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Assessing the Efficiency of Ports in India, Seychelles and Mauritius-A Non Parametric Approach

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ABSTRACT

The evaluation of port productivity leads to port improvement. The critical positioning of ports requires it to continuously improve since ports are pivotal to the health of a nation's economy. This paper examines the trend in the productivity of selected Africa and South Asian Ports for the period of 2018-2022, using the Malmquist based Data Envelopment Analysis. The review of literature lays further credence to the importance of this paper as there has been a paucity of articles on the efficiency level of these selected Indian Ocean Ports that spans two continents, Africa, and South Asia. Hence, this paper contributes to the growing body of knowledge on the efficiency analysis of ports using Data Envelopment Analysis based Malmquist Productivity Index. Evaluation of port performance contributes to effective policy planning, port improvement and port competitiveness. The result of the research shows that 50% of the port experienced decline in port productivity during the eight years of examination. 30% of the ports showed improvement in productivity and 20% was stagnant in terms of productivity. Indeed the pandemic affected all the selected ports and 66% of the port examined are on the path to full recovery in terms of productivity

1. Introduction.

The evaluation of port efficiency is pivotal to port improvement. When port efficiency is not measured continuous improvement is missing. The onus of evaluating Indian Ocean port lies in ensuring that improvement occurs amongst the selected ports. The Indian Ocean region is quite critical as Kannangara, Collins & Waidyatilake (2018) posits that the Indian Ocean is a key arena for the movement of oil and goods from around the world. Furthermore, this region covers approximately 20% of the world's water surface, a quarter of the world's landmass, and three-quarters of global oil reserves, iron, and tin. The Indian Ocean is home to major sea routes connecting the Middle East, Africa and East Asia with Europe and the Americas. (Kannangara, et al ,2018).

Ports are points of convergence and interface between two geographical domains of freight circulation; the land and the maritime domains (Rodrigue and Notteboom,2020) (Nanyam & Kumar Jha, 2023). The role of maritime ports in the economics of trade and transport is one of great significance and complexity (Merkel & Holmgren, 2017). According to UNCTAD (2021) over 80% of the country's exports are conveyed by sea. The seaports are critical for the seamless facilitation of international trade (Mabrouk, Elmsalmi, Aljuaid, Hachicha, & Hammami, 2022). Nonetheless, Ports are critical to economic activity in offshore areas as they take up the role of both entry and exit point to the world for transportation in the international trade process.(Farzadmehr, Carlan, & Vanelslander, 2023). The Port serves as a lifeline connecting several industries. Farzadmehr et., al (2023) posits that ports also act as a crucial connection between sea and land transport. Hence, facilitating intermodal and multimodal transportation. The implication of over 90% of international trade been done via the sea port is that ba-

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sic needs, niceties and necessities of life which includes, food, medicines, furniture, equipment, tools, clothing and textiles and many other essentials and raw materials are transported via the sea. Hence, the bottle necks and delays at the ports translates to inefficiency and costs of transportation both to government and the transporter.

This give credence to the need for constant evaluation of port performance. Therefore, port evaluation cannot be once off thing; actually constant monitoring of port performance will go a long way to mitigate the operational risks.

Operational risks factors include people, process, systems, that are internal to the ports and external factors. Internal or External disruptions can cause minor or major interruption in port operations. A typical example of a major external interruption is the Covid-19 pandemic. The Covid-19 pandemic disrupted the global supply chain and affected the efficiency of the ports. This study will also examine the recovery of selected Indian Ocean Ports from the Pandemic. This paper contributes to the body of knowledge by evaluating the port performance of selected Indian Ocean ports prior to the Covid -19 and the post Covid-19 pandemic.

The purpose of this research is to determine and evaluate the productivity of selected Indian Ocean Ports, since the efficiency of these ports is pivotal to 28 nations located in three continents. The selected ports are in Africa, Indian and Island Ocean nations. The following is the structure of this article, Section 1 covers the general introduction, Section 2 is devoted to the review of articles; Section 3 explains the research methods, Section 4 discusses the results, Section 5 deals with the conclusion and recommendations.

