CENTRAL EUROPEAN REVIEW
OF ECONOMICS AND MANAGEMENT

ISSN 2543-9472; eISSN 2544-0365

Vol. 2, No. 3, 155-174, September 2018

www.cerem-review.eu
www.ojs.wsb.wroclaw.pl

Measuring productivity and efficiency of seaports in India using DEA technique

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Abstract:

Aim: In this paper we are looking at the seaports (in India called 'major ports') from the context of its trade and India's strategic importance in trade world after the initiation of economic reforms in 1991. It empirically estimates the levels of productivity and efficiency of seaports in India. This paper applies DEA technique to assess productivity and efficiency of seaports in India.

Design/Research methods: DEA technique is extensively used in the literature of economics to provide measures of firms' technical efficiency. These measures rank the firms by looking at their apparent performances over a period of time. DEA is a frontier model which is non-parametric since no functional specification or form is required to be mentioned.

Conclusions/Findings: The DEA results as discussed and reported in the paper have shown how Indian ports are performing over the years. This investigation alone is not sufficient to develop a benchmark in the port system of India. Rather it will do well to have a closer look at the Indian ports from the physical and financial performance point of view. This study made use of data envelopment analysis (DEA) to generate what we call an efficiency benchmarks and assessment of the Indian ports sector. With this modest attempt to investigate the port sector of India several issues are in the open one can further analyze and come to desired conclusions.

Originality/value of the paper: The main role of a port is to transfer goods between two transport modes. As far as Indian ports are concerned, there are few studies with regard to productivity and efficiency of the port sector. Since, there is an attempt in recent years to overhaul the infrastructure sectors of the Indian economy and especially seaports. There is a need to look at issues in port sector as well. Productivity and efficiency concerns should be the main aspect of the benchmarking of the performance of today's Indian ports.

Limitations of the research: Second stage DEA, distance function approach, Bayesian techniques, Carlo Monte techniques, can be alternatively used.

Key words: Productivity, Efficiency, Frontier, Parametric, Non-parametric, DEA.
JEL: C14; D24

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Received: 27.08.2017, Revised: 15.11.2017, Revised: 08.03.2018, Revised: 04.07.2018, Accepted: 22.07.2018
doi: http://dx.doi.org/10.29015/cerem.529

1. Introduction

The transport sector of the Indian economy which comprises of railways, roads, ports and airways, have been the main focus for years from the policy makers of the country and especially more so since the ushering of economic reforms in 1991. Given the overall transport sector's contribution to the economic growth and development of this country, we need to relook at the policies and programs of the transport sector at large from the context of development of the economy. Ports are one such area in the entire transport sector of the economy which takes the major chunk of the budget of the Union Government. Investments in ports require huge amounts in terms of money and machinery. Table 1 shows investments in the transport sector of the Union Government during the first nine five year plans (1951-2002). Planning Commission is now replaced by NITI (National Institution for Transforming India) and such five year plans have been discontinued.

India has an extensive coastline of 7517 Kms, spread on the western and eastern shelves of the mainland and also along the Islands. Its coast is spread along nine States and four Union Territories. The nine coastal states of India namely; Gujarat, Maharasthra, Goa, Karnataka, Kerala (West Coast) and Tamil Nadu, Andhra Pradesh, Orissa, West Bengal (East Coast) have in all 12 major ports and around 200 minor and intermediate ports (often referred to as non-major ports).

The major ports of India are six on the west coast namely, Kandla, Mumbai, Jawaharlal Nehru (near Mumbai), Mormugao, New Mangalore and Cochin, and six on the east coast Tuticorin, Chennai, Vishakapatnam, Paradip, Kolkatta, and Haldia (though Haldia is a satellite port of Kolkatta). The Ennore Port Limited (EPL), being a newly constructed major port, is the first corporate major port registered under the Companies Act, 1956. It was commissioned in the year 2001.

