SA-TIED
Southern Africa – Towards Inclusive Economic Development

REPORT

Development of a strategic plan for port performance improvement in South African container terminals

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About the project

Southern Africa –Towards Inclusive Economic Development (SA-TIED)

SA-TIED is a unique collaboration between local and international research institutes and the government of South Africa. Its primary goal is to improve the interface between research and policy by producing cutting-edge research for inclusive growth and economic transformation in the southern African region. It is hoped that the SA-TIED programme will lead to greater institutional and individual capacities, improve database management and data analysis, and provide research outputs that assist in the formulation of evidence-based economic policy.

The collaboration is between the United Nations University World Institute for Development Economics Research (UNU-WIDER), the National Treasury of South Africa, the International Food Policy Research Institute (IFPRI), the Department of Monitoring, Planning, and Evaluation, the Department of Trade and Industry, South African Revenue Services, Trade and Industrial Policy Strategies, and other universities and institutes. It is funded by the National Treasury of South Africa, the Department of Trade and Industry of South Africa, the Delegation of the European Union to South Africa, IFPRI, and UNU-WIDER through the Institute's contributions from Finland, Sweden, and the United Kingdom to its research programme.

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REPORT

Development of a strategic plan for port performance improvement in South African container terminals

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Abstract: This study aims at developing a strategic plan for performance improvement in South African container ports. To do so, the paper first reviews recent work and literature on the performance of South African container terminals, then analytically benchmarks their operational efficiency vis-à-vis selected regional and international comparators. The results show that South African container terminals not only operate below their optimal potential, but that the observed trend of efficiency deterioration has been mainly driven by inefficiencies in technology use and uptake. Complementing the analysis and benchmarking of terminals' operational efficiency, an assessment of associated trade and logistics performance was carried out, with the results showing several gaps in hinterland connectivity, trade costs, and procedural efficiency. A parallel analysis was undertaken to emphasise the interplay between port performance and efficiency on the one hand, and port competition and governance on the other hand. While recognising the uniqueness of the institutional framework of the port sector in South Africa, the study found that the absence of intra-port and inter-port competition coupled with the lack of a well-designed terminal licencing scheme further contribute to port inefficiency and congestion. In view of the study findings, a 10-point strategic plan was put forward spanning short-, medium-, and long-term measures.

Key words: port performance, container terminals, performance regulation, benchmarking analysis, port competition, port governance, strategic plan

JEL classification: L920, L11, R4, D24

Acknowledgements: This study's analytical benchmarking approach uses a similar DEA technique and software used in two previous studies by the Author, namely the 2015 COMCEC Study on 'Evaluating the ownership, governance structures and performances of ports in the OIC member countries' and the 2016/18 World Bank Study 'Making the Most of Ports in West Africa'. While the DEA technique, analytical formulation and software used are the same across those reports, the benchmarked ports and input data and variables used are different and so are the efficiency rankings, results, and performance analysis.

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Abbreviations and acronyms

APMT	AP Moller Terminals
BOO	Build-Operate-Own
BOT	Build-Operate-Transfer
BPR	Business Process Re-Engineering
BSC	Balanced Score Card
CARG	Cargo Growth
CCT	Cape Town Container Terminal
CFS	Container Freight Station
COLS	Corrected Ordinary Least Squares
CPPI	Container Port Performance Index
CSP	Cosco Shipping Ports Limited
CTCT	Cape Town Container Terminal
CTQI	Container Terminal Quality Indicator
DBFM	Design Build Finance and Maintain
DBFO	Design Build Finance and Operate
DCT	Durban Container Terminal
DEA	Data Envelopment Analysis
DMU	Decision Making Unit
DPW	Dubai Port World
DRC	Democratic Republic of Congo
FCL	Full Container Load
GDP	Gross Domestic Product
GPCS	Global Pricing Comparator Study
HHI	Hirschman-Herfindahl Index
ICD	Inland Container Depot
ICT	Information and Communication Technology
IMO	International Maritime Organisation
ITF	International Transport Forum
ITO	International Terminal Operator
JOC	Journal of Commerce
KPI	Key Performance Indicators
LCL	Less than Container Load
LOA	Length Overall (Berth's/Ships)
LPI	Logistics Performance Index
LSCI	Liner Shipping Connectivity Index
MFP	Multi-factor Productivity
MPI	Malmquist Productivity Index
MSC	Mediterranean Shipping Company
NATCOR	KwaZulu Natal – Gauteng Corridor
NCT	Ngqura Container Terminal
NPUF	National Port Users' Forum

O&M	Operations & Maintenance
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
PCCs	Port Consultative Committees
PEC	Pure Economic Efficiency
PECT	Port Elizabeth Container Terminal
PFP	Partial Factor Productivity
PPP	Public Private Partnership
PSA	Port of Singapore Authority
PSP	Private Sector Participation
PTIP	Port Tariff Incentive Program
RMG	Rail Mounted Gantry (Crane)
ROR	Rate of Return
RTG	Rubber Tired Gantry (Crane)
SADC	Southern African Development Community
SAMSA	South Africa Maritime Safety Authority
SEC	Scale Efficiency
SFA	Stochastic Frontier Analysis
SFP	Single Factor Productivity
SOE	State Owned Enterprise
SPV	Special Project /Purpose Vehicle
STAT	Ship Turnaround Time
STS	Ship-To-Shore (Crane)
TAS	Truck Appointment System
TC	Technical Change
TEC	Technical Efficiency
TEU	Twenty-foot Equivalent Unit
TFP	Total Factor Productivity
TFR	Transnet Freight Rail
TNPA	Transnet National Port Authority
TOPS	Terminal Operator Performance Standards
TOR	Terms of Reference
TPT	Transnet Port Terminals
UNCTAD	United Nations Conference on Trade and Development
VfM	Value for Money
WB	World Bank
WEGO	Weighted Efficiency Gains from Operations
WTO	World trade Organisation

Executive summary

Concerns about congestion, delays and inefficiencies in South African container ports have been highlighted in several governmental, industry and consulting reports which have been carried out over the past two decades or so. Too often though, the focus on most studies was on short-term solutions and tactical options which, despite some transient success, did little to address deep-rooted inefficiency and congestion problems resulting in performance traps and misalignment with port strategy, planning and long-term policy.

In view of persistent congestion problems and forthcoming institutional changes in the sector, there is a renewed interest in reviewing and examining the performance of South Africa's main container ports with a view to identifying gaps and bottlenecks and suggesting recommendations that should serve as a strategic plan for performance improvement and wider policy reform. To do so, the approach put forward in this Study is to develop a Strategic Plan based on an analysis of three main areas where the causes and symptoms of port congestion and poor performance can be observed and acted upon: port efficiency and performance benchmarking, port competition and governance framework, and terminal concessions and private sector participation.

Following a review of the literature on South Africa's container-port performance, an analytical benchmarking of South Africa's container port efficiency was carried out in order to measure, track, decompose and analyse the operational efficiency of the main four container terminals in South Africa (Durban, Cape Town, Ngqura, and Port Elizabeth) both over time and vis-à-vis comparable benchmarks. The results show a downward trend of efficiency deterioration in the past 10 years across South African container terminals against an upward trend of efficiency improvement for regional and global comparators. Particularly over the past 5 years, the performance of South African container terminals has been on average 20% less than the average performance of comparator benchmarks, and up to 35% below their optimal potential. Further analysis to examine the sources of (in)efficiency has found that the drag on port productivity was mostly driven by a steep deterioration in technical change (technological progress) over the past 5 years as evidenced compared with less severe losses in pure efficiency and marginal gains from scale efficiency.

Complementing the analytical performance benchmarking, an assessment of trade logistics performance was carried out using seminal and empirical work on countries' performance in ports and logistics. The analysis shows that while South Africa still tops the African continent in areas such as overall logistics performance, it does not lead in trade costs and procedural efficiency. South African ports fall behind in shipping and hinterland connectivity which brings to light the importance of developing transhipment services and upgrading hinterland connectivity and logistics services.

Aside from the analysis of port and logistics performance, the assessment of port competition and institutional government found that both intra and inter container port competition is practically inexistent in South Africa, while competition for the port market is also absent due to the 'evergreen' licence granted to Transnet Port Terminals (TPT). In terms of institutional setting and organisational structure, the assessment highlighted the uniqueness of the port's institutional setting in South Africa and commended the recent policy decision to corporatize the Transnet National Ports Authority (NPA), but also warns against the risks of institutional gaps and overlaps and the lack of a clear orientation towards service fragmentation and commercialisation. The assessment of regulatory governance has also praised the role and work of the Ports' Regulator while pointing out the need to move existing tools of price and performance regulation towards yardstick incentive regulation.

Looking at the framework of container port concessions and private sector participation (PSP), the Study found that the policy intention to introduce PSP in container ports in South Africa has not been accompanied by a clear strategy and implementation plan especially PSP project preparation and contract structuring. An overview of the current arrangements of terminal operating licences has uncovered several gaps in areas directly impacting container port performance including but not limited to contract duration, investment requirements, throughput targets, performance standards, concession fees and tariff charges.

Based on the above assessment, the Study concludes with ten (10) recommendations put forward as short-, medium-, and long-term measures and forming the key pillars for strategic action plan for port performance improvement in South African container terminals.

1 Introduction and project overview

1.1 Background

Ports are critical maritime, trade and logistics infrastructure facilities and play a key role in the transportation of freight and people. From a public policy perspective, ports are viewed as economic catalysts for the markets and regions they serve whereby the aggregation of port services and activities generates socio-economic wealth and benefits such as in terms of tax income, job creation, business generation, supply of hard currency, inter-sector multiplier effect, as well as spatial, agglomeration, and other spill-over effects.

Along with their economic and social impacts, ports play a key role in a country's trade and logistics efficiency. Because they are controllable aspects of global supply chains, ports deserve a particular attention as they can account for a significant proportion of transport, logistics and trade costs. Efficient port operations significantly lower transport and trade costs whereas port delays and inefficiencies impose excessive costs on logistics and supply chains.

For South Africa, ports constitute important gateways and play a key role in the country's trade and logistics system. South Africa relies heavily on its ports to serve its international trade since most of the country's foreign trade is conveyed by sea. Such reliance on ports is further accentuated by the country's economic and trade geography which is marked by long distances to trade markets and extensive hinterlands and transit corridors.

South African ports also play a key role in spatial and regional integration, both within the country and with neighbouring markets. Many ports in South Africa have a close spatial proximity to major urban and economic agglomerations. They also provide indispensable transit accessibility for adjacent landlocked countries and regions across the Southern African Development Community (SADC).

Despite their strategic, trade and economic importance, South African ports remain operationally inefficient and logistically expensive compared with global benchmarks. Excessive costs and inefficiencies hinder trade and economic development. Port congestion is usually synonymous with vessel and truck queues, cargo hold-up and delays, and traffic jams and disruptions in and around terminal facilities as well as across landside and hinterland connections. Persistent congestion at South African container ports has seen shipping lines imposing congestion charges on importers and exporters using those ports, which has at times led to the diversion of shipping services to neighbouring ports resulting into a loss of revenue and market share.

Quite independently of the costs shouldered by shipping lines and often passed on to shippers and cargo interests, delays and inefficiencies in ports impose additional costs on businesses and supply chains through increased cost of cargo waiting and inventory and delayed just-in-time production and distribution processes.

Concerns about congestion, delays and inefficiencies in South African container ports have been highlighted in several governmental, industry and consulting reports, which pointed to low operational productivity, lengthy and cumbersome procedures, under-investment in both port capacity and landside hinterland connections, poor organisation and operations of intermodal services, low human capital development in the freight sector, and the lack of integration in both virtual and physical links with land-based transport and logistics systems.

In view of those studies and reports, several recommendations and action plans have been proposed over the past two decades with a view to improving the performance and reducing congestion at South African container ports. Too often though, most of the recommendations put forward were short-term operational and tactical solutions, which despite some transient success, did little to address what has become an endemic congestion problem. The user, managerial and, at times, political pressure to pursue tactical options and resolve short-term port performance gaps often leaves long-term congestion problems unresolved or may even expand them, i.e., 'port performance gets better before getting worse'. As evidenced in many ports around the world, the apparent bias in South African container ports towards short-term solutions often overlooks deep-rooted congestion problems, resulting in performance traps and misalignment with port strategy, planning and long-term policy.

Improving the performance of the container port sector in South Africa has long been on the agenda of various port and policy stakeholders; and there is a renewed interest due to recent and forthcoming changes in the sector. It is therefore timely to review and examine the performance of South Africa container ports with a view to identifying gaps and bottlenecks and suggesting recommendations that should serve for a strategic plan and wider policy reform.

1.2 Project objectives

This Project seeks to develop a strategic plan for port performance improvement in South African container terminals. As per the TOR's requirements, a strategic plan is required that diagnoses the causes of poor performance of container operations and identifies the key actions for achieving world class port performance standards with specific recommendations with respect to the followings:

- Management;
- Business processes and systems;
- Human resources and training;
- Infrastructure/superstructure investment;
- Governance and Institutional arrangements; and
- Private sector participation in container terminals.

1.3 Approach and methodology

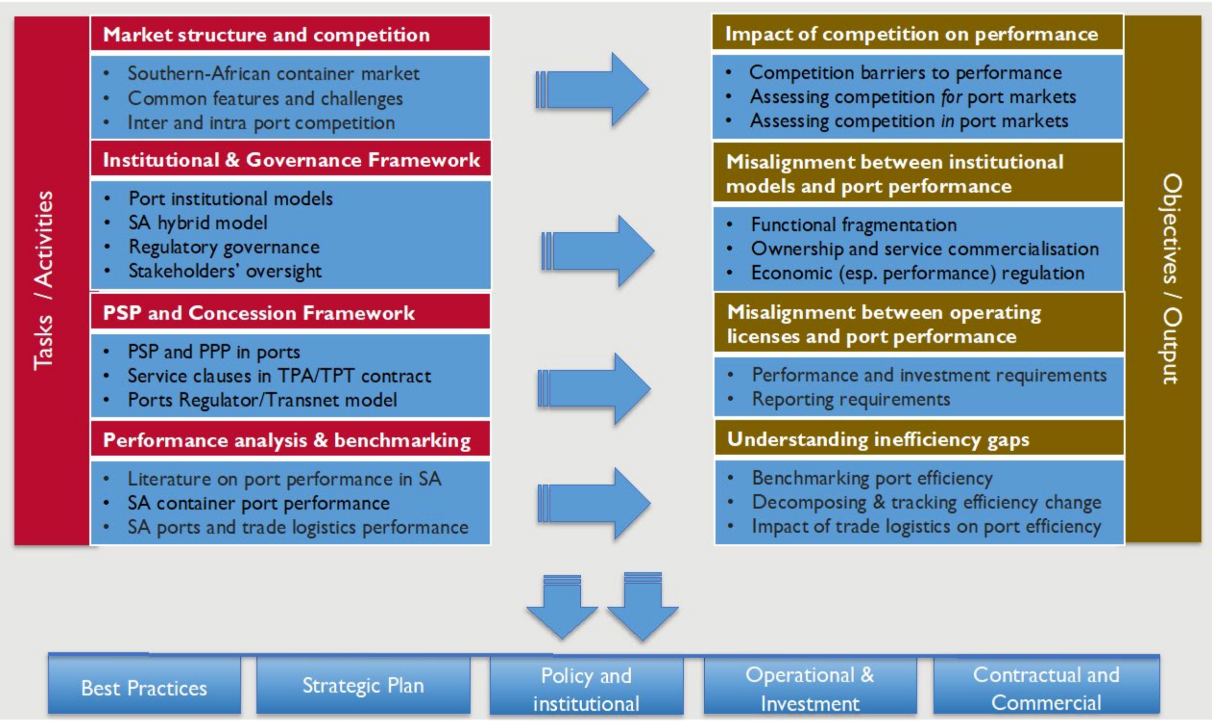
In line with the above, the approach put forward by the Consultant is to develop a Strategic Plan based on an analysis of three main areas where the causes and symptoms of port congestion and poor performance can be observed and acted upon:

- A benchmarking analysis of the operational efficiency of the main container ports and terminals, Durban, Cape Town and Ngqura, using analytical tools namely Data Envelopment Analysis (DEA) and the Malmquist Productivity Index (MPI), in order to track and decompose port productivity both over time and vis-à-vis regional and international benchmarks. The benchmarking analysis will constitute the core of the assessment of the performance of the South African container port system, covering various aspects such as port operations, equipment and labour productivity, and management and business processes.
- An analysis of the competitive framework and the institutional and governance structures in order to assess their impacts on port performance improvement and monitoring, then formulate options for further competition, institutional, governance and policy reform. This work covers areas related to the competition landscape, the

economics of port monopolies, the institutional and organisational structures and their impact on port competition and performance standards, and the importance of economic and performance regulation in shaping and monitoring infrastructure and operational performance. The combined analysis of those components would allow a deeper assessment of container port systems in South Africa, an understanding of the drivers of and constraints on port performance and congestion, and a broad comparison against international best practices and benchmarks.

- An analysis of Private Sector Participation (PSP) in port systems, especially through Public Private Partnership (PPP) and concessions. A review of the current operating licences framework and its compatibility with international best standards in port concessioning and concession contracts is carried out with a view of identifying gaps and formulating remedy options and solutions along a strategic plan for container terminal concessioning and PSP in South Africa.

Figure 1: Project methodology



Source: author's elaboration.

2 Review of port performance and South African ports

2.1 Overview of port performance approaches

Most practical and theoretical approaches to port performance and benchmarking can be reduced to four broad categories: performance metric and snapshot indicators, productivity index methods, efficiency (frontier) approaches, and process and optimisation models.

2.1.1 Performance metrics and snapshot indicators

Performance metric and snapshot indicators represent the bulk of the conventional and practical port literature and are comprised of numerous metrics covering various functional and operational aspects of port systems. Depending on the scope and emphasis of port performance measurement and benchmarking, such metrics are often grouped into structured sets of port Key Performance Indicators (KPIs). Port KPIs focus primarily on vessel and user's performance with less emphasis on investors' (e.g., financial) and societal (e.g., safety and environmental) performance dimensions. Examples of snapshot KPIs in ports include service indicators (ship turn-around-time, cargo dwell time), utilisation indicators (berth occupancy, asset utilisation) and throughput indicators (port throughput, gate output). Sometimes, composite snapshot indicators are used to account for the link between two snapshot metrics or indices, for example TEU-hour per metre of quay or TEU-hour by ship size.

2.1.2 Productivity index methods

The main problem with snapshot and composite measures is that they only provide an activity measure rather than a performance measure. A productivity index can be loosely defined as the ratio of the output quantity to the quantity of input used. Depending on the definition of the inputs and outputs, and on the methodology used to calculate them, existing productivity measures for ports can be divided into two major categories: Single Factor Productivity (SFP) vs. Total Factor Productivity (TFP) indices.

SFP indices compare the volume measure of a single output to the volume measure of the corresponding input use. SFP examples in ports include berth productivity measured as the TEU handled (output) per metre of quay (input), crane productivity measured as crane move (output) per number of cranes deployed (input), labour productivity measured as TEU or ton handled (output) per gang or man hour used (input), and gate productivity measured as number of in/out trucks per gate. The problem with SFP is that its concept is no longer valid under a multi-input/multi-output production technology such as that of ports. Port studies often compare SFP indicators over time or between ports, but this could be misleading because no account is taken for the quantities of other inputs and outputs. In container ports, single factor productivities are highly intertwined and maybe the cause or the consequence of each other. For instance, berth productivity is highly dependent on both yard and gate productivities, as well as on the productivity of the nautical system.

The main advantage of TFP indices is that they reflect the joint impacts of the changes in combined inputs on total output. Analytically, a TFP index is estimated by calculating the ratio of the weighted sum of outputs over to the weighted sum of inputs. Several TFP indices such as the Törnqvist index, the Malmquist index and the Fisher index have been widely used to assess productivity change of both firms and countries. Nevertheless, only a few studies and reports have estimated or used a TFP index for ports which denote the perceived difficulty from practitioners to define and construct a TFP index.

2.1.3 Efficiency (frontier) approaches

While the productivity concept and its applications provide a valid measurement and assessment of port performance, it is not estimated vis-à-vis a norm or a benchmark. This has led performance studies to focus instead on the efficiency concept, the latter denotes a normative productivity, for instance in relation to an underlying technology or a standard benchmark. The frontier concept denotes the lower or upper limit to a boundary-efficiency range. Under this approach, a port or terminal is defined as efficient when it operates on the frontier and inefficient when it operates away from it (below it for a production frontier and above it for a cost frontier).

Analytically, frontier functions can be either deterministic or stochastic depending on whether certain assumptions are made regarding error composition and the data used. Broadly, two main techniques are used: parametric techniques such as the 'stochastic frontier analysis' (SFA) and/or non-parametric techniques such as 'data envelopment analysis' (DEA).

Over the past two decades, there has been an exponential rise in using frontier methods in port performance and benchmarking, with the literature almost evenly split between the use of DEA vs. SFA techniques. Too often though, both methodologies have been applied mechanistically by researchers who have little understanding of port practice. Some observed gaps and discrepancies include (i) the validity of (input/output) variable definition and selection, (ii) technology variations in port operating systems and handling configurations, (iii) procedural differences in terminal operations, (iv) market and network structures of port and terminal systems, and (v) the interplay between controllable and uncontrollable factors.