2. Review of Literature.

The evaluation of port performance is primarily aimed at assisting in improving port operations and providing useful information for port development planning and strategy (Suárez-Alemán, Sarriera, Serebrisky, and Trujillo, 2016). Port performance is measured from the perspective of maritime, terminal and hinterland operations (Rodrigue, Slack and Notteboom, 2013). Port performance is holistic. Failure in one aspect will affect the other areas in the chain. The concept of port performance is formed by two interconnected components; efficiency and effectiveness, however a third component has been added which is resilience, (Notteboom, Pallis and Rodrigue ,2022). Other study posits that there are two main research lines on the performance of seaports, these are productivity-evaluation and efficiency-evaluation (Baran and Gorecka, 2015). Productivity considers actual outputs such as the number of container throughputs that the port handles per day, week, month and yearly. This also includes vessel visits which is the number of vessels that makes use of the port. The productivity evaluation approach includes the ship, receiving and delivery operations. The Efficiency Evaluation approach deals with the optimal inputs that will give the desired outputs. Miller & Hyodo, (2022), posits that port efficiency is the ability of a port to obtain the maximum output under a given amount of inputs. Notteboom, Pallis and Rodrigue (2022) also agrees that Port efficiency is a multi-dimensional concept that refers to operational performance, particularly the maximization of the produced output or the production of a given output with limited possible resources. For the port authority or the port itself as a whole, such competition can serve as a management method to improve the efficiency of port activities. Competition between operators or providers of facilities within the same port can generally increase port efficiency and improve services (Notteboom, et., al 2022).

Transportation efficiency promotes the competitiveness of a supply chain (Coyle et al., 2013). Efficiency is making use of minimum inputs to get maximum outputs (Bogetoft and Lars, 2011). Port efficiency analyses the ability of a port to obtain the maximum output under a given amount of inputs or with the minimum amount of inputs under a given amount of outputs. (Suarez-Aleman. et al., 2016). Port efficiency has become increasingly important because ports are part of the connecting links between different transport modes in the global logistics chain; hence, container terminals are vital to the efficiency of the whole maritime supply chain (Kutin, Nguyen and Vallee, 2017). Efficiency levels in the ports greatly affect the competitiveness of countries as ports represent an essential link in the transportation chain (Infante and Gutierrez, 2013). Beyond their pivotal role in the global trade network, the efficiency of container ports and terminals is also a key issue for operators due to intensifying port and terminal competition worldwide (Kutin et al., 2017).

On the other hand, inefficient port functioning affects the cost of importing and exporting goods, therefore harming the country's competitiveness (Infante and Gutierrez, 2013). A port can also become a significant bottleneck and economic setback in the event of inferior performance. (Low, Wei, Loon and Zhang, 2013).

2.1. The Selected Indian Ocean Ports.

The Indian Ocean region consists of 28 states, spans across three continents and covers 17.5% of global land area. (Kannangara, et.,al 2018). The Ports examined include 13 major ports from India, which are; Deendayal (Kandla), Mumbai, Mormugao, New Mangalore, Cochin, Chennai, Ennore (Kamarajar), Tuticorin (V O Chidambaranar), Visakhapatnam, Paradip and Kolkata (including Haldia) and Jawaharlal Nehru Port. In addition to this, there are the Port of Seychelles and Mauritius. These ports are displayed in Figure 1 and Figure 2.

3. Research Methods.

Data envelopment analysis (DEA) is a methodology for measuring the relative efficiencies of a set of decision-making units (DMUs) that uses multiple inputs to produce multiple outputs. Real input and output data are fundamentally indispensable in conventional DEA. Our focus in this chapter is on basic DEA models for measuring the efficiency of a DMU relative to similar DMUs to estimate a "best practice" frontier. Farhad Hosseinzadeh Lotfi, Masoud Sanei, Ali Asghar Hosseinzadeh, Sadegh Niroomand, Ali Mahmoodirad, (2023).

Figure 1: Selected Ports in India.

Source: Sea News.