The entries relating to the development of maritime ports are in the Seventh Schedule of the Constitution of India and therefore come under the purview of the Centre and the States as well. The twelve major ports of India are placed in the Union List of the Indian Constitution and, are such statutory bodies (trusts) administered by the Ministry of Shipping, Government of India under the provisions of the Major Port Trust Act, 1963 and Indian Ports Act, 1908.

Table 1. Planned investments in the transport sector in India 1951-2002

Sector	1st Plan (1951 -56)	2nd Plan (1956 -61)	3rd Plan (1961 -66)	Annual Plans (1966-69)	4th Plan (1969-74)	5th Plan (1974-79)	Annual Plans (1979-84)	6th Plan (1980-85)	7th Plan (1985-90)	Annual Plans (1990-92)	8th Plan (1992-97)	9th Plan (1997-2002)
Railways	217	723	1326	509	934	2063	714	6585	16549	10208	32302	46405
Roads & Bridges	147	242	440	309	862	1701	467	3887	6335	3656	16095	47600
Road Transport	-	-	27	55	128	503	143	1276	2151	986	3538	5933
Ports	28	33	93	53	249	488	57	725	1513	668	2302	5331
Shipping	19	53	40	32	155	469	147	468	720	939	3033	2909
IWT	-	-	4	6	11	16	6	63	188	57	152	280
LH&LS	-	-	4	2	6	9	2	*	*	4	25	58
Civil Aviation	23	49	49	66	177	294	132	957	1948	1055	7249	6599
Other Transport	-	-	-	-	-	-	-	-	72	118	244	1851
Transport total	434	1100	1983	1032	2522	5543	1668	13961	29476	17691	64940	117325
Transport as % of total plan	22.05	23.50	23.15	15.60	15.98	14.08	-	13.02	13.51	14.12	13.00	-

Source: Govt. of India, Planning Commission, Vision 2020 Transport, Mahesh Kapoor Report, 2002; * Included in the port sector

As far as Indian ports are concerned, there are few studies with regard to productivity and efficiency of the port sector. Studying Indian ports is crucial in today's competitive and globalized environment especially after the initiation of economic reforms in India in 1991. Accordingly, this study was necessitated to put things in right perspective for the seaports of India as regards to productivity and efficiency. Since, there is an attempt in recent years to overhaul the infrastructure sectors of the Indian economy and especially seaports. There is a need to look at issues in port sector as well. Productivity and efficiency concerns should be the main aspect of the benchmarking of the performance of today's Indian ports. Efficiency is indeed core in policy considerations and hence need to be quantified objectively in order to help monitor progress of the port sector.

With this background in mind, our objectives of this study clearly spell out our intention to carry forward our work on ports. The study had set two objectives- to undertake a comprehensive review of seaports in India and to empirically estimate the levels of productivity and efficiency of seaports in India. Both this objectives are being fulfilled with this study on seaports of India. The study employed the literature review and the author's own survey carried out for the study period of two years (2012 to 2014). The required data for our empirical analysis spans for eighteen years (1996 to 2014).

2. Literature survey

Ports are engines of growth and development for the economies they serve. They are thus the economic drivers of entire economies. A nation's international links and trade depends upon good port infrastructure and services. Ports form a vital link in the overall trading chain and, consequently, their level of performance and efficiency determines to a large extent a nation's international competitiveness (Tongzon, Ganesalingam 1994). Ninety five percent of the Indian overseas trade in volume terms and seventy five per cent in value terms are sea-borne.

Seaborne traffic depends on seaports for all its operations, since ports acts as interfaces between maritime and inland modes of transport (roads, railways or inland navigation system). Therefore, in order to have an efficient maritime transport system, seaports must work efficiently so as to benefit the users (shippers, exporters/importers, etc.) adequately. The basic objective of a seaport is to provide for goods and passengers a fast and safe transit through its facilities, so that generalized costs for passengers (fare + time) and for shippers (tariffs + storage time) are minimized. Another role that some large seaports play is to serve as hubs for connection and transshipment, allowing cargoes on different long-haul routes to be served more efficiently by several ships (Trujillo, Nombela 1999).