2.1.4 Process and optimisation methods

Process approaches seek to examine port operations and processes in view of performance measurement and improvement. They often rely on expert judgement, perception surveys, process modelling and optimisation, and various benchmarking process toolkits, but each of these requires a thorough bottom-up investigation and may be very expensive and time consuming.

Process and optimisation methods often involve a micro-investigation into detail operational and procedural aspects such as working arrangements for crane assignment and container retrieval, working strategies for stacking and segregation, queuing and distribution of vessel calls, and many other details. As such, such methods are not appropriate for performance benchmarking, instead they are better suited for continuous process optimisation within a specific port or terminal. Indeed, much of the literature on the subject is either theoretical or case specific.

2.2 Review of the literature on SA container port performance

This section summarises recent literature, including studies and policy reports, about South Africa's container port performance and efficiency. Broadly speaking, despite ongoing concerns about low performance and long delays and congestion in South African container ports, relatively few studies have addressed the issue in the depth and breadth required. Among these, worth noting the following recent publications.

2.2.1 The competitiveness of ports in emerging markets: case of Durban (ITF 2014)

In 2014, the International Transport Forum (ITF), a division of the Organisation of Economic Cooperation and Development (OECD) published a paper on the competitiveness of the South African port system with a particular emphasis on the port of Durban.

In its Chapter on port efficiency, the OECD paper, quoting figures from the Ports Regulator, suggests that the Port of Durban is one of the most expensive ports in the World due largely to the (additional) imposition of uniform cargo dues by TNPA across South African ports. On turn-around-time, the paper also found Durban to be under-performing compared with the main hub ports in Africa (e.g., Tangier-Med and East-Said) and globally (e.g., Antwerp, Hong Kong). However, Durban scores favourably in comparison to the many congested ports in West and East Africa (e.g., Aqaba, Mombasa). The paper also touched upon hinterland connectivity issues including local road congestion and gate access as well as the lead time lag of port-bound rail service.

As with many studies on the subject, the OECD report uses two main conventional snapshot indicators to assess and benchmark Durban's performance both over time and across selected ports. However, neither the definition of the indicators nor the methodology used to assess the port performance allow for an analysis of the productivity let alone the efficiency of container port operations in Durban and elsewhere. The selection of comparative ports also leaves a lot to be desired with many of the selected ports having distinctly different market and operating features than those of Durban. Last, but not least, the report was very thin on solutions and recommendations put forward, namely calling for more autonomy of TNPA and further analysis of port supply chain's performance rather than the port's internal performance alone.

2.2.2 Port benchmarking report: SA terminals 2015/16 (Ports Regulator 2016)

The Ports Regulator of South Africa published a port benchmarking report in 2016 with a view to benchmarking the performance of South African ports against a sample of selected international ports. For container operations, the Benchmarking Report included 4 domestic container terminals (Durban, Cape Town, Port Elizabeth, and Ngqura) and 17 international container ports from Europe, Asia and the Americas but none from Africa. Using the 2014 publicly available data, the study carried out a cross-sectional analysis of domestic container terminals against the selected 17 international peers across six KPIs: terminal utilisation, berth productivity, ship turn-around time, gross crane moves per hour, container dwell time, and time spent at anchorage.

The analysis showed that South African container terminals perform below global averages in berth and crane productivity while depicting higher utilisation rates. On time indicators such as ship turn-around time and time spent at anchorage, South African terminals have shown even lower performance than the global average. On the plus side, the report showed that South African container terminals made significant progress in reducing cargo dwell time but were less successful in reducing ship turn-around-time, while facing huge challenges in hinterland and intermodal connectivity. Although the Report was a follow up on previous work, unfortunately, it was not updated since 2016. This could have provided an opportunity to the Ports Regulator to refine its set of port performance metrics and methodology, and to potentially move away from snapshot indicators to the more robust productivity indicators.

2.2.3 Competition in East & Southern Africa: prospects and challenges (Humphreys et al. 2019)

This is a broad study of the port sector in East and Southern Africa aimed at investigating the gap in existing capacity and justification of planned capacity in view of projected demand growth. In attempting to answer those questions, the report reviews various aspects ranging from port demand, capacity, and hub development scenarios to port performance, competition, governance, and policy.

In its Chapter 4, the report evaluates the individual performance of the ports in the region, focusing on 3 areas of performance: spatial and operating efficiency (ship turn-around time, quay-productivity, container dwell time, and truck turn-around time), maritime access and connectivity (draft and LOA, number of calls, maritime connectivity, and berth capacity and utilisation), and technical efficiency (gap between observed and theoretical production). Across most indicators, the South African ports in the study (Durban, Cape Town, Port Elizabeth, and East London) performed favourably compared with their regional peers, but less so against leading African and global ports.

Domestically, both Durban and Cape Town have outperformed Port Elizabeth and East London across most performance areas and indicators. Where South African ports seem to underperform vis-a-vis their regional peers is in the area of technical efficiency; which suggests that the country's ports are not operating to their full potential to make efficient use of infrastructure capacity and minimise port and logistics costs.

Unlike the OECD report outlined above, this World Bank (WB) report provides a far more comprehensive and richer analysis while covering a wider spectrum of port performance indicators. Nonetheless, the report still uses snapshot indicators to measure spatial and operating "efficiency", while for the measurement of technical efficiency no information was provided on how the SFA methodology used was designed and implemented; for instance in terms of the formulation of the underlying production function, the assumption and parameters used for the estimation of the production frontier, the operationalisation of the selected data and variables, and statistical testing of randomness and outliers. Both shortcomings may put some limitations on the robustness of part the analysis and the validity of some results, yet the report presents relevant conclusions and puts forward some interesting recommendations. In particular, the analysis shows that while Durban and Cape town container ports consistently lead their regional peers, they both operate at about 50% of global efficiency benchmarks suggesting a significant potential for efficiency improvement and capacity utilisation. Another noteworthy observation is the strong correlation between higher port efficiency and presence of specialised private terminal operators, such situation is not currently applicable to South African container ports.

2.2.4 Container Terminal Quality Indicator (DNV GL and SCI, certification index)

In 2008, Germanischer Lloyd, now DNV GL in cooperation with the Global Institute of Logistics, introduced the Container Terminal Quality Indicator / System (CTQI/ CTQS), a collection of 70 snapshot indicators for measuring terminal's performance in the following areas: management systems, internal factors (KPIs), external factors, and performance evaluation. Under CTQI, terminals are scored on a 100-point scale and receive certification if they achieve 50 points or more. The CTQI was established as a performance certification and benchmarking programme where container terminals are assessed through formal and perception surveys. Initially, the programme was relatively successful with a buy-in from a dozen port terminals, it somewhat faded and was not applied since 2015/2016.

2.2.5 JOC port productivity database (Journal of Commerce, published annually)

The US Journal of Commerce (JOC) started publishing its port productivity database reports in 2013, which has since become an annual publication. The JOC reports and productivity database is powered by information provided by the Port Import Export Reporting Service (PIERS), part of HIS Markit, and data shared by container shipping lines and carriers. The JOC reports and database focuses exclusively on a rather simple container berth productivity metric, expressed as the total time of ship stay at berth divided by the number of containers (TEUs) handled, then rank container terminals globally as well as by vessel size, port type and location and operator status. The JOC berth productivity rankings and database use a single and basic metric which is neither robust nor representative of the overall container port performance let alone its productive efficiency, yet it provides port customers with a genuine glimpse of a port performance and give them a chance to put some pressure on the terminal operators. The Ports Regulator has also used JOC data in its 2015/2016 Ports Benchmarking Report.

2.2.6 UNCTAD port performance indicators (UNCTAD, published annually)

The United Nations Conference on Trade and Development (UNCTAD) has been publishing data and policy reports on port performance and productivity indicators, mostly through its RMT (Review of Maritime Transport) annual flagship publication as well as via its Maritime Statistics database, both publicly accessible. Most recently, UNCTAD has incorporated data on liner port connectivity, number of port calls and time spent in ports drawing from various sources including marine traffic and HIS data among others. The 2020 data are aggregated at country level and shows that for South Africa the median stay of containerships in the country ports is 3.32 days which is at the lower performance scale even compared with neighbouring and similar economies in Africa (2.02 days in Mozambique, 1.05 days in Namibia, 0.96 days in Egypt and 0.78 days in Morocco).

2.2.7 The Republic of South Africa operational diagnostic: Durban container terminal and the Natal-Gauteng rail corridor (World Bank 2020, consulting report)

This is a report that presents the work and findings of an onsite study undertaken by the WB in late 2019 and early 2020 to carry out a detailed operational diagnostic of the performance of Durban container port operations and the associated Transnet Freight Rail's (TFR) KwaZulu Natal – Gauteng Corridor (NATCOR) operation.

On the port side, the World Bank team undertook a detailed assessment of several KPIs based on in-person observations of port operations and working processes. Overall, 10 KPIs were assessed namely container vessel's waiting time, turn-around time, berth occupancy and utilisation, container moves per ship working hour and per gross crane hour, crane intensity, average port hours, truck turn-around time, truck appointment system and train turn-around time.

The report found several gaps between reported KPIs (by TNPA, TPT and DCT) and observed ones (by the WB team or from independent data), which suggests discrepancies in the way KPI data is collected, measured, and conveyed. Most KPIs also failed to achieve TNPA targets for 2019/2020; instead, they indicated a deterioration of efficiency over time (compared with 2018) and vis-à-vis comparable ports and terminals. What's more, some of the KPI targets, such as for ship turn around tine, are already set at a too low performance bar suggesting that even if they are achieved inefficiency costs and delays are imposed on ships, shippers, and supply chains.

Elsewhere, KPIs such as berth utilisation and crane intensity fall well below those of comparable ports which explains low productivity levels and inefficient utilisation of resources in Durban port. On the port yard and landside area, the report found that some of the solutions put in place, such as the replacement fleet of Straddle Carriers and the new Truck Appointment System (TAS), are either insufficient or ineffective at addressing poor and deteriorating container port performance. The study also reports on observed safety and maintenance gaps as well as on the lack of people's engagement and inefficient operating processes.

The report provides a list of recommendations spread across short-, medium-, and long-term horizons. Both short-term and medium-term recommendations are operational in nature with specific actions that can be executed in a quarterly operational plan. The long-term recommendations put forward four tactical decisions focusing on management and procedural arrangements which can be part of an annual or semi-annual action plan.

This WB consulting study is a good example of process-type case analysis of container port performance. It is based on on-site observation and expert judgement coupled with some comparative analysis with best-operating practices and procedures. As such, the study is geared towards operational and tactical solutions for optimising capacity management and continuously improving operational tasks and work processes. Not only the study provides some relevant operational and tactical solutions, but the approach and methodology used can also be replicated by Durban port managers and incorporated in an annual exercise for performance monitoring and improvement. Although not explicitly specified in the report, it seems that this approach is put forward to set (and revise) annual targets as per TNPA's annual plans and incentive port regulation.

The downside of this type of exercises is that they do not provide a strategic view of port performance and would be less relevant for strategic performance benchmarking, let alone for regulatory and yardstick benchmarking. At the same time, some of the observations based on expert judgment often require additional optimisation analysis for testing and validation. For instance, the report relies on the TNPA's figure of a 69% berth occupancy ratio in 2019 for both container piers while applying a 'rule of thumb' threshold of 60% berth occupancy for ship queuing and congestion. Yet in operational port planning and scheduling, neither figure can be used without a detailed analysis of ship queuing in both piers, such analysis requires detailed mathematical estimation and/or simulation modelling of berth capacity and occupancy using such information as berth parameters, ship's arrival rate and probability distribution, service time, and queuing discipline and structure. In addition, process mapping and Business Process Re-Engineering (BPR) may be required to provide a detailed view of existing port processes, identify the main constraints and bottlenecks, and suggest improved or new working and operating processes.

2.2.8 Container Port Performance Index 2020: a comparable assessment of container port performance (World Bank and IHS Markit 2021):

This report is the latest addition of global port performance benchmarks and is the inaugural edition of the Container Port Performance Index (CPPI), a new initiative by the World Bank in collaboration with IHS Markit. The CPPI is constructed based on two different approaches, an expert judgement (administrative) approach and a statistical approach using Factor Analysis (FA). The empirical data underpinning the CPPI is drawn from the IHS Markit's port performance program which is the same database used by the JOC port productivity (JOC was acquired by IHS in 2014). The CPPI is based on a central metric of port hours of ships call; disaggregated by 5 ship size groups ranging from a low of <1,500 TEU to a high of >13,500 TEU and 10 call size (move) groups ranging from a low of <250 moves to a high of >6,000 moves. In the administrative approach, the index is structured based on some expert judgement from the CPPI team, from aggregating arrival and berth hours to appraising port hours performance and indexing performance scores relative to average ship size groups. In the statistical approach, factor analysis is applied on a global dataset comprised of 5 ship size groups, 10 call size bands and two-part berth information (port-to-berth and on-berth) to construct performance scores for all ports in the sample. The final CPPI is the weighted average of the 5 sub-indices.

The CPPI scores show that the top 50 ranked ports are dominated by ports in East Asia and the MENA region with the top port in Africa being the port of Tangier-Med of Morocco in the 27th positions (none of the other African ports feature in the top 50). South African ports score bottom in the rankings with Cape town, Durban, Port Elizabeth and Ngqura ranked in 347, 348, 349 and 351 positions respectively under the statistical approach, and in similar positions under the administrative approach.

The CPPI is another attempt to construct a port performance index drawing from IHS data while trying to inject some expert judgement and statistical added value to make sense of a large, incomplete and at times inconsistent dataset. By their own admission, the report authors outline the several limitations to both the administrative and statical approaches and one could list several analytical and practical anomalies in the methodology and approach used. The study provides little or no insight into the factors that could explain the ranking prominence of some ports compared to others, for instance the deep-sea scale, hub status and transhipment propensity of the top ranked ports. More importantly, the CPPI focuses only on waterside and berth productivity, ignoring or overlooking both landside and hinterland productivity factors which for many ports around the world, including the South African container terminals, have a heavier weight and importance than ship performance indices. Despite its numerous shortcomings, the CPPI can provide some relevant indications on how certain ports can relate to comparable peers but also confirms the results and observations from other studies which single out the particularly poor performance of South African terminals in waterside and berth areas.

3 Benchmarking the efficiency of South Africa's container terminals

The primary aim of performance benchmarking studies is to measure and compare productive efficiency across time and/or between observations, sometimes referred to as Decision Making Units (DMUs). The concept of efficiency has been traditionally measured by the ratio of outputs over inputs of a DMU. Broadly, efficiency can be defined as the ability of an observation to produce a given or target output in a manner that is economic and efficient. In a multi-input and multi-output environment, performance benchmarking entails a further dimension because of the variations in the number and proportions of the sets of input used to produce a given set of output both across time and between DMUs. Understanding such variations, their causes and implications is important for port operators, users, regulators, and policy makers in order to assess various degrees and sources of productivity.

It is very important to underline the fundamental difference between terminal efficiency which denotes a dynamic measure of output/input productivity versus port KPIs which are often snapshot indicators, of physical activity measures such as crane move per hour and terminal's dwell time. While KPIs can be useful to reflect and compare snapshot operational terminal activities at a specific time or period, they cannot be used to derive and benchmark technical efficiencies over time and across port terminals.

The main purpose of benchmarking container-terminal efficiency in the context of this Study is to measure, track, decompose and analyse the operational efficiency of container terminals in South Africa both over time and vis-à-vis comparable benchmarks. The analytical work reported in this section relates to the inputs or resources that a container terminal uses to produce its output(s). As such, factors outside the terminal operator's control such as the efficacy of customs arrangements, the quality of hinterland connections, and the efficiency of trade facilitation procedures are not considered in this benchmarking analysis. Such aspects are addressed in a subsequent analysis in Chapter 4.

3.1 Methodology and data

3.1.1 Analytical method

Earlier we reviewed performance measurement and benchmarking methods used for port operations and demonstrate that a valid benchmarking analysis should be defined relative to an assessment of best practice, i.e., the level of efficiency should be measured relative to an efficiency frontier. We also show that several benchmarking techniques can be used to estimate the efficiency frontier. In this study, DEA was selected over SFA. On the one hand, the structure of container port production depicts different handling configurations and operating systems, which makes the estimation of a functional form under SFA very difficult to apply in the context of international port benchmarking. Programming techniques are less restricted to sample size than econometric models and can estimate technical efficiency for both individual inputs and the overall production process. On the other hand, both the multi-output nature of port production and the lack of detailed data are likely to limit the practicality of econometric methods. Unlike SFA which requires the specification of a production function, DEA is a non-parametric linear programming technique which determine optimal weights that minimise the distance between the frontier and DMU under consideration, subject to disposability and convexity constraints. Appendix A provides a detailed description of the DEA method and formulation used for this Study.

Throughout this exercise, we adopt an input orientated model. Container-ports in South Africa have little control over their output, measured here as TEU throughput, since the country's container throughput is dominated by captive traffic. Even so, the choice of model orientation is unlikely to impact overall benchmarking results, although individual efficiency scores may change slightly.

In addition to measuring and benchmarking port efficiency through DEA, we would like to track and decompose total factor productivity (TFP) using an index that can be derived and be compatible with the DEA methodology. To do so, we advocate the use of Malmquist DEA technique. The Malmquist Productivity Index (MPI) requires the estimation of a distance function; but the latter can be directly specified under DEA. Appendix B describes the MPI and its decomposition structure.

3.1.2 Sample terminals

We start with a dataset for the four South African container terminals (Durban Container Terminal – DCT, Cape Town Container Terminal –CTCT, Ngqura Container Terminal –NCT, and Port Elizabeth Container –PECT). Nine regional and global container ports have been carefully selected to reflect the characteristics of South African container terminals by focusing on medium-sized domestic and regional gateways with good hinterland connectivity while excluding pure transhipment, transit and large deep-sea hubs. The selected container benchmarking comparators include 9 regional and global container terminals as listed below:

- Alexandria International Container Terminal (AICT), Egypt;
- Sines MPS Container Terminal (MPS), Ghana;
- Dar Salam Tanzania International Container Terminal Services (MERSINS), Tanzania;
- Aqaba Container Terminal (ACT), Jordan;
- Jakarta International Container Terminal (JICT), Indonesia;
- Port Qasim International Container Terminal (QICT), Pakistan;
- Mersin International Port (MIP), Turkey;
- Sines' Container Terminal (TXXI), Portugal;
- Callao Port Container Terminal (CPCT), Peru.

3.1.3 Data and variables

For the data used, the choice of variables is based on a high-level aggregation of container-terminal operations with a view to utilizing available and reliable data on operational performance and ensuring homogeneity between observation units. In defining dataset variables, we considered the variations in handling configurations and technology for instance by using indices that account for the variations of operating and technological performance for Ship-to-Shore (STS) and yard-staking gantry cranes. Each generic port configuration usually incorporates a corresponding set of capital and labour mix; therefore, no cost or labour data is required for benchmarking operational efficiency. The variables selected for this study consist of seven inputs and one output as outlined in Table 1.

Data was sourced directly from the websites and annual reports of sampled ports and terminals. We also used other publicly available information including from UNCTAD's and WB's port publications. Some data inconsistencies were spotted for in input data changes following capacity expansion programmes which may be reported at different times. Because the benchmarking analysis is based on annual observations, any new capacity or expansion was recorded in the year reported by the relevant port or terminal, though in practice the actual date may fall in the preceding or the subsequent year.

The dataset consists of annual observations of sampled container terminals and spans the period from 2010 to 2019. This is because we wanted to select a long enough time scale that would allow us assess productivity changes over a reasonable period, given port life cycle and capacity management and planning features. The year 2020 was deliberately omitted in order to isolate any potential outlying impact of the COVID19 pandemic. In a dynamic context, panel data prevail over times-series and cross-sectional data, and as such an observation or DMU is defined as a container terminal-year, for instance DCT-2019 or CPCT-2013. The combination of 13 terminals, 8 variables, and a 10-year timeframe has resulted into a panel dataset of 130 observations and 1,040 data points.

Table 1: Input and output variables

	Variables	Description	Unit
Inputs	Terminal area	Total terminal area in square meters	1000 m2
	Max draft	Maximum draft in the terminal	Meter
	Length overall/ LOA	Total quay length in meter	Meter
	Quay crane index	N. of quay cranes * Lifting capability index	TEU
	Yard crane index	N. of yard cranes * Ground storage capacity * Stacking height	TEU
	Trucks & vehicles	Internal trucks, tractors, and other supporting vehicles	Number
	Gates	Number of gate lanes, and railway tracks at the gate	Number
Outputs	Terminal throughput	Annual total throughput	1000 TEU

Note: lifting capability index (in TEU) is calculated as follows: Conventional 20f t= 1, Twin 20ft = 2, Tandem 40ft = 2, Two tandems = 4, Triple 40ft = 6.

Source: author's elaboration based on data described in Section 3.1.3.

