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THE EFFECT OF PRIVATISATION ON SEAPORT PRODUCTIVITY: A DEA-MPI BASED COMPARATIVE ANALYSIS OF PRE- AND POST-CONCESSION AT THE DAR ES SALAAM MARITIME TERMINAL

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ABSTRACT

Seaports are vital components of the global supply chain, and their efficiency and productivity are critical factors in facilitating international trade and economic development. In response to increasing competition and the need for enhanced performance, many governments around the world have pursued various port reforms, with terminal concessions being one of the most significant strategies. This study assesses the effect of privatisation on seaport productivity by comparing pre-concession operations under a public entity, i.e., Tanzania Ports Authority (TPA), with the post-concession operations under a private entity, i.e., Dubai Ports World (DP World), at Dar es Salaam seaport. The Data Envelopment Analysis-Malmquist Productivity Index (DEA-MPI) model is deployed to reveal the change in efficiency, technology, and productivity over a 12-month period of operations under each terminal operator. The findings show notable disparities in efficiency, technological, and productivity change over the period of analysis. More specifically, the privatisation of container operations has increased operational efficiency, and improved seaport technology and productivity over the period of analysis. The increase in productivity at Dar es Salaam seaport is exhibited in terms of increased cargo throughput and reduced ship turnaround time. The study concluded that terminal concessions can significantly enhance seaport performance when supported by positive efficiency change and technological change.

Introduction

Seaports are vital components of the global supply chain, and their efficiency and productivity are critical factors in facilitating international trade and economic development. In response to increasing competition and the need for enhanced performance, many governments around the world have pursued various port reforms, with terminal concessions being one of the most significant strategies. Terminal concessions involve the transfer of the management and operations of seaport terminals to private companies. The concessionaires are expected to introduce advanced technologies, better management practices and capital investment. Thus, the container terminal concessions are aimed at improving port performance and increasing port competitiveness in the global supply chain through reduced bottlenecks, improved cargo handling operations, shortened ship turnaround times and increased port throughput.

The trend of privatising and granting terminal concessions has become widespread over the past few decades, with seaports across the world adopting this model. Studies show that private sector involvement in port operations can lead to greater innovation, improved service levels and more efficient use of port facilities. For instance, Alaneme *et al*. (2021) and Nwanosike (2014) highlight the positive effect of terminal concessions on the performance of seaports in both developed and developing economies. Nevertheless, terminal concessions are associated with risks, such as reduced public control, loss of job security, underinvestment and poor service quality, if not aligned with stakeholders' goals. Thus, it is imperative to undertake empirical studies to assess the effect of terminal concessions on seaport efficiency and productivity.

In a similar vein, the trend of granting terminal concessions continues to gain traction in Africa, as states seek to optimise seaport operations through advanced technologies and enhanced management practices. For instance, the Tanzania Ports Authority (TPA) entered into a 30-year terminal concession with the DP World in 2023 to operate and modernise the Dar es Salaam seaport, including operations of berths 0-7 (i.e. eight berths). The aim is to modernise the port infrastructure and improve operational efficiency. In this concession agreement, the concessionaire (DP World) is committed to an initial investment of USD250 million, with a potential total investment of USD1 billion, to upgrade the seaport and implement hinterland logistics projects including investments in temperature-controlled storage facilities and improve connections to rail-linked logistics (DP World, 2023). In addition, the concessionaire is expected to connect East Africa and broader Sub-Saharan Africa with global markets, driving economic growth through job creation and enhanced access to products and services and creating value for all stakeholders (DP World, 2023).

Several factors have motivated the awarding of the terminal concession at Dar es Salaam seaport, including terminal operational inefficiency, increased port congestion, prolonged ship turnaround times and inadequate infrastructure (East African, 2023). More specifically, the operational inefficiency limited the seaport's capacity to handle growing demand, disrupting regional supply chains and limited Tanzania's competitiveness in global markets. Further, the effect of operational inefficiency spilled over across multiple stakeholders, including shipping companies, exporters, importers and end consumers, due to increased costs, shipment delays and reduced reliability (UNCTAD, 2022). Nevertheless, while there has been improvement in seaport infrastructure and cargo handling capabilities, questions remain regarding the effect of terminal concession on seaport efficiency and productivity.

This study, therefore, assesses the effect of terminal concession on seaport productivity based on a comparative analysis of pre- and post-concession operations at Dar es Salaam seaport. Specifically, the study seeks to compare the efficiency and productivity of the container terminal under public and private management (i.e., TPA and DP World). This paper is structured as follows: The literature review is presented in section 2; The research methodology is presented in section 3; The results and discussion are presented in section 4; and section 5 presents the conclusions.

Literature Review

Empirical evidence on the relationship between privatisation and seaport productivity suggests that the success of privatisation is often dependent on a variety of contextual factors, including the management of strategic resources (i.e. labour, technology, process). In addition, to rigorously assess the effect of these factors, scholars frequently employ advanced analytical tools, notably non-parametric models like DEA and MPI. This section presents prior studies focusing on the interplay between privatisation and seaport productivity, the effect of seaport strategic resources on productivity and the application of the DEA-MPI model in seaport efficiency and productivity.

Privatization and Seaport Productivity

Ghate (2025) used a regression model to provide an in-depth examination of the policy shift towards seaport privatisation in India. The findings suggest that a Public-Private Partnership (PPP) project incrementally reduces average vessel turnaround time, average pre-berthing delay and manpower, while enhancing average output per berth shift day and overall profit. Cano-Leiva *et al*. (2023) assessed the performance of privately managed solid bulk and general cargo terminals and found them to have enhanced technical efficiency. Antoniou *et al*. (2019) examined the effect of seaport privatisation at Limassol seaport, Cyprus. Adler *et al*. (2022) applied a regression model to estimate the performance of major Indian seaports based on the drivers of efficiency, which includes ownership structure. The results suggest that the average seaport efficiency has increased gradually over time.

Dasgupta and Sinha (2016) applied a Data Envelopment Analysis (DEA) model to assess the effect of liberalisation on the efficiencies of container terminals at major seaports in India. The results show that the efficiencies of container terminals to a large extent are affected by privatisation. Omoke *et al*. (2015) examined the impact of concessions on Nigerian seaports. The results show that berth occupancy and vessel turnaround time improved significantly. Pagano *et al*. (2013) used financial econometric techniques to assess port performance during government operation and private sector operation. The results provide an estimate of the savings and effectiveness gains from privatisation. Heng and Tongzon (2005) measured the seaport efficiency based on the ownership structure. The results show that privatisation is a useful strategy for sports to gain a competitive advantage.