Port efficiency varies widely from country to country and, specially, from region to region. It is a well-known fact that some Asian ports (Singapore, Hong Kong) are the most efficient ports in the world, while some of the inefficient ports are in Africa (Ethiopia, Nigeria, Malawi) or in Latin America (Colombia, Venezuela, Ecuador) (Micco, Perez 2001). Of late, with port reforms in the world in the form of privatization and public-private partnership agreements, there are many investments in port sector under these agreements which are doing exceptionally well and have turned their terminals into profitable ventures.

Poitras et al. (1996) focuses on port efficiency and competitive environment in port industry. According to them ports efficiency is important for trade, economic development of the region and to face international competitive environment. DEA model was applied to measure port performance and efficiency of 23 ports across the world. The DEA empirical analysis uses two output measures: the number of twenty feet equivalent units (TEUs) containers handled per berth hour and the total number of containers handled per year both 20 and 40 foot. The input measures used are: container mix, average delays in commencing stevedoring (calculated as a difference between the berth time and gross working time), average quay crane productivity represented by the number of containers lifted per quay crane hour, the number of gantry crane present at the port, the frequency of container ship calls, and the average government port charges per container. The empirical findings of their DEA model are the set of two results for the CCR (Charnes, Cooper and Rhodes) and additive DEA models. Their results reveal that the CCR model identifies more substantially more inefficient ports (13 vs. 4) than the additive model, and ignoring a marginal increase for Port of Jakarta, attributes a higher level of inefficiency to those ports which are judged to be inefficient using both the models. Further commenting on their result depends upon the assumption they made about the production technology of ports. Ports that are judged to be inefficient with variable returns to scale (VRS) will also be inefficient with linear production relations, but not otherwise. Besides efficiency rankings their results also identify the efficient facet being used for comparison as well a combination of the inputs which are being inefficiently utilized and the deviation of specific outputs from the efficient level. The final conclusion of their findings is that port efficiency results depends upon the type of DEA model employed which, in turn depends upon the assumption made about the returns to scale properties of the port production function.

Tongzon (2001) examines the efficiency with respect to containerized cargoes across ports recognized for their high level of performance in Asia and Europe. Their study uses two outputs and six input measures of port performance for sixteen container ports for the year 1996. The output measures are cargo throughput and ship working rate, whereas port inputs are number of berths, number of cranes, and number of tugs, terminal area, delay time and labour (proxy to the number of port authorities' employees). Empirical results for CCR (Charnes, Cooper and Rhodes) models and additive DEA models ranked ports for efficiency. CCR model identifies six ports as slightly inefficient, while the additive model identifies three as inefficient ports. This is true as CCR model fits a linear production technology and the additive models features variable returns to scale, which require a larger number of ports to define the efficiency frontier. Again, ports that are judged to be inefficient with variable returns to scale will also be inefficient with linear production technology, but not the converse. Further, a ports' operational efficiency level does not depend solely on its size or its function (i.e., whether it is a hub or feeder port). Size of the port is not a determinant of port efficiency.

Barros (2003) on Portuguese port authorities set out an objective to measure and compares the efficiency and performance of a sample of Portuguese seaports to indirectly infer the role of incentives introduced by the Portuguese policy regulation. The activity they are studying of Portuguese seaports is the work carried out by the port authorities i.e. multi-output. The output variables comprise of ten indicators: ship, movement of freight, gross tonnage, market share, break-bulk cargo, containerized cargo, roll-on/roll-off (ro-ro) traffic, dry bulk, liquid bulk, and net income. Whereas the input variables consist of two indicators: labour measured by number of workers and capital measured by the book value of the assets. Their analysis show mixed results but, overall it can be said that the majority of the seaports are in the efficient frontier. Mean technical, allocative and economic efficiencies with constant returns to scale, declined for Portuguese seaports from 1999 to 2000, indicating incentive policy regulation has failed to drive the Portuguese seaports towards the efficient frontier. While in the case of variable returns to scale the mean value of all efficiencies is improving slightly during the period. Barros (2003) concludes that the results and the implications the reforms had on the Portuguese seaports. Especially the port of Aveiro is an exception to the efficiency results. In final the study proposes some managerial guidelines – the Portuguese Maritime Port Agency must upgrade inspection procedures regarding seaport activities in order to provide explicit incentives for increasing productive efficiency. Further scope of the data must be expanded to include contextual factors beyond managerial control. Data gathered must be published and there should be transparency in data information and dissemination to all stakeholders of the Portuguese seaports. And finally, benchmarks were provided for improving the operation of least performing seaports.

