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RESEARCH ARTICLE

The Size Effect of Indian Major Ports on its Efficiency Using Dea-Additive Models

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Abstract

The main aim of this paper is to find out the size effect and its efficiency of Indian Major Ports using DEA –Additive models. The hypothesis is tested in this paper size is not a determinant factor of port efficiency. The findings based on 1993-2011 data shows both bigger ports (Mormugao, JNPT) as well as smaller ports (Ennore, Tuticorin) had efficient port operations. This paper also found that JNPT had operated as super efficient port among the major port in India through DEA – A&P.

Keywords*: Additive Models, Data Envelopment Analysis, Major ports in India.*

Prelude

Logistics plays an important role in the country's economic development. Logistics have an effect on productivity, distribution efficiency, interest rates, energy availability and energy costs [1]. As logistics become more and more important for a country's international competitiveness in an industry, the race for an international logistical hub is increasingly fierce. India spends about 14 percent of its GDP on logistics sector [2]. A report by the Asia Development Bank (2007) that on this current trend, 2 billion tons of cargo to be pass through the Indian Ports in the year 2015-16. This projected that, the volume of goods entering and leaving the goods, India's ports will increase significantly. It meant that the capacity as well as the efficiency of the ports not overlooked and should be made to the priority of Indian ports and its facilities. The main strategy used to decrease the international port competitiveness is the 'mega hub port'. This strategy brought down from the principle of 'economies of scale'- the faith on that a bigger port would have guaranteed for better efficiency in handling cargo and also attracts more volume of international shipment. However, some of the studies argued that the size is not a determinant factor for achieve better efficiency, because some bigger ports might actually become a source of inefficiency [3-4]. So it is necessary to study the port efficiency in respect of its efficiency.

Literature Review

Data envelopment analysis (DEA) has been applied to measure the relative efficiency of DMUs of many studies. Data envelopment analysis in their studies of port sector. Martinez-Budria et al [5] studied the Spanish port performance. Tongzon [6] measured the performance of 16 terminals in various countries. Itoh [7] analysed Japanese port performance. The efficiency of two Greek and four Portuguese ports. Cullinane et al [8] evaluated the world's top 30 container ports and privatization benefits. All the above studies evidenced the use of DEA analysis techniques to measure the efficiency of port sector.

Al-Eraqi, A. S et.al [9] studied the efficiency of Middle Eastern and East African sea ports. This study used panel data in 22 port of Middle Eastern and East African region. The study employed DEA (CCR and BCC) for measuring the efficiency scores of the ports. The authors concluded that small ports are efficient while big ports are inefficient. Coto - millan, P et.al [3] examined the economic efficiency of 27 Spanish ports during 1985-89. In the study they used frontier cost function, which enabled classification of the different Spanish ports. The study concluded that most efficient ports are those which are smaller size and managed under a more centralized regime. Rios and Macada [10] analysed the relative efficiency of container terminals of Mercosur using Data Envelopment Analysis. This study found that 60% of the terminals were efficient in the 3-year period. Sohn, J and Jung, G [11] examined the relationship between size of a port and its efficiency to find the performance growth in the transshipment market. The study obtained data from 16 major Asian ports. Two of the most widely used port efficiency analysis is DEA and SFA which were used in this study. From the study, it is observed that larger Asian ports show better cargo handling efficiency in relative terms. Turner, H et al. [12] analysed top 26 seaports in

US and Canadian region. From the study it is suggested that rail, roads connections improve significantly the port productivity. The study concludes that bigger ports are efficient.

In the light of above literature reviews it was observed that, most of the authors have used DEA for measuring the port efficiency but there were no much studies targeting on Indian Ports and their efficiency. Hence, this study attempts to measure the relative efficiency of Indian Major Ports using DEA -Additive CRS & VRS and DEA – A & P super efficiency model.

Methodology

Objective and Data

The main objective of the paper is to find out size effect of Indian Major Ports on it efficiency using DEA- Additive models. The analysis is closely relates to size and the efficiency of ports with the close input variable from land, labour and equipments. This study tested the hypothesis size is not a determinant factor of efficiency on Indian Major Ports. In order to examine the efficiency of ports a period of nineteen years i.e. 1993 - 2011 have been considered for this study. The whole study is based on secondary data, which was collected from the port authorities, Indian Ports Association, CMIE and India Stat databases.