Comprehensive reviews of the impact of seaport privatisation and performance in developing countries are provided by Gong *et al*. (2012) and Vasigh and Howard (2012). While considerable attention has been given to the overall impact of terminal concessions on seaport productivity, understanding the effect of resource constraints on seaport productivity is paramount.

Seaport Strategic Resources and Seaport Productivity

Strategic resources in seaports include a skilled and qualified workforce, financial resources and critical facilities such as wharves, cranes, berths and storage areas. According to the Resource-Based View Theory (RBVT), these resources are crucial in the strategic management of seaports (Witcher, 2020). This study, nonetheless, dwells on the strategic resources that are directly related to the operational performance of the seaport. The literature includes studies that explore the effect of seaport resources on its operational efficiency.

For instance, Matei (2024) assessed the efficiency of Danube seaports based on factors such as seaport infrastructure, storage areas and equipment availability. The study found that ports with well-managed storage areas and strategic resource allocation achieved better efficiency scores. Nduna (2022) analysed the role of infrastructure and superstructure in enhancing terminal performance. The study found that capacity expansion and resource optimisation positively impacts the efficiency and productivity of container terminals. Mokhtar *et al*. (2020) assessed the efficiency of fishing seaports and found that while some terminals operated at optimal efficiency, a significant portion required resource adjustments to enhance efficiency. Abudu *et al*. (2021) analysed the impact of improve infrastructure under terminal concessions in boosting efficiency in Ghanaian seaports. They found that modernising handling equipment improved cargo handling capacity and reduce turnaround times.

Miller and Hyodo (2022) assessed the effect of crane availability and berth length on seaport efficiency in Latin America. Ben Mabrouk *et al*. (2022) examined the relationship between technological advancements and seaport efficiency, and found that advancement of technology has a correlation with seaport efficiency. A study by Caldas *et al*. (2024) found that management models and regional economic conditions determine seaport container efficiency. Ugboma and Oyesiku (2020) conduct a study focusing on Nigerian seaports to examine the effect of handling equipment on seaport operational efficiency. They found that upgrades in handling equipment improve seaport throughput and minimise vessel turnaround times. Ducruet and Itoh (2022) examined the relationship between technological upgrades and ship turnaround times at global container seaports and found that improvement in handling equipment enhance cargo throughput and overall operational efficiency. In the analysis of seaport operational efficiency, researchers and practitioners used various mathematical models. Nonetheless, DEA-MPI models are found to be more effective in this aspect. The next section examines studies from around the world on comparative analysis of seaport efficiency and productivity based on DEA and/or DEA-MPI models.

Application of DEA-MPI Model in the Analysis of Seaport Efficiency and Productivity

There are several studies that deploy DEA and DEA-MPI models to analyze seaport performance (Table 1). These studies use various input and output variables, including storage area, berth length, number of cargo handling equipment, average draft (i.e. draught) and number of workers as input variables; and container throughput and ship calls as output variables.

Table 1: DEA-MPI studies on seaport performance

Author	Scope	Inputs	Output	Method	Time Period
Atsunyo and Tetteh (2025)	Global ports efficiency and productivity	Number of berths, Quay length, Number of cranes, Number of terminals, Maximum draught	Annual cargo throughput	DEA-MPI	2015-2023
Ibeh (2025)	Comparative analysis of container port performance in West Africa	Terminal area, Quay length, Bridge cranes, Reach Stackers	Throughput	DEA-SBM, DEA-MPI	2010-2022
Danladi *et al*. (2025)	Productivity change in container ports within worldwide lower middle-income countries	Berth length, Storage area, Equipment	Container throughput	DEA-MPI	2001-2012
Nguyen *et al*. (2024)	Assessment of analysis of seaport operators in Vietnam	Total assets, Owner's equity, Liabilities, Operational expenses	Revenue, Net profit	DEA-MPI	2015-2020
Tetteh *et al*. (2024)	Impact of privatization on terminal efficiency	Number of berths, Quay length, Maximum draught, Number of quay cranes	Container throughput, Ship calls, Waiting time	DEA-CCR	2007-2021

Nong and Duc-Son (2023)	Port efficiency evaluation	Capital, Operational expenses, Labor	Revenue and cargo throughput	AHP, DEA-MPI	2015-2021
Li *et al*., (2022)	Operational efficiency and total factor productivity of container terminals in China	Number of employees, Number of berths, Total length of berths, Number of equipment	Container terminal throughput, Net cargo weight	DEA-SBM, MPI	2017-2020
Bernal *et al*. (2022)	Efficiency analysis of Spanish container ports	Container yards, Equipment, Gantry cranes, Berth length, Berth depth	Finish time, Ship calls	DEA-CCR, MPI-DEA	2019-2020
Ben Mabrouk *et al*. (2022)	Evaluation of the technical efficiency and the change in productivity of the most important Tunisian seaports	Number of berths, Number of gears, Number of workers	Volume of cargo	DEA-MPI	2005-2016
Kang *et al*. (2021)	Comparative analysis of productivity and efficiency of container terminals in Busan new port	Berth length, Number of quay cranes, Terminal area	Container throughput	DEA-MPI	2017-2019
Iyer and Nanyam (2021)	Technical efficiency analysis of container terminals in India	Draft, Quay length, Yard area, Quay cranes, Yard equipment	Container throughput	DEA-MPI	2015-2018
Adeola Osundiran *et al*. (2020)	Evaluating port efficiency of Sub-Saharan African ports	Number of berths, Number of cranes, Number of tugs, Length of the quay	Container throughput	DEA-MPI	2008-2015

Ngangaji (2019)	Efficiency of container terminals in East Africa ports	Quay length, Terminal area, Number of ship-to-shore gantry cranes, Rubber tyre gantry cranes, Rail mounted gantry cranes, Mobile cranes, Reach stackers, Forklifts, Empty handlers, Terminal tractors	Container throughput, Ship calls	DEA	2008-2018
Kalgora *et al*. (2019)	Efficiency of five main seaports along the West African coast	Labour, Quayside cranes, Yard gantry cranes, Reach stackers, Quay length, Terminal area, Draught	Container throughput	DEA	2005-2016
Van Dyck (2015)	Efficiency of six major dedicated terminals in West Africa	Total quay length, Terminal area, Number of quayside cranes, Number of yard gantry cranes, Number of reach stackers	Container throughput	DEA	2006-2012
Baran and Górecka (2015)	Seaport efficiency and productivity of 18 world leading container ports	Number of berths, Terminal area, Storage capacity, Quay length	Annual container throughput	DEA-MPI	Cross-sectional (2012)
Almawsheki and Shah (2015)	Efficiency of 19 container terminals in the middle eastern region	Terminal area, Quay length, Quay cranes, Yard equipment, Maximum draft	Container throughput	DEA	Cross-sectional (2012)

Source: Authors' Compilation from Literature (2025)

Table 1 gives the justification for the application of the DEA-MPI model for measuring the productivity of the container terminal at Dar es Salaam seaport during the pre-concession and post-concession. This analytical approach provides a robust framework for measuring the relative efficiency of ports and tracking productivity changes over time, offering valuable insights beyond simple performance indicators. The DEA-MPI model is detailed in the next section.