Figure 2: Map of the Port of Seychelles and Mauritius.

Source: Britannica, 2024.

MPI deals with efficiency over time, instead of examining the snapshot of performance at one specific time, MPI considers performance (changes) across different periods (Ohene-Asare, 2018). The Malmquist model captures the variations in the port performances in the selected ports over a period. In the computation of DEA MPI, two significant issues are emphasised, firstly it is the efficiency catch up also known as technical efficiency and the boundary shift technological change, which is also known as the technology change. The Malmquist model allows for the determination of the drivers of productivity which could be efficiency or technology. According to Lee, Leem, Woo Lee and Choonjoo Lee (2010) Malmquist Productivity Index(MPI) measures the productivity changes along with time variations and can be decomposed into changes in efficiency and Data Envelopment Analysis technology with DEA like nonparametric approach. Productivity decomposition into technical change and efficiency catch-up necessitates the use of a contemporaneous version of the data and the time variants of technology in the study period. The study period is for 2018-2022.

3.1. Inputs and Outputs.

The inputs and output used for the evaluation of the fourteen ports includes the following;

Number of Container Berths: The number of berths is significant in container port/terminal productivity. This is because the greater the number of berths the more containers that the port can handle.

Number of Cranes: This is important in container productivity. It enhances container productivity. Another factor that could influence port productivity is the presence of newer quay-side gantry cranes (QSG) and their capability to serve large vessels (Turner et al., 2003). Also, the number of cranes at a container terminal has a direct effect on how fast or slow a particular ship is worked on at the terminal because when there are more cranes at the terminal, it increases the number of containers handled per-ship-hour. When there are more ship cranes at a port, the terminal can handle more ships at the same time, and this increases the scalability of the port (Tetteh et al., 2016).

Length of Quay: This is an essential input in container productivity. This is because, the longer the quay, the greater the ability of the container port to increase its productivity. The length of quay also determines the ability of the vessel to turn - around time. This is because it mirrors the size of a ship, which can be granted an allocation at a particular unused berth at a time.

Outputs are:

Container Throughput: The output of a container terminal is seen in the number of TEUs it can clear, tranship or handle. The number of TEUs that a terminal handle determines its productivity (Turner et al., 2003).

4. Results and Discussion.

The essence of the Malmquist Productivity Index lies in the measurement of port productivity over time. It measures the total factor productivity change in instances of multiple inputs and outputs. This section examines the decomposition of the MPI into Efficiency Change and Technology Change.

Where:

Xt and Xt+1 input vectors of dimension at time t and t +1

Yt and Yt+1 corresponding k- output vectors

Dt and Dt+1 denote an input

$$D(x, y) = max\ f_{()}(\rho : (s/\rho s \in L(y))) \quad (1)$$

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

Figure 3: The Malmquist Productivity Index.

$$M\left(Y_{t+1}, X_{t+1}, Y_t, X_t\right) = \underbrace{\frac{D^t\left(Y_{t+1}, X_{t+1}\right)}{D^t\left(Y_t, X_t\right)}}_{\text{Efficiency change}} \underbrace{\left[\frac{D^t\left(Y_{t+1}, X_{t+1}\right)}{D^{t+1}\left(Y_{t+1}, X_{t+1}\right)} X \frac{D^t\left(Y_t, X_t\right)}{D^{t+1}\left(Y_t, X_t\right)}\right]^{1/2}}_{\text{Technological Change}}$$

Source: Malmquist, 1953.

= (x:y can be produced with x).P in equation (1) 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

4.1. Efficiency Change.

Efficiency change indicates the role of managers in ensuring efficiency over time. Table 1, displays the trend in efficiency change for the period of 2015-2022. The Port of Kolkota experienced decline in managerial efficiency from 2016-2019. However, an 8% increase in efficiency change occurred between 2019-2020. However, the decline in managerial efficiency continued for the subsequent years till 2022. Unlike equations, figures are referred to for the first time before submission. Future references should be made after the presentation. The Port of Haldia also had a decline in efficiency for the year 2019-2021. However, a slight increase in efficiency change occurred between 2021-2022. The Port Paradip, Chennai, New Mangalore, Mormugao, Mumbai, Kamaraja and Victoria had a consistent efficiency change of 1.