Data Envelopment Analysis –Overview

Data Envelopment Analysis (DEA) is developed by Charnes et al [13], the DEA technique is essentially a linear programming technique that converts multiple inputs and outputs into a measurement of efficiency. According to Saha and Ravisankar [14] that DEA maximize the selected weights of each DMUs so that there is no negative weight. Each DMU uses the same weights for evaluating its efficiency, and the results of the efficiency ratio is restricted to 1 (one). Marinho [15] affirms that DEA technique set score for each DMU that represents units' relative performance. Normally, these scores fixed from 0% to 1% or from 0% to 100%. The efficient unit acquires the value equal to 1% or 100%.

In Data Envelopment Analysis the CCR model [13] measures the constant return to scale and the BCC model, measures the variable return to scale and does not assume proportionality between inputs and outputs. DEA application can be input-oriented model and output-oriented model. Input-oriented DEA minimizes the input so that the desired level of output is achieved. Output-oriented DEA maximize the output while the inputs all kept at constant level. Both input and output oriented model seek maximum efficiency, minimizing inputs and maximizing outputs. The DEA approach seems to be relevant for the objective of this study, not only because of non-parametric method but also because it does not require an explicit a priori determination of relationships between the input and output variables.

In terms of model orientation the input – oriented data envelopment analysis is closely related to operational and managerial issues, while the output-oriented model is closely associated with planning and strategies [8]. With the expansion of economic liberalization and port sector reforms many ports must frequently review their capacity in order to ensure that they can provide satisfactory services to port users and maintain their competitive edge. Based on the perspective, this study used DEA- Additive models and DEA – A&P model to evaluate the efficiency of major ports in India.

DEA Models

Additive Models

In basic DEA models we distinguish between Input and Output oriented models. But DEA – Additive model measures the combination of Input- Output orientation in single model.

$$
\begin{aligned}
&\max\ z = es^{-} + es^{+} \\
&s\,t \\
&\qquad x_0 = X\lambda + s^{-} \\
&\qquad y_0 = Y\lambda - s^{+} \\
&\qquad e\lambda = 1 \\
&\qquad \lambda \geq 0,\ s^{-}, s^{+} \geq 0
\end{aligned}
$$

DEA–Andersen and Petersen–Super Efficiency Model

Standard DEA models measures the relative efficiency on decision-making units but it does not allow the ranking of the units. Super efficiency model, which measures the super efficient performance among the efficient units.

$$
\begin{aligned}
&Min\ \ \theta - \varepsilon\left[\sum_{i=1}^{m} S_i^{-} + \sum_{r=1}^{s} S_r^{+}\right] \\
&s\,t \\
&\sum_{\substack{j=1 \\ j\neq p}}^{n} \lambda_j y_{rj} - S_r^{+} = y_{rp} \quad , r = 1,\dots,s \\
&\sum_{\substack{j=1 \\ j\neq p}}^{n} \lambda_j x_{ij} + S_i^{-} = \theta x_{ip} \ , i = 1,\dots,m \\
&\lambda_j \geq 0 \qquad\qquad j = 1,\dots,n \\
&S_r^{+}, S_i^{-} \geq 0 \qquad r = 1,\dots,s\ , i = 1,\dots,m
\end{aligned}
$$

Compilation of Input and Output Variables

Fig.1: Compilation of input and output variables

Variables	Contents	Relevant Literature
Input Variable	No of Berth	Rios and Macada [10]
	Berth Length	Al-Eraqi A. Salem [9], Cullinane K et. al [4], Cullinane and Wang [8],
	No of Equipments	Al-Eraqi A. Salem [9] Rios and Macada [10], Cullinane and Wang [8]
	No of Employees	Rios and Macada [10]
Output Variable	Container Throughput (TEU)	Cullinane K et. al [4], Cullinane and Wang [8]
	Total Traffic	Coto-Millan et. al. [3], Al-Eraqi A. Salem [9]

In this study, the compile lists of input and output variable in accordance with the relevant literature as shows in the above table, after taking into consideration the availability of data and the correlation among the variables, the researcher finally select the inputs and outputs to be used in the various DEA models.

While evaluating the port operational efficiency, it was mainly container throughput (TEU), total cargo handling and the number of berths that were used as the productivity indicators, and so in this study such outputs were initially selected to measure port efficiency. On the other hand, port infrastructure and equipments (such as wharves, granes, straddle) land, manpower are all resource inputs that contribute to the port's productivity. The equipments have become particularly important, because the loading and unloading function is to achieve with the help of equipments. For this reason the ports berth length and number of berths brings an important influence to bear on the measurement of a port's efficiency.