Research Methodology

This section outlines the research methodology employed to compare pre- and post-concession terminal performance at the Dar es Salaam seaport. The section begins with a description of the study area, followed by the identification and operationalisation of variables relevant to the research objective. Subsequently, the description for data collection is detailed. Finally, the section presents the DEA-MPI approach for measuring the efficiency and productivity of seaports.

Study Area

This study focuses on the Dar es Salaam seaport, Tanzania's main seaport and a critical gateway for East and Central Africa. The seaport handles over 90% of Tanzania's international trade and connects the landlocked countries of Burundi, Rwanda, Malawi, Zambia and DRC Congo to global markets (Massami & Manyasi, 2021). Recently the seaport operations have been concessioned to a private operator (DP World) with the view of modernizing the seaport and increasing its efficiency. Nonetheless, the privitisation of terminal operations to the DP World has sparked public debate on whether the concessionaire has improved the seaport's productivity through increased operational efficiency and technological change. This study seeks to give scientific evidence on the status of the seaport's productivity, pre- and post-concession.

Variables

The core function of a seaport container terminal is to handle containers from ships and overland transport modes. Thus, container throughput and ship turnaround times were selected as output variables, while storage area capacity, utilised berth length, number of workers, cargo handling equipment, operational equipment and average draft (berth depth) were selected as input variables, as indicated in Table 2. The selected variables are suggested by various studies as they are related to measuring the efficiency and productivity of ports (Lin *et al*., 2014; Mwendapole, 2015; Adeola Osundiran *et al*., 2020; Ben Mabrouk *et al*., 2022). Further, container throughput was selected as an output variable since it is a metric used by all seaports to determine trade volume (Nganganji, 2019).

Table 2: Input and output variables for DEA-MPI model

Input Variables	Output Variables
X_{1k} =Storage area capacity (m^2)	Y_{1k} = Container throughput
X_{2k} =Berth length (m)	Y_{2k} = Average ship turnaround time
X_{3k} =Average draft (m)	
X_{4k} = Number of workers	
X_{5k}= Cargo handling equipment	
X_{6k} =Operational equipment	

Source: Authors' Compilation (2025)

Data Description

Types of data determine specific objective(s) of the study and vice versa (Al Iraqi *et al.*, 2014). The data were collected from secondary sources, primarily official statistics provided by the TPA and DP World. The two entities entered into a concession agreement in October 2023. The datasets span two distinct periods: July 2021 to June 2022, representing the pre-terminal concession phase under TPA management, and July 2024 to June 2025, representing the post-terminal concession phase under DP World management. The raw data were examined to determine missing values, outliers, and inconsistencies**.** To ensure comparability across Decision-Making Units (DMUs), all variables were standardised into consistent measurement units**.** It is worth noting that the choice of July 2021 to June 2022 as the pre-concession period, instead of July 2022 to June 2023 and July 2023 to June 2024 periods, was due to the unavailability of TPA's statistical data during the July 2022 to June 2023 period and incomplete of statistical data for both entities during the July 2023 to June 2024 period since DP World officially started full operations at the Dar es Salaam seaport in April 2024. Therefore, the July 2021 to June 2022 and July 2024 to June 2025 data were used for input and output variables of TPA and DP World respectively as indicated in Tables 3, 4 and 5. However, the exclusion of the data during the July 2022 to June 2023 and July 2023 to June 2024 periods is a potential limitation of this study.

Table 3: Input variables on seaport infrastructure and physical capacity

Period	TPA 2021-2022			DP World 2024-2025		
	Storage Area Capacity (m²)	Berth Length Utilized (m)	Average Draft (m)	Storage Area Capacity (m²)	Berth Length Utilized (m)	Average Draft (m)
July	2,600	1,580	11.5	2,600	1,580	14.5
August	2,600	1,580	11.5	2,600	1,580	14.5
September	2,600	1,580	11.5	2,600	1,580	14.5
October	2,600	1,580	11.5	2,600	1,580	14.5
November	2,600	1,580	11.5	2,600	1,580	14.5
December	2,600	1,580	11.5	2,600	1,580	14.5
January	2,600	1,580	11.5	2,600	1,580	14.5
February	2,600	1,580	11.5	2,600	1,580	14.5
March	2,600	1,580	11.5	2,600	1,580	14.5
April	2,600	1,580	11.5	2,600	1,580	14.5
May	2,600	1,580	11.5	2,600	1,580	14.5
June	2,600	1,580	11.5	2,600	1,580	14.5

Source: TPA (2021/2022) and DP World (2024/2025) monthly statistical bulletin

From Table 3, it is observed that both TPA and DP World utilise equal land and quay space, namely 2,600 square metres of storage area and 1,580 metres of berth length. Thus, any observed variations in port performance between the two operators would be attributable to differences in other variables, including operational management, technology and labour efficiency. The notable change lies in the average berth depth (i.e. draft), which has increased from 11.5 metres under TPA management to 14.5 metres under DP World management. The increase in draft could have major operational implications, including accommodation of larger vessels.

Table 4: Work force input variable

Period	TPA 2021-2022	DP World 2024-2025
	Number of Workers	Number of Workers
July	1,706	480
August	1,706	480
September	1,706	480
October	1,706	480
November	1,706	480
December	1,706	480
January	1,706	480
February	1,706	480
March	1,706	480

April	1,706	480
May	1,706	480
June	1,706	480

Source: TPA (2021/2022) and DP World (2024/2025) monthly statistical bulletin

Table 4 shows that TPA employed 1,706 workers at a time, whereas DP World operated with only 480, a workforce reduction of over 70%. The significantly reduced labour force under DP World suggests a strategic shift toward automation, lean operations and process optimisation. This transition reflects global best practices in port management, where human resources are effectively utilised alongside technology to achieve higher productivity.