Park and De (2004) study on Korean ports for their performance and efficiency. A four stage DEA was applied, to overcome the limitations of basic DEA models: alternating the consideration of the variables as inputs and outputs to measure the productivity (stage 1), profitability (stage 2), marketability (stage 3), and the overall efficiency (stage 4). The outputs selected for estimation depends on what is being merchandise: total merchandise and number of ships (productivity); income (profitability); customer satisfaction (commercialization and global efficiency). The variables used as inputs are –docking capacity and cargo handling capacity (productivity and overall efficiency), cargo throughput and number of ship calls (profitability) and income (marketability). The efficiency result of CCR as well as BCC models for 11 Korean ports is ranked in order of productivity, profitability, marketability and overall efficiency. Efficiency results with reference to returns to scale was also calculated and the ports were classified as decreasing returns to scale, increasing returns to scale and constant returns to scale with both CCR and BCC models.

Cullinane et al. (2004) study on efficiency of container terminals of a sample of 25 ports comprised of a cross-sectional data 200 observations for the period 1992-1999(8 years). The product output that is measured by them is a container terminals in TEUs (twenty feet equivalent units), whereas the productive input used by them is the capital which also measures the work input (i.e. it incorporates input labour). Analysis says that efficiency of container terminals is not influenced by the size of the port. Most of the ports have constant returns to scale, which indicated that the scale of production is not the main source of inefficiency, which means port competition and competitiveness may have a major and direct impact on the measured levels of efficiency within container ports. There are other reasons of inefficiency in port production like differences in port ownership or governance, locational advantages and the form and level of competition faced.

Cullinane et al. (2005) study employs mathematical programming approach to measure container port production efficiency to the top 30 container ports of the world in 2001. The study uses alternative techniques of DEA and Free Disposal Hull (FDH) model. The results of these two techniques give interesting insight into current efficiency rankings and gives different variations. Use of appropriate variable definition of input and output factors is crucial element in meaningful applications of DEA and FDH. It is clear from this that a combination of DEA and FDH analysis can be of great significance and value to managerial decisions of ports and terminals and to the strategic decisions of port authorities.

Chudasama and Pandya (2008) study is the first one measuring efficiency of Indian ports by making use of Data Envelopment Analysis (DEA). Their main objective is to bring out the actual working and performance of the port sector in India. Port input variables used in their study are seven: No. of Cranes, No. of Berths, Storage area in Sq. mts, Average pre-berthing time in Days and Average turnaround time in days. The single output variable taken by them is Cargo Volume in million tonnes. The results of their study reveal a complete efficiency picture of Indian ports for the year 2005-06. DEA-BCC model yield a higher efficiency estimates than DEA-CCR model with average values of 0.98 and 0.86 respectively. Out of the 12 ports, 7 ports were identified as efficient and 5 ports turned out to be relatively inefficient when DEA-CCR model was applied. When DEA-BCC model was applied, all the ports except Paradip turned out to be efficient in the analysis. Empirical results also show that large scale of production is more likely to be associated with high efficiency scores. For instance correlation between efficiency score and port output is 0.84 for the DEA-CCR model. Another observation of their study is that port output is significantly correlated with number of vessels handled and the storage area. And lastly empirical results reveal that there exists waste in the production at 5 sample ports. The average efficiency of these 5 ports derived from DEA-CCR model amounts to 0.86. This shows that in theory the ports under study can on average increase their outputs to 1.16 (=1/0.86) times as much as their current level, by using the same level of inputs.