Table 1: Efficiency Change.

	EFFICIENCY CHANGE						
	EC						
PORT	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Kolkota Doc Syst	1.71	0.63	0.98	0.98	1.08	0.89	0.98
Haldia Doc Syste	0.99	1.01	1	1	0.98	0.98	1.01
Paradip	1	1	1	1	1	1	1
Visakhapatnam	1.21	1	0.99	1.06	0.94	1.09	1
Chennai	1	1	1	1	1	1	1
Chudabaranam	1.05	1	1	1	1	1	0.96
Cochin	1.28	0.9	1.03	1.01	0.99	1.13	0.96
New Mangalore	1	1	1	1	1	1	1
Mormugao	1	1	1	1	1	1	1
JL Nehru	0.85	1.18	1	1	1	1	1
Mumbai	1	1	1	1	1	1	1
Deendayal	1	1	1	1.02	1.15	1.09	0.92
Kamarajah	1	1	1	1	1	1	1
Port Louis	1	0.97	1.03	1	1	0.99	0.91
Port Victoria	1	1	1	1	1	1	1

Source: Osundiran, 2024.

4.2. Technology Change.

Technology change refers to the role of technology in enhancing efficiency. The Port of Paradip, Mormugao, Mumbai, Kamarajah and Victoria, had TC=1 for the 7 years. This means that there was no improvement in Technological change. The Port of Visakhapatnam, New Mangalore, experienced consistent improvement in Technological change. The other ports such as Kolkota, Hadia, Chennai, Chudabranam, Cochin, Jl Nehru, and Port Louis experienced decline in Technology change. Table 2 reflects the trend in Technology Change.

Table 2: Technology Change.

	TECHNOLOGY CHANGE						
	TC						
PORT	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Kolkota Doc Syst	0.33	0.94	0.61	0.61	0.57	0.62	0.58
Haldia Doc Syste	0.6	0.68	0.7	0.63	0.63	0.65	0.64
Paradip	1	1	1	1	1	1	1
Visakhapatnam	1.02	1.59	1.67	1.73	1.81	1.54	1.66
Chennai	0.81	0.98	0.99	1	0.97	0.97	1
Chudabaranam	0.75	0.95	1.03	0.95	1	1	1.07
Cochin	0.4	0.64	0.62	0.67	0.71	0.68	0.85
New Mangalore	2	2	2	2	1.98	1.76	1.66
Mormugao	1	1	1	1	1	1	1
JL Nehru	0.59	0.87	1.08	0.99	0.95	0.96	1.07
Mumbai	1	1	1	1	1	1	1
Deendayal	1	1	1	0.99	0.98	0.97	1.07
Kamarajah	1	1	1	1	1	1	1
Port Louis	0.87	1.01	1.1	1.03	0.95	1.01	1.05
Port Victoria	1	1	1	1	1	1	1

Source: Osundiran, 2024.

4.3. The Malmquist Productivity Index.

Table 3: The Malmquist Productivity Index.

	Malmquist Productivity Index						
	MPI						
PORT	2015-2016	2016-2017	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022
Kolkota Doc Syst	0.57	0.59	0.59	0.6	0.61	0.56	0.57
Haldia Doc Syste	0.6	0.69	0.7	0.64	0.61	0.64	0.64
Paradip	1	1	1	1	1	1	1
Visakhapatnam	1.24	1.59	1.65	1.83	1.69	1.68	1.66
Chennai	0.81	0.98	0.99	1	0.97	0.97	1
Chudabaranam	0.79	0.95	1.03	0.95	1	1	1.03
Cochin	0.52	0.58	0.64	0.68	0.7	0.77	0.82
New Mangalore	2	2	2	2	1.98	1.76	1.66
Mormugao	1	1	1	1	1	1	1
JL Nehru	0.5	1.03	1.08	0.99	0.95	0.96	1.07
Mumbai	1	1	1	1	1	1	1
Deendayal	1	1	1	1.01	1.12	1.06	0.98
Kamarajah	1	1	1	1	1	1	1
Port Louis	0.87	0.98	1.13	1.03	0.95	1	0.95
Port Victoria	1	1	1	1	1	1	1