Pearson Correlation Results

In order to further confirm whether the selection of input and output variables is able to fully explain the effect on port efficiency. The input and output variables need to conform to 'isotonicity' i.e. as inputs increase, outputs should not decrease. This may be verified using correlation among the variables. So, that the variables that are not positively correlated are eliminated. The variable show the correlation below 0.6, indicating that there is no need for variable elimination. The variables selected for this study are influential in terms of explaining port efficiency.

Results & Discussion

Summary Statistics for the Sample

The sample included in the analysis of 8 Major ports in India during 1993-2011. The required secondary data for this analysis taken from the port authorities, annual report of the ports, India stat and CMIE database.
Table 4 shows the additive model Constant return to scale and its ranks of major ports in India during 1993 -2011. Standard DEA measures both input-oriented and output-oriented but Additive model measures the combination of input and output oriented. From the table it is reveals that Mormugao, Tuticorin, Ennore and JNPT had efficient all the years. Chennai port shows inefficient all the study years except 2007-2011 where it shows efficient. Paradip port also found to be relatively inefficient although except 2001, 2009-11, for which it shows efficient. Mumbai port shows efficient first 6 years later it went to inefficient. The port of Cochin shows inefficient during the period of study. From the table it is found that the ports like Mormugao, Tuticorin, Ennore and JNPT were found to be technically efficient compare with other Major Ports of India. That shows these ports found technologically well in doing logistics activities. The other ports like Chennai, Paradip, Mumbai and Cochin found to be technically inefficient, so these ports should have concentrate on its technological up gradation and infrastructure development.

Rank wise performance of the ports Mormugao, Tuticorin, Ennore and JNPT shared first position among 8 major ports. Followed by Paradip ports had occupied fifth position with the average of 0.791. Chennai port had acquired six positions among the major ports in India. The least performance of the ports Mumbai and Cochin shared 7 & 8 position among the major ports of India.

Table 5 shows the DEA-Additive Variable Return to Scale model and its ranks for the same 8 Major Ports in India during 1993-2011. The port operations of Mormugao, Chennai, Tuticorin, Ennore and JNPT were rated as being efficient over the period of time. The port Paradip was being rated as efficient during the study periods except in the years 2002, 2004, 2005 and 2008, where it shows inefficient operations. Mumbai port shows efficient operations, but during last 5 years it shows inefficient at extremely low level. The port of Cochin was again rated as being relatively inefficient all the years. Comparing with the DEA-Additive CRS to DEA-Additive VRS

Fig.2: Pearson correlation results

	Total traffic	Noof equipment	No of employees	No of berth	Container	Berth length
Total traffic	1.000					
No of equipment	0.265	1.000				
No of employees	0.356	0.208	1.000			
No of berth	0.438	0.217	0.936	1.000		
Container	0.473	0.737	0.060	0.004	1.000	
Berth length	0.507	0.245	0.882	0.970	0.045	1.000

Fig.3: Summary Statistics for the Sample

	Output		Input			
	Total Traffic	Container Throughput	No of Berths	Berth Length	No of Equipment	No of Employees
Mean	25264.17	413.5804	16.74825	3229.400	106.7203	5898.483
Median	21182.00	145.0000	12.00	2590.00	71.00	3511.00
Maximum	64299.00	4271.00	49.00	7653.00	467.00	26614.00
Minimum	3007.00	0.00	2.00	560.00	9.00	8.00
Std. Dev.	15843.97	814.68	13.35	2116.30	110.76	6288.60
Skewness	0.76	3.30	1.45	0.85	1.26	1.87
Kurtosis	2.55	13.93	4.14	2.69	3.99	5.92
Jarque-Bera	14.81	971.01	58.03	17.71	43.84	134.35
Probability	0.00	0.00	0.00	0.00	0.00	0.00
Sum	3612777.00	59142.00	2395.00	461804.30	15261.00	843483.00
Observations	143	143	143	143	143	143

