at the southern tip of the African continent. The Port of Cape Town serves cargoes moving between Europe and the western hemisphere and the Middle East and Australia, especially containers [62]. The Port of Cape Town is crucial for the exportation of grapes to the Scandinavian countries [64].

3.2. The Port of Coega

The Port of Coega (Ngqura) is the most recently built and developed port in South Africa. It is a deep-water port located on the east coast of South Africa. The Port of Ngqura is an excellent deep-water transhipment hub offering an integrated, efficient and competitive port service for containers in transit to the global market [64].

3.3. The Port of Durban

The Port of Durban is located in Durban and is South Africa's premier multi-cargo port handling over 80 million tons of cargo per annum [63]. Sixty percent of all South African containers are handled at the Durban Container Terminal, the largest of its kind in the southern hemisphere [34]. This port is a critical hub for the entire Southern African region, serving as trade networks to the Far East, Middle East, Australasia, South America, North America, and Europe. It also serves as a transshipment hub for East Africa and Indian Ocean islands [34].

3.4. The Port of East London

The East London Terminal is South Africa's only river port, fully equipped and trading with the world's leading automotive brands [63]. The East London Terminal (MPT) is notable for its large grain silo and the Roll on and Roll off terminal that is located on the South African coastline [63].

3.5. The Port of Port Elizabeth

The Port of Port Elizabeth is managed by Transnet National Ports Authority and is situated in Algoa Bay on the south-eastern coast of Africa, midway between the Ports of Durban and Cape Town [63]

3.6. Research Methods

This is a Quantitative Research Design that makes use of cross-sectional data. This is a retrospective study design. The Malmquist productivity Index is a non-parametric tool for evaluating port productivity over a while. [37] introduced the Malmquist total factor productivity index before its conversion to the frame of DEA. [37] defined a quantity index (QI) as a ratio of distance functions where it evaluates observation relative to an indifference curve (IC). This research uses the DEA-MPI method to examine the efficiency, technology, and drivers of productivity from 2010 to 2023 for the Ports of Cape Town, Coega, Durban, East London, and Port Elizabeth. [58] further attests that the DEA-Malmquist index method is a method for studying the efficiency value of dynamic DEA, which was first proposed by Malmquist as a non-parametric method for measuring total factor productivity. For the evaluation of application efficiency, Data Envelopment Analysis (DEA) can only be used for static efficiency comparison of decision-making units in a certain year, while Data Envelopment Analysis with the introduction of the Malmquist Index can analyze the dynamic efficiency value of the data in consecutive years [58]. Therefore, with regards to the analysis of the efficiency value of ports in several years of the study, this paper chooses the DEA-Malmquist index method for analysis.

The advantage of this approach is that it reveals the time when the differences in impact productivity and efficiency are [36]. According to, [30] the Malmquist index breaks down productivity change into two components: Catch-up captures the change in technical efficiency over time, and Frontier-shift, which captures the change in technology occurring over time. The Malmquist Productivity Index (MPI) measures changes in the total factor productivity between two points by calculating the ratio of the distances of each data point from a common technology [36]. The Malmquist index is a geometric mean of two indices, evaluated concerning period t and period t+1 technologies [25]. Equation (1) shows the Malmquist equation. The Malmquist equation is the product of efficiency change and technological change.

$$M(Y_{t+1}, X_{t+1}, X_t) = \underbrace{\frac{D^t(Y_{t+1,}X_{t+1})}{D^t(Y_{t,}X_t)}}_{Efficiency\ change} \underbrace{\frac{D^t(Y_{t+1,}X_{t+1})}{D^{t+1}(Y_{t+1,}X_{t+1})} X \frac{D^t(Y_{t,}X_t)}{D^{t+1}(Y_{t,}X_t)}}_{Technology\ change}$$

Equation (1): The Malmquist Productivity Index Formula.
Source: Malmquist (1953)

Where:
X_t and X_{t+1} input vectors of dimension at time t and t +1
Y_t and Y_{t+1} corresponding k- output vectors
D_t and D_{t+1} denote an input
D(x,y) = max(ρ: ($s/\rho s \in L(y)$)
(1)

Where L(y) represents the number of all input vectors with which a certain output vector y can be produced, that is L(y) = (x: y can be produced with x).