Table 5: Container terminal equipment input variable

Periods	**TPA 2021-2022**		**DP World 2024-2025**	
	Handling Equipment	Operational Equipment	Handling Equipment	Operational Equipment
July	42	448	66	537
August	42	448	66	537
September	42	448	66	537
October	42	448	66	537
November	42	448	66	537
December	42	448	66	537
January	42	448	66	537
February	42	448	66	537
March	42	448	66	537
April	42	448	66	537
May	42	448	66	537
June	42	448	66	537

Source: TPA (2021/2022) and DP World (2024/2025) monthly statistical bulletin

Table 5 shows a marked increase in equipment provision following the terminal concession to DP World. The total number of cargo handling and operational equipment increased significantly, with DP World operating 66 cargo handling equipment compared to 42 equipment operated with TPA, an increase of 57 per cent. For operational equipment, DP World operates with 537 units versus the 448 run by TPA, an increase of 20%.

The increase in cargo handling and operational equipment could result in faster ship turnaround and increased container throughput.

Table 6: Container throughput and ship turnaround time

Period	TPA 2021-2022		DP World 2024-2025	
	Port Container Throughput (TEUs)	Avg. Ship Turnaround Time (Days)	Port Container Throughput (TEUs)	Avg. Ship Turnaround Time (Days)
July	55,030	10	165,752	3
August	90,678	9	198,291	3
September	64,740	10	197,319	2
October	89,902	9	187,284	3
November	59,263	13	183,685	2
December	88,959	11	196,186	3
January	58,922	10	189,312	3
February	88,412	10	195,484	2
March	61,996	9	204,015	3
April	84,026	12	216,312	2
May	59,332	9	228,844	2
June	84,218	9	230,868	2

Source: TPA (2021/2022) and DP World (2024/2025) monthly statistical bulletin

From Table 6, the monthly average container throughput achieved by private operator DP World is 199,446 TEUs against 73,790 TEUs by public operator (i.e. TPA), or an improvement of approximately 170%. Similarly, the average ship turnaround time by DP World is 2.5 days compared with TPA's 10.1 days, a reduction of 75%. Thus, the implementation of the terminal concession has reduced seaport congestion and demurrage charges to shipping lines. More specifically, the shipping companies had been transferring the demurrage charges to Tanzanian exporters and/or importers. It should be noted that exporters and/or importers always take into account these costs as part of their total logistics costs. This has affected the competitiveness of Tanzanian exports and increased the price of imported goods in the local market.

Methods for Measuring Efficiency and Productivity

The purpose of the study was to compare the productivity of Dar es Salaam seaport container terminal, pre- and post-concession. To this end, the study develops and applies a mathematical model which combines the Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI), and hence known as the DEA-MPI model. The DEA model is used for efficiency measurement while the MPI is used for computing the productivity level.

Data Envelopment Analysis (DEA)

The DEA model is a non-parametric method for gauging the efficiency of Decision-Making Units (DMUs). The DEA approach has recently attracted many scholars and is often chosen over other approaches in efficiency determination (Adeola Osundiran *et al.*, 2020). On the one hand, Charnes *et al*. (1978) proposed an input-oriented DEA model, which assumes Continuous Returns to Scale (CRS). Banker *et al*. (1984) introduced the output-oriented DEA model, which assumes Variable Returns to Scale (VRS) to address alternative sets of assumptions. This study uses the VRS model as stated in Equation (1):

$$\begin{aligned} & Max\ \phi \\ & \text{S.t} \quad x_{it} - \sum \lambda_k x_{ik} \geq 0, \qquad \forall i \in \{1,2,\dots,I\},\ \forall k \in \{1,2,\dots,K\} \\ & \qquad -\phi y_{jt} + \sum \lambda_k y_{jk} \geq 0, \qquad \forall j \in \{1,2,\dots,J\},\ \forall k \in \{1,2,\dots,K\} \\ & \qquad \sum \lambda_k = 1, \qquad \forall k \in \{1,2,\dots,K\} \\ & \qquad \lambda_k \geq 0, \qquad \forall k \in \{1,2,\dots,K\} \end{aligned} \quad (1)$$

Where:

ϕ: The efficiency score of the DMU under consideration (DMU_k). When $\phi=1$, the DMU_k is efficient (on the frontier); when $\phi < 1$, the DMU_k is inefficient (below the frontier), and ϕ suggests the proportional increase in outputs needed to be efficient.

x_{ik}: Amount of input i used by DMU_k.

x_{it}: Inputs of the DMU being evaluated.

y_{jk}: Amount of output j used by DMU_k.

y_{jt}: Outputs of the DMU being evaluated.

λ_k: Weights are assigned to peer DMUs and show which DMUs are used to form the efficient frontier.

$k \in \{1,2,\dots,K\}$ represents the total number of DMUs.

It is worth noting that ϕ, defines an efficiency change (EFFCH) reported by DEAP Version 2.1 Software.

Malmquist Productivity Index (MPI)

The MPI is a method for measuring productivity change over time. It uses DEA results to measure the productivity change, between two periods t and t+1. The MPI decomposes productivity change into two components, namely efficiency change (Catch-up) and technological change (Frontier shift). The efficiency change (EFFCH) demonstrates how much a DMU has moved closer to (or further from) the efficiency frontier meanwhile the technological change (TECHCH) demonstrates how much the frontier itself has shifted over time due to innovation or industry-wide improvements. In order to measure the productivity of the container terminal, the MPI uses the Total Factor Productivity Index (TFPI) to measure the TFP change between two data points by computing the ratio of the distances of each data point relative to a common technology. This study uses the output-based MPI adapted from Fare *et al.* (1994).

If the period t+1 technology is used as the current period technology, the TFPI of the Output-Oriented MPI between period t (the base period) and period t+1 (the current period) is the ratio of the output-oriented distance functions between two periods and is given by equation (2

$$M_k(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{\delta_k^{\ t+1}(x_{t+1}, y_{t+1})}{\delta_k^{\ t+1}(x_t, y_t)}$$

Where $\delta_k^{(t+1)}(x_{t+1}, y_{t+1})$ represents the distance from the period t+1 to period t. A value of M_k>1, indicates positive TFP growth from period t to period t+1 while a value of M_k<1, indicates a TFP decline. Generally, productivity between period t and t+1 declines if M_k<1, it remains unchanged if M_k=1, and it improves if M_k>1.