3. Methodology

Based on the review, we are now in a position to state the methodology to be use for this study. The Malmquist DEA technique is a non-parametric technique to compute technical efficiency when panel data is available. The Malmquist DEA technique was elaborated by Caves, Chriestensen and Diewert (1982) and Fare et al. (1994b). The Malmquist total factor productivity (TFP) index measures the TFP change between two data points by calculating the ratio of the distances of each data point relative to a common technology. This TFP change can be decompose into technical change and technical efficiency change. If the period *c* technology is used as the current period technology, the Malmquist (input-oriented) TFP change index between period *b* (the base period) and period *c* (the current period) can be written as:

$$m_i^c\left(q_b, x_b, q_c, x_c\right) = \frac{d_i^c\left(q_c, x_c\right)}{d_i^c\left(q_b, x_b\right)} \quad (1)$$

Note that in the above equation the notation $d_i^c\left(q_c, x_c\right)$ represents the distance from the period *c* observation to period *b* technology. A value of m_i greater than one indicates positive TFP growth from period *b* to period *c* while a value less than one indicates a TFP decline. According to Fare et al. (1994b) these two periods (*b* and *c*) indices are only equivalent if the technology is Hicks input neutral.

Following Fare et al. (1994b) specifies an input-oriented Malmquist productivity change index between period '*b*' (base period) and period '*c*' (current period) as:

$$m_i\left(y_b, x_b, y_c, x_c\right) = \left[\frac{d_i^c\left(y_c, x_c\right)}{d_i^b\left(y_b, x_b\right)} \mathrm{X} \frac{d_i^b\left(y_c, x_c\right)}{d_i^c\left(y_b, x_b\right)}\right]^{1/2} \quad (2)$$

where:

y_c and y_b represent vector of outputs in period c and b respectively

x_c and x_b represent vector of inputs in period c and b respectively

An equivalent way of writing the Malmquist TFP index given in equation 2 is as follows:

$$m_i(y_b, x_b, y_c, x_c) = \frac{d_i^c(y_c, x_c)}{d_i^b(y_b, x_b)}\left[\frac{d_i^b(y_c, x_c)}{d_i^c(y_c, x_c)} X \frac{d_i^b(y_b, x_b)}{d_i^c(y_b, x_b)}\right]^{1/2} \quad (3)$$

Where the ratio outside the square bracket measures the change in the input-oriented measure of Farrell technical efficiency between period '*c'* and '*b'* i.e. the efficiency change is equivalent to the ratio of technical efficiency in period '*b*' to the technical efficiency in period '*c*'. The remaining part of the equation 3 is a measure of technical change. It is the geometric mean of the shift in technology between the two periods evaluated at y_b and also at y_c. Thus the two terms in equation 3 are:

$$\text{Efficiency change} = \frac{d_i^c(y_c, x_c)}{d_i^b(y_b, x_b)} \quad (4)$$

and

$$\text{Technical change} = \left[\frac{d_i^b(y_c, x_c)}{d_i^c(y_c, x_c)} X \frac{d_i^b(y_b, x_b)}{d_i^c(y_b, x_b)}\right]^{1/2} \quad (5)$$

The DEA Malmquist techniques involves estimation of four distance functions in equation 2 which will involve four linear programming (henceforth referred as LP) problems, and subsequently, computation of TFP change using either equation 2 or 3. The four LPs are given below:

We begin by assuming CRS technology. The CRS input oriented LP is stated as below:

$$
\begin{aligned}
&\left[d_i^b\left(x_b, y_b\right)\right]^{-1} = \max_{\phi,\lambda,} \phi, \\
&st \\
&-\phi y_{jb} + y_b \lambda \geq 0, \\
&x_{jb} - X_b \lambda \geq 0, \\
&\lambda \geq 0,
\end{aligned}
\qquad (6)
$$