P in equation (2) can be understood as a reciprocal value of the factor by which the total inputs could be maximally reduced without reducing output.

M= measures the productivity change between periods t and t+1. Productivity declines if M<1, remains unchanged if M=1, and improves if M>1.

According to [74], the results of the MPI can be any of the following:

- DMU0, MPU0>1: A progress occurs in period t+1 ratio to t.
- DMU0, MPU0< 1: A regression occurs in period t+1 ratio to t.
- DMU0, MPU0= 1: No progress or regression occurs in period t+1 ratio to t.

4. Findings/Results

This section examines container outputs in terms of throughput for the Ports of Cape Town, Coega, Durban, East London, and Port Elizabeth. Container throughput is quite critical because it is a major determinant of employment and port productivity. [4] opine that Container port throughput is calculated and measures the volume of container traffic analysed by the Twenty Ft Equivalent Units (TEU) handled by a nation's seaport**.** Port authorities are managers of the port and are engaged in the promotion and development of the port [47].

4.1. The Port of Cape Town

This section examines the trend in the container throughput for the years 2010-2023. The focus of emphasis is on the pre-COVID, COVID-19, and post-COVID era. Figure 3 shows several fluctuations in the container throughput, most especially a 13.2% decrease in container throughput for the Port of Cape Town from 2019 until 2020, which was as a result of the pandemic. However, the port recovered briefly between the period of 2021 and 2022. However, there is a slump of 9.1% in container throughput for the period of 2022 and 2023.

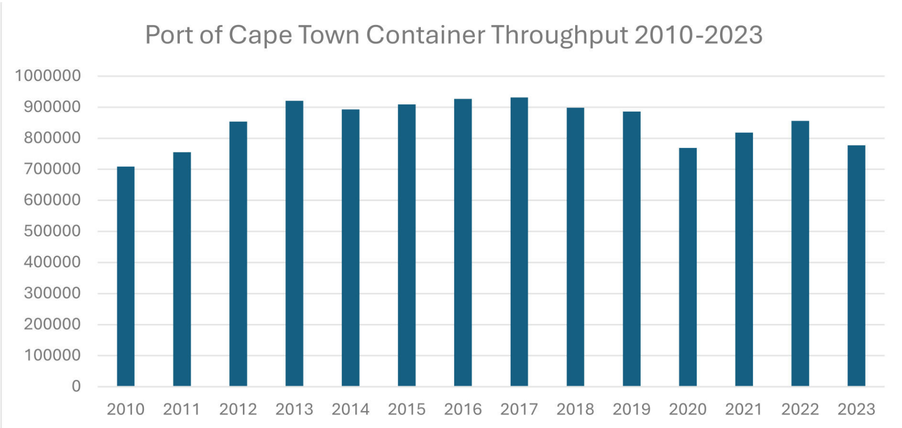

Figure 3: The Port of Cape Town Container Throughput
Source: Made by author according to [64]

4.2. The Port of Coega

This section examines the container throughput fluctuations for the Port of Coega, especially during the pre-COVID, COVID, and post-COVID era. Figure 4 shows several fluctuations in the container throughput, most especially a 23.7% decrease in container throughput for the Port of Coega from 2019 until 2020, which was a result of the pandemic. However, there was a sharp increase of 32.1% in 2021. However, for 2022 and 2023 there has been a steady decline of 16.1% and 5.6% respectively.