3.2 DEA results

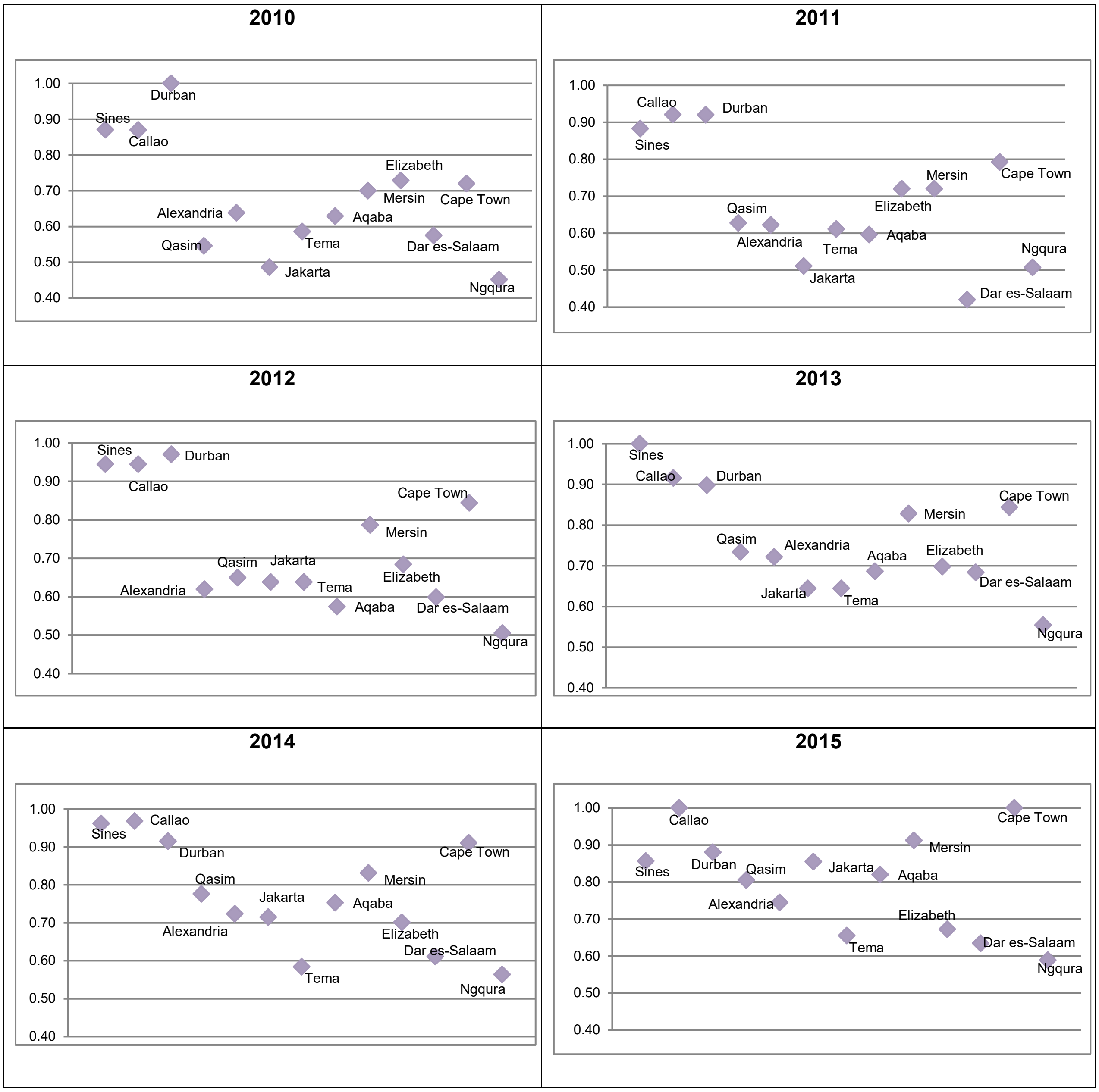
In this section, we present the results of the benchmarking analysis for South African container ports under two DEA approaches: the contemporaneous (cross-sectional) DEA and the inter-temporal (panel-data) DEA. Under the former, an annual frontier is constructed at a single point in time (a year) so that a terminal is benchmarked against a small sample of annual observations. Under the latter, a single frontier is constructed from all observations made throughout the study period (10 years) so that each terminal-year is treated as a separate observation and benchmarked against all observations.

3.2.1 Cross-sectional analysis

Appendix C reports the results of the efficiency estimates of South African terminals the contemporaneous DEA. Figure 2 shows the annual performance rankings of the container terminals under study in the years 2010 through to 2019. Across the study period, South African terminals have performed differently with efficiency scores ranging from a low score of 0.45 (45%) to the maximum score of 1.0 (100%). Durban and Cape Town have achieved the highest efficiency score of 1.0 (100%) twice, in 2010 and 2015 respectively. Ngqura has scored the lowest container efficiency rating of 0.45 (45%) in 2010, but this was most likely due to low demand in the first years of operation. For Port Elizabeth, efficiency scores remained broadly the same within the threshold range of 0.633 and 0.773. For peer container terminals, Sines (TXXI) and Callao (CPCT) have achieved the highest score of 100% three times each; while Mersin (MIP) and Aqaba (ACT) have each achieved the 100% once. At the lower end of the scale, Dar es Salaam (TICTS), Tema (MPS) and Jakarta (JICT) scored well below average, especially in the first five years of observation.

The general picture shows a downward trend of efficiency deterioration in the past 10 years across South African container terminals against an upward trend of efficiency improvement for regional and global comparators. The exception was Ngqura which recorded efficiency gains over the same period.

Figure 2: Efficiency scores of South African and comparator terminals under DEA cross-sectional analysis



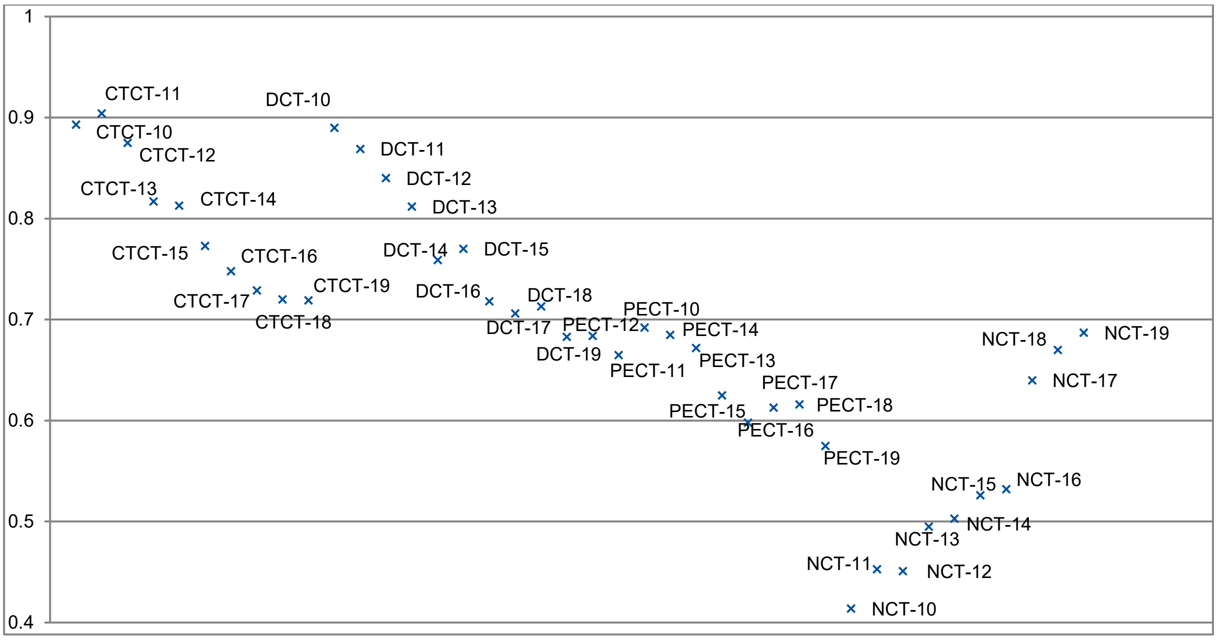
(figure continues on next page)

Source: author's elaboration based on data described in Section 3.1.3.

3.2.2 Panel data analysis

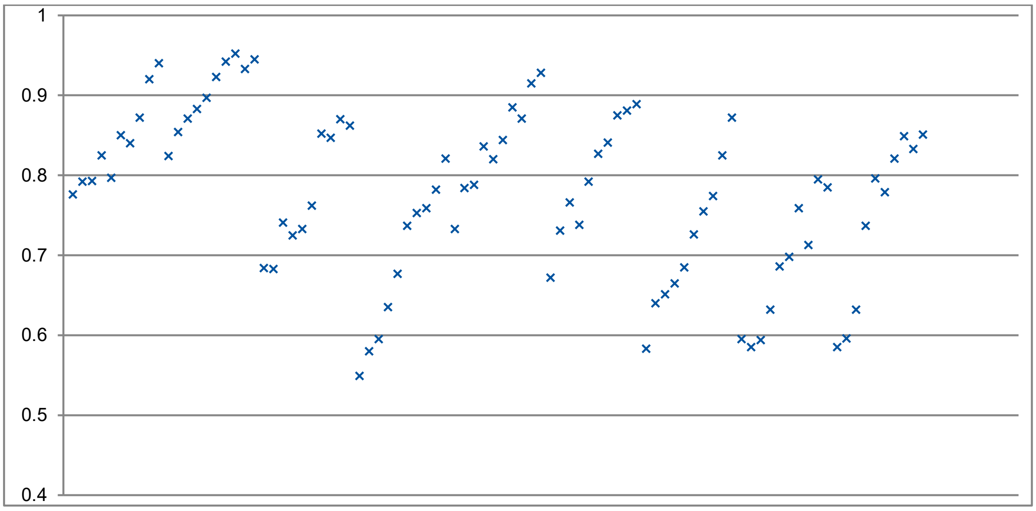
Appendix D shows the full results of inter-temporal DEA. Unlike in the cross-sectional analysis, none of the South African terminal observations has achieved the maximum efficiency rating of 100%; the highest score was of 90.4% registered by Cape Town -2011. The analysis also shows that South African container terminals depict a general trend of deteriorating operational efficiency over time compared with an ascending efficiency trend for regional and global comparators. This is particularly the case for Durban and Cape Town, while Ngqura has been the outlier in the sample having enjoyed a surge in its productive efficiency due to its recent history and steady increase in container throughput.

Figure 3: Efficiency estimates of South African terminal observations under DEA panel data analysis



Source: author's elaboration based on data described in Section 3.1.3.

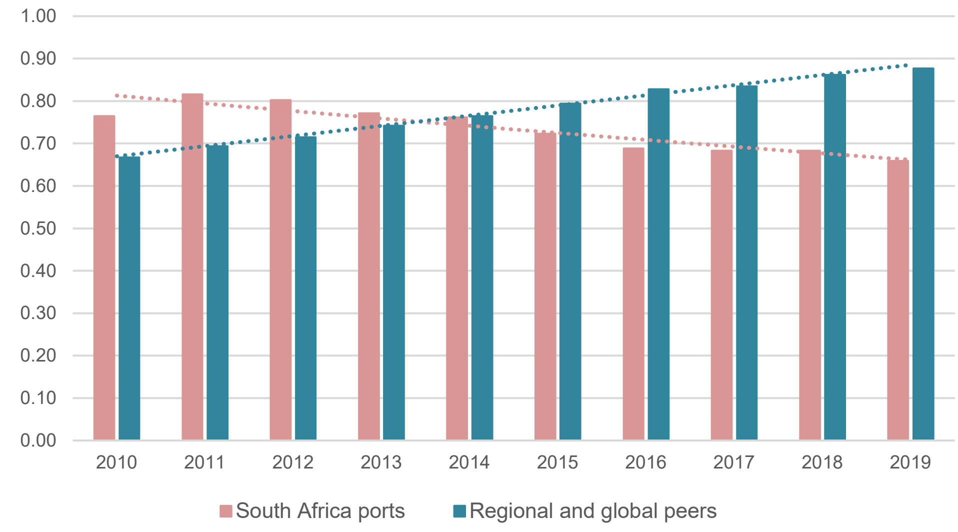
Figure 4: Efficiency estimates of regional and global terminal observations under DEA panel data analysis



Source: author's elaboration based on data described in Section 3.1.3.

Further analysis shows that there is substantial waste in the production of the South African container terminals especially over recent years. Over the past 5 years, the performance of South African terminals is on average 20% less than the average performance of other terminals in the sample, and up to 35% below their optimal potential. Moreover, the distribution of efficiency scores among the observations shows uneven results with low performing terminals dominating the observation sample. Over half of the South African terminal observations (22 terminal-years) have an efficiency score below 0.7; while over two-third of the total observations (31 terminal-years) scored an efficiency rating below 0.75. This indicates that, in theory, South African container ports can, on average, increase the level of their efficiency by as much as 25% to 35% from their current level while using the same inputs. Combining these results with other issues on supply capacity (see further below); there seems to be a general operational slack in the system estimated around 25%-35% and where underutilized resources (inputs) can be more efficiently used to achieve higher capacity. This obviously depends on the adequate approaches to production being implemented and the appropriate scale of production adopted.

Figure 5: Yearly combined average efficiency scores, under DEA panel data analysis



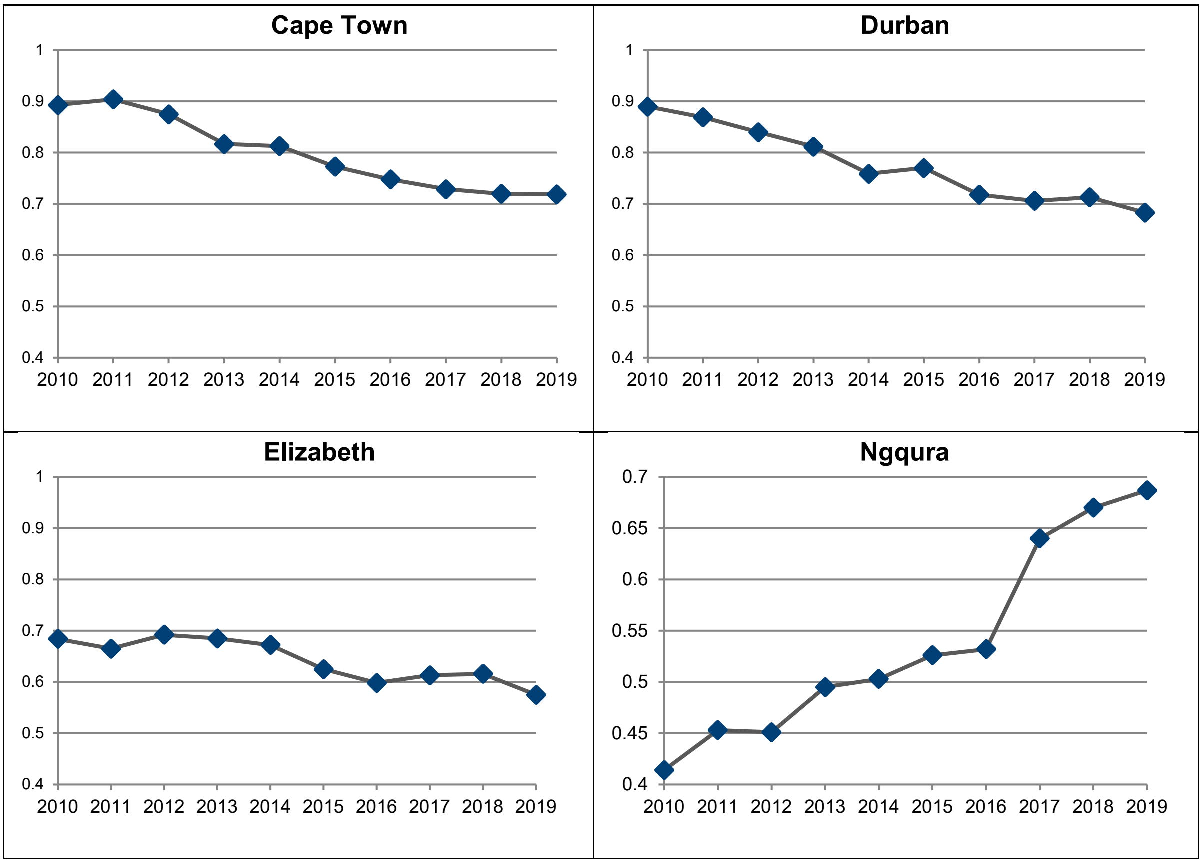
Source: author's elaboration based on data described in Section 3.1.3.

Figure 5 shows the time-series evolution of average terminal efficiency scores in each year of the study period, based on inter-temporal DEA. On average, the combined performance of container terminal comparators (non-SA) under panel data analysis has increased by over 30% over the past 10 years, from just-below 67% in 2010 up to 88% in 2019, that is about 3% annual performance improvement. Conversely, South African container terminal efficiency under inter-temporal DEA has decreased by about 15% from a high of 76% in 2010 to 66% in 2019, equivalent to 1.5% annual decline in performance. Combining both sets of figures, the efficiency gap between South African container terminals and comparator peers has dramatically deteriorated over the past 10 years by almost 45%. If the outlying effect of Ngqura (being the only newly built port terminal in the sample) is excluded, the performance gap exceeds the 50% threshold. Compared with African comparators, Tema, Dar es Salaam and Alexandria, the gap is even wider (at about 62%) given the low 2010 performance base of these regional peers which is below the 3.5% average performance increase under the DEA cross-sectional analysis.

The main outcome from the above is that the overall efficiency of South African container terminals in the past 10 years has markedly deteriorated while increasing for comparator regional and global ports. The comparator ports have been selected to reflect similar size, market and operating conditions to South African container ports, and given the input-orientation of the DEA analysis and that none of the terminals in the sample (except Ngqura) has experienced a major capacity expansion over the observation period, the results imply that South African ports suffer from a structural and potentially inherent performance gap which requires further analysis and examination.

As far as individual container terminals are concerned, Figure 6 shows the evolution of performance scores for each container terminal under study, under inter-temporal DEA.

Figure 6: South African terminal efficiencies under DEA panel data analysis



Source: author's elaboration based on data described in Section 3.1.3.

Cape Town, Durban, and Elizabeth container terminals have all registered a sustained downward trend across the past ten years, while Ngqura was the exception with an upward sustained trend over the same period. For Cape Town, the drop in efficiency seems to have stabilised over the past 2 to 3 years but is still 25% less than its 2010 high record. Durban, on the other hand, has experienced the largest and most sustained drop in efficiency over the years which reflect the pressure on the port to keep up with demand and the critical constraints on container-port capacity. Port Elizabeth depicts somehow a different pattern albeit still depicting a downward trend; the port seems to be suffering from a loss of market share to Ngqura with both its throughput and efficiency scores having stagnated in the past 5 years. Lastly, Ngqura has experienced an upward efficiency trend which seems to be driven by an accelerated traffic growth since the port opening in 2009. Even though, terminal efficiency has only increased equally or less proportionally than the increase in terminal throughput, implying that the port has not (yet) benefited from scale efficiencies (see further below).

3.2.3 Results by terminal group

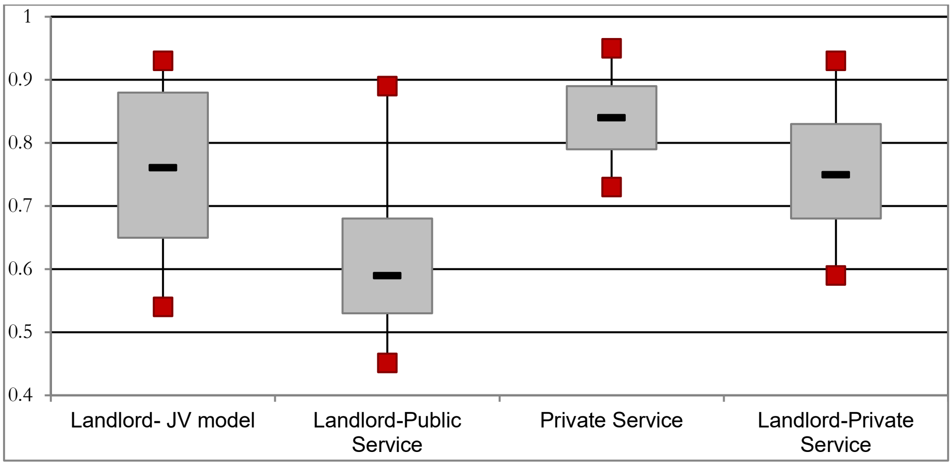
In this section, we use the results of the DEA analysis to compare South African ports according to their institutional structure and scale features.

Terminal efficiency and institutional structure

To examine whether there is a relationship between port institutional structures and productive efficiency, we classify terminals into five groups according to their institutional arrangements. The purpose of this analysis is to see whether there is some correlation between the institutional structural of the ports and their respective efficiency scores.

Figure 7 shows the variation of productive efficiency by type of institutional ownership across the 13 container terminals under study. The grey box represents the inter-quartile range of efficiency scores where the median is indicated by the black centre line and the lower and upper edges of the box are the first and third quartiles, respectively. The extreme values (minimum and maximum scores) are represented by the squares at both ends of the lines which extend beyond the grey box. Accordingly, the fully private service model (Callao, Mersin, and Sines) depicts the highest efficiency ratings. The hybrid institutional model representing both the landlord-private-service model (Qasim, Alexandria, Dar es Salaam) and the landlord-joint-venture model (Aqaba, Jakarta, Tema) also depict a relatively high efficiency ratings, but the JV model seems to show wider variations depending on whether the JV involves active public sector participation (Tema, Jakarta) or a passive one (Aqaba). Last in the ranking is the landlord-public-service model represented by South African ports and showing the lowest average efficiency. Those results suggest that ports with PSP tend to outperform those with no PSP.