Table 4: DEA-Additive constant return to scale

	Mormugao	Chennai	Paradip	Tuticorin	Cochin	Ennore	Mumbai	JNPT
1993	1.000	0.611	0.607	1.000	0.455	-	1.000	1.000
1994	1.000	0.597	0.573	1.000	0.484	-	1.000	1.000
1995	1.000	0.611	0.861	1.000	0.547	-	1.000	1.000
1996	1.000	0.608	0.855	1.000	0.443	-	1.000	1.000
1997	1.000	0.676	0.915	1.000	0.491	-	1.000	1.000
1998	1.000	0.626	0.759	1.000	0.390	-	1.000	1.000
1999	1.000	0.621	0.928	1.000	0.390	-	0.725	1.000
2000	1.000	0.582	0.955	1.000	0.339	-	0.469	1.000
2001	1.000	0.545	1.000	1.000	0.316	-	0.375	1.000
2002	1.000	0.437	0.516	1.000	0.260	1.000	0.294	1.000
2003	1.000	0.492	0.479	1.000	0.252	1.000	0.255	1.000
2004	1.000	0.488	0.458	1.000	0.242	1.000	0.257	1.000
2005	1.000	0.735	0.539	1.000	0.277	1.000	0.268	1.000
2006	1.000	0.837	0.804	1.000	0.229	1.000	0.227	1.000
2007	1.000	1.000	0.858	1.000	0.248	1.000	0.187	1.000
2008	1.000	1.000	0.917	1.000	0.230	1.000	0.161	1.000
2009	1.000	1.000	1.000	1.000	0.230	1.000	0.133	1.000
2010	1.000	1.000	1.000	1.000	0.208	1.000	0.080	1.000
2011	1.000	1.000	1.000	1.000	0.207	1.000	0.270	1.000
Mean	**1.000**	**0.709**	**0.791**	**1.000**	**0.328**	**1.000**	**0.511**	**1.000**
Rank	1	6	5	1	8	1	7	1

Table 5: DEA -Additive variable return to scale

	Mormugao	Chennai	Paradip	Tuticorin	Cochin	Ennore	Mumbai	JNPT
1993	1.000	1.000	1.000	1.000	0.467	-	1.000	1.000
1994	1.000	1.000	1.000	1.000	0.479	-	1.000	1.000
1995	1.000	1.000	1.000	1.000	0.571	-	1.000	1.000
1996	1.000	1.000	1.000	1.000	0.701	-	1.000	1.000
1997	1.000	1.000	1.000	1.000	0.720	-	1.000	1.000
1998	1.000	1.000	1.000	1.000	0.638	-	1.000	1.000
1999	1.000	1.000	1.000	1.000	0.352	-	1.000	1.000
2000	1.000	1.000	1.000	1.000	0.317	-	1.000	1.000
2001	1.000	1.000	1.000	1.000	0.305	-	1.000	1.000
2002	1.000	1.000	0.813	1.000	0.262	1.000	1.000	1.000
2003	1.000	1.000	1.000	1.000	0.259	1.000	1.000	1.000
2004	1.000	1.000	0.715	1.000	0.249	1.000	1.000	1.000
2005	1.000	1.000	0.831	1.000	0.281	1.000	1.000	1.000
2006	1.000	1.000	1.000	1.000	0.231	1.000	1.000	1.000
2007	1.000	1.000	1.000	1.000	0.260	1.000	0.226	1.000
2008	1.000	1.000	0.167	1.000	0.242	1.000	1.000	1.000
2009	1.000	1.000	1.000	1.000	0.236	1.000	0.136	1.000
2010	1.000	1.000	1.000	1.000	0.211	1.000	0.082	1.000
2011	1.000	1.000	1.000	1.000	0.213	1.000	0.099	1.000
Mean	**1.000**	**1.000**	**0.922**	**1.000**	**0.368**	**1.000**	**0.818**	**1.000**
Rank	1	1	6	1	8	1	7	1

Note: Ennore port stated its operations in 2002only.

Table 6: DEA -A&P Super Efficiency Model

	Mormugao	Chennai	Paradip	Tuticorin	Cochin	Ennore	Mumbai	JNPT
1993	3.141	0.797	0.753	2.063	0.512	-	1.032	6.446
1994	3.296	0.748	0.719	2.143	0.504	-	1.073	5.190
1995	2.144	0.636	0.866	2.248	0.577	-	1.171	6.063
1996	2.650	0.632	0.862	1.983	0.500	-	1.119	7.043
1997	2.448	0.728	0.926	1.962	0.535	-	1.101	6.945
1998	2.672	0.692	0.773	2.093	0.416	-	1.078	7.824
1999	2.300	0.741	0.951	1.882	0.501	-	0.900	10.000
2000	2.208	0.742	0.978	2.152	0.480	-	0.641	10.000
2001	2.402	0.767	1.076	2.182	0.429	-	0.451	10.000
2002	3.789	0.508	0.824	2.124	0.297	10.000	0.336	10.000
2003	2.255	0.641	0.708	1.731	0.263	10.000	0.275	10.000
2004	2.496	0.674	0.663	1.727	0.253	10.000	0.277	10.000
2005	2.452	0.797	0.745	1.916	0.283	10.000	0.306	10.000
2006	2.084	0.922	0.812	1.805	0.230	10.000	0.318	8.389
2007	1.945	1.027	0.871	1.634	0.254	10.000	0.317	8.756
2008	1.835	1.157	0.932	1.407	0.238	8.091	0.324	9.802
2009	2.358	1.253	1.101	1.420	0.249	5.370	0.286	9.647
2010	2.243	1.258	1.193	1.183	0.242	3.543	0.242	9.857
2011	2.337	1.467	1.168	1.179	0.228	3.344	0.296	9.209
Mean	**2.477**	**0.852**	**0.891**	**1.833**	**0.368**	**4.229**	**0.608**	**8.693**
Rank	3	6	5	4	8	2	7	1