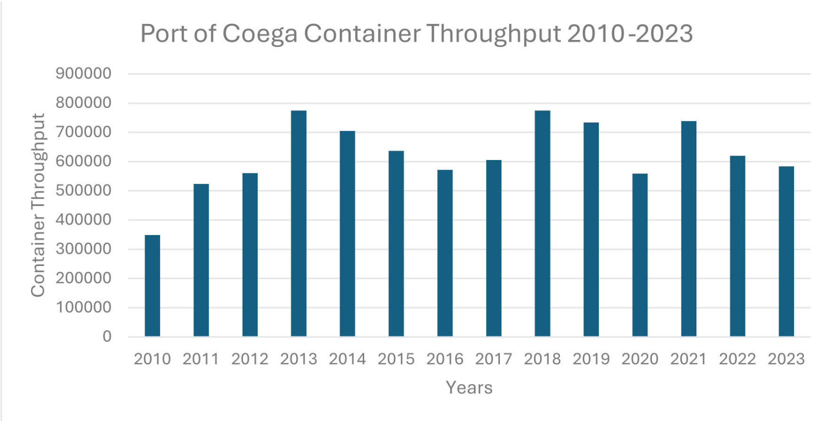

Figure 4: Port of Coega Container Throughput
Source: Made by author according to [64]

4.3. The Port of Durban

This section examines the fluctuations in container throughput specifically for 2019 onwards. Figure 5 shows a decline of 6.3% between 2019 and 2020, due to the pandemic. Like the other ports, the Port of Durban was affected by the COVID-19 pandemic. From then onwards, there has been a gradual decline of 3.2% and 1.2% in container throughput productivity from 2021 to 2023.

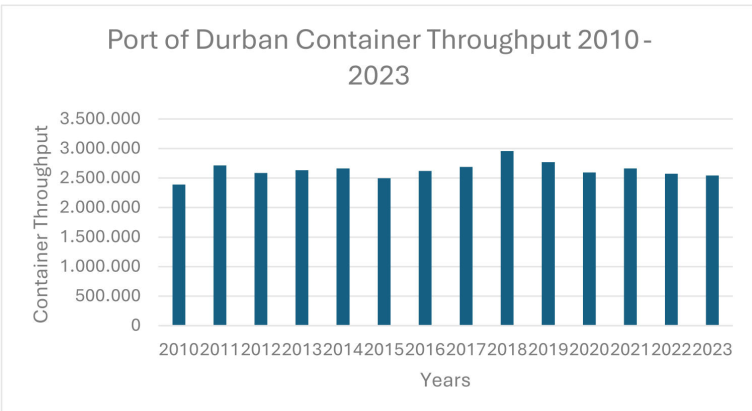

Figure 5: Port of Durban Container Throughput
Source: Made by author according to [64]

4.4. The Port of East London

This section examines the oscillations in container throughput from 2010-2023. However, there has been a very sharp fall in container throughput from 2016 to 2020. Figure 6 shows a 6.2% decline in container throughput for the Port of East London from 2019 to 2020. However, the port experienced an upward increase of 28% and 31.2%, between 2020 and 2022 respectively. Unfortunately, there has been a decline of 7.6% in the container throughput for 2023.

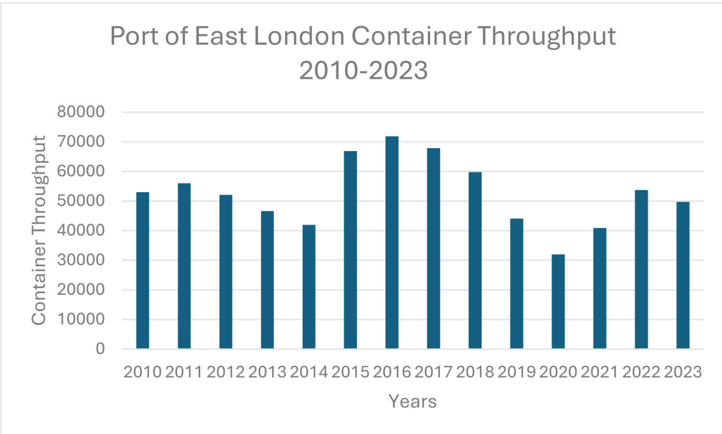

Figure 6: Port of East London Container Throughput
Source: Made by author according to [64]

4.5. Port Elizabeth

This section examines the fluctuations in container throughput specifically for 2010 to 2023. Figure 7, shows a sharp decline of 62% in container throughput for the Port of Port Elizabeth, between 2018 and 2019. From then onwards, there has been a steady increase of 12.8% in container throughput between 2019 and 2020. Amazingly, there was an increase of 13% during the Covid-19 era. The Port container throughput for the Port of Elizabeth was not affected by the pandemic. For the subsequent years, the port has gradually increased in its container throughput output.