Figure 7: Variation of productive efficiency across port institutional structures

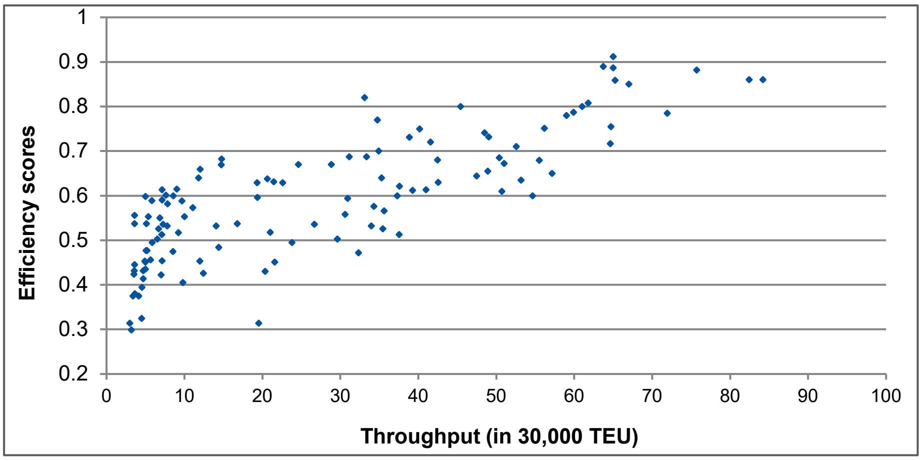


Source: author's elaboration based on data described in Section 3.1.3.

Terminal efficiency and production scales

The relationship between scale of production and operational efficiency can be inferred directly from the results of the DEA analysis. The results from applying an input orientation show that out of the total number of 130 terminal-years in the sample 36 exhibit constant returns to scale, 78 exhibit increasing returns to scale, and 14 exhibit decreasing returns to scale; all 2010-2019 years combined. This is better illustrated in Figure 8 where the average tendency for the relationship between efficiency scores and production scale (as measured by container throughput) is plotted.

Figure 8: Relationship between efficiency and production scale



Source: author's elaboration based on data described in Section 3.1.3.

Table 2 shows the results of correlation tests to examine the relationship between the size of a port throughput and its productive efficiency. For South Africa, the small values of both coefficients indicate a positive correlation that is not highly significant, most possibly due to the medium size of container terminals in the country. Further tests reveal a weak correlation between the standard deviation of efficiency scores and the scale of production (Table 3). Those results may also imply that some variations in efficiency exist between South African container terminals, such variations are not mainly driven by terminal size and further analysis is required to investigate the drivers of port efficiency.

Table 2: Relationship between throughput size and productive efficiency

DEA model	Type of data	Correlation between throughput and efficiency	
		Pearson correlation	*Spearman's rank order correlation*
Constant returns-to-scale	Panel data	0.557	0.193
	Cross-sectional data	0.569	0.228
Variable returns-to-scale	Panel data	0288	0.216
	Cross-sectional data	0.284	0.189

Source: author's elaboration based on data described in Section 3.1.3.

Table 3: Relationship between variations in efficiency scores and scale of production

DEA model	Type of data	Correlation between throughput and efficiency change	
		Pearson correlation	*Spearman's rank order correlation*
Constant returns-to-scale	Panel data		
Variable returns-to-scale	Panel data	-0.262	-0.177

Source: author's elaboration based on data described in Section 3.1.3.

3.3 MPI results

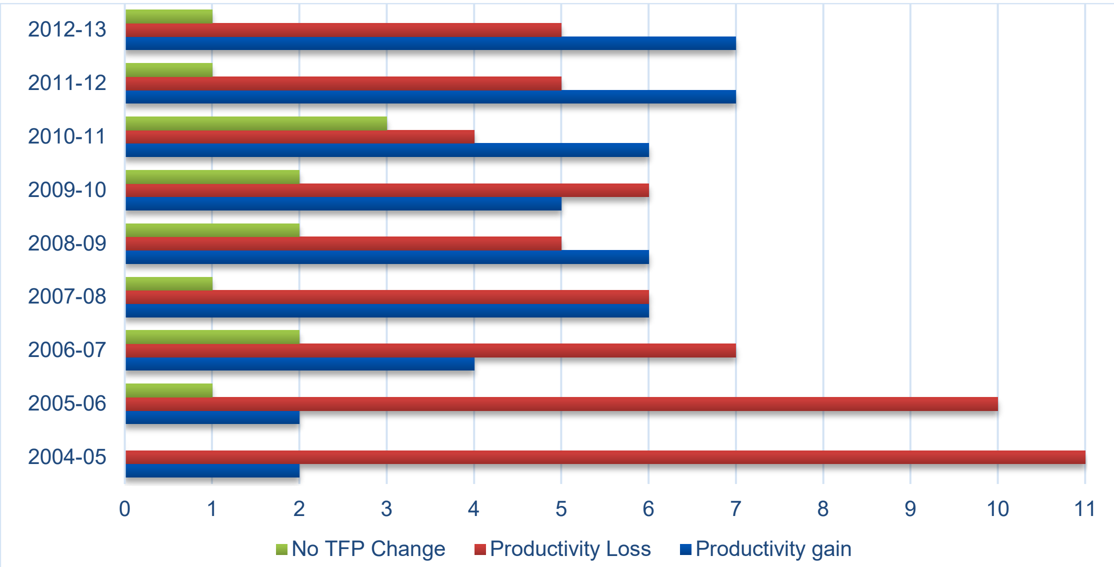
In the context of this study, the Malmquist Productivity Index (MPI) can be used both for identifying the sources of port efficiency and for assessing total factor productivity growth. On the one hand, the MPI can be decomposed into three various indices namely (i) the pure technical efficiency change (PEC) representing pure efficiency change, (ii) the scale efficiency change (SEC) representing the effects of scale production, and (iii) the technological change (TC) representing the frontier shift effects. This feature makes the MPI a particularly attractive technique for measuring changes in, and decomposing the sources of, productivity. On the hand, the MPI can track changes in port productivity over time, for instance before and after the implementation of institutional reform. At the same time, the MPI can be used to examine whether any convergence in port productivity has taken place over time, especially for port groups with similar ownership and institutional structures.

3.3.1 MPI and sources of efficiency

The results of the total productivity analysis show that on a year-by-year basis during the study period, 45 terminal observations (of which only 3 South African) have achieved a productivity gain (MPI>1), 59 observations (of which 30 South African) have experienced a productivity loss (MPI<1) and 13 terminals (of which 3 South African) recorded no change in total factor productivity (MPI=1).

Figure 9 shows the variations of productivity change for South African container terminals only. Overall, the average productivity was regressing in most year-pairs but with varying degrees of productivity change both across pairs of years and between terminals. More specifically, it shows that much of the productivity decline took place post 2016 against productivity gains dominating from 2010 till 2015. In 2015-16, there was an even split between productivity gains and losses.

Figure 9: Distribution of MPI results by year-pairs for all container terminals in the sample



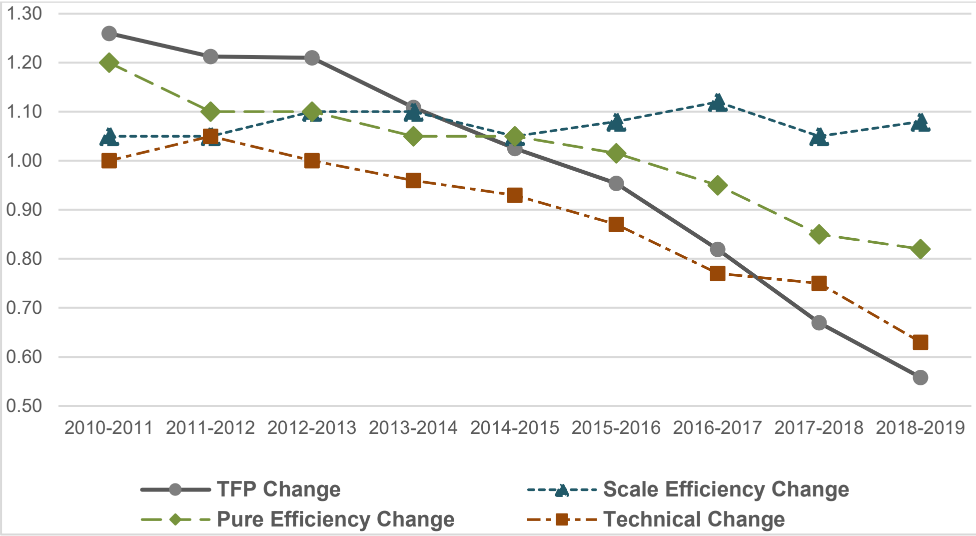
Source: author's elaboration based on data described in Section 3.1.3.

Looking further into the sources of productivity loss in South African terminals, the analysis suggests that Total Factor Productivity (TFP) change and its sub-categories do not all follow similar trends:

- Pure Efficiency Change (PEC) follows a similar trend to that of TFP. However, productivity losses due to PEC seem to be less severe than those for TFP suggesting that the drag on TFP is mostly due to other sources of in(efficiency).
- Technical Change (TC) has been in the Red (MPI<1) since 2012 with further productivity losses incurred in the past 5 years. In 2019, TC stands at 0.62 suggesting a steep deterioration of technological progress in South African terminals over the years.

- Scale Efficiency Change (SEC) has been positive (MPI>1) across all observation periods; showing somewhat a different trend to TFP, PEC and TC. However, with a SEC hanging just above 1, this suggests that only a small or insignificant productivity gains were achieved due to economies of scale. This is consistent with the relatively medium to upper-medium size of container terminals in South Africa, and because no major capacity expansion has taken place in the past decade. This is also broadly in line with the results shown by regional and global terminals in the sample.

Figure 10: Average values of MPI and its efficiency sources for South African ports on a year-by year basis



Source: author's elaboration based on data described in Section 3.1.3.

To further investigate the relationship between various sources of efficiency, Table 4 shows the correlation between the multi-year total productivity change and its sub-categories.

- Starting with scale efficiency (SEC), this shows low correlations with TFP across the pair-years despite variations between the years. Those results infer that the impact from the economies of scale is smaller, if not negligible, compared with the ones emanating from technological progress (TC) or a better utilisation of resources (PEC).
- For pure efficiency change (PEC), the results show moderate correlations with TFP across the pair-years despite variations between the years. Those results show that productivity gains achieved from the rationalisation of input use have a moderate to high impact on the decline of the overall efficiency (TFP) of South African container ports over the observation period.
- For technical change (TC), this component has the highest correlation with TFP especially in the periods from 2014 till 2019. It is during this period that no major technological investment has taken place in South African container ports. In operational terms, a high TC in container ports generally translates into lower labour intensity and higher automation and equipment use, and better results in digitising and streamlining administrative and procedural arrangements.

Table 4: Correlation of the multi-year MPI and its sources of efficiency change

Period	MPI decomposition		
	MPI-SEC	MPI-PEC	MPI-TC
2010-11	0.512	0.566	0.560
2011-12	0.491	0.530	0.690
2012-12	0.446	0.660	0.740
2013-14	0.521	0.530	0.753
2014-15	0.386	0.750	0.897
2015-16	0.501	0.775	0.906
2016-17	0.817	0.965	0.897
2017-18	0.721	0.971	0.921
2018-19	0.788	0.920	0.943

Source: author's elaboration based on data described in Section 3.1.3.

In the absence of higher correlations from scale efficiencies, the technical change component seems to be the main driver of TFP decline during the study period, followed by the pure efficiency component. It shows that South African container terminals have lagged both in technological progress and technical efficiency. For the former, technological progress is manifested by upgrades and updates in port hardware and software operating systems in line with the industry's modern practices in terminal automation, digitisation, and other technological solutions. For the latter, it reflects operational optimisation and intensity both remain below international standards across several operational areas.

3.3.2 MPI and impact of PSP

One way to assess the impacts of port ownership structure on terminal efficiency is to track TFP change of terminals that are private sector dominated against that of terminals that are public sector dominated. For the purpose of this analysis, private-sector dominated ports are those that fall under the (pure) private-service model as well as hybrid landlord options (landlord-JV model and landlord-private-service model), while public sector dominated ports are those that fall under the full public service model currently adopted by South African container terminals. Table 5 shows the scores of MPI and its sub-categories for the two different institutional port groups.

Table 5: MPI and its sources of efficiency for terminals by ownership type

Index	Terminal group	N	Mean	Std. deviation	Minimum	Maximum
MPI	Private sector dominated	6	0.996	0.083	0.762	1.664
	Public sector dominated	7	0.844	0.244	0.525	0.986
	Total	13	0.817	0.237	0.525	1.664
PEC	Private sector dominated	6	0.985	0.107	0.719	1.386
	Public sector dominated	7	0.735	0.078	0.710	1.007
	Total	13	0.890	0.107	0.719	1.386
SEC	Private sector dominated	6	1.560	0.124	0.636	1.656
	Public sector dominated	7	0.894	0.204	0.394	1.048
	Total	13	1.113	0.203	0.394	1.656
TC	Private sector dominated	6	1.169	0.159	0.939	1.348
	Public sector dominated	7	0.657	0.122	0.438	0.797
	Total	13	1.002	0.130	0.438	1.348

Source: author's elaboration based on data described in Section 3.1.3.

The results indicate that for private sector operated terminals, both the total productivity change (TFP/MPI) and the pure efficiency change (PEC) were almost constant during the study period, while scale efficiency change (SEC) and technical change (TC) have both experienced productivity gains. On the other hand, public sector ports recorded productivity losses in TFP/MPI and all its components, with most losses being recorded in the categories of technical change (TC) and pure efficiency change (PEC). This suggests that private-sector ports generally outperform their public-sector ports. The latter group, represented by South African container terminals, suffered productivity losses in technological change due to underinvestment in new technology and operating systems. South African terminals also suffered from losses in pure efficiency due to public sector inertia and the lack of best practices and knowledge management solutions that is usually transferred with global private operators. These empirical findings provide a good basis for promoting PSP in South African container ports and the institutional models presented above.

4 Assessing the impact of trade logistics on container port performance

An efficient port logistics system is a key driver for business competitiveness and economic growth. Because they are controllable aspects of global supply chains, ports and logistics deserve particular attention in a country's competitiveness and trade efficiency.

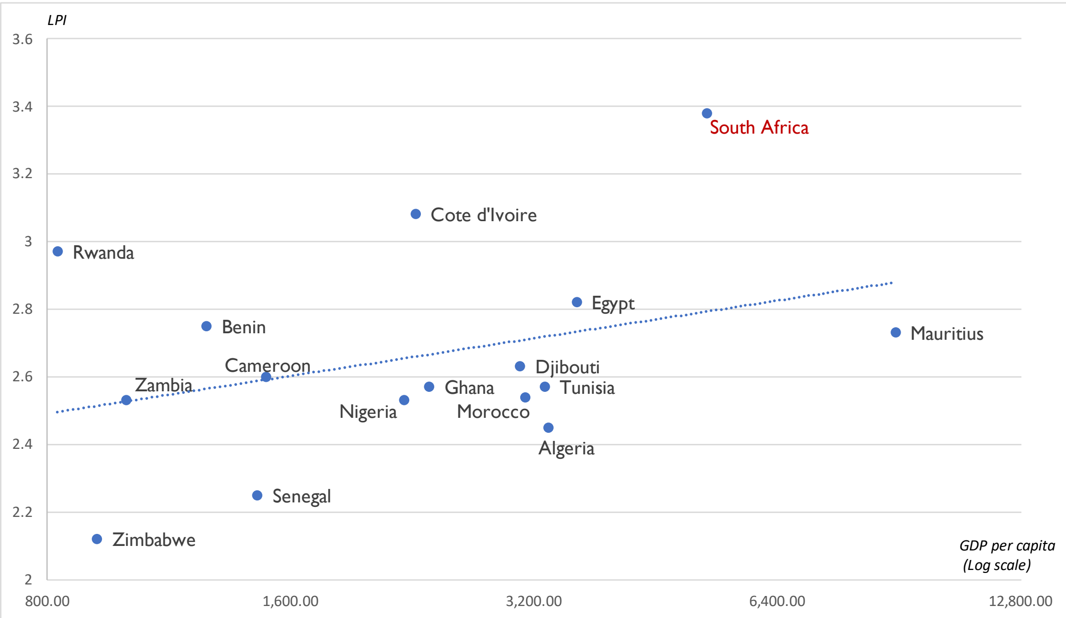
Underpinning the performance of ports and freight logistics are several factors, which besides the productive efficiency of container terminals, include factors such as the quality of infrastructure, the connectivity to shipping and logistics markets, the competency of operators and service providers, and the efficiency of customs and trade facilitation procedures. Therefore, it is important to assess these factors in the context of the South African container port system with a view of formulating operational and policy recommendations. Among several seminal and empirical work on countries' performance in ports and logistics, worth mentioning the WEF's Quality of Port Infrastructure (QPI), the World Bank's Logistics Performance Index (LPI), the UNCTAD's Liner Shipping Connectivity Index, and the IFC/WB Trading Across Borders. Table 6 below shows the score rankings of South Africa in each of those indices compared with those of selected African countries.

4.1 Levels of income and logistics performance

The LPI is the World Bank's benchmarking tool to measure a country's logistics performance. The index takes into account factors such as logistics competence and skills, the quality of trade-related infrastructure, the price of international shipments, and the frequency with which shipments reach their destination on time. The scores of the international LPI reflect perception evaluations of logistics professionals located outside the country, thus providing qualitative information of how a country's trading partners perceive the efficiency and quality of its logistics services.

In the African continent, South Africa achieves the highest LPI score but the gap with other countries has been shrinking since 2004. Figure 11 shows is a persistent gap between middle-income and lower-income countries, yet income alone is not the only determinant of a country's logistics performance.

Figure 11: Relationship between income and logistics performance in selected African countries



Source: author's elaboration based on data described in Section 3.1.3.

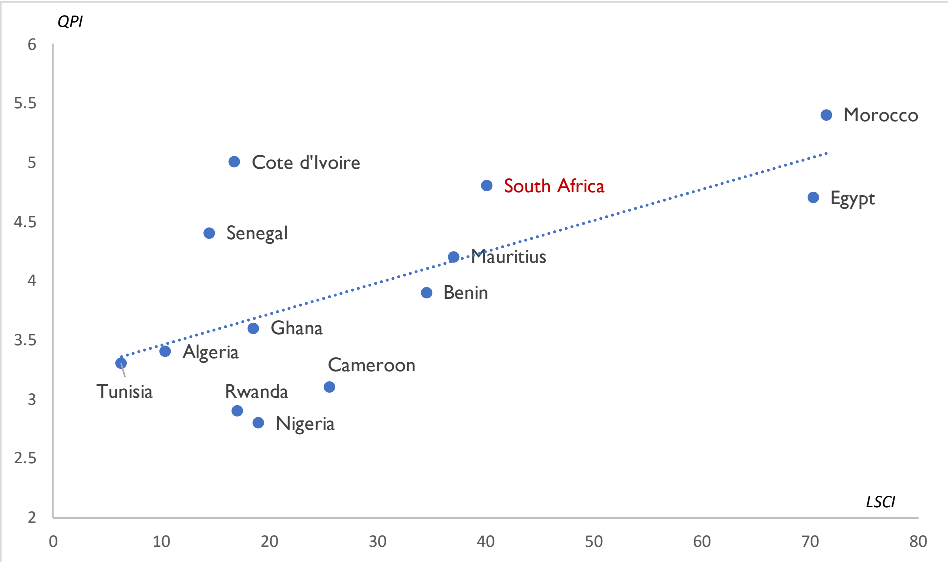
4.2 Quality of infrastructure and logistics connectivity

From an international logistics perspective, a country's relevance depends on its connectivity to international shipping and logistics networks. UNCDAT's LSCI is an index that measures a country's connectivity to the international container shipping network and by extension to global trade markets. In Africa, the countries most connected to the global shipping network are Morocco and Egypt owing to their large transhipment hubs. South Africa's connectivity is almost half of Morocco's, stressing the need to develop a large container transhipment and interlining hub in the country.

Figure 12 shows the relationship between LSCI and the WEF quality of port infrastructure. Among the two indices, the QPI is particularly highly correlated with the LSCI components 'number of companies' and 'largest vessel size'. It comes as no surprise that a carrier's decision to provide services from/to a country's ports using its largest ships is closely related to the country's port infrastructure and capacity.

Countries such as Morocco and Egypt have benefited from their large transhipment hubs, respectively Tangier-Med and East-Port Said, and connected to a wide network shipping routes and services, which in turn has reduced time and cost of trade (see infra). For South Africa to join these countries and become a regional and global leader in network servicing, a strategy whereby international shipping lines are requested to set up and operate a transhipment port in the country is urgently required.

Figure 12: Relationship between liner connectivity and quality of port infrastructure in some African countries



Source: author's elaboration based on data described in Section 3.1.3.

4.3 Logistics performance and procedural efficiency

The performance of a port logistics system also relates to the cost, efficiency, and timeliness of trade facilitation procedures. Countries which lack natural access to large seaports and transport hubs, e.g., Rwanda, can compensate by streamlining customs and trade procedures to reduce transaction time and cost. Conversely, countries such as Côte d'Ivoire and Djibouti cancel out the benefits of maritime connectivity by imposing lengthy procedural lead times and very high trade costs. Unlike for the overall LPI, South Africa does not lead the continent in through trade cost and procedural efficiency. This brings to light the importance of hinterland logistics connectivity and the need to develop integrated systems linking dry port and inland terminals to transit and gateway seaports and transport hubs in neighbouring countries.

