Is There Any Efficiency Difference between Input and Output Oriented DEA Models: An Approach to Major Ports in India

Dr. T. Rajasekar
Post Doctorate Fellow
Department of Commerce
Pondicherry University
Pondicherry, India – 605014
Email: rajakudal@mail.com

Dr. Malabika Deo
Professor
Department of Commerce
Pondicherry University
Pondicherry, India – 605014
Email: deo_malavika@yahoo.co.in

Abstract

In this paper, an attempt has been made to measure the efficiency difference between input and output oriented Data Envelopment Analysis (DEA) models for major ports in India over the period of 1993 - 2013. It was assumed that there is no difference between the efficiency of ports based on its orientation i.e. either input oriented or output oriented. Based on the empirical results, the operational efficiency of the ports like JNPT, Kandla, Mormugao and Ennore was observed as efficient ports in both the orientation. Thus can be conclude that there is no difference in efficiency identification of Decision Making Units (DMUs). The results also indicates that steps to be taken to strengthen the operation of inefficient ports, more specifically to upgrade the infrastructure of the ports, some ports need technological improvement. However the caution should be taken while interpreting the efficient ports like JNPT, Kandla, Mormugao and Tuticorin, they may be better in comparison to the other ports in India but may not be the same, when compared with world ports. This should strive for still better operational to be at par with efficient ports in rest parts of the world.

Keywords: Data Envelopment Analysis, Technical Efficiency, Scale Efficiency, Input – Output oriented Model, Major Ports in India

1. Introduction

Logistics plays a pivotal role in the economic development of the nation. Logistics have a consequence on productivity, distribution efficiency, interest rates, energy availability and energy costs (Razzaque, M. A. 1997). Majority of the goods are being transacted through logistics chain movement, thus making logistics very important for any country's competitive edge. Currently India spends about 14 percent of its GDP on logistics sector (Ujjainwala, K. 2008). Taking in to account the total world trade almost 77% of the total volume of world trade is effected through water, while a mere 16% of tradable goods are transported overland, 6.7% through pipeline trade and only 0.3% through air (Loyds, M. I. U. 2007). According to Cullinane, K et al, 2002, water based transport is the backbone of development of many countries in the world. Geographically, India is surrounded by ocean on three sides, it is obvious that its economic development also enormously depend upon its international trade transaction through sea route which is 90% of the India's total export and import trade through ocean route automatically makes the ports, the major catalyst for effecting the country's foreign trade. Based on the report of Asian Development Bank (2007), if the present trend continues for future, around 0.002 trillion tons of cargo are expected to pass through the Indian ports during the year 2015-16. As the ports are vehicles for effecting trade, their efficiency carries utmost importance for the country's trade progress. There are several studies which tried to analyse operational efficiency of ports in and around the world. Some of studies indicated that bigger ports are inefficient Coto-Millan, P et al. (2000), Cullinane, K et al. (2004).

While some other studies identified that bigger ports as efficient Cullinane, K et al. (2002), Turner, H et al. (2004), Tongzon, J. L and Heng, W. U (2005) and Wang, T. F., and Cullinane, K (2006). Apart from the above observations the studies like Cullinane, K et al (2004), SusilaMunisamy and Gurcharan Singh (2011) reported indistinct relationship between size and efficiency. As the earlier studies are inconclusive, present study trues to evaluate the operational efficiency of major ports in India. Most of the researchers have used either input oriented model or output oriented DEA model to come to the conclusion, which have varied from study to study, hence are effort has been made to evaluate operational efficiency using both the models to arrive at a definite conclusion.