The remaining three LP problems are simple variants of this:

$$
\begin{aligned}
&\left[d_i^c\left(x_c, y_c\right)\right]^{-1} = \max_{\phi,\lambda,} \phi, \\
&st \\
&-\phi y_{jc} + y_c \lambda \geq 0, \\
&x_{j,c} - X_c \lambda \geq 0, \\
&\lambda \geq 0,
\end{aligned}
\qquad (7)
$$

$$
\begin{aligned}
&\left[d_i^b\left(x_c, y_c\right)\right]^{-1} = \max_{\phi,\lambda,} \phi, \\
&st \\
&-\phi y_{j,c} + y_b \lambda \geq 0, \\
&x_{j,c} - X_j \lambda \geq 0, \\
&\lambda \geq 0,
\end{aligned}
\qquad (8)
$$

$$\begin{aligned}
&\left[d_i^c\left(x_b, y_b\right)\right]^{-1} = \max_{\phi,\lambda,} \phi, \\
&st \\
&-\phi y_{jc} + y_c \lambda \geq 0, \\
&x_{jc} - X_c \lambda \geq 0, \\
&\lambda \geq 0,
\end{aligned} \qquad (9)$$

Note that in LP's 7 and 8, where production points are compared with technologies from different time periods, the ϕ parameter need not be ≥ 1, as it must be when calculating Farrell efficiencies. The point could lie above the feasible production set. This will most likely occur in LP 7 where a production point from period *c* is compared with technology in period *b*. If technical progress has occurred, then a value of $\phi < 1$ is possible. It could also possibly occur in LP 9 if technical regress has occurred but this is less likely.

Also note that the φ and λ's likely to take different values in the above four LPs. All the above LPs must be solved for each firm in the sample. Thus in our case there are 12 firms (port trusts) and assume two time periods, 48 LPs must be solved. An extra time periods are added, one must solve an extra three LPs for each firm (to construct a chained index). If there are *T* time periods, then *(3T-2)* LPs must be solved for each firm in the sample. Hence, if there are *I* firms, then there are *I x (3T - 2)* LPs to be solved. In case of our study on ports *I=12* firms (port trusts) and *T=18* time periods, this would involve *12 x (3x18-2) =624* LPs.

The above approach can be extended by decomposing the (CRS) technical efficiency change into scale efficiency and a 'pure' (VRS) technical efficiency measure. This requires solution of two additional LPs (when comparing two production points). This would involve repeating LPs 8 and 9 with the convexity restriction *(N1'λ=1)* added to each. This provides estimates of distance functions relative to a variable returns to scale (VRS) technology. The number of LPs calculated accordingly increases from *N x (3T - 2)* to *N x (4T - 2).*

4. Data sources

The database used for this study is annual data relating to production (outputs) and productive factors (inputs) of twelve major ports of India. The data spans over 18 years period starting from 1996-97 and ending in 2013-14. This enabled us to get a fair idea about the functioning and progress of major ports of India in the last three years of last millennium and fifteen years of present millennium. This provides a panel of data of 216 observations which is adequate enough to adopt DEA (non parametric) method to estimate productivity and efficiency of major ports of India. In this study the latest port (Ennore Port Limited) could not be included because it was commissioned only in the year 2001. From the point of view of operational performance, Kolkatta and Haldia are taken as separate ports, otherwise, from the financial performance point of view it is always clubbed as a single major port. The 12 major ports covered by the study are: Chennai, Cochin, Haldia, Jawaharlal Nehru, Kandla, Kolkatta, New Mangalore, Mormugao, Mumbai, Paradip, Tuticorin and Visakhapatnam. These ports are spread across eastern and western coast of India. Six ports each being on both side of the coast. Four of the major ports Kolkatta, Mumbai, Chennai and Mormugao are the oldest being more than a century old.