Table 6: Relevant port and logistics efficiency indicators for South Africa and selected African countries

	LPI (WB) 2018	Burden of customs procedures 2017	Lead time		Documentary compliance		LSCI 2020 (UNCTAD)	QPI 2017 (WEP)
			to export	to import	Cost to export	Cost to import		
	1-5 (worst to best)	1-7 (7 is best)	days	days	$/container	$/container	Max 100	1-7 (7 is best)
South Africa	3.38	4.2	3	3	55	676	40.11	4.8
Côte d'Ivoire	3.08	4.1	4	10	136	456	16.76	5
Rwanda	2.97	5.3	2	3	110	282	16.96	2.9
Egypt	2.82	3.9	2	3	100	554	73.28	4.7
Benin	2.75	3.5	14.0	N/A	80	599	34.49	3.9
Mauritius	2.73	4.6	1	2	128	372	37.03	4.2
Djibouti	2.63	N/A	2	3	95	1055	25.53	N/A
Cameroon	2.6	3.4	5	9	306	1407	25.5	3.1
Tunisia	2.57	3.1	4	3	200	596	6.3	3.3
Ghana	2.57	3.9	1	4	155	553	18.5	3.6
Morocco	2.54	4.5	2	5	67	228	78.5	5.3
Nigeria	2.53	2.9	3	3	250	1077	18.96	2.8
Zambia	2.53	3.7	9	6	200	380	N/A	2.3
Algeria	2.45	3.4	4.0	5	374	409	10.36	3.4
Senegal	2.25	4.6	1	3	96	702	14.45	4.4
Zimbabwe	2.12	2.9	5	10	170	562	N/A	3.1

Source: compiled by the author.

5 Assessment of the competition, institutional, and governance frameworks in South African Ports

5.1 Competition frameworks and markets

Ports face growing competition both within and outside the port market, resulting into different forms and levels of port competition. On the one hand, competition *for* port markets refers to the competition for the award of port concessions and licences. Sometimes, licensing requirements limit the number of competitors for each service which may reduce the competition for port markets into a competition for the *exclusive right to provide services*. On the other hand, competition *in* port markets can be classified as either *intra-port* or *inter-port* competition. Intra-port competition occurs between terminal operators and service providers within the same port and sometimes even within the same terminal. Inter-port competition takes place between ports sharing similar or shared hinterlands and increasingly between ports competing for further forelands and network supply chains where hub-and-spoke, transhipment, feedering and transit services are often involved. Port competition can also be assessed by examining the structure and dynamics of industrial organization in the markets for container ports, liner shipping and maritime logistics. This includes strategies of internationalisation, consolidation, and vertical and horizontal integration in the port, shipping and logistics industry, especially with the rise and dominance of international container terminal operating companies.

Pursuant to the port reform and the Ports Act of 2005, Transnet Ports Terminals (TPT) a subsidiary of the state-owned enterprise Transnet SOC Ltd. which also controls TNPA and other freight divisions, was awarded an auto-renewal (evergreen) operating licence on all container terminal facilities in South Africa. This effectively created a public sector monopoly over container ports and terminals in the country, therefore impeding inter-port and intra-port competition in the container market.

5.1.1 Competition for container port markets

The Ports Act of 2005 outlines the general conditions for the provisions of port services, the operation of port facilities and the use of port land. Under such conditions, the TNPA as the ports' landlord is mandated to enter into licencing agreements with other parties, including private sector interests, for the construction, design, financing, operation, and maintenance of port facilities as well as for the provision of port and associated services. The Act broadly promotes licencing as a tool for promoting port competition and specifies that each licence must set out operating rules and conditions including on the scope, duration, operational performance standards, and tariffs and pricing control mechanisms.

To date, over 100 operating licensees have been granted by TNPA to various operators including from the private sector. However, container cargo handling services have been exclusively reserved to TPT. TPT seems to have been granted an outright operating licence without competitive tendering including for the 'exclusivity' to provide container handling services within and across South African ports. Furthermore, the 'evergreen' licence granted to TPT over container terminal operations further prohibits competition for container port markets. Even where the advantages of service bundling and resource pooling outweigh those of unbundling and product decoupling, the licensing of exclusive rights for operating container port services should not be awarded on a permanent or indefinite basis, but rather on a limited time period licences or concessions. This would allow new market entrants to compete during the re-tendering of those port licences and concessions.

The absence of competitive tendering combined with the lack of appropriate licencing conditions have resulted into TPT enjoying a monopolistic position in a captive hinterland, therefore having no market threat or contractual requirements to spur them towards improving port performance and efficiency. This situation is quite unique and at odds with international best practice in intra-port competition and terminal concessioning. We are not aware of any modern port system where container terminal concessions and operating licences have been granted on both an exclusive and evergreen basis to a single operator.

5.1.2 Competition in container port markets

Intra-port competition

Intra-port competition, while possible in South African container market, does not practically exist. With the growth of container traffic and the shift towards port terminalisation, most South African container ports are large enough to be operated by several service providers with a view to promoting intra-port competition.

Durban already has two container terminals which could have been licenced or concessioned to separate terminal operators rather than to a single to operator (TPT). Cape Town is also nearing capacity and there is demand and commercial justification for an additional container terminal in the port. Ngqura port can also establish intra-port competition especially if international port operators are brought in to develop transhipment terminals. Elsewhere, service unbundling could also be used to vertically separate port services (marine services, cargo handling, logistics distribution, etc.) and allocate them to different suppliers.

Over recent years, there have been discussions and plans for the need of a horizontal unbundling of the container port market in South Africa through PSP including potential strategic partnerships and/or joint-ventures with international operators; yet no concrete strategic plan was put in place to-date.

Inter-port competition

Between South African container ports, all container terminals are controlled and managed by TPT in ways that prohibit inter-port competition. Although TPT is managerially and operationally organised into separate port terminals, those do not operate as independent entities from an accounting, legal and commercial perspective, which reduces, if not eliminate, any incentive for them to compete.

Furthermore, TNPA as the landlord authority has done little to stimulate competition and rivalry between its ports. At corporate level, Transnet has been managing its port, rail and freight divisions in ways that coerce cross-subsidisation rather than promote competition between them. Competitive pricing is equally missing in the domestic container port market given that infrastructure tariffs and charges are uniformly set (TNPA) and regulated (Ports Regulator) across all ports. At policy level, the South African Department of Transport also adopts complementarity, rather than rivalry, between the country's container ports therefore limiting the potential for inter-port competition.

As a measure of container port market concentration, we have estimated the Hirschman-Herfindahl Index (HHI) for South Africa and 3 other countries, Malaysia, Colombia and the UK, each representing different continents and port institutional structures. The container market share of South Africa's TPT is close to 100% with an HHI of 9,900 points. This is the closest to a monopoly situation by any country or competition authority definition.

Table 7: Container terminal HHI for South Africa and selected countries

Country	Market share test (%)	HHI
South Africa		9,900
TPT- Durban, Cape Town, Elizabeth, Ngqura, E. London	98.1	
Other	9.9	
Malaysia		5,577
MMC- Northport, TPT (without APMT), Penang, Malacca	48.2	
HPH- Westport	30.4	
Other- including APMT/TPT	20.4	
Colombia (Atlantic Coast)		3,175
Barranquilla	15.2	
Santa Marta	14.4	
Cartagena Society	51.2	
CONTECAR	8.4	
El Bosque	10.8	
United Kingdom		2,813
DPW- London Gateway and Southampton	33.6	
HPH- Felixstowe and Thamesport	40.1	
Forthsport- Tilbury	7.8	
ABP- Immingham	6.9	
Peelport- Liverpool	5.5	
Other	6.2	

Source: author's calculations based on data described in Section 3.1.3.

Inter-port competition for hub networks and transit forelands

Aside from inter-port gateway competition for domestic hinterlands, South African container ports compete directly or indirectly for transhipment and transit container markets. For the former, South Africa has long had an aspiration to develop one or a combination of its container ports as a major transhipment hub, most recently with the development and promotion of Ngqura as a deep-sea transhipment facility. For the latter, South Africa ports have a geographical and infrastructural advantage to compete for transit cargo bound to landlocked countries in Southern Africa.

South Africa is linked to the worldwide liner shipping network by End-to-End (ETE) services which connect the country's coastline directly with the major industrialised regions of Europe, the Americas, East Asia and Australasia and indirectly with interlining, relay and feedering services connecting with main line services via hub and transhipment ports around West and East Africa and further away in South Asia and North Africa. With on-going and planned expansions for deep-sea container facilities in East and West Africa, we expect inter-port competition to intensify significantly on the hub and spoke and transhipment markets, with direct impacts on South African container ports. While at this stage it is too early to pronounce on future dynamics for hub and transhipment services in Southern Africa, our reading from the strategies of the main shipping lines and global terminal operators in the region suggests that they tend to combine their existing transhipment hubs in North Africa, East Asia and the Indian Ocean with West, East and Southern

Africa. This strategy could be most detrimental to South African ports unless they can attract or partner with global operators.

On the competition for shared and extended hinterlands, this has been most noticeable in the transit market for the neighbouring landlocked countries of Zimbabwe, Zambia and Botswana and as far afield as Malawi and even the DRC. South African ports serve many landlocked countries in the region and have long dominated the market of transit cargo. However, many ports in the region have started to challenge South African's ports position and compete for a larger share of the landlocked markets.

5.2 Institutional setting and organisational structure

The success of any port system depends on the adequacy of the institutional structure in place and on the capabilities of public agencies in charge of the port sector. Traditionally, ports have been owned, operated, and regulated by state-controlled public organizations. However, both the introduction of Private Sector Participation (PSP) in ports and the emergence of new forms of port administration have led to the adoption of new models of port ownership and institutional structuring. Current models for classifying port organizational and institutional structures are categorised by one or a combination of the following criteria: the ownership structure (public, private, or both), the administrative organization (national, regional, local, etc.), and the level and scope of devolution (statutory independence, financial autonomy, etc.).

Due to the variety and dissimilarity of port assets, roles, functions, and services; analysing the ownership structure of ports and terminals is not always a straightforward categorisation between public and private sector ownership. This has led to the emergence of generic port institutional models including the landlord, public service, private service and tool models, or a combination of some or all of these. Other models of port devolution include autonomous, trust and corporatized ports.

In South Africa, the institutional structure of the container port sector represents a unique hybrid landscape where a national landlord authority (TNPA) and a monopoly terminal operator (TPT) are both divisions of the same SOE entity (Transnet). Despite the Ports Act of 2005 calling for an independent port authority, TNPA has till now operated as a division of Transnet. Only recently, on 22 June 2021, that the President of South Africa announced the incorporation TNPA as an independent subsidiary of Transnet and ordered the appointment of an interim board to oversee the establishment of the new entity. In the same announcement, the President reaffirms that state ownership of the ports remains the Government policy and that TNPA and its assets will remain in the ownership of the state, but there is role for the private sector to partner with the state in both improving terminal operations and investing in new infrastructure. This announcement represents a crucial step in implementing the overdue port reform and allows NPA to transition into a more commercially driven port developer. Nonetheless, it still falls short of a fully market-oriented and liberalised port system as outlined in Table 8.

Table 8: Public and private roles in a port-liberalised economy

Public	Private
• Policy and strategy maker • Sector developer and promoter • Implementing policy principles and strategies • Regulator (economic and technical)	• Capital financing and development • Operations of port assets and facilities • Provision of port activities and services • Improving efficiency and service quality

Source: adapted from presentation proceedings (Bichou 2015).

While in few countries, e.g., UK and Australia, port corporatization has been used as pathway towards full privatisation, the most-commonly pursued route for port corporatization envisages a government-owned autonomous port authority with (container) terminals operated by the private sector. Countries where port reform has seen corporatized port authorities working alongside state-owned terminal operators, e.g., Indonesia, Greece, New Zealand, etc.; have faced challenges in implementing port reform and establishing clear demarcation lines between the role and functions of the port authority and those of the state-owned terminal operator(s).

Beyond the challenges of port corporatization, the current setting of the container port sector in South Africa suffers from a lack of clear orientations towards service fragmentation and commercialisation.

5.2.1 Fragmentation structure and orientation

The current process of TNPA corporatisation and transition towards a managed port liberalisation system is commendable but may not be enough to solve potential gaps and overlaps or to provide a clear orientation towards desirable forms of fragmentation. Fragmentation may have different meanings but in the context of this paper, we focus on four areas of interest:

- Industrial fragmentation means separating different activities according to the degree of industrial specialisation such as in terms of basic infrastructure development, terminal operations and services, intermodal and logistics activities, etc. It may also mean organising port assets and operations according to their industrial and cargo base, often leading to a process of port terminalisation. To some extent, there is a wide use of industrial fragmentation in South African ports.
- Spatial fragmentation refers to the geographical and spatial organization of the sector, e.g., local versus national, decentralised versus centralised, etc. In South Africa, the management and organization of container ports remain quite centralised in the hand of a national operator and a centralised port agency therefore suppressing any potential of regional or spatial set up.
- The combination of industrial and spatial fragmentation is often referred to as service fragmentation. It aims at separating port activities according to their strategic importance, for instance between ports of national interest and those of local or regional interest or between ports with a gateway function and those with a transit or transhipment orientation. In highly monopolistic port markets, service fragmentation often leads to the unbundling of port services to create and promote competition. Despite several policy papers advocating varying strategic orientations within and between container ports in South Africa, neither form of service fragmentation is used in practice.
- Functional fragmentation means allocating management (administration), operations, policy (strategy) and regulatory functions to separate entities. This form of fragmentation is desirable and is to some degree already in place, but the effectiveness of separating policy, management, regulation and operations maybe constrained by competition between public agencies or by unclear or blurred rules on who does what and why.

In South Africa, the container port institutional set-up is not organised in a way that reflects an orientation towards spatial or service fragmentation. Instead, the fragmentation structure currently in place has not been effective and has led to various forms of institutional gaps and overlaps. Examples of institutional gaps in the South African container port market include gaps in several components of market regulation as well in the organization and management of PSP and terminal concessions. Examples of institutional overlaps in the South African port system can be observed across industrial and service components most notably given the practical and structural difficulty to separate landlord port functions from terminal operations within Transnet.

5.2.2 Ownership and service commercialisation

Other contentious issues in the port institutional structure in South Africa relate to cross ownership and cross subsidisation:

- Under cross ownerships, Transnet concurrently act as the landlord owner, developer and operator. Even with the on-going corporatization process of NPA, cross-ownership arrangements between NPA and TPT effectively blurs the boundaries between planning, strategy, operational and commercial functions and makes it difficult to allocate responsibilities among them.
- A Government or public authority that retains a financial stake in an operating company has a conflict of objectives between enhancing the profitability of the incumbent versus improving the quality and quantity of port services. The current approach where Transnet retains control of both TNPA and TPT not only creates a barrier to entry for the private sector but also inhibits port competition and efficiency. Transnet carries out both statutory and commercial functions in ports and freight sectors thus encouraging cross-subsidisation and inefficiency and putting an unnecessary financial and ethical burden on the South African Government to support them. The current process of NPA corporatization may partly but not fully solve this issue given the links between NPA and TPT.
- Last, but not least, while the tariff strategy does not allow cross-subsidisation between TNPA and Transnet. Since similar port tariffs are uniformly charged across container ports in South Africa, this may encourage cross-subsidisation of the loss-making ports, terminals and/or services from the surpluses earned by profit-making units, hence restricting price competition and leading to a loss of economic efficiency.

5.3 Regulatory framework and governance

5.3.1 Scope of regulatory governance

Key to port operations, management, and policy is the extent to which governments and public entities are involved in the aspects of technical and economic regulation. Regulators are public authorities empowered by legislation to licence and monitor the sector's operators and regulate their activities with regards labour, safety, security, and environmental sustainability (technical regulation). Technical regulation of South African ports is under the remit of both TNPA as the landlord and conceding authority and to a lesser extent by SAMSA as the technical maritime regulatory authority.

Regulators are also in charge of market or economic regulation which is set to ensure effective competition between and within port markets. The thematic coverage of economic regulation includes market access, competition, pricing and the regulation of PSP and PPP concessions including investment and performance requirements. Governments and public authorities should also aim at remedying potential or demonstrable market failures and other hindrances to the wider trade, economic and social objectives. However, economic (or market) regulation is only required when there is not enough competition in order to ensure that prices can be set by the market.

- Where there is competition in the market such as in the case of inter-port competition, the Government's role should focus on reducing or preventing intervention and ensuring neutrality so that the market can function properly.
- Where there are few suppliers or in case of a monopoly, the Government may introduce competition for the market through service unbundling or competitive bidding between suppliers.
- Elsewhere, yardstick competition may also be introduced in order to oversee the operations of regulated industries, for instance as a tool to regulate port pricing and tariff charging.

In South Africa, the economic regulation of ports is entrusted to the Ports Regulator, but the remit of the latter does not cover all aspects of economic regulation. In particular, the Ports Regulator regulates NPA but not TPT therefore having no direct tools of monitoring terminal performance.

5.3.2 Price and tariff regulation

For price regulation, the Ports Regulator partly assumes this function by regulating the TNPA tariff books (port dues and related charges) but not TPT tariffs including Terminal Handling Charges (THCs). In 2015, the Regulator developed a Tariff Strategy which lays out the principles, guidelines and methodology of price regulation. Broadly, the Strategy is based on cost-plus pricing, specifically target pricing, and Rate-of-Return (ROR) regulation, commensurate with the principles of asset valuation and profitability de-risking, respectively. The Strategy uses tariff discrimination in ways that promote 'strategic' sectors, but still applies the same tariff structure and charges across South African ports.

In terms of methodology, ROR regulation has the advantage of providing incentives for infrastructure development and reducing investment risks for regulated firms, especially if port development is carried out by public-sector entities. However, in doing so, it provides them with few incentives to operate efficiently and may instead offer them a 'gold-plating' mechanism for boosting the base rate (Averch–Johnson effect). To try and correct this and promote incentive regulation, the Ports Regulator uses tools such as the Port Tariff Incentive Program (PTIP). The other drawback of the ROR regulation relates to the estimation of the asset base rate and the computation of the allowable ROR. This is especially the case where cost accounting is used instead of economic (marginal) costing, the latter is more relevant to publicly funded port assets and infrastructure.

As the port sector in South Africa transits towards corporatization and PSP, the focus of the regulatory intervention may need to shift from promoting infrastructure development to incentivising productivity and cost efficiency. This is because the conditions of port development and investment will then be set as part of the concession contract with the private operator, or the JV public-private entity, the latter bearing some, if not much, of the investment and development risk. In such cases, price-cap regulation becomes a far more attractive approach than ROR regulation.

Price cap regulation sets a price cap or ceiling to be charged based on several factors such as production inputs, efficiency savings and inflation. In so doing, price cap regulation separates the regulated firm's profits from its costs, thus providing incentives to cut costs. This difference in impact means that regulated firms have a stronger incentive to lower their costs because they keep more of the cost savings under price cap regulation than they would if they were subject to ROR regulation. The price cap is often expressed as an RPI-X formula where prices are adjusted to RPI

(Retail Price Inflation) minus efficiency savings and improvements (X-factor). Setting the X-factor often requires a benchmarking analysis of factor productivity and growth of the regulated ports.

Evidence from many countries (e.g., Australia, Peru, and India) shows that regardless of the methodology of price regulation in ports, customers' pressure is likely to draw attention to the performance of the regulated ports themselves. Regulators must then be prepared to benchmark the productive efficiency of those ports, both over time and vis-a-vis regional and international peers, while establishing mechanisms that incentivise (penalise) the most (least) performing ports. This has resulted in a shift of regulatory focus and methodological approach towards yardstick regulation.

The Ports Regulator publishes annually a Global Pricing Comparator Study (GPCS), but this is only used as a tool of measurement rather than a benchmarking tool. Additionally, the Regulator published in 2016 a port benchmarking report comparing the performance of South African ports against selected global ports. This report was also used as a measurement tool only and was not updated since then. It is therefore possible, and highly advisable, that the two sets of work be upgraded and integrated in ways that link regulatory port price control with yardstick competition and productive efficiency.

5.3.3 Performance monitoring and regulation

Performance monitoring and regulation for South Africa's container ports is carried out at two institutional levels: first by TNPA as the landlord authority, the granting and implementing agency of terminal concessions and operating licences; then by the Ports Regulator as the agency entrusted with the economic regulation of the port sector and the monitoring of TNPA.

In December 2013, TNPA introduced the Terminal Operator Performance Standards (TOPS) and rolled it out across its ports. For each container terminal, TOPS are set, and their targets reviewed annually against actual performance. However, the way in which TOPS KPIs and targets are constructed and implemented has many drawbacks:

- First, initial targets started from a low baseline which explains why some of the most recent targets are still below international benchmarks. Some targets may not even be properly justified from an operational and strategic view, for instance on why transhipment container dwell time targets for Cape town are markedly generous than those for Durban, unless if there is a concerted policy to attract more transhipment traffic into Cape town port.
- Second, a terminal performance is compared against its allocated targets only and not against those of other South African terminals let alone other regional and global container terminals. TOPS have been used as a limited one-year time-series analysis instead of using them as part of a broader cross-sectional and panel-data analysis.
- Third, although compared to actual performance and the targets are supposed to be revised upwards every year, the same targets show a downward movement in efficiency terms when traced on a multi-annual basis.
- Fourth, the TNPA is meant to use the TOPS programme as part of its licencing conditions, however this does not seem to be the case since neither incentive rewards were granted to, nor punitive actions were taken against, the best and worst terminals, respectively.
- Last, but not least, the objective of TOPS is to improve container port performance over time. Given that that (i) targets have been revised downwards since the introduction of the scheme and (ii) most if not all studies and reports on the subject

point towards a deteriorating performance in South African container terminals; there must be something fundamentally wrong with the scheme. One explanation could be the absence of investment requirements linked to performance standards.