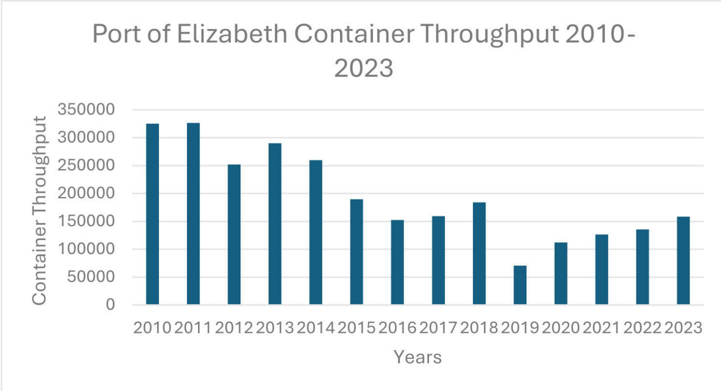

Figure 7: Port Elizabeth Container Throughput
Source: Made by author according to [64]

4.6. The Efficiency Change

This section examines the efficiency change for the selected South African Ports of Cape Town, Coega, Durban, East London, and Port Elizabeth. The Malmquist Productivity Index is the product of the Efficiency Change and Technology Change.

The Pim-Dea V.3.0 software [21], calculates the efficiency change for the selected ports from 2010 until 2023. The inputs include the number of container berths, the number of cranes, the number of tugs, and the length of the quay. The outputs consist of the container throughput.

Table 1 shows the various levels of efficiency for the selected ports. Efficiency change (EC) propels managerial efficiency that causes movement upward or downwards on the production possibility frontier. The Ports of Cape Town, Coega, Durban, East London, and Port Elizabeth, show an average EC=one. This refers to a static efficiency level, therefore revealing no improvement. This result lays credence to the operational challenges affecting the South African Ports.

Table 1: Efficiency Change

Efficiency Change													
Name	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Port of Cape Town	0,96	1,22	0,96	1,06	1,11	0,99	0,98	0,87	0,88	0,93	1,04	1,08	0,92
Port of Coega	1	0,81	1,23	0,96	1,04	0,92	1,04	1,05	1	0,92	1,08	1	0,97
Port of Durban	1	1	0,97	1,03	1	1	1	1	1	1	1	1	1
Port of East London	1,06	1,2	0,78	1,88	1,65	1	1	1	1	1	1	1	1
Port of Port Elizabeth	1	1	1	1	1	1	1	1	1	1	1	1	1

Source: Author, 2024

Table 1 is visually described in Figure 8. The Port of East London in 2013 and 2014 had the EC greater than one. This refers to improvement in efficiency change. However, this increase and operational efficiency tapered off to mean no improvement.