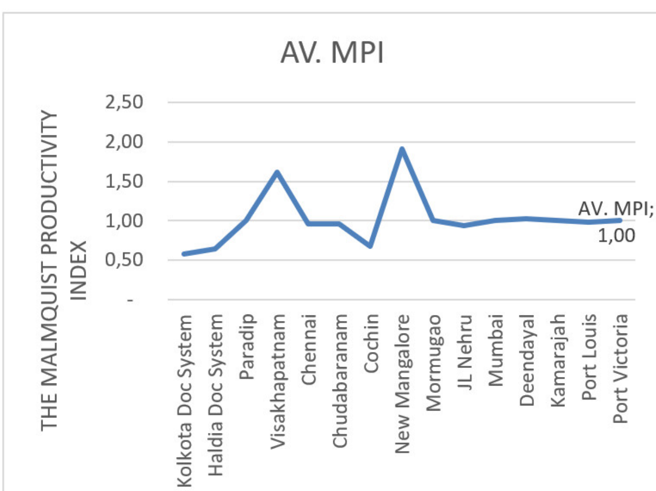
Source: Osundiran, 2024.

The Malmquist productivity Index is a veritable tool for analyzing changes in sea port productivity. The MPI is derived from the product of the Efficiency Change and Technological Change. Table 3 shows the Malmquist Productivity Index. Throughout the years of examination, the Kolkota Doc System, Haldia Doc System, Cochin , had a decline in productivity as indicated by the MPI of less than one. This shows no improvement in the port productivity. The Port of Paradip, Mormugao, Mumbai, Kamaraja and Victoria showed a MPI of 1. This is indicative of the fact that there is no improvement in productivity, hence productivity is stagnant. Ports like Visakhapatnam, New Mangalore showed improvement in productivity for all the years examined. The Port of Deendayal and Port Louis exhibited improvement in productivity for only three years. Furthermore, the port of Mangalore and Deendayal showed productivity during the Covid-era, albeit it was a decline when compared to the previous years.

4.4. The Average Malmquist Productivity Index.

Most of the universities are focused on providing primary maritime education and therefore conduct Bachelor courses in Nautical Science and Marine Engineering. These courses conform to the STCW requirements and prepare the students for a career at sea. However, masters' courses are also conducted on a few subjects. These include shipping management, port management, transportation and logistics, maritime law, marine sciences, coastal management, etc. The PhD courses are more flexible and usually available in broad areas of research related to a variety of maritime fields. Incidentally PhD courses are less frequent than masters' courses.

Figure 4: The Average Malmquist Productivity Index.

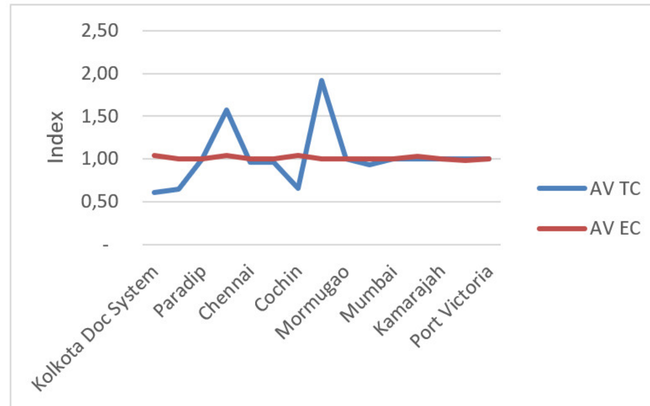


Source: Osundiran, 2024.