- As further explained in section 6.3.5 below, a persistently stagnant or declining performance is a sign of capacity-constrained port terminals, therefore requiring investment in both infrastructure and technology. This explanation is also supported by the results of the DEA and MPI analysis in Chapter 3, which indicate, among others, a steep productivity decline in Technological Change (TC) especially over the past five years.
- A recent report published by the Ports Regulators identified some of the shortcoming of TOPS especially around the KPIs and targets used. To overcome these, a consulting project was out on tender with the objective of helping the Regulator develop a model for assessing the extent to which TOPS, its KPIs and targets can lead to a better and efficient use of port infrastructure and capacity.

In 2018, the Ports Regulator introduced the Weighted Efficiency Gains from Operations (WEGO) scheme. Under the 2020 tariff methodology review, the WEGO allows TNPA's profit to increase (decrease) by up to 7.5% for a 10% increase (decrease) on an annual improvement of a KPI port basket. The port KPIs and their suggested weights are submitted by the TNPA and the PCCs to the Regulator who then takes the decision regarding the final basket of KPIs and their weightings on an annual basis. The weighting and methodology of the WEGO has improved over the years but even the Ports Regulatory acknowledges that this is an evolving process and both the KPIs and weight methodology may change in the future. The WEGO decision is akin in its general approach to the broader objective of incentive regulation but has not evolved (yet) into a yardstick incentive regulation.

5.3.4 Stakeholders' oversight

The Ports Act calls for the appointment of Port Consultative Committees (PCCs) at local and national levels. Local PCCs are established for each port and consist of local port users, the Harbour Master, local representatives of TNPA, SAMSA, local and provincial governments and organised port labour. The national PCC consists of representatives of local PCCs, government departments, TNPA, the National Port Users' Forum (NPUF) and organised labour. The purpose of PCCs is to provide a forum for exchanging views between TNPA and port interests. In particular, the Ports Act requires TNPA to consult with the PCCs for matters related to port plans and development.

PCCs are equivalent to port users and similar groups in other ports, with the difference that PCCs are dominated by public sector bodies rather than port users and customers. Specifically, port and terminal operators are not constituent members of PCCs nor are other relevant public sector agencies such as trade and customs agencies. In addition, the scope of work of PCCs is limited to a basic consultative setting which limits their influence over the management and monitoring of port performance.

6 Port PSP and concessions in South Africa

Despite Private Sector Participation (PSP) having been introduced and successfully implemented in bulk ports and intermodal facilities across South Africa, no PSP experience in container terminal handling and operations has been recorded yet in the country. Over the past decade or two, there has been a renewed discussion on the need to open the container port market to private operators but also to revisit the current institutional structure and consider the corporatisation of TPT. Most recently, the South African Government and TNPA formally opted for opening the container port market to the private sector. Nonetheless, no specific framework has been published on the strategic objective, the business plan, the project structuring and the tendering process for opening the country's container market to PSP. Currently, the only PSP framework available is that of Transnet along the dedicated PPP unit in the Treasury, while the Department for Transport is yet to publish its PPP framework.

Experience from elsewhere has shown that where PSP in ports has been tried without an appropriate plan or coherent strategy, this has often led to low investor interest and at times to non-compliant and failed tenders. Even where was PSP introduced, this has not always been beneficial to port users and customers and has at times increased, rather than reduced, trade and logistics costs. The lack of proper strategic framework, project preparation and contract structuring has often led a counter-productive PSP in container port operations, especially on areas related to inducing competition, improving performance and reducing the price and cost of port services.

This Chapter looks at various forms of PSPs in container ports and provides guidance on the most relevant ones to the South African port landscape. The Chapter also provides insights on the typical framework and contractual clauses in container terminal concessions with a view to using them as reference benchmarks both for reviewing existing agreements between TNPA and TPT as well as for structuring future concession and PPP contracts with the private sector.

6.1 Drivers of PSP in ports

Relative to private investors and operators, there is a general view that public owners and operators are (i) less able (and have fewer incentives) to control costs, (ii) slower to adopt new technologies and management practices, and (iii) less responsive to the needs of port users and customers. Over the past 2 decades or so, state owned ports have been moving away from the public service model to a landlord or alternative model in order to introduce and substantially increase PSP in ports. The main drivers of this development have been several folds:

- The rapid growth in cargo traffic and throughput, which has put great pressure on existing facilities but has not been matched by parallel efforts in capacity planning and expansion.
- The limited success of state-owned ports in improving port performance and productivity.
- Economies of scale in the industry have led to the emergence of few global operators able to dictate ports of call and the location of gateway and transhipment facilities.
- Economic and budget constraints restricting public funding for port projects. There has also been a growing perception among cash strapped governments of the financial benefit from PSP.
- Suitable legislation, institutional and governance frameworks allowing PSP to take place and thrive in the port sector.

6.2 Forms of PSP in ports

PSP in ports can take several forms: management contracts, partial divestiture to strategic equity partnerships, joint ventures, full divestiture, and concessions of various kinds.

6.2.1 The management model for existing port assets

Two main categories fall under the above heading: management contracts (including operations and maintenance) and leases (including leasehold contracts).

Under Management Contracts, a port or terminal facility is run and managed by a specialised port management company which provides management services bringing operational skills and know-how while the public sector retains control over all the assets. Management contracts tend to be input specific, as opposed to Operation and Maintenance (OM) agreements which are more output focused and usually involve performance requirements. In both management contracts and OM contracts, port fees are paid by the user to the port authority (TNPA) which, in return, pays a fee to the private operator based on its input and/or performance results.

Under lease contracts, a port leases an asset, or the right to use it, for an agreed period, to a private operator who is responsible for operating and maintaining the facility but not for financing it. Leasehold agreements are simple rental agreements with mostly land or warehouse facilities being leased. Some lease contracts have inbuilt development requirements, often obligatory or event-triggered, while others include a renewal clause that applies when an operator enters into a long-term lease contract.

Leases and management contracts are generally unattractive to terminal operating companies due to the inability to control factors which influence performance, including staff retention and employment conditions. At the same time, given the management structure and life cycle of TNPA facilities, the consultant does not believe a management model would be the most suitable model for PSP in South African container ports. Nonetheless, there may be instances where lease or leasehold options become viable, especially if TNPA decides to unbundle certain container terminal services.

6.2.2 The concession model

A concession grants the operator the right to use the assets/services conferred to him. The operator takes full responsibility (and risk) for operation and investment, while the public authority retains ownership of the asset during the concession period. There are at least 3 types of concession models:

- Operating concessions (e.g. affremage): The operator will be operating the existing assets from the outset of the concession (although often new build projects are called concessions) and will collect revenues from user charging.
- BOT-type concessions: A BOT (Build-Operate-Transfer) project, or one of its variants (DBOT, DBFO, DBFM, BLT, etc.) typically involves new investments by the private sector who retains exclusive use of them for a fixed period of time before transferring them over to the public sector. The BOT-type concession often involves the set-up of a Special Purpose Vehicle (SPV) company.
- Private Finance Initiative (PFI) projects: Those are usually long-term contracts for services that include the financing and construction of assets and facilities. Under a PFI, the private sector will have responsibility for financing, constructing, maintaining, and/or servicing the facility throughout the contract term, in return of a regular payment over the lifetime of the contract.

The concession model has been increasing in popularity in the container port sector especially as it provides a good framework for demarcating the role and responsibilities of the port authority as grantor or conceding authority and the terminal operator as concessionaire. For South Africa, the concession model could be used successfully in two ways. On the one hand, new operating concession agreements that are appropriately designed along international best practice (see below) should replace existing ever green contracts between TNPA and TPT. On the other hand, BOT-type concessions would be suitable for new or upgraded container port facilities, for instance in Durban and Cape Town where additional capacity is required.

6.2.3 The public-private joint venture model

This model operates broadly as described in the management or concession models above with the difference that the public sector has a stake in the SPV which is set up to hold either a management-investment contract or a development rights contract for new port facilities.

The Joint Venture (JV) model has been used in several ports around the world but have shown mixed results depending on how the JV project and contract have been designed and implemented. At one end of the scale, the port JV has involved the public sector retaining a large controlling stake in the SPV, this has translated into the port authority having a significant influence in the detailed provisions of the contract. This model, which may be seen as a safeguard to legacy state-owned ports in a transition towards further PSP, has been less successful and at times controversial. At the other end of the scale, the JV is sometimes structured in a way that the port authority is a passive investor simply injects equity in the SPV with no monitoring or influence over the operations and management of the terminal. This model has been implemented in many countries, most recently in West and East Africa but has often been ineffective and at times counter-productive especially in countries with inadequate port oversight and regulatory institutions. Where the port JV has proven to be most successful is where the set up was structured in a way that the public sector has a monitoring role rather than an operational role. This has provided private operators with the freedom to implement change, improve performance and induce growth while enabling the authority and/or regulator to monitor the operators' work and progress. This model has been successfully implemented in many ports across Europe, South-East Asia and the MENA region, and can be used a benchmark model for the South African container port of Ngqura where a strategic JV partnership with international operator(s) is needed if the port is to achieve its long-term objectives of becoming a major transhipment hub.

6.2.4 The divestiture model

Port divestiture involves the Government or public sector existing port assets being sold fully to the private sector. The divestment programme of port assets and facilities usually starts with the reorganization of port assets and liabilities along commercial lines, which can facilitate the valuation and sale process, followed by a public or restricted share offering. This model has been widely used in full privatisation programmes in the UK and Australia and recently Turkey and Greece. Port divestiture and privatisation may also be the results of BOO (Build-Operate-Own) contracts which basically provide freehold private terminal development and ownership. This was the case for many Asian ports, particularly in South Korea, China, and Malaysia in the 1990s and early 2000s and has also been implemented most recently in some African ports, e.g., Sokhna in Egypt.

6.3 Features of PSP in ports

This section aims at presenting and analysing the typical contractual clauses enclosed in container terminal concession agreements in order to provide guidance to existing licencing agreements from TPA to TPT as well as future concession contracts between TPA and private investors.

6.3.1 *Objectives of port concessions*

When opening container terminals to PSP, governments and port authorities are generally driven by one or several motivations:

- *Enact port reform*: The conceding party wants to use PSP as part of a wider institutional and policy reform for modernising the sector, introducing competition and reducing inefficiencies. One way of achieving this is to require minimum performance targets from the tendering candidate. This usually translates into highly selective technical qualification criteria in the tender process and is contractually secured through a range of KPIs and prescribed performance requirements.
- *Maximise financial gains*: The government is set is to obtain the highest financial offer from the tendering parties in order to recover public investment in basic infrastructure or use the PSP transaction to fill gaps in port and government budgets. The financial objective often translates into a high price for the entry ticket and/or concession fee payments.
- *Spur economic growth*: The government aims to boost the economic development of the port, its hinterland, and its supply chain. The hope is that private sector investment, operational efficiencies and market know how would reposition the port in its markets, increase traffic, attract additional investment, and generate wider socio-economic benefits. Such objectives typically translate into investment obligations and throughput targets.
- *Increase safety and environmental standards*: The government wishes to improve health, safety and environmental practices in the port and uses PSP as a tool to achieve higher standards. A few examples exist where the port has been concessioned primarily to improve HSE standards, for instance where safety accidents and environmental degradation have reached unacceptable levels.

6.3.2 *Scope of port activities*

Most port PSP contracts impose strict limits on what private operators are allowed to do, usually in terms of the types of cargo they are allowed to handle. The design of PSP transactions is usually done at terminal level rather than for the whole port. Intended to encourage efficiency through terminalisation, this is also used as a tool to promote inter-port and intra-port competition.

Over the past decade, there has been a trend over vertical integration of port services. This has translated into PPP and concession contracts being awarded for integrated services, for instance between cargo handling and marine services, or between port and landside (railroad, dry port, etc.) developments. Integrated port and landside concessions maybe one of the solutions to the observed inefficiencies of container port systems and related hinterland and freight distribution in South Africa.

One innovative option that has been proven very successful of late is the structuring of a master concession that combines both port cargo handling operations with intermodal and freight terminal services. To alleviate seaport congestion while providing extra capacity at lower cost, many countries around the world have established dry ports located further inland near commercial and industrial centres but connected to the seaport via integrated, sometimes dedicated, railroad freight networks. A dry port is an Inland Customs Depot (ICD) that operates under a customs regime as a final bill of lading destination with a unique port code. Goods destined to or originating from the dry port are not processed in the seaport, the latter becomes a mere transit point for those goods and containers. For this to function properly, an integrated intermodal service should be provided throughout the logistics chain linking the dry port to seaport. This is often achieved by having the port concessionaire, or one of its SPV members, operating as an Intermodal Service Provider (ISP) and interfacing terminal cargo handling with inland transport and logistics services. Such types of integrated concessions can be well suited for South African ports by linking container port concessions with rail corridor development and services.

6.3.3 Duration

The duration of the container terminal agreements usually ranges from 15 to 35 years, depending on concession and contract type. Economic logic suggests that a concession duration should be linked to the payback period and the rate of return required by investors. Generally, the economic life of port assets does not extend beyond 25 to 30 years depending on the conditions prevalent in the terminals under consideration. However, for countries or projects with perceived high cost or risk, longer duration concessions are quite common. Sometimes, a port concession with two or three consecutive-term duration is used for port projects with phased developments. In any case, no automatic evergreen clause has ever been used in port PSP concessions and the current arrangement between TNPA and TPT is somewhat unique and must be aligned with international best practice.

6.3.4 Characteristics of private investors

The choice of the "right" private investor(s) is an important success factor in PPPs. Several factors can be considered including the structure of the consortia, the choice of large versus small investors, which is often reduced to the choice between foreign or local investors, the priority given to captive versus non-captive terminal users, and the institutional and commercial origin of the terminal operator.

In the last three decades, there has been a trend towards the internationalisation and consolidation of container port operations, which has led to the emergence of international terminal operators with extended bargaining power, higher performance levels, and global management practices. Broadly, there are four types of market players in international port operations: terminal operating port authorities such as PSA and DP World; terminal operating shipping lines such as APMT, TIL and Cosco Ports; terminal operating companies such as HPH, ICTSI, Bolloré and SSA Marine Service; and terminal operating shippers such as Hyundai and UECC.

As part of its plans to introduce PSP in container ports, the TNPA and South African government have to devise a strategy to target and attract the most suitable terminal operators for each of its container ports and terminals. For instance, terminal operating shipping lines are the ones to attract for container transhipment facilities whereas terminal operating companies and terminal operating port authorities are most suited to gateway ports. Sometimes, the choice is narrowed down between operators with a strong regional presence (e.g. such as Bollore, DP World, and APM Terminals) and those without it, with a track record in managing small and medium sized port terminals (e.g. ICTSI and SSA Marine).

6.3.5 Investment requirements and throughput targets

Most port PPPs and concessions set out an investment programme for the duration of the concession. Obligatory investments are often prescribed in the agreement; but experience has shown that obligatory programmes lasting more than 5 years are rapidly overtaken by technological and market changes. To correct this, indicative investment programmes are used instead and can be modified by mutual consent. In an indicative investment, the first phase of a development plan is compulsory whereas subsequent phases are often event-triggered to reflect market and demand changes over time.

Next to investment requirements, port concessions often require a minimum throughput guarantee. Generally expressed in TEUs per year for container terminals, throughput targets are calibrated to the size, the attractiveness, and the growth potential of the terminal, then translated into a volume commitment to be achieved by the concessionaire, failing which compensation is due to the port authority. For new terminal assets, the required volumes typically gradually increase and often includes an exempted ramp-up period for the 1st year or two.

Both investment requirements and throughput targets should be tallied with the concession's business plan and project structure which includes, among others, the institutional and legal structure, the commercial arrangements, and the financial structure. The latter are often the culmination of months of due diligence and preparatory work including detailed feasibility studies and traffic forecasts. The current arrangements between TNPA and TPT for the operations of South Africa's container terminals do not seem to include a prescribed programme of investment requirements and throughput targets, except for some annual targets which are neither warranted nor binding; and there is a need to review those along the lines mentioned above. For future agreements with the private sector, appropriate preparatory work and due diligence should be caried out to develop the project's business plan and establish investment, volume and other project targets and requirements.

6.3.6 Performance standards

Most concession agreements specify operational performance obligations often expressed as KPI targets such as vessel and crane productivity, equipment availability and ship and truck turnaround times. In terminals with historically low performance, performance requirements are gradually raised year after year so as to leave sufficient time for the concessionaire to bring terminal performance up to acceptable standards.

A common shortcoming in contract performance requirements is for KPI targets to be set in a fairly low base only for them to be achieved easily or worse to be overtaken by technological and other market changes. Furthermore, many port authorities do not have the technical capacity to monitor those targets or wiliness to exercise pressure on the concessionaire to improve terminal performance. One way to address this is to link operational performance with concession fees and other incentive-based mechanisms. Modern port concessions incorporate performance requirements based on regularly updated performance standards. Where concession ports are subject to economic regulation, regulators often use yardstick benchmarking as a tool to link port efficiency with price regulation.

The above epitomises the licence arrangements between TNPA and TPT as well as the Weighted Efficiency Gains from Operations (WEGO) programme for performance-based price incentives. The latter was first published by the Ports Regulator in March 2019 which included the final approved port performance KPIs and corresponding weights for the 2019/20 tariff year. Those are based on preliminary information submitted by TNPA in 2018 (baseline) and subsequent year (2019) financial information and KPI change, as well as submissions by port users represented by Port Consultative Committees (PCCs). The current WEGO is based on 5 KPIs: ship turn-around time, ship productivity indicator, anchorage waiting time, berth productivity, and ship working hours; but the Ports Regulatory acknowledges that this is an evolving process and both the KPIs and methodology may change in the future. The WEGO decision is akin in its general approach to the broader objective of incentive regulation but has not evolved (yet) into benchmarking and yardstick regulation.

6.3.7 *Concession fees and tariff charges*

Most port PPPs are user-fee commercial arrangements where, unlike in availability payment, financial compensation usually flows from the operator to the grantor. In ports, concession fees include one or a combination of the followings: entry tickets, fixed concession fees, variable concession fees and revenue share arrangements (see Table 9).

As for port tariffs, a distinction exists between concessions which are free to set their own tariffs, and those whose tariffs are regulated, either by a formula within the concession agreement or by the port authority or an independent regulator. PPP concessions have been successfully used as a tool to reduce excessive tariffs as part of a wider port reform, most recently in Latin American ports. This could serve as benchmark for South African ports which are often described as being too price excessive.

Table 9: Variations of port concession fees

Payment structure	Description
Fixed rents	Fixed rents generate a steady cash flow to the authorities. The rents can be further segmented by activity, facility type, location, etc.
Lump sum	Fixed rents may be converted into one upfront lump sum payment. This can be used by the public authorities to fund other (related) investments.
Entry tickets	Entry tickets are a type of lump sum payment in addition to the rents (or variable payment mechanism). It can be used as an add-on allowing skimming the intrinsic value of the project. Sometimes, operators are asked or encouraged to bid on the entry ticket.
Royalties	Royalty implies a charge per activity or volume handled. The royalty can be combined with the fixed rents.
Variable throughput charges	The payment mechanism can be fully or partly variable allowing throughput risk sharing. Typically, a fee per TEU is charged, and the fee rates can be adjusted using sliding scales and traffic bands in order to incentivize throughput optimization.
Revenue/Profit share	Revenue and profit shares are dependent on the financial performance of the project PPP and imply a risk/reward sharing mechanism.
Performance driven payments	Some port authorities use performance-based incentives where performance targets are set against rewards or penalties as a function of measurable KPIs.

Source: author's elaboration.

6.4 Looking ahead: introducing PSP in South African container ports

From the above analysis, one can conclude that while the intent to introduce PSP in container ports in South Africa is timely and commendable, the strategy and business plan for doing is still lacking or requires further clarification. Areas of particular interest include the objectives and scope of PSP which in return informs about the forms of PSP involvement, the tendering process and the specific features of PSP concessions including but not limited to contract duration, investment requirements, throughput targets, performance standards, concession fees and tariff charges.

Best practice benchmarks and guideline recommendations were provided on how to implement those in the South African container port context, both for future PSP concessions and for existing arrangements between TNPA and TPT. Experience from elsewhere has also shown that introducing PSP in container ports should not be seen as the outcome of a port reform but rather as a tool to achieving such reform including for enhancing inter-port and intra-port competition, improving port and freight performance, reducing transport and trade costs, and spurring economic growth and spill over impacts. It is therefore paramount that prior to PSP introduction, a clear strategy and implementation plan for PSP project preparation and contract structuring be developed and formulated for South African container terminals then communicated to port users and prospective investors.

7 Summary, conclusions, and recommendations

For South Africa, container ports constitute important gateways and play a major role in the economic development of their hinterlands and in the trade and logistics efficiency of the country's supply chains. Improving the performance, private sector participation (PSP), and competitiveness of the container port sector in South Africa has long been on the agenda of various port and policy stakeholders; and there is a renewed interest due to resurging port delays and congestion and recent political and policy statements for the need to accelerate port investment and reform agenda.

7.1 Summary and conclusions

This Report examines the performance of South African container ports both in terms of their technical efficiency, productive change and competitive benchmarks and in relation to the underlying container port markets and competition in South Africa as well as the institutional and governance frameworks that underpin current port ownership and management structures. The results from both the analytical benchmarking and the expert assessment have uncovered several shortcomings, gaps and overlaps across market, operational, institutional, governance and policy levels.