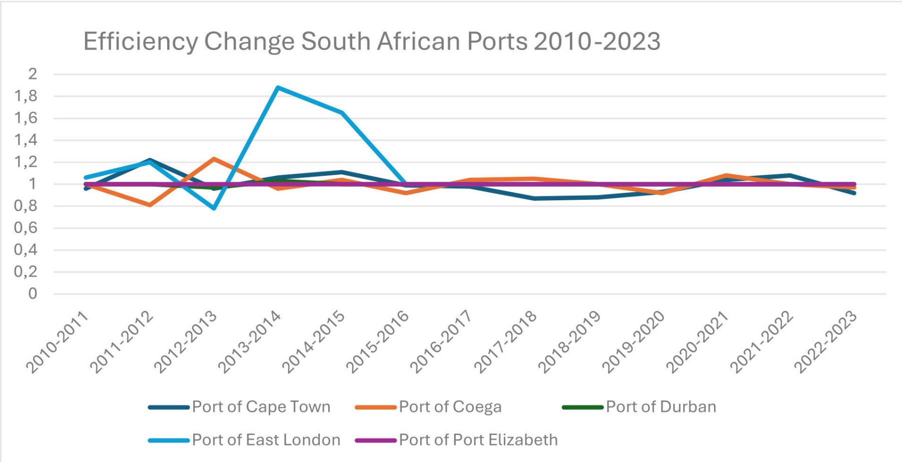

Figure 8: Efficiency Change
Source: Author, 2024

4.7. The Technology Change

The technology change is the other aspect of the MPI. This refers to evaluating the ports based on improvements in technology. There are various technologies being used at these selected ports such as Navis Sparcs N4, General Cargo Operational System (GCOS), and Electronic Data Interchange (EDI). The Pim-Dea V3.0 was used to calculate the technological change, values above 1 represent technological progress in the sense that more can be produced using fewer resources [8]. Technology change (TC) causes an outward shift in the production frontier. When ports have TC=one, then there is no improvement in technology. When TC<one then there is a need for technological advancement. Table 2 illustrates the results of a technological change for the five selected South African Ports. On average, except the Port of East London that shows a slight increase in Technological change, all other ports maintained a TC=1. The spike is depicted in Figure 9.

Table 2: Technology Change

Technology Change													
Name	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Port of Cape Town	1,12	0,93	1,13	0,91	0,91	1,03	1,03	1,1	0,92	0,94	1,03	0,97	0,99
Port of Coega	1,07	0,66	1,17	0,85	0,96	0,98	1,02	1,22	0,9	0,83	1,22	0,84	0,97
Port of Durban	1,22	0,76	1,05	0,98	0,92	1,05	1,03	1,1	0,94	0,88	1,03	0,97	0,99
Port of East London	1	0,77	1,15	0,48	2,21	1,07	0,94	0,88	0,74	0,72	1,28	1,31	0,92
Port of Port Elizabeth	1,05	0,91	1,33	0,57	0,89	0,8	1,04	1,16	0,38	1,59	1,13	1,07	1,17

Source: Author, 2024

Table 2 is visually described in Figure 9. The Port of East London in 2014 and 2016 had a TC greater than one. This refers to improvement in technology change. However, this increase and operational efficiency tapered off to mean no improvement.

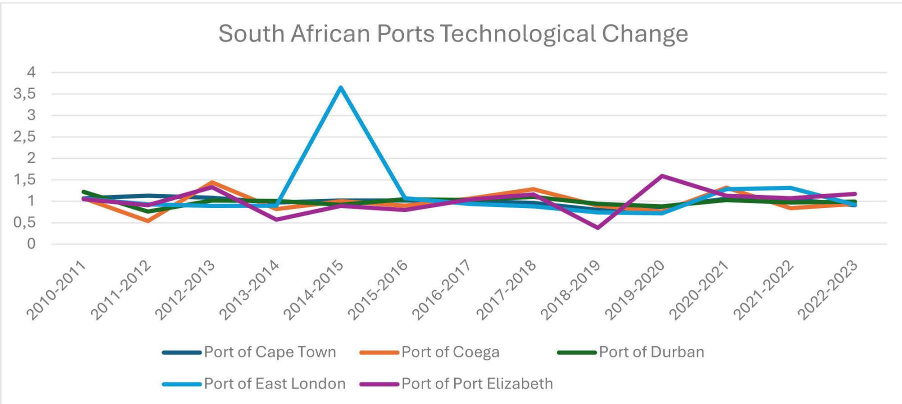

Figure 9: Technology Change
Source: Author, 2024

4.8. The Malmquist Productivity Index

The significance of the Malmquist Productivity Index is its ability to measure productivity over the years. In this case, it is for 2010 until 2023. The Malmquist Productivity Index is calculated by multiplying TC and EC. Where the MPI>one, it implies progress in productivity; where MPI<1, it signifies a decline in productivity, and MPI=one indicates stagnancy. The results of the research reveal on average MPI=1.07 which is a slight improvement in Productivity, for the Ports of Cape Town, Coega, and Durban. The Port of East London has a slightly higher but negligible productivity Index of MPI=1.27. Port Elizabeth had MPI=1.09. Table 3 and Figure 10 provide the MPI results for the five selected ports.