The production (output) variable taken for non parametric estimation the two output variables taken are–volume of cargo traffic in million tonnes and number of vessels handled. We believe that there is some correlation between the volume of cargo handled and the number of vessels handled at the port. There are various measures of port's inputs (productive factors) in this study. The seven inputs are land, labour, number of cranes, number of other equipments, number of berths, etc. Land is approximated by the storage area in square meters. It includes transit shed, warehouse container freight station, open area, etc. Labour is measured by the number of workers employed in each port. It consists of workers of all types – official, administrative, non-administrative and workers who load and unload ships (stevedores). The capital input is measured as number of berths in each port of study. Berth is a basic infrastructure for the ships. Whole lot of other infrastructure is used through the berth like number of cranes – which consists of Mobile, Wharf, Container Yard and Quay Cranes also, and number of other equipments used in cargo handling operation – which consists of Fork/Top lift Truck, Reach Stacker, Tractors, Trailers, Locomotives, Dozers, Excavators, etc. Taking all this into consideration berth is used a proxy for a capital input for this study. Also a good performance measure for a port is also the average pre-berthing time in days and average turnaround time in days, which is also included as inputs in this study. All these inputs are taken together for DEA, especially because DEA allows use of multiple outputs and inputs. These inputs are significant because they state the quality, quantity, capacity of infrastructure and operational performance of the ports. Further, capital investment to provide berth, cranes and other equipment incurred by the port authorities is huge running into crores of rupees and is spent over a particular range of period.

The required panel data for eighteen year period (1996-97 to 2013-14) was sourced from secondary sources. The major sources of our data collection comes from various issues of 'Economic Intelligence Service, Centre for Monitoring Indian Economy, Mumbai, "Infrastructure", "Basic Port Statistics of India", published by Ministry of Shipping, Government of India, and "Major Ports of India: A profile", published by Indian Ports Association, New Delhi. Besides, Annual Administration Reports of Major Ports (various issues) were also referred to compile the entire data set for this study. This data set is also supplemented by several visits to some of the port trust offices.

5. Empirical analysis and results

Performance evaluation and benchmarking are a widely used method to identify and adopt best practices as a means to improve the performance and increase productivity. Accordingly, this study has attempted to take stock of the Indian port scenario and provide possible benchmarks to policy makers and regulators in India. The non parametric estimation is carried out by using the software package called DEAP Version 2.1 (Coelli 1996b). The DEAP software employed in this study was developed at the Centre for Efficiency and Productivity Analysis, University of New England, Australia and is described by Tim Coelli (1996b).

We calculate Malmquist Productivity Index summary as well as the efficiency change, technical change and scale change components for each port in our sample and for all ports (at different time periods). First, we present malmquist indices for all the ports at different time periods. All the indices presented in the Table 2 are relative to the previous year and hence the indices begin with year 1996-97 as the base year.

Table 2. Malmquist productivity index – summary of annual means, 1996-97 to 2013-14

Year	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity (TFP) Change
1996-97	1.000	1.000	1.000	1.000	1.000
1997-98	0.978	1.118	0.997	0.981	1.093
1998-99	0.983	1.123	0.988	0.996	1.104
1999-2000	0.987	1.132	0.994	0.993	1.118
2000-01	1.007	1.196	1.016	0.991	1.204
2001-02	0.956	1.057	0.985	0.971	1.011
2002-03	1.000	1.098	1.001	0.999	1.098
2003-04	0.987	1.167	0.956	1.033	1.152
2004-05	1.063	0.968	1.050	1.012	1.029
2005-06	1.012	1.005	1.013	0.999	1.017
2006-07	1.010	1.022	1.004	1.007	1.032
2007-08	0.955	1.881	0.952	1.004	1.796
2008-09	0.993	0.492	1.039	0.956	0.489
2009-10	1.059	1.021	1.003	1.056	1.082
2010-11	0.915	0.904	0.958	0.955	0.827
2011-12	1.069	0.959	1.053	1.015	1.025
2012-13	1.019	1.076	0.992	1.028	1.097
2013-14	0.997	1.081	1.008	0.989	1.078
Mean	0.999	1.047	1.000	0.999	1.046

Source: authors' own elaboration

Out of the 18 year period Indian ports exhibit scale efficiency for 7 years (2003-04, 2004-05, 2006-07, 2007-08, 2009-10, 2011-12 and 2012-13). That means they exhibits scale inefficiency for 11 years. Five indices are presented for all the ports in each year in the next five columns after the year column and for the different ports (for over all time periods) in Table 2. These five indices relate to efficiency change, technical change, pure efficiency change, scale efficiency change and Total Factor Productivity (TFP) change. From the Malmquist DEA analysis, TFP Index can be decomposed into technical efficiency change and technical change. Referring to

Table 1 the average total factor productivity change for all the 12 ports for the study period was 1.046, i.e. a growth of 4.6 percent over the sample period which can be best described as marginal considering the massive port structure. Further, there is hardly any improvement in the efficiency score and the technical change for the entire period was 4.7 per cent.