2. Literature Review

Most commonly DEA model is applied to measure the relative efficiency of Decision – Making Units (DMUs). There exist several studies which tried to measure the operational performance of the ports in different region. The noteworthy studies those have measured the relative efficiency of ports in different regions through output oriented DEA models are Roll, Y and Hayuth, Y (1993), Martinez-Budria*et al.* (1999), Coto-Millan, P (2000), Tongzon, J. L (2001), Itoh, H (2002), Cullinane, K and Song, D. W (2002), Barros, C. P and Athanassiou, M (2004), Turner, H et al (2004), Cullinane, K and Song, D. W (2006), Cullinane, K et al (2005), Rios. L . R and Macada, A. C. G (2006), Al – Eraqi, A. S et al (2008), Sohn, J and Jung, G (2009), Rajasekar, T and DeoMalabika (2012, 2013, 2014, 2014). Those studies which measured the operational efficiency in different organizations through input oriented DEA models are Guzowska, M and Strak, T (2010), Xiong, X et al (2011), Hoang, V, A and Alauddin, M (2012), Kordrostami, S and Noveiri, M (2012), Micajkova, V and Poposka, K (2013), Nasiripour, A. A et al (2014) etc.

From the review of earlier studies, it was identified that very few studies have measured operational efficiency with the combination of input and output oriented DEA models. Coming to Indian context, no in-depth study have been reported using both input and output oriented models. Hence it is attempted to analyse in this piece of research work operational efficiency of Indian major ports using both input oriented and output oriented data envelopment.

3. Methodology

3.1. Objective and Data

The present research work has carried out the evaluation of operational efficiency of major ports in India using input and output oriented DEA models during the period 1993-2013. Input and output variables are selected based on the basis of logical justification. The present study used input variables on the basis of land, labour and equipment's i.e. number of berth, berth length, number of employees and number of equipment's available in the port. Because these variables are instrumental for handling traffic in port sector. The output variables chosen for the present study are container trade and total traffic. Data used in the study are secondary in nature and have been collected from the respective port authorities, CMIE data bases and India Stat websites. The input output variables chosen also derive support from the below mentioned literature.

Compilation of Input and Output Variables

Variables	Contents	Relevant Literature
Input Variable	No of Berth	Rios and Macada (2006), Liu (2008)
	Berth Length	Al-Eraqi A. Salem (2008), Cullinane K et. al (2006), Cullinane and Wang (2006),
	No of Equipments	Al-Eraqi A. Salem (2008), Rios and Macada (2006), Wu and Lin (2008), Cullinane and Wang (2006), Liu (2008)
	No of Employees	Roll and Hayuth (1993), Rios and Macada (2006),
Output Variable	Container Throughput (TEU)	Valentine and Gray, Wu and Lin (2008), Cullinane K et. al (2006), Cullinane and Wang (2006),
	Total Traffic	Coto-Millan et. al. (2000), Valentine and Gray, Al-Eraqi A. Salem (2008), Liu (2008)

3.2. Data Envelopment Analysis – Overview

The technique of data envelopment analysis (DEA) was invented by Charnes et al in 1978. This technique has the base of linear programming and which assumes relationship of the input and output variables in linearity for measuring the efficiency. DEA set score for each decision making units for its relative performance. In general, DEA score is restricted from 0 to 1% or 0 to 100%. The efficient unit obtains the value equal to 1 or 100% as the case may be.

Basically data envelopment application can be classified into input and output-oriented. Input-oriented model minimize the inputs for a desired level of output to be achieved and output oriented model maximize the outputs while input kept at constant level. Both input and output oriented model seeks to maximize the outputs, minimize the inputs and thus maximize the efficiency. In general, input oriented model closely focuses on operational and managerial issues whereas output oriented model is more associated with planning and strategy (Cullinane, K et al, 2005). In the present competitive world and port sector reforms far and wide, most of the ports continuously keep reviewing their capacity utilization in order to make sure that they can give better services to the society and port users. Keeping this in mind the present study used both input oriented and output oriented DEA models for measuring the efficiency of major ports in India.

*3.*3. Pearson Correlation Results

	Total traffic	No of 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

Selection of input and output variables should be such that, they should be reflecting the efficiency of port operations. To rightly select the input and output variables for the study Pearson correlation test has been used. According to Jenkins and Anderson, 2003 the variables showing coefficient below 0.6 in the correlation test indicates that there is no need for variable elimination. Whereas the coefficient above 0.6 can be dropped as per the specification to reflect the efficiency of port sector.