Fare *et al*. (1994) specifies the TFPI of the Output-Oriented MPI between period t (base period) and period t+1 (the current period) as the geometric mean of two indices and is given by equation (3)

$$M_k(x_t, y_t, x_{t+1}, y_{t+1}) = \left[\frac{\delta_k^{\ t+1}(x_{t+1}, y_{t+1})}{\delta_k^{\ t}(x_t, y_t)} \times \frac{\delta_k^{\ t}(x_{t+1}, y_{t+1})}{\delta_k^{\ t+1}(x_t, y_t)}\right]^{\frac{1}{2}}$$

Where y_t and y_{t+1} represent vector of outputs in period t and t+1 respectively; and x_t and x_{t+1} represent vector of inputs in period t and t+1 respectively. Similarly, the Malmquist TFPI can be expressed in another form as given by equation (4)

$$M_k(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{\delta_k^{\ t+1}(x_{t+1}, y_{t+1})}{\delta_k^{\ t}(x_t, y_t)}\left[\frac{\delta_k^{\ t}(x_{t+1}, y_{t+1})}{\delta_k^{\ t+1}(x_{t+1}, y_{t+1})} \times \frac{\delta_k^{\ t}(x_t, y_t)}{\delta_k^{\ t+1}(x_t, y_t)}\right]^{\frac{1}{2}}$$

The ratio outside the square bracket measures the change in the Farrel Technical Efficiency between period t+1 and t, which is equivalent to the ratio of Technical Efficiency in period t+1 to the Technical Efficiency in period t (Farrel, 1957). The remaining part of the equation (4) represents Technological Change, which is the geometric mean of the shift in technology between the two periods t and t+1 (Adeola Osundiran *et al*., 2020). It is important to note that the DEA-MPI model involves estimation of four (4) distance functions in equation (3), which leads to four (4) Linear Programming (LP) problems. Based on equation (1)

$$
\begin{aligned}
& Max\ \phi = \delta_k{}^{t+1}(x_{t+1}, y_{t+1}) \\
& \text{S.t} \quad x_{it+1} - \sum \lambda_k x_{ik} \geq 0, \quad \forall i \in \{1,2,\dots,I\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad - \phi y_{jt+1} + \sum \lambda_k y_{jk} \geq 0, \quad \forall j \in \{1,2,\dots,J\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad \sum \lambda_k = 1, \quad \forall k \in \{1,2,\dots,K\} \\
& \quad \lambda_k \geq 0, \quad \forall k \in \{1,2,\dots,K\}
\end{aligned}
\tag{5}
$$

$$
\begin{aligned}
& Max\ \phi = \delta_k{}^{t}(x_{t+1}, y_{t+1}) \\
& \text{S.t} \quad x_{it+1} - \sum \lambda_k x_{ik} \geq 0, \quad \forall i \in \{1,2,\dots,I\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad - \phi y_{jt+1} + \sum \lambda_k y_{jk} \geq 0, \quad \forall j \in \{1,2,\dots,J\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad \sum \lambda_k = 1, \quad \forall k \in \{1,2,\dots,K\} \\
& \quad \lambda_k \geq 0, \quad \forall k \in \{1,2,\dots,K\}
\end{aligned}
\tag{6}
$$

$$
\begin{aligned}
& Max\ \phi = \delta_k{}^{t+1}(x_{t}, y_{t}) \\
& \text{S.t} \quad x_{it} - \sum \lambda_k x_{ik} \geq 0, \quad \forall i \in \{1,2,\dots,I\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad - \phi y_{jt} + \sum \lambda_k y_{jk} \geq 0, \quad \forall j \in \{1,2,\dots,J\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad \sum \lambda_k = 1, \quad \forall k \in \{1,2,\dots,K\} \\
& \quad \lambda_k \geq 0, \quad \forall k \in \{1,2,\dots,K\}
\end{aligned}
\tag{7}
$$

$$
\begin{aligned}
& Max\ \phi = \delta_k{}^{t}(x_{t}, y_{t}) \\
& \text{S.t} \quad x_{it} - \sum \lambda_k x_{ik} \geq 0, \quad \forall i \in \{1,2,\dots,I\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad - \phi y_{jt} + \sum \lambda_k y_{jk} \geq 0, \quad \forall j \in \{1,2,\dots,J\},\ \forall k \in \{1,2,\dots,K\} \\
& \quad \sum \lambda_k = 1, \quad \forall k \in \{1,2,\dots,K\} \\
& \quad \lambda_k \geq 0, \quad \forall k \in \{1,2,\dots,K\}
\end{aligned}
\tag{8}
$$

In order to solve the DEA-MPI model, the Data Envelopment Analysis Program (DEAP) Version 2.1 was used.

Results and Discussions

This section presents the empirical findings and critically discusses the results derived from the pre-and post-concession productivity of container terminals at Dar es Salaam seaport. The discussion begins by detailing the input and output variables used in the analysis and their descriptive statistics. Following this, the efficiency change is analysed to determine if each DMU is moving closer to or further from its respective production frontier, reflecting improvements or declines in how efficiently known technology is applied. The third subsection focuses on technological change, which captures shifts in the production frontier itself, representing innovation and the adoption of new technologies. Then the total factor productivity for each DMU is discussed to give a broad measure of their productive performance. Finally, a comparative ranking of pre- and post-concession productivity at the Dar es Salaam seaport is presented to highlight their relative performance and competitive edge.

Comparison of the Values of Input and Output Variables Between TPA and DP World

This sub-section provides a comparative analysis of systematically selected inputs and outputs from the terminal operations of the Tanzania Ports Authority (TPA) and DP World. The variables analysed encompass terminal infrastructure and physical capacity, labour force, operational and handling equipment, container throughput, and ship turnaround time. The input variables of the two terminal operators are analysed first, followed by the analysis of their output variables.

Comparison of Infrastructure and Physical Capacity

The values of the input variable related to infrastructure and physical capacity managed by TPA and DP World are depicted in Figure 1.

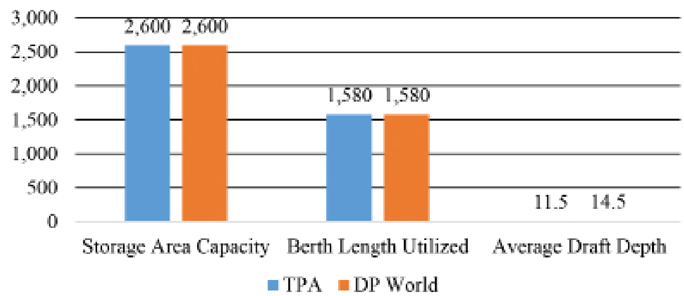

Figure 1: Comparison of infrastructure and physical capacity between TPA and DP World
Source: TPA (2021/2022) and DP World (2024/2025) statistical bulletin

From Figure 1, it is revealed that both terminal operators have equal storage area capacity (2,600 m^2), and berth length (1,580 m). However, DP World has the advantage of operating at an average draft of 14.5 metres (i.e. after dredging) compared to TPA which operated when the average draft was only 11.5 metres. A deeper draft enables DP World to accommodate larger vessels which previously could not be handled by the Dar es Salaam seaport. In addition, the deeper draft under DP World entails more seaport throughput. Thus, DP World is expected to be more productive than TPA.