Next, we turn to a summary description of the average performance of each port over the entire 1996-2014 time period. All this information is presented in Table 3.

Table 3. Malmquist productivity index – summary of firm means, 1996-97 to 2013-14

Ports	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Total Factor Productivity Change
Chennai	1.003	1.089	1.000	1.003	1.093
Cochin	0.999	1.020	1.000	0.999	1.019
Haldia	1.000	1.077	1.000	1.000	1.077
JNPT	1.000	1.068	1.000	1.000	1.068
Kandla	1.000	1.058	1.000	1.000	1.058
Kolkatta	1.000	1.065	1.000	1.000	1.065
N. Mangalore	1.000	1.086	1.000	1.000	1.086
Mormugao	0.983	1,001	1.000	0.983	0.985
Mumbai	1.000	1.023	1.000	1.000	1.023
Paradip	1.000	1.039	1.000	1.000	1.039
Tuticorin	1.000	1.012	1.000	1.000	1.012
Visaz.	0.999	1.029	1.000	0.999	1.028
Mean	0.999	1.047	1.000	0.999	1.046

Source: authors' own elaboration

Note that if the value of the Malmquist index or any of its components is less than 1, which denotes regress or deterioration in performance, whereas values greater than 1 denote improvements in the relevant performance. Also, note that these measures capture performance relative to the best practice in the sample, where the best practice represents a 'world frontier', and the world in our case is defined as the ports in our sample. Now let us look at the Table 2, we see that, on average, productivity increased marginally over the 1996-97 to 2013-14 period for the ports in our sample – the average change in the Malmquist productivity index was 4.6 per cent as a whole. Moreover on an average, that growth was due to innovation (technical change) rather than improvements in efficiency (efficiency change). Moving to results across the ports, we note that Chennai has 9.3 per cent and New Mangalore has 8.6 per cent total factor productivity change on average, and that the entire change for both ports was due to innovation (technical change). In fact, for both ports technical change was the highest in the sample. (i.e. Chennai New Mangalore made use of modern technology). The total factor productivity change for Mormugao was lowest or best one could say was negligible at 0.985. Mormugao's total factor productivity change was far below than the sample average 4.6 percent. Of late this port on the west coast of India handles 40 per cent of the country's export of the cargo as iron ore and it is considered to be a main port for iron ore export in India. However, after 2012 the business of iron ore shrink due total ban imposed by the Supreme Court of India on account rampant illegal ore extraction is some states of India including Goa. Probably the dismal performance of Mormugao port may be due to this impact.

The DEA results as discussed and reported above have shown how Indian ports are performing over the years. This investigation alone is not sufficient to develop a benchmark in the port system of India. Rather it will do well to have a closer look at the Indian ports from the physical and financial performance point of view.

6. Conclusion

The main role of a port is to transfer goods between two transport modes. This activity requires coordination of a large number of activities that can be organized in many different ways. As pointed out by Friedrichsen (1999), the assessment of the performance of a port must, thus, be to address the efficiency of the overall port system. This concern we feel should be the main aspect of the benchmarking of the performance of today's Indian ports. Efficiency is indeed core in policy considerations and hence need to be quantified objectively in order to help monitor progress of the port sector. This study made use of data envelopment analysis (DEA) to generate what we call an efficiency benchmarks and assessment of the Indian ports sector. Alternatively this process can be also done in a number of ways like second stage DEA, distance function approach, Bayesian techniques, Carlo Monte techniques, etc. No doubt, with this attempt to investigate the port sector of India several issues are in the open one can further analyze and come to desired conclusions.

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