values obtained DEA-Additive VRS models were higher values. The reason is that DEA-Additive CRS model it measures the constant return to scale where the DEA-Additive VRS measures the variable return to scale. Rank wise listed DEA-Additive VRS shows Mormugao, Chennai, Tuticorin, Ennore and JNPT had occupied first positions with full of efficient. Followed by

Paradip and Mumbai had ranked as sixth and seventh positions. The least efficient ports of Cochin was ranked last positions among 8 Major ports in India.

Table 6 Shows the DEA- A & P Super efficiency model of Major Ports in India during 1993-2011. Super efficiency ranking method is the most widespread ranking method and the model was followed by many of the researchers for evaluating higher efficiency. The larger the value of the super efficiency measure the higher an observation is ranked among the efficient units. Super-efficiency measures can be calculated for both inefficient and efficient observations. In the case of inefficient observations the values of the efficiency measure do not change, while efficient observations may obtain higher values. From the table it is found that JNPT shows higher efficiency all the years with the average value of 8.693 and acquired first position among the Major Ports of India. Followed by Ennore port shows higher efficiency over the period of time with average value of 4.229 and took second position among 8 major ports. Mormugao port also rated as super efficient units with average of 2.477 and occupied third position. The port of Tuticorin shows higher efficient although with an average of 1.833 and took fourth super efficient port among the Major Ports of India. The other ports like Chennai, Paradip, Mumbai and Cochin were showed as inefficient because the DEA – A&P super efficiency do not measure the inefficient unit.

From the table it is found that the four efficient ports of Mormugao, Tuticorin, Ennore and JNPT under DEA-Additive CRS and DEA-Additive VRS. This table shows among the ports which earns higher efficiency and ranked as per the efficiency. Through the DEA-A&P model it is ranked that JNPT, Ennore, Mormugao and Tuticorin ranked with higher efficiency.

Conclusion

The Data Envelopment Analysis technique is widely used to measure the relative efficiency of ports. This research adopted the DEA – Additive models to examine the relative efficiency of Major ports in India during 1993-2011. In the present paper the selection of input and output variable were chosen taking in to consideration the variables closely related to the ports efficiency like number of berths, berth length, number of equipments, number of employees, container throughput and total cargo. The results of this analysis revealed that Mormugao, Turicorin, Ennore, and JNPT were found efficient ports during the study period under DEA-Additive -CRS model along with Chennai port had efficient under DEA – Additive VRS model. The study also found that JNPT, Ennore, Mormugao and Tuticorin ports were earned higher efficiency and ranked accordingly. From the study it is revealed that both bigger ports (JNPT, Mormugao) as well as smaller ports (Ennore, Tuticorin) showed efficiency. So, it is proved that there is no significant difference between size and its efficiency of the port. However caution should be taken in interpreting Mormugao, Tuticorin, Ennore and JNPT as the most efficient ports. They may be the better in comparison but not the best, where there exists little room for further betterment.

From this study it is found that some of the Indian ports are inefficient. Therefore, it is critical to strengthen its container handling operations and make them more efficient and smooth flowing. This study makes few recommendations to strengthen the port performance in future.

The study found that some of the ports are inefficient so the port management must think about the long-term plan for equipment improvements and also the government of India needs to boost up its efforts to upgrade the infrastructure facilities in its major ports.

The government of India must think about its road/IT infrastructure in the major ports, specifically connectivity of these ports with highways to speed up the cargo movement.

To improve competitive growth in terms of cargo volume or container volume, the ports need to have adequate and acceptable infrastructure facilities as the existing infrastructure is not sufficient in the present level to meet the new demands and growth of the country's foreign trade.

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