A review of the literature on South African container port performance shows that despite historical and ongoing concerns about low performance, delays and congestion, relatively few studies have addressed the issue in the depth and breadth required. Most recent studies by the OECD, the Ports Regulator and the World Bank have shed further lights on performance and competition issues; however, as with the plethora of port performance indices, the studies use conventional snapshot indicators that are biased towards berth productivity and unfairly benchmarked against ports with different market and operating conditions. Most importantly, snapshot port KPIs are not suitable for the analysis of container-port productive efficiency nor for the assessment of the sources of, and shifts in, technical efficiency and technological change. Furthermore, these and previous studies have put forward several short-term operational and tactical solutions which, despite some transient success, did little to address what has become an endemic port performance problem. The obsession for pursuing tactical solutions, sometimes under customer or political pressure, often leaves structural performance problems unresolved and may even exacerbate them in the long run.

To address the above, an analytical benchmarking study was carried out to estimate and benchmark the productive efficiency of South African container terminals both over time and vis-à-vis selected regional and international comparators:

- The results from the cross-sectional (contemporaneous DEA) analysis show that over the 2010-19 study period, South African container terminals have performed differently. The container terminals in both Durban and Cape town have performed well in the first half of the observation period before deteriorating post 2015, Ngqura container terminal has recorded significant efficiency gains mainly due to the new capacity effect, while Port Elizabeth container terminal has stagnated in its efficiency due to growth problems. Collectively, the general picture shows that the overall efficiency of South African container terminals in the past 10 years has markedly deteriorated while increasing for comparator regional and global ports.
- The panel-data (inter-temporal DEA) analysis confirms the downward trend of efficiency deterioration for domestic container ports against the upward trend of efficiency improvement for regional and global port comparators. In particular, the analysis shows that over the past 5 years, the performance of South African container

terminals is on average 20% less than the average performance of comparator ports and up to 35% below their optimal potential. This underlines the general operational slack in the system where underutilized resources (inputs) can be more efficiently used to achieve higher capacity.

Next to the DEA analysis, an MPI analysis was used to examine the sources of port efficiency and track changes in productivity over time:

- The analysis shows that on a year-by-year basis, only 3 South African terminals have achieved a productivity gain, against 30 terminal-years experiencing a productivity loss and only one terminal-year recording no change in productivity. Specifically, the analysis shows that much of the productivity decline took place in the periods after 2016.
- Looking further into the sources of productivity change, the analysis shows that most of productivity losses experienced by South African terminals are due to a sustained deterioration in technical change (technological efficiency) followed by a more recent deterioration in pure efficiency. This suggests that the country's ports must invest in automation and superior handling configurations while embracing new digitisation systems and technologies.
- The MPI analysis was also used to assess the impacts of port ownership structures on terminal efficiency. The results show that private sector and JV operating models excel compared with South Africa's public sector model. These findings provide a good basis for promoting PSP in South African container ports including through the landlord-JV and concession-based models.

To complement the analysis of container-port efficiency, an assessment of port logistics and trade performance was carried out. Empirical and survey data from various sources was compiled and analysed to show that despite South Africa leading the continent in many areas of logistics performance, it lags other African countries in logistics connectivity and procedural efficiency. This brings to light the need for a transhipment-hub strategy and the urgency of hinterland logistics connection and integration, both requiring innovative thinking around PSP concessions and investor attraction.

To further examine the context within which South African container terminals are managed and operated, a detailed assessment of the competition, institutional and governance framework of the South African container port system was undertaken with a view to identifying and addressing the most relevant aspects that constrain the country's container port performance:

- Competition in most of its forms is absent from the South African container market. Neither inter-port competition nor intra-port competition exist due to restrictive policy frameworks and institutional structures. Similarly, there has been no record of competition for the exclusive right to provide container (handling) services, and there is no competitive pricing between South Africa's container ports and terminals.
- Institutionally, the unique hybrid model of South African container ports limits spatial and service fragmentation while the cross-ownership structure blurs the boundaries between port planning, strategy, operational and commercial functions.
- For the governance and regulatory framework, the establishment of a sector's regulator made South Africa one of the most advanced countries in port economic regulation. Nonetheless, the Ports Regulator remit does not cover performance regulation nor extend to monitoring the operator's (TPT) performance and concession delivery. Attempts to circumvent this through the WEGO program are constrained by

methodological and practical difficulties for setting and monitoring annual performance targets. The Regulator's use of Rate of Return (ROR) price regulation is also not geared towards performance-based and yardstick pricing competition.

- The review of PSP and concession regulation in South Africa's container ports has also revealed several gaps and limitations. The current licencing arrangements between TNPA and TPT do not seem to include or follow best-practice standards in relation to contract duration and exclusivity, operational and performance standards, throughput targets and investment requirements, and reporting and monitoring obligations.
- As for PSP, and despite recent policy statements, no framework was put forward (yet) on the strategic objectives, business plan, project structuring and tendering process for opening the country's container market to the private sector. One salient factor which is rarely discussed in South Africa's port strategy and policy statements is whether the urgently needed container capacity expansion is best served by the public sector or the private sector. Given the scale of investment required and the constraints on the public purse, a paradigm shift must take place to promote private sector financing and operations of container port expansion in the country. However, as shown in several other ports, PSP in ports alone is not always the magic solution to container terminal development financing and operational performance especially if it is not preceded and accompanied by proper project preparation and advisory, detailed Value for Money (VfM) assessment, and adequate framework for PPP monitoring and regulatory oversight.

7.2 Recommendations and way forward

To overcome the above gaps and shortcomings, the Report puts forward several recommendations and provides some best practice benchmarks from both regional and global port settings. Some of the recommendations put forward have a short-to-medium term strategic planning horizon while others are most relevant for a long-term port policy and reform agenda.

7.2.1 Short-to-medium term measures

Short-to-medium term recommendations span a time horizon of 3 to 5 years and are based on capacity management solutions, i.e., no additional or new port capacity is built or released, and on the assumption that no major institutional, regulatory or policy change is made.

Improve the productive efficiency of terminal operations

As shown in the analysis of container port performance, the productive efficiency of most South African container terminals has been deteriorating fast in the past 5 years. Within the existing capacity, the analysis has shown that the country's terminals operate below their optimum level by about 30% to 35%. This underlines a general operational slack and resources underutilisation, or resource wastage, which should be addressed by TPT, specifically for Durban and Cape town container terminals which have experienced the worse productivity loss over recent years. The analysis has also shown that the main sources of productive inefficiency lie in technological and pure efficiencies, which suggests that TPT should consider a programme of equipment modernisation and upgrade, operational and process optimisation, and broader digitisation and automation of operating and working processes.

Many reports, including a recent World Bank study, have put forward a number of operational measures to tackle congestion and delays in South African container ports. While some of these measures may be relevant and indeed useful in relieving port congestion, it is our conviction that detail operational and process optimisation measures should be mostly left to the terminal operators (TPT) who know best the terminals and their operating conditions. The thrust of the port's reform process that was launched over 15 years ago is to enable the terminalisation and operational specialisation through a dedicated national port operator (TPT). As outlined in Chapter 4 on port PSP and concession arrangements, prescribed port KPIs have little usefulness in practice for improving port performance. Instead, we recommend a shift in performance management and monitoring away from prescribed KPIs and towards concession-based performance targets and regulation-based yardstick benchmarks.

Introduce and enforce performance targets for TPT operating licences

As discussed above, the current licencing arrangements between TNPA and TPT do not seem to have incorporated any meaningful set of performance obligations. This is a gap that should be filled by incorporating appropriate performance targets and linking them to payment obligations, be they licence fees paid by TPT to TNPA or other payment or financial transfer arrangements.

The performance targets themselves should be based on a proper assessment of port capacity and optimal benchmarks along the analysis of productive efficiency carried out in this Report. By setting efficiency-based performance benchmarks, the operator (TPT) is given the freedom to choose any mix of input resources, operating technologies and working processes that best achieve the efficiency targets rather than being prescribed too detailed KPIs which may or not be relevant to its input use. Ultimately, performance requirements and benchmarks should be an essential part of a realistic business plan for each of the container terminals under study, outlining among others medium and long-term capacity, throughput targets, concession or rent fees, and phased investment requirements.

Redesign the WEGO pricing incentive along yardstick benchmarking principles

Next to introducing performance targets, economic and price-incentive regulation should be designed in ways that promotes efficiency and competition. The current WEGO programme is a good start, but as previously discussed it suffers from structural and methodological difficulties. The Consultant recommends that the programme be redesigned to become part of a larger yardstick benchmarking exercise, the latter should be held regularly, every 2 to 3 years, to update on changes in efficiency frontiers and benchmarks. In the long run, the Ports Regulator should align its price regulation methodology with yardstick benchmarking and away from Rate of Return (ROR) price regulation.

Introduce inter-port competition through performance and pricing mechanisms

While awaiting a broader strategy for enhancing port competition through PSP and concessions, port competition can be introduced in the short-term through the levers of performance and pricing. By setting appropriate performance targets for each container terminal and linking those targets to licencing fees and financial payments, the terminals will be indirectly competing against each other. Similarly, both TNPA and the Ports Regulator should allow for price differentiation between terminals by establishing a maximum price cap rather than prescribing tariff charges. This way, a TPT terminal would be able to use price discrimination in combination with performance commitments in ways that attract more customers and compete with other TPT ports and terminals.

Improve trade logistics and procedural efficiency

Increasingly complex transport and trade logistics processes are having a significant impact on port and logistics efficiency. As shown in earlier analysis, South Africa lags behind many African countries in trade costs and procedural lead times, which has a cascading effect on container processing and lead times in and around ports. Port user interests such as the NPCC and NPUF should push for the establishment of similar trade logistics performance targets similar to those of the WEGO, potentially as part of a wider Trade and Transport Facilitation Committee (TTFC).

7.2.2 Long-term and policy recommendations

Long term recommendations span a time horizon of 5 to 10 years and are based on capacity expansion solutions and the introduction of major institutional, regulatory and policy reform.

Formulate a coherent port policy

Generally, a port policy is formulated based on two understandings: (i) the role of ports in the country's logistics, trade, and economic development and (ii) the set of policy measures that are needed in order to support and further promote this role. The aim of policy formulation under any port setting is to provide an overview and justification of a set of policy orientations and coherent strategic goals, and action plans. Coherence is in this context means that policy orientations and strategic goals must be essentially consistent and fully compatible with the measures and plans put in place to implement them.

Currently, the policy framework and practical functioning of the container port system in South Africa does not provide a clear indication whether port policy follows a protection-oriented, a market-oriented and/or a market regulated port policy. A case in point is the complementarity policy between South African container ports which is not compatible with market requirements for inter-port competition and terminal specialisation, nor does it fit the strategic objectives of port corporatisation and sectoral reform. A revised or new port strategy should be elaborated in ways that port policy, strategy and action plans are bound together and where key public stakeholders including the DoT, the DPE and the DTIC are fully engaged in a shared perception and vision of the container port system.

Port policy orientations and strategic objectives that require particular attention include, but are not limited to, the followings:

- Planning and investment policies outlining port development plans and projects and the sources and structure of their financing and investment including through PPP and/or partial privatisation.
- Institutional policies outlining the sector's institutional setting and the role of, and interaction between, various agencies in port planning, development, management, and regulation.
- Regulatory and licensing policies outlining the scope of technical and economic regulation and the licensing process and mechanisms applicable to port infrastructure and services.
- Pricing, cost recovery, taxation and subsidy policies refer to the principles that govern tariff setting, taxation and subsidisation and the mechanisms for the financing and cost recovery of public port infrastructure and related systems.

Re-evaluate institutional frameworks, market structuring and coordination mechanisms

A major component of port policy in South Africa is a re-evaluation of the current institutional framework in ways that ensures it becomes compatible with broad policy orientations on market access, competition and PSP and PPP concessioning, As discussed above, the institutional structure of container ports in South Africa is marked by cross-ownership, functional fragmentation, and a lack of coordination between implementing agencies. Policy makers should therefore decide and clarify whether the current institutional structure is suitable and desirable for introducing competition to container port services. If not, measures should be put in place to redesign institutional roles and functions for the ownership and provision of container port infrastructure and services.

Improving and sustaining port performance and productivity depends on the extent to which competitive pressures can be brought to bear either in or for port markets. In South Africa, public sector enterprises are still exclusively dominant in container port and logistics markets, therefore it is important to undertake market restructuring before market opening. However, structuring the market to achieve greater competition is not a straightforward process and must be given proper due diligence and consideration. As such, port policy should establish a clear framework for port competition as part of a broader strategy to open the port market including to private and foreign entrants.

For any port policy to work, sufficient institutional coordination is required to ensure that the interests of various agencies are harmonized and coordinated in line with policy goals and orientations. Clarifying the responsibilities of Transnet, TNPA, TPT and other relevant agencies (Ports Regulator, DoT, DPE, DTIC, etc.) in ways that reduce fragmentation, avoid conflict, and fill institutional gaps should be a top priority for policy makers. Another desired area of institutional coordination is between agencies that intersect with port planning and development. Port policy should therefore aim at developing a planning and institutional framework to coordinate and integrate port plans with intermodal and logistics plans as well as with city and urban plans across areas of common interest.

Last, but not least, port policy should decide on a clear path for (or against) developing a transhipment port facility, and if so, enact the required planning, institutional and regulatory measures to support this development.

Establish policy guidelines for PSP and port concessioning

As outlined above, the current policy and institutional setting in South Africa is not conductive to PSP and competition in container port markets. Even where policy statements and strategic orientations are formalised towards promoting PSP in ports, the objectives and guidelines for PSP and PPP concessions are often missing or at best thin on the process and details of implementation.

Policy guidelines are therefore required to develop a targeted strategy for introducing PSP in ports along clear guidelines for the tendering process and regulation of licencing and concessions in container ports and terminals. This Report outlined the guidelines and best practice benchmarks on container port concession features and main contractual clauses. It also highlighted the need to use PSP and PPP concessions as a tool to achieving policy and reform objectives including for enhancing port competition, improving port and freight performance, and reducing transport and trade costs. It is therefore paramount that prior to PSP introduction and/or terminal concessioning, clear policy guidelines are formulated along a strategic plan for preparation, implementation, and monitoring.

Integrate port with hinterland systems

Port development strategies traditionally aimed at logistics integration at the water interface. In recent years, the inland component of the port system has become a key factor in shaping logistics performance and competitiveness. At the same time, physical and capacity constraints at berths, along with the trend of standardisation of water-side operations, suggest that more focus must be placed on land-interface logistics operations.

The South African port institutional model has many shortcomings, but one of the potential benefits of having an integrated port and freight operator is to develop integrated intermodal systems linking gateway seaports with inland terminals and Regional Distribution Centres (RDC) via integrated and seamless freight services. One way to achieve this is for Transnet to assume the Intermodal Service Provider (ISP) function which would provide the conditions for developing dry ports that operate as B/L origin or destination locations, with unique customs and port codes. This relieves congestion at seaports while providing additional capacity and bringing cargo consolidation and distribution near industrial or cosmopolitan centres. Currently, most inland terminals in South Africa do not operate as final B/L dry ports except City Deep. The lack of an ISP integrator coupled with rail capacity restrictions is a major obstacle against integrating port and rail services, and there is a need to reflect on the possibility of offering horizontal port and rail concessions as part of PSP reform in the long run.

Update the Ports Act along policy and strategic orientations

The Ports Act of 2005 provides the backbone and legal underpinning of the port system in South Africa. As port policy and strategic orientations are encouraged (and hopefully set) to undergo major changes, there will be a need to revisit and update the Act along those policy changes and orientations.

In addition to the main policy and strategic orientations outlined above, the Act could consider re-organising the institutional set up for container port markets, extending the functional role of the Ports Regulator to include the tasks of performance and concession regulation, formalising and strengthening the role of port stakeholder and user groups, and adding statutory instruments on dry ports' legal, institutional, and organisational settings.

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Appendix

A Data envelopment analysis

A.1 Introduction to DEA

An important aspect to consider when using productivity index methods is the fundamental difference between productivity and efficiency. Although the two measures seem to be closely related, each denotes a different performance measurement concept. Productivity is a descriptive measure whereby a productivity index provides a comparison between firms but uses no reference technology for a benchmark. Efficiency, on the other hand, is a normative measure in that the benchmarking of firms is undertaken with reference to an underlying technology.

The frontier concept in this context denotes the lower or upper limit to efficiency with respect to the inputs consumed and outputs produced by a decision-making unit (DMU). Under this approach, a DMU is defined as efficient when it operates on the frontier and inefficient when it operates away from it (below it for a production frontier and above it for a cost frontier). Early attempts to construct a frontier used ordinary least squares regression techniques to fit a function (often a cost or production function), which is then shifted to become a frontier. Stochastic Frontier Analysis (SFA) is a more sophisticated version of this approach. The objective is to construct a non-observable frontier from a set of best obtainable positions. The method used to identify the frontier may be parametric (econometric) or non-parametric (linear programming). Unlike econometric (parametric) models, non-parametric approaches do not require a pre-defined function but use linear programming techniques to determine a frontier. Techniques belonging to the non-parametric approach include DEA and FDH (Free Disposal Hull). These techniques can handle multiple outputs and multiple inputs.

The rationale behind DEA is that in seeking to solve the issue of DMUs (for example ports) assigning different weights to their respective inputs and outputs, each DMU is allowed to set a combination of weights that puts it in the most favourable position vis-à-vis others. The method works by solving a series of linear programming problems and selecting the optimal solution that maximises the efficiency ratio of weighted output to weighted input for each DMU. The efficiency frontier is constructed from the envelope of these linear combinations.

Assuming a set of K DMUs (k=1,…,K) in the sample, each with M inputs (j=1,…,M) and N outputs inputs (i=1,…,N). the efficiency ratio of the DMU k can be defined as the ratio of its weighted sum of outputs over its weighted sum of inputs:

$$E_k = \frac{u_1 y_{1k} + u_2 y_{2k} + \dots}{v_1 x_{1k} + v_2 x_{2k} + \dots} = \frac{\sum_{i=1}^{N} u_i y_{ik}}{\sum_{j=1}^{M} v_j x_{jk}} \qquad (1)$$

where x_{jk} and y_{ik} are the amounts of j^{th} input and i^{th} output consumed and produced by DMU k, respectively. u and v correspond to (M x 1) and (N x 1) vectors of input and output weights, respectively.

The DEA formulation starts with specifying a mathematical problem that maximises the efficiency of DMU k subject to the efficiency of all other DMUs being less than or equal to 1. The weights are the variables of this problem, and the solution gives the most favourable weights and an efficiency score for each DMU.

$$
\begin{aligned}
&Max_{u,v}\left(u'y_k / v'x_k\right)\\
&st \quad u'y_k / v'x_k \leq 1, \quad k = 1,2,...,K\\
&\quad u,v \geq 0
\end{aligned}
\tag{2}
$$

The problem with the fractional formulation in (2) is that it has an infinite number of solutions. To avoid this, the constraint $v^{'}x_k = 1$ is imposed, which provides (3) which is a linear programming problem.

$$
\begin{aligned}
&Max_{\mu,\upsilon}\left(\mu' y_k\right)\\
&st \quad v' x_k = 1\\
&st \quad \mu' y_k - v' x_k \leq 0 \quad k = 1,2,...,K\\
&\quad \mu, v \geq 0
\end{aligned}
\tag{3}
$$

Each DMU selects input and output weights that maximise its efficiency score and the problem is run *K* times to identify the relative efficiency scores of all DMUs. The formulation in (3) is known as DEA-CCR (after Charnes, Cooper, Rhodes) for constant returns to scale (CRS). The dual of (3) is (4) where is a dual variable referring to the unity constraint in (3) while λ is a *K*x1 vector of dual variables relating to the second set of constraints in (3).

$$
\begin{aligned}
&Min_{\theta,\lambda}\theta\\
&st \quad - y_i + Y\lambda \geq 0\\
&\theta x_j - X\lambda \geq 0\\
&\lambda_1 ..., \lambda_k \geq 0
\end{aligned}
\tag{4}
$$

An additional constraint, shown in (5), leads to the DEA-BCC (after Banker, Charnes, Cooper) model, which allows for variable returns to scale (VRS).

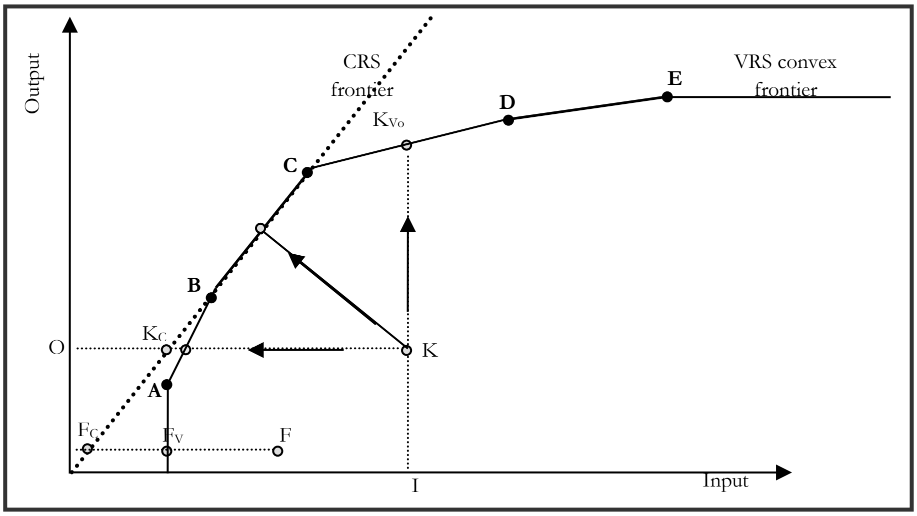
$$
\begin{aligned}
&Min_{\theta,\lambda}\theta\\
&st \quad - y_i + Y\lambda \geq 0\\
&\theta x_j - X\lambda \geq 0\\
&\lambda_1 ..., \lambda_k \geq 0\\
&N1'\lambda \leq 1
\end{aligned}
\tag{5}
$$

where *N*1 is a *N*x1 vector of 1.