Figure 4 displays the overall Malmquist Productivity Index average for the eight years examined. Seven of these ports which includes Kolkota Doc Systesm, Haldia Doc System, Chennai, Chudabaranam, Cochin, J.L Nehru and Port Louis displayed a decline in productivity. However, Ports such as Visakhapatnam, New Mangalore and Deendayal displayed and increase of 62%, 91% and 2% respectively over the period of examination. Ports such as Paradip, Marmugao, Mumbai, Kamaraja and Victoria had an average of MPI=1, which is in indicative of stagnancy in Port productivity.

4.5. The Drivers of Port Productivity.

Figure 5: Drivers of Port Productivity.



Source: Osundiran, 2024.

The drivers of Port Productivity refers to the source or the root of productivity for the selected Ports over the eight year period. From Figure 5, the main drivers of port productivity is Technology. Technology is a driving force that promotes productivity.

4.6. Container Throughput Productivity.

The container throughput is a sure evidence of the productivity of the port. This section examines the productivity of the port from 2015-2022. This period includes the Pre-Covid, Covid and Post Covid era. A close comparison of the year 2020, (since covid actually started towards the end of 2019) and 2021 shows that 60% of the Ports examined experienced decline in port productivity. These are Kolkota Doc System, Haldia Doc System. Chudabaranam,New Mangalore, Mormugao, JL Nehru, Mumbai, Port Louis and the Port Victoria. However, between, 2021 and 2022, 27% of the port experienced a decline in productivity. Container Port Productivity increased for 66.7% of the port examined. So by 2022, Ports such as Kolkota Doc System, Haldia Doc System, Visakhapatnam, Chennai, Chudabaranam, Cochin, New Mangalore, JL Nehru, Kamarajah and Port Victoria have recovered in terms of the container throughput productivity. Even though there has been a steady decline in container throughput productivity for the Port of Mumbai, throughput output remains the same for 2021 and 2022. Table 4, shows that the selected ports are recovering from the aftermath of Covid.

Conclusions.

This research examined 15 Ports over an eight year period. The importance of ascertaining the productivity of the ports lies in enhancing decision making. Even though Covid-19 has gone, we are still in unprecedented times. There is need for Ports to evaluate their productivity in other to enhance their competitiveness.

Table 4: Container Port Productivity for Selected Indian Ocean Port. 2015-2022.

DMU	2015	2016	2017	2018	2019	2020	2021	2022
Kolkota Doc System	528000	578000	636000	640000	652000	675000	538000	570000
Haldia Doc System	102000	85000	136000	156000	178000	169000	149000	165000
Paradip	4000	5000	2000	7000	13000	12000	16000	10000
Visakhapatnam	248000	243000	367000	389000	450500	409000	481000	512000
Chennai	1552000	156000	1495000	1549000	1620000	1384000	1387000	1602000
Chudabaranam	580000	612000	642000	698000	739000	804000	762000	781000
Cochin	366000	419000	491000	556000	595000	620000	690000	736000
New Mangalore	63000	76000	95000	115000	131600	153000	150000	152000
Mormugao	25000	26000	30000	32000	37000	32000	22000	14000
JL Nehru	4467000	449000	4500000	4833000	5133000	5031000	4677000	5685000
Mumbai	45000	43000	43000	42000	27000	27000	25000	25000
Deendayal	0	3000	5000	117000	244000	447000	515000	493000
Kamarajah	0	0	0	3000	57000	128000	198000	480000
Piort Louis	361109	388514	379371	451446	469011	438078	436398	407825
Port Victoria	50069	59682	67893	71632	74487	78677	70279	85634

Source: Osundiran, 2024.

The research showed that the selected Ports Productivity was affected by the pandemic. 60% of the port examined experienced decline in container throughput productivity. The research also indicated that as at 2022, 67% of the Port have recovered from the pandemic interms of the container throughput.

The Malmquist productivity index was used to analyse port productivity in the context of efficiency change and technology change. On average over the eight year period only 20% of the port showed growth in terms of productivity. Whilst 30% of the port showed no improvement in terms of productivity over the examination period. On the other hand 50%, of the ports examined experienced a decline in terms of productivity.

The research was also able to identify, Technology has a major driver or propelling force for productivity. This study hereby recommends the application of technology has a tool to enhance productivity.

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