Table 3: The Malmquist Productivity Index

Malmquist Productivity Index													
Name	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Port of Cape Town	1,07	1,13	1,08	0,97	1,02	1,02	1,01	0,96	0,8	0,87	1,06	1,05	0,91
Port of Coega	1,07	0,54	1,44	0,82	1	0,9	1,06	1,28	0,9	0,76	1,32	0,84	0,94
Port of Durban	1,22	0,76	1,02	1,01	0,92	1,05	1,03	1,1	0,94	0,88	1,03	0,97	0,99
Port of East London	1,06	0,93	0,89	0,9	3,65	1,07	0,94	0,88	0,74	0,72	1,28	1,31	0,92
Port of Port Elizabeth	1,05	0,91	1,33	0,57	0,89	0,8	1,04	1,16	0,38	1,59	1,13	1,07	1,17

Source: Author, 2024

Figure 10 shows port productivity of the selected port on average. Even though, MPI is greater than one. The increase was a slight improvement in productivity.

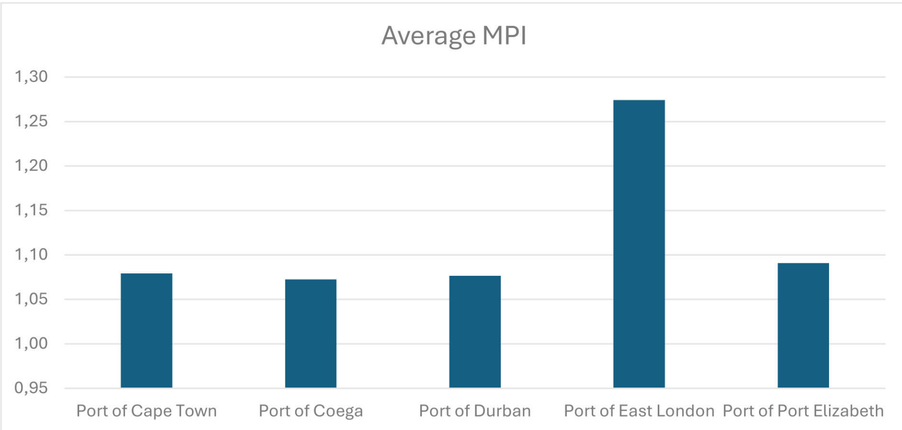

Figure 10: Average Malmquist Productivity Index for Selected South African Ports. Source: Author, 2024

5. Conclusion/Implications/Recommendations

The non-parametric evaluation of South African Ports is quite critical for the South African Port health. The analysis shows that the Port has not improved tremendously in terms of Technology and Operational efficiencies. With the slight increase in productivity, there is room for improvement. The implication of this is tremendous on the Port Stakeholders and South African Economy.

The Malmquist Productivity Index is a crucial tool for measuring productivity. The need for structural changes and Port Reform is pivotal as evidenced in the recent World Bank report that was published in May 2021, which ranked the Ports of Cape Town, Ngqura, Gqeberha, and Durban as 4 of the 5 worst ports in the world in operational efficiency [31].

To enhance productivity, management of logistics and implementation of strategies are crucial [38]. Digitalization is a key to port efficiency. Port efficiency can be enhanced through huge investment in Technology. This study recommends that the South African Ports should invest in new technology such as Block Chain Technology, etc. [65] states that investing in new technology such as interactive data exchange, artificial intelligence, and other new processes allows for increased efficiency and agility in global supply chains. Port Evaluation reveals the true state of the Port and enables Port management to make a decisive decision on what can be done to improve port efficiency.

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