The models in equations (4) and (5) are output oriented. Input-oriented models can be formulated in the same way using duality in linear programming. The choice of orientation depends on the objective of the benchmarking exercise (input conservation versus output augmentation), and on the extent to which inputs and outputs are controllable. Both models should estimate exactly the same frontier, with the same set of DMUs being identified as efficient under either model. However, efficiency scores of inefficient DMUs may differ under VRS.

In the simple scenario of a single-input and a single-output, Figure A1 illustrates DEA models and efficiencies under different orientations and scale technologies. The DEA frontier consists of a convex hull of intersecting planes which envelops the efficient data points A, B, C, D and E. Note that only units B and C are efficient under both CRS and VRS, which confirms that DEA-CRS is more restrictive than DEA-VRS. For the inefficient DMU K, the projection towards the CRS frontier (the straight line) makes point K_C the new target, while points K_{Vi}, $K_{Vo,}$ and K_A are the VRS targets for the input, output and additive orientations respectively. Unlike the CCR or BCC model the additive model is un-oriented, i.e. it does not differentiate between input or output orientation which means that a reduction of input with a synchronous enhancement of outputs is possible.

Figure A1: DEA production frontier under a single-input/single-output scenario

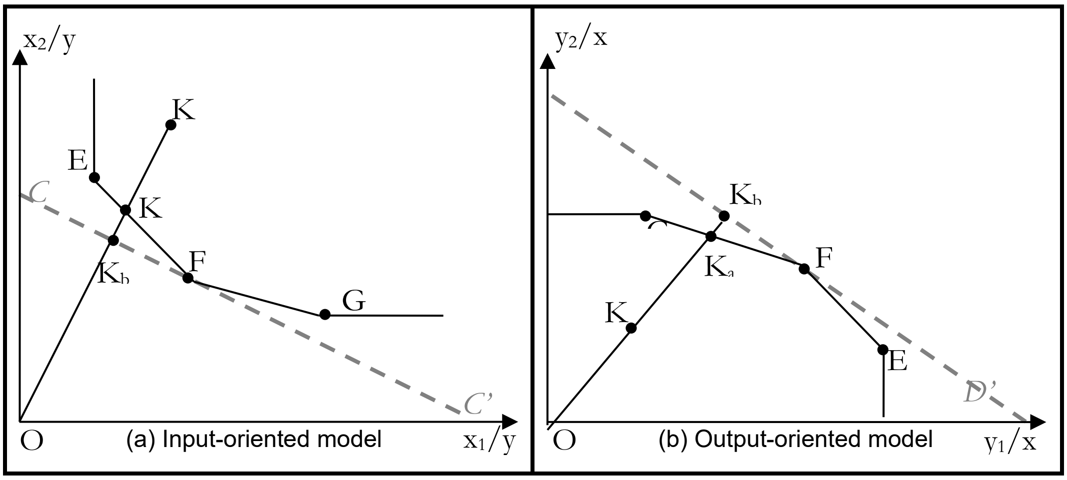


Source: author's elaboration.

Another way of illustrating DEA input and output orientations is by analysing production sets of either two inputs (x_1, x_2) and one output (y) for the input-oriented model, or one input (x) and two outputs (y_1, y_2) for the output-oriented model. Figure A2 depicts TE (technical efficiency) and AE (allocative efficiency) measures in both orientations.

When cost and price information are available, one can draw the iso-cost line CC' (combination of x_1 and x_2 giving rise to the same level of cost expenditure) for the input-oriented model and the iso-revenue line DD' (combination of y_1 and y_2 giving rise to the same level of revenue) for the output-oriented model. Allocative efficiencies for input (AE_i) and output (AE_o) orientations can therefore be calculated, corresponding in our example to the ratios OK_b/OK and OK/OK_b, respectively. The overall economic efficiency (EE) can be measured as the product of TE and AE in each model. Finally, note that the reference set or peers for the inefficient DMU K are E and F in the input-oriented model, and F and G in the output-oriented model.

Figure A2: Illustration of DEA models, excluding the effect of technological change



Source: author's elaboration.

A.2 DEA models used in this study

In order to estimate and compare efficiency scores under a stationary frontier over time, we conduct contemporaneous and inter-temporal DEA analyses using cross-sectional and panel data, respectively. In the context of cross-sectional data, the contemporaneous approach compares observation units within the same time-period, e.g. one year. In the context of panel data, the inter-temporal approach pools all data over the total time observed, e.g. total number of years. By using both approaches, the selected port DMU is benchmarked against varying sample sizes while still assuming constant technology over time.

Although contemporaneous and inter-temporal analyses are useful for estimating and comparing technical efficiency, they can be misleading in a dynamic context because neither approach accounts for possible shifts of the frontier over time. Furthermore, there is no means of checking whether the frontier is moving or stationary over time. To ensure a DMU's efficiency is tracked over time while allowing for shifts in the efficiency frontier, several time-dependent versions of DEA have been developed, notably DEA window analysis. Under DEA window analysis, also referred to as window DEA, DMUs in selected time-periods are included simultaneously in the benchmarking analysis. Depending on the width of the window, the technique may be conducted in terms of contemporaneous, inter-temporal and locally inter-temporal analyses. Contemporaneous and inter-temporal analyses correspond to the basic DEA approaches described above where the window width is equal to *1* (one) and *T* (total time or number of years observed), respectively. The locally inter-temporal analysis compares subset DMU observations at different but successive time windows where each DMU-observation is only compared with the alternative subset in the single window, assuming a constant frontier during each window. Under this approach, the window width is larger than one and less than all periods combined, but it is usually set for a three-year period.

Although the locally inter-temporal window analysis seems an attractive technique for tracking changes in efficiency over time, it has many limitations. First, the technique is akin to a moving average procedure where the technology remains constant in each window. Second, a DMU under window DEA is only compared with a subset of data and not with the whole data set. Indeed, the width of the window is usually defined arbitrarily given that no underlying theory or analytical evidence that validates the use of a particular window size exists. In the context of benchmarking container-port efficiency, the overlapping subsets derived from successive windows wrongly imply that the container port production is somehow discontinuous over the study period. Last, but not least, because the efficiency of a DMU observation in a particular window is calculated more than once and hence included in several windows, it is not obvious how to define the frontier in the same window-period. This issue hinders the application of total factor productivity (TFP) analysis such as through the Malmquist productivity index (MPI). For instance, Asmild et al. (2004) recommended that it is not appropriate to decompose Malmquist indices based on window DEA into standard frontier shift and catching up effects (see Appendix B).

In this study we use DEA to measure and benchmark container-port efficiency. Primarily, DEA seeks to measure technical efficiency without using price and cost data or specifying a functional formulation. A common feature of port benchmarking studies is the use of operational data due to the difficulty to obtain port costs and prices. When formulating DEA, we use an input orientation given the emphasis of this section on operational structure and port efficiency (equation 6). DEA-CCR and DEA-BCC models are used to express constant returns to scale (CRS) and variable returns to scale (VRS), respectively.

$$
\begin{aligned}
& Min\theta_k \qquad w.r.t \qquad \lambda_1,\ldots\ldots,\lambda_n \\
& \text{s.t. } \theta x_{ik} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0 \qquad i = 1,2,\ldots,m \\
& -y_{rk} + \sum_{j=1}^{n} \lambda_j y_{rj} \geq 0 \qquad r = 1,2,\ldots,s \\
& \lambda_j \geq 0 \qquad j = 1,\ldots,n \qquad \text{(CCR)} \\
& \sum_{j=1}^{n} \lambda_j = 1 \qquad \text{(BCC)}
\end{aligned}
\tag{6}
$$

Where:

x_{ij} and y_{rj} are the respective amounts of i^{th} input and r^{th} output consumed and produced by DMUj

λ_j $(j = 1,2,\ldots,n)$ are non-negative scalars representing input and output weights such.

B Malmquist productivity index

B.1 Introduction to TFP and MPI

The basic definition of total factor productivity (TFP) is the rate of transformation of total input into total output. In this thesis, we focus on total factor productivity change, hereafter abbreviated to TFP, rather total factor productivity growth (TFPG), the latter being an established branch of economic growth and statistical accounting.

The TFP concept incorporates multiple inputs (M) and outputs (S) to measure (and sometimes decompose) productivity change over time or between firms. So often, the TFP concept is reduced to multi-factor productivity (MFP) measures relating one measure of output to a bundle of inputs. A TFP index is determined by calculating the ratio of the weighted sum of outputs with respect to the weighted sum of inputs, with its general formula being expressed as follows:

$$TFP = \sum_{s=1}^{S} \omega_s Y_s / \sum_{m=1}^{M} \omega_m X_m \qquad (1)$$

Where ω_m are input weights and $\omega_s$are output weights, each must sum to 1

In general, the weights are the cost shares for the inputs and the revenue shares for the outputs under the assumption that input and output markets achieve productive efficiency. This is the case of the Törnqvist index (Törnqvist, 1936), a widely used TFP index in productivity studies. Equations (2) and (3) show Törnqvist input and output indices from the base period t to the period$t+1$, respectively. Because they attempt to construct a measure of total output over total input, TFP indices such as the Törnqvist index are widely used in benchmarking studies.

$$T_i = \prod_{m=1}^{M} \left[x_{mt}/x_{m(t+1)}\right]^{\frac{\omega_{m(t+1)}+\omega_{mt}}{2}} \qquad \text{Input index (2)}$$

$$T_o = \prod_{s=1}^{S} \left[y_{st}/y_{s(t+1)}\right]^{\frac{\omega_{s(t+1)}+\omega_{st}}{2}} \qquad \text{Output index (3)}$$

Where:

$x_{m(t+1)}$and $x_{mt}$are quantity of m^{th} input in periods $t+1$ and t, respectively

$y_{s(t+1)}$ and $y_{st}$are quantity of s^{th}output in periods $t+1$ and t, respectively

$\omega_{mt}$and $\omega_{m(t+1)}$are the m^{th}input cost shares in periods $t$and $t+1$, respectively

ω_{st} and$\omega_{s(t+1)}$ are the s^{th}output revenue shares in periods $t$and $t+1$, respectively.

The above TFP measures are based on quantity data and market prices; but the latter may not be available or may not be appropriate for weight aggregation. Port data are often not available at terminal or cargo-type level. Sometimes, prices may have little economic meaning for productivity measurement of non-market activities such as port operations in certain countries or under specific institutional and management systems. In addition, the non-frontier approach to TFP measurement relies on a number of assumptions, for instance the competitive characteristic of markets and the efficient behaviour of firms, but such conditions rarely hold in practice.

To incorporate all such sources of efficiency while recognising the limitations of the non-frontier TFP approach, researchers use the Malmquist TFP index constructed by estimating a distance frontier. The Malmquist productivity index (MPI) is defined as the measure of TFP change of two data points by calculating the ratio of the distances of each point relative to a common technology. To avoid deciding on which period to define as the reference technology, Färe et al. (1994) proposes a geometric mean of two TFP indices evaluated between periods t and $t+1$ as the base and the reference technology periods, respectively (see Equations 4 and 5 below). This allows input and output weights to be calculated directly, which eliminates the need for price data. In addition, no assumption is required on the firm's efficient behaviour (i.e. profit maximisation or cost minimisation).

$$M_o(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_o^t(y_{t+1},x_{t+1})}{d_o^t(y_t,x_t)} \frac{d_o^{t+1}(y_{t+1},x_{t+1})}{d_o^{t+1}(y_t,x_t)}\right]^{1/2} \quad \text{(Output orientation) (4)}$$

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_i^{t+1}(y_t,x_t)}{d_i^{t+1}(y_{t+1},x_{t+1})} \frac{d_i^t(y_t,x_t)}{d_i^t(y_{t+1},x_{t+1})}\right]^{1/2} \quad \text{(Input orientation) (5)}$$

The main advantage of TFP indices is that they reflect the joint impacts of the changes in combined inputs on total output. This feature is not accounted for when single or partial factor productivity indicators are used. However, the TFP methodology is a non-statistical approach and does not allow for the evaluation of uncertainty associated with the results. Furthermore, TFP results depend largely on the technique used and the definition of weights, which implies that different TFP indices may yield different efficiency results. In many cases, the use of the appropriate TFP approach is reduced to a trade-off between the requirement of large datasets in the econometric approach and the simplifying assumptions in the index approach.

B.2 MPI model used in this study

Recall the formulation of the Malmquist input-oriented index as shown in equation (6):

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \left[\frac{d_i^{t+1}(y_t,x_t)}{d_i^{t+1}(y_{t+1},x_{t+1})} \frac{d_i^t(y_t,x_t)}{d_i^t(y_{t+1},x_{t+1})}\right]^{1/2} \quad (6)$$

The Malmquist productivity index (MPI) is the geometric mean between two indices, the first evaluated against period $t+1$ technology and the second evaluated against period$t$ technology.

Equation (6) can be expressed as (7) whereby the left-hand part measures the change in technical efficiency (TEC), representing the catching up effect, while the right-hand part measures technological change (TC), representing the frontier shift effects*1*. Färe et al. (1992) use DEA distance functions to calculate the CRS Malmquist index.

$$M_i(y_t, x_t, y_{t+1}, x_{t+1}) = \frac{d_i^t(y_t,x_t)}{d_i^{t+1}(y_{t+1},x_{t+1})} \left[\frac{d_i^{t+1}(y_t,x_t)}{d_i^t(y_t,x_t)} \frac{d_i^{t+1}(y_{t+1},x_{t+1})}{d_i^t(y_{t+1},x_{t+1})}\right]^{1/2} \quad (7)$$

In order to measure TFP using the above MPI expression, CRS distance functions are required. This is because the technical efficiency change (TEC) entails changes in both scale efficiency (SE) and non-scale technical efficiency (pure technical efficiency: PEC). Since the DEA VRS model does not capture the impact of production scale on efficiency, the MPI under VRS distance functions is not able to measure changes in scale efficiency. Hence, it may be misleading as to the extent of frontier shift effects.

Färe and Lovell (1994) and Färe et al. (1994) suggest an enhanced TFP decomposition that relaxes the CRS assumption while allowing for the measurement of scale efficiency change. By introducing some VRS distance functions, technical efficiency change (TEC) can be decomposed into a pure technical efficiency change (PEC) component and a scale-efficiency change (SEC) component. Equation (7) can therefore write as (8) where superscripts V and C refer to VRS and CRS technology, respectively. Equation (8) decomposes the TFP change (TFPC) into various sources of efficiency change, and is expressed as follows:

$$M_i = \frac{d_i^{t(V)}(y_t, x_t)}{d_i^{t+1(V)}(y_{t+1}, x_{t+1})} \left[\frac{d_i^{t+1(V)}(y_{t+1}, x_{t+1})}{d_i^{t(V)}(y_t, x_t)} \frac{d_i^{t(C)}(y_t, x_t)}{d_i^{t+1(C)}(y_{t+1}, x_{t+1})} \right] \left[\frac{d_i^{t+1(C)}(y_t, x_t)}{d_i^{t(C)}(y_t, x_t)} \frac{d_i^{t+1(C)}(y_{t+1}, x_{t+1})}{d_i^{t(C)}(y_{t+1}, x_{t+1})} \right]^{1/2}$$

$$TFPC = PEC \times SEC\ X\ TC \qquad (8)$$

C DEA efficiency estimates of South African container terminals and comparator peers under cross sectional analysis

Table C1: Cross sectional efficiency scores

Terminal	2019	2018	2017	2016	2015	2014	2013	2012	2011	2010
Sines	1.00	1.00	0.95	1.00	0.86	0.96	1.00	0.95	0.88	1.00
Callao	1.00	0.98	1.00	0.94	1.00	0.97	0.92	0.95	0.92	1.00
Durban	0.75	0.74	0.76	0.83	0.88	0.91	0.90	0.97	0.92	0.75
Qasim	0.84	0.85	0.83	0.83	0.81	0.78	0.73	0.62	0.63	0.84
Alexandria	0.82	0.85	0.81	0.78	0.74	0.72	0.72	0.65	0.62	0.82
Jakarta	0.82	0.78	0.78	0.86	0.85	0.72	0.64	0.64	0.51	0.82
Tema	0.88	0.67	0.65	0.66	0.65	0.58	0.64	0.64	0.61	0.88
Aqaba	1.00	0.92	0.88	0.83	0.82	0.75	0.69	0.57	0.60	1.00
Mersin	0.94	0.96	1.00	0.95	0.91	0.83	0.83	0.79	0.72	0.94
Elizabeth	0.63	0.62	0.67	0.67	0.67	0.70	0.70	0.68	0.72	0.63
Dar es-Salaam	0.62	0.60	0.67	0.66	0.63	0.61	0.68	0.60	0.42	0.62
Cape Town	0.83	0.86	0.85	0.88	1.00	0.91	0.84	0.84	0.79	0.83
Ngqura	0.77	0.75	0.72	0.60	0.59	0.56	0.55	0.51	0.51	0.77

Source: author's elaboration based on port data described in Section 3.1.3.

D DEA efficiency estimates under panel data analysis

Table D1: Panel data efficiency scores

Terminal-year	Efficiency scores	Terminal-year	Efficiency scores	Terminal-year	Efficiency scores
Sines-10	0.776	Aqaba-10	0.672	Cape Town-10	0.893
Sines-11	0.792	Aqaba-11	0.731	Cape Town-11	0.904
Sines-12	0.793	Aqaba-12	0.766	Cape Town-12	0.875
Sines-13	0.825	Aqaba-13	0.738	Cape Town-13	0.817
Sines-14	0.797	Aqaba-14	0.792	Cape Town-14	0.813
Sines-15	0.85	Aqaba-15	0.827	Cape Town-15	0.773
Sines-16	0.84	Aqaba-16	0.841	Cape Town-16	0.748
Sines-17	0.872	Aqaba-17	0.875	Cape Town-17	0.729
Sines-18	0.92	Aqaba-18	0.881	Cape Town-18	0.72
Sines-19	0.94	Aqaba-19	0.889	Cape Town-19	0.719
Callao-10	0.824	Dar es-Salaam-10	0.595	Durban-10	0.89
Callao-11	0.854	Dar es-Salaam-11	0.585	Durban-11	0.869
Callao-12	0.871	Dar es-Salaam-12	0.594	Durban-12	0.84
Callao-13	0.883	Dar es-Salaam-13	0.632	Durban-13	0.812
Callao-14	0.897	Dar es-Salaam-14	0.686	Durban-14	0.759
Callao-15	0.923	Dar es-Salaam-15	0.698	Durban-15	0.77
Callao-16	0.942	Dar es-Salaam-16	0.759	Durban-16	0.718
Callao-17	0.952	Dar es-Salaam-17	0.713	Durban-17	0.706
Callao-18	0.933	Dar es-Salaam-18	0.795	Durban-18	0.713
Callao-19	0.945	Dar es-Salaam-19	0.785	Durban-19	0.683
Mersin-10	0.733	Alexandria-10	0.549	Elizabeth-10	0.684
Mersin-11	0.784	Alexandria-11	0.58	Elizabeth-11	0.665
Mersin-12	0.788	Alexandria-12	0.595	Elizabeth-12	0.692
Mersin-13	0.836	Alexandria-13	0.635	Elizabeth-13	0.685
Mersin-14	0.82	Alexandria-14	0.677	Elizabeth-14	0.672
Mersin-15	0.844	Alexandria-15	0.737	Elizabeth-15	0.625
Mersin-16	0.885	Alexandria-16	0.753	Elizabeth-16	0.598
Mersin-17	0.871	Alexandria-17	0.759	Elizabeth-17	0.613
Mersin-18	0.915	Alexandria-18	0.782	Elizabeth-18	0.616
Mersin-19	0.928	Alexandria-19	0.821	Elizabeth-19	0.575
Tema-10	0.583	Qasim-10	0.684	Ngqura-10	0.414
Tema-11	0.64	Qasim-11	0.683	Ngqura-11	0.453
Tema-12	0.651	Qasim-12	0.741	Ngqura-12	0.451
Tema-13	0.665	Qasim-13	0.725	Ngqura-13	0.495
Tema-14	0.685	Qasim-14	0.733	Ngqura-14	0.503
Tema-15	0.726	Qasim-15	0.762	Ngqura-15	0.526
Tema-16	0.755	Qasim-16	0.852	Ngqura-16	0.532
Tema-17	0.774	Qasim-17	0.847	Ngqura-17	0.64
Tema-18	0.825	Qasim-18	0.87	Ngqura-18	0.67
Tema-19	0.872	Qasim-19	0.862	Ngqura-19	0.687
Jakarta-10	0.585				
Jakarta-11	0.596				
Jakarta-12	0.632				
Jakarta-13	0.737				
Jakarta-14	0.796				
Jakarta-15	0.779				
Jakarta-16	0.821				
Jakarta-17	0.849				
Jakarta-18	0.833				

Source: author's elaboration based on port data described in Section 3.1.3.