Comparison of Labour Force Utilization

The values of the input variable related to labour force utilisation by TPA and DP World are depicted in Figure 2. The reduction in workforce under DP World suggests a shift toward automation, lean operations and process optimisation, which are hallmarks of modern terminal operations. The intensive use of technology reflects the best global practices in seaport management, where human resources are effectively utilised alongside technology to achieve higher productivity. On the one hand, the reduction of employees leads to job losses, which conflicts with one of the seaport's objectives of job creation. On the other hand, an efficient port enables seamless global supply chains and, thus, creates jobs in other sectors. Based on the two contrasting views, a further study is welcome to assess whether the terminal concession has created more jobs for Tanzanians. Furthermore, port efficiency is increased if container throughput and/or vessel turnaround times are maintained or increased despite the reduction in workforce.

In Figure 2, the higher bar with 1,706 workers represents TPA 2021-2022 meanwhile the shorter bar with 480 workers represents DP World 2024-2025

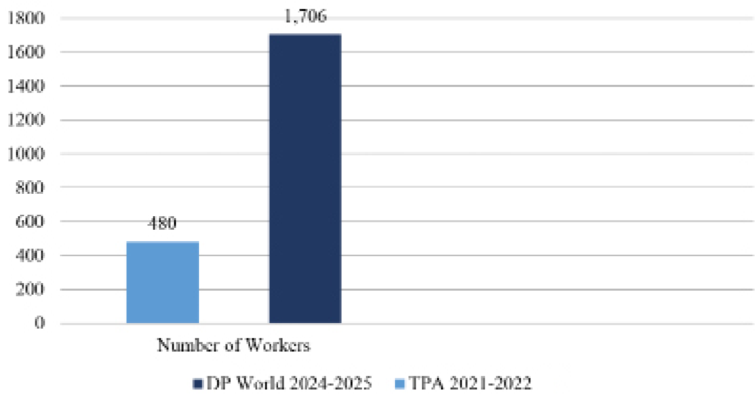

Figure 2: Number of workers

Source: TPA (2021/2022) and DP World (2024/2025) statistical bulletin

Comparison of Equipment Utilization

The values of the input variable associated with equipment utilization by TPA and DP World are depicted in Figure 3.

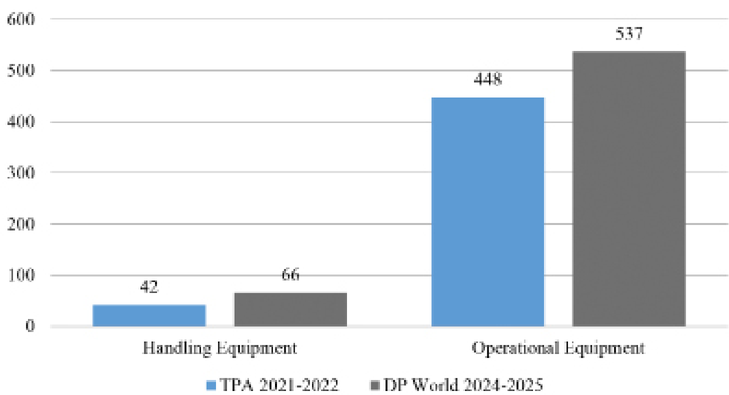

Figure 3: Container terminal equipment

Source: TPA (2021/2022) and DP World (2024/2025) statistical bulletin

From Figure 3, it is evident that DP World possesses more handling and operational equipment than TPA. More seaport equipment, ceteris paribus, means more seaport throughput. Thus, based on the aspect of seaport equipment, DP World (i.e. post-concession) is expected to be more productive than TPA (pre-concession).

Comparison of Operational Output Performance

The values of the output variables (i.e. container throughput and ship turnaround time) for TPA and DP World are depicted in Figure 4.

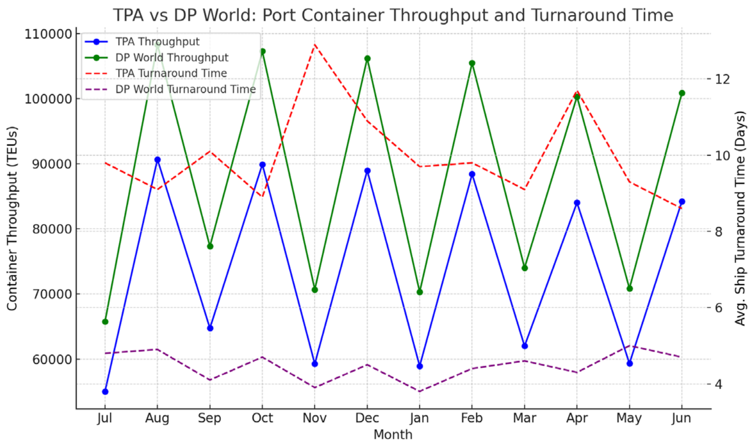

Figure 4: Operational output performance

Source: TPA (2021/2022) and DP World (2024/2025) statistical bulletin

From Figure 4, it is apparent that DP World outperforms TPA in terms of container throughput. This means that the concession brought higher productivity to the port. In addition, DP World achieves a notably shorter average ship turnaround time than TPA (i.e. pre-concession). This indicates higher operational efficiency after the concession was granted. These findings mirror those in a study in India by Ghate (2025), who found that the privatisation of seaport operations reduces average vessel turnaround time and enhances average container throughput. The results are also concomitant with Omoke *et al*. (2015), who examined the impact of concessions on Nigerian seaports and found improvement in berth occupancy and vessel turnaround time. Thus, terminal concessions have a positive performance if accompanied by optimal resource utilisation and/or investment in technology.

Efficiency Change

The Efficiency Change (EFFCH) in the MPI, assesses how well a container terminal utilizes its resources to give outputs, independent of technological progress. Thus, container terminals with EFFCH < 1 indicates a decline in efficiency level, which would warrant further investigation into operational challenges. On the other hand, container terminals with EFFCH >1 implies an improvement in efficiency level while a container terminal with EFFCH =1 suggests that the container terminal is performing consistently over time, with no significant improvements in operations. The EFFCH for both TPA and DP World over the period of analysis are presented in Table 7 and depicted in Figure 5.

Table 7: Efficiency change (EFFCH)

Months	TPA	DP World
July-August	1.000	1.000
August-September	1.000	1.000
September-October	1.000	1.000
October-November	1.000	1.000
November-December	1.000	1.000
December-January	1.000	1.000
January-February	1.000	1.000
February-March	1.000	1.000
March-April	1.000	1.000
April-May	1.000	1.000
May-June	1.000	1.000

Source: Authors' compilation from DEAP version 2.1 (2025)

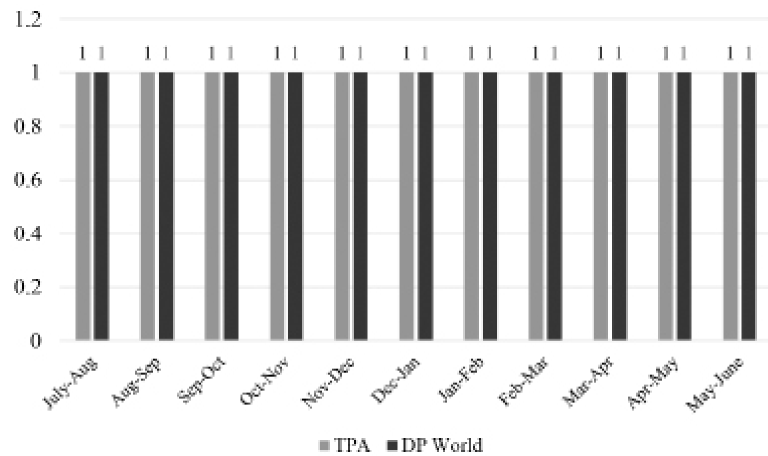

Figure 5: TPA and DP World efficiency change

Source: Authors (2025)

From Table 7 and Figure 5, it is revealed that both TPA and DP World attained the efficiency change (EFFCH =1) based on the monthly analysis. In addition, both TPA and DP World achieved the average efficiency change (*EFFCH*=1.000) over the period of analysis. Efficiency did not improve after the concession despite significant improvements in output (i.e. container throughput and ship turnaround time) because of a corresponding increase in some inputs (e.g. average draft, handling and operational equipment) and hence keeping the output-input ratio constant. This shows that the container terminal's efficiency remains consistent, allowing for planning and operations to continue with predictable performance. The results contrast with the findings of prior studies by Matei (2024) and Ugbona and Oyesiku (2020) who argue that seaport resources (i.e. infrastructure, storage area, equipment) have a positive efficiency change. Thus, the concessionaire (DP World) is called to improve the operational efficiency through optimal utilisation of the available container terminal resources.

Technological Change

In MPI, a technological change (TECHCH) indicates the extent to which the frontier has shifted over time interval [t, t+1] due to innovation or industry-wide improvements. Thus, the technological change (TECHCH) assesses the extent to which the change in technology influences container terminal productivity. A technological change value of 1 (TECHCH=1) means no change in seaport technology, a value less than 1 (TECH<1) indicates technological deterioration (i.e. a move away from the production frontier), and a value greater than 1 (TECHCH >1) signifies technological progress (i.e. a shift towards the production frontier). The TECHCH for both TPA and DP World over the period of analysis are presented in Table 8 and depicted in Figure 6.

Table 8: Technological change

Months	TPA	DP World
July-August	1.332	1.094
August-September	0.802	1.222
September-October	1.255	0.795
October-November	0.674	1.213
November-December	1.333	0.844
December-January	0.863	0.982
January-February	1.219	1.245
February-March	0.869	0.834
March-April	1.027	1.261
April-May	0.943	1.029
May-June	1.239	3.197

Source: Authors (2025)

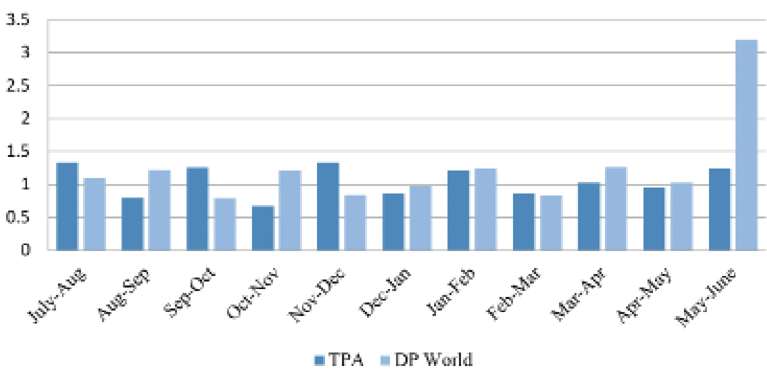

Figure 6: TPA and DP World technological change
Source: Authors (2025)

From Table 8 and Figure 6, it is evident that both TPA (pre-concession) and DP World (post-concession) experience technological change over the periods of analysis. In the case of TPA, the minimum technological change (TECHCH=0.674<1) is observed during the month of October-November 2021, whereas the maximum technological change (TECHCH=1.333>1) is observed during the month of November-December 2021. In the case of DP World, the minimum technological change (TECHCH=0.795<1) is observed during the month of September-October 2024 whereas the maximum technological change (TECHCH=3.197>1) is observed during the month of May to June 2025. Furthermore, TPA attained the average technological change (<u>*TECHCH*</u>=1.051>1) over the period of analysis. Meanwhile, DP World attained the average technological change (<u>*TECHCH*</u>=1.247>1) over the period of analysis. This reveals a progressive technological change during the pre-concession (i.e. TPA operations) and post-concession (i.e. DP World operations) over the period of analysis. The findings are confirmed by other scholars. For instance, Ben Mabrouk *et al*. (2022) report that technological advancements have a positive effect on seaport efficiency. Similarly, Ducruet and Itoh (2022) expound that improvement in handling equipment enhances cargo throughput and overall seaport efficiency.

Values of Total Factor Productivity (TFP Values)

The drivers of container terminal productivity during both pre-concession and post-concession are efficiency and technology. Thus, the product of efficiency change (EFFCH) and technological change (TECHCH) is MPI, as indicated in Table 9 and depicted in Figure 7. If MPI= 1, it indicates consistency in productivity; If MPI < 1, it shows a decline in productivity, and If MP1 > 1, it signifies a progress in productivity. The calculated MPI values for TPA and DP World over the period of analysis are presented in Table 9 and depicted in Figure 7.

Table 9: MPI values

Months	TPA (Pre-concession)			DP World (Post-concession)		
	EFFCH	TECHCH	MPI	EFFCH	TECHCH	MPI
July-August	1.000	1.332	1.332	1.000	1.094	1.094
August-September	1.000	0.802	0.802	1.000	1.222	1.222
September-October	1.000	1.255	1.255	1.000	0.795	0.795
October-November	1.000	0.674	0.674	1.000	1.213	1.213
November-December	1.000	1.333	1.333	1.000	0.844	0.844
December-January	1.000	0.863	0.863	1.000	0.982	0.982
January-February	1.000	1.219	1.219	1.000	1.245	1.245
February-March	1.000	0.869	0.869	1.000	0.834	0.834
March-April	1.000	1.027	1.027	1.000	1.261	1.261
April-May	1.000	0.943	0.943	1.000	1.029	1.029
May-June	1.000	1.239	1.239	1.000	3.197	3.197

Source: Authors (2025)

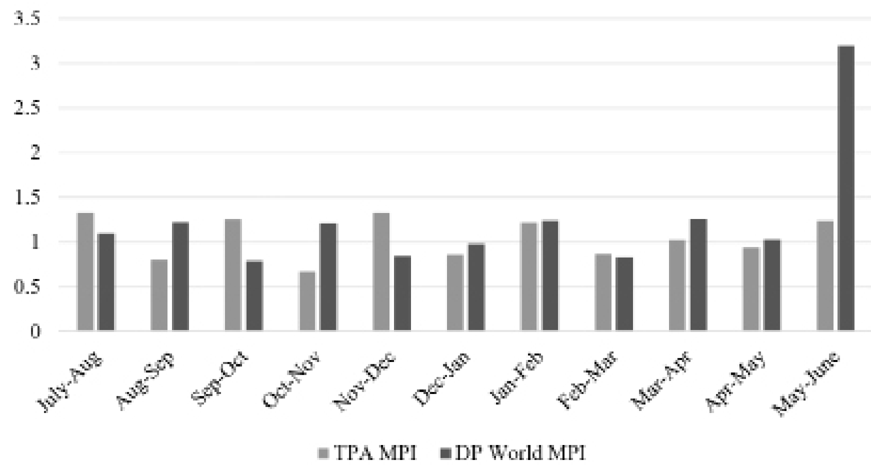

Figure 7: TPA and DP World MPI values

Source: Authors (2025)

From Table 9, it is evident that all changes in container terminal productivity (i.e. MPI Values) are solely attributable to technological change (TECHCH). In the case of TPA, the minimum productivity change is observed during the month of October-November 2021 (MPI=0.674<1), whereas the maximum productivity change (MPI=1.333>1) is observed during the month of November-December 2021. In the case of DP World, the minimum productivity change (MPI=0.795<1) is attained during the month of September-October 2024, whereas the maximum productivity change (MPI=3.197>1) is observed during the month of May-June 2025. TPA attained the average productivity change ($\underline{MPI}$=1.051>1) over the period of analysis. DP World attained the average productivity change ($\underline{MPI}$=1.247>1) over the period of analysis. The findings reveal that container terminal productivity was higher after the concession (i.e. under DP Word operations) than during pre-concession phase (i.e. under TPA operations). The findings are in line with the views of other scholars. Matei (2024) and Cano-Leiva *et al*. (2023) posit that privatisation has a positive effect on seaport productivity. In a similar vein, Dasgupta and Sinha (2016) argue that privatization has a significant impact on the productivity of a container terminal. A similar study by Abudu *et al*. (2021) in Ghanaian seaports reveals that a terminal concession leads to improved cargo handling capacity and reduced ship turnaround time. Thus, the terminal concession at Dar es Salaam seaport has brought a positive change in container terminal throughput and ship turnaround time, which aligns with prior studies. However, the attained productivity level is fuelled by improved technological change. Consequently, the concessionaire should improve the efficiency change through optimal use of seaport resources.

Ranking of Container Terminal Productivity Between Pre-Concession Phase and Post-Concession Phase

In this study, the average MPI values ($\underline{MPI}$) are considered as a basis for ranking the two terminal operators: TPA (pre-concession phase) and DP World (post-concession phase). Container terminals with $\underline{MPI}$>1qualify for benchmarking. Meanwhile the container terminals with $\underline{MPI}$<1need improvement. Consequently, both container terminal operators improved productivity albeit at various percentages as shown in Table 10.

Table 10: Ranking of container terminal operators at Dar es Salaam seaport

Rank	Container Terminal	MPI	Interpretation
1	DP World	1.247	24.7% productivity growth
2	TPA	1.051	5.1% productivity growth

Source: Authors' Compilation (2025)

Table 10 reveals that container terminal operations under DP World were more productive (24.7% productivity growth) than TPA operations (5.1% growth). Consequently, privatisation of the container terminal has positively and significantly impacted operations.

Conclusions

This study assessed the effect of privatisation on seaport productivity by comparing the pre-concession operations under a public entity (i.e. TPA) and operations after a concession was granted to a private entity (i.e. DP World) at Dar es Salaam seaport. The DEA-MPI model was deployed to give changes in efficiency, technology, and productivity over a 12-month period of operations under the public entity and private entity. The model used secondary data for input and output variables collected from official statistics provided by the private and public entities. The findings highlight notable disparities in efficiency, and technological and productivity change over the period of analysis. Specifically, the container terminal's efficiency remained consistent during both pre- and post-concession. On the other hand, the private entity attained a higher positive technological change than the one attained by a public entity over the period of analysis. Furthermore, the private entity attained a higher productivity than the public entity. Consequently, privatisation of container terminal operations at Dar es Salaam seaport is a viable investment decision. This study provides insights for policy makers for the development of the port industry and the economy. Specifically, the study presents an optimisation model that can be applied by policy makers and seaport managers in order to make maritime container terminals more productive and competitive. In order to get a deeper understanding of the impact of privatisation on container terminal operations at Dar es Salaam seaport, future studies should conduct a benefit-cost analysis (BCA) on the TPA-DP World concession agreement in the Tanzanian maritime supply chains.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

Author Contributions Statement

The authors confirm contribution to the paper as follows: Study conception and design: Erick P. Massami, Cuthbert G. Nyange; data collection: Cuthbert G. Nyange; analysis and interpretation of results: Erick P. Massami, Cuthbert G. Nyange; draft manuscript preparation: Cuthbert G. Nyange. All authors reviewed the results and approved the final version of the manuscript.

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