4.Results & Discussion

4.1. Input Oriented Models

Table – 1, shows input oriented standard CCR results for major ports in India. As per this model the ports which obtained exactly 1.00 will be treated as efficient and less than 1 will be treated as inefficient. From the table it is evident that the ports of JNPT, Kandla, Mormugao, and Ennore were proved to have efficient port operation during 1993-2013, whereas the ports of Chennai, Cochin, Haldia, Kolkata and Visakhapatnam showed inefficient operation throughout the study period. The other ports like Mumbai, New Mangalore, Paradip and Tuticorin were found to be with fluctuating performance during the study period. The port of Mumbai was efficient in first two years and later on became inefficient. New Mangalore port was found inefficient during 1993 – 2001 and for the rest of the period it was indicated as an efficient unit. The ports of Paradip and Tuticorin showed efficiency in the initial years and later they became inefficient.

Input oriented DEA – BCC model presented the table – 2 depicted that JNPT, Kandla, Mormugao, Tuticorin and Ennore were rated as efficient ports during the study period. The ports like Chennai, Haldia, Mumbai, New Mangalore, Paradip and Visakhapatnam showed fluctuating performance during the study period. The other ports like Cochin and Kolkata were found to be inefficient throughout the study period. The results indicate that DEA – BCC obtained better results comparatively DEA – CCR results. The reason behind, BCC operates variables returns to scale whereas CCR operates constant return to scale. Table 3 presents the input oriented relative efficiency of the major ports of India during 1993 to 2013. It is observed that JNPT, Kandla, Mormugao, and Ennore were more efficient as compared to the remaining major ports of India. The ports of New Mangalore, Tuticorin and Visakhapatnam were observed to be scale-inefficient in most of the study period.

This shows that these ports need to improve their utilization of resources through modernization of the port facilities. The Ports like Cochin, Haldia, Kolkata, Mumbai and Paradip were observed to be pure technically inefficient in most of the years. This suggests that these ports are technologically lagging behind. Thus, technological upgradation should be under taken to make them efficient.

DEA – Additive models measures how the firms are efficiently using their resources. Standard DEA- BCC and DEA – CCR models are input and output oriented models respectively whereas DEA-Additive model takes the combination of input and output. From table 4, it is revealed that the ports like JNPT, Kandla, Mormugao, and Ennore have used their resources efficiently throughout the study period. The ports of Chennai, Cochin, Haldia, Kolkata and Visakhapatnam were seen with inefficient utilization during all the years of the study. The ports like Mumbai, New Mangalore, Paradip and Tuticorin were found to be having fluctuating performance in utilizing their resources during the study period. The efficient ports seem to have modern technology so that the utilization has been successful and also without delay but at the same time inefficient ports need to concentrate on their technological upgradation to show efficient utilization of resources.

Table – 5 results presents the utilization of capacity under variable returns to scale for major ports in India during 1993 – 2013. The results of the JNPT, Kandla, Mormugao, Tuticorin and Ennore port operation showed that they were efficiently utilizing the resources throughout the study period. The port of Chennai, Haldia, Mumbai, New Mangalore, Paradip and Visakhapatnam were found to be having fluctuating performance in utilization of resources throughout the study period. The other ports like Cochin and Kolkata were rated as inefficient unit throughout the study period.

DEA – Anderson & Peterson (1993) model measures super efficiency among major ports in India. Super efficiency ranking method developed by Anderson and Peterson in the year 1993, is the most popular method, as the model was followed by many of the researchers for measuring the efficiency of decision making units. Super efficiency model identifies both the efficient and inefficient observations. The efficient DMUs may obtain higher value whereas for inefficient DMUs the measure of efficiency score do not change. From table 6, it is found that the port of JNPT had highest efficiency among major ports in India with 8.891 followed by Ennore port with 4.196 score. Mormugao port also was rated as superefficient with 1.92. The port of Kandla had efficiency score of 1.459 during the study period thus identified as one of the super-efficient port. Other ports like Chennai, Cochin, Haldia, Mumbai, Kolkata, New Mangalore, Paradip, Tuticorin and Visakhapatnam were rated as inefficient ports, because DEA – A & P do not measure inefficient observations.

Table 1: Input Oriented – Standard CCR

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.74	0.51	0.72	1.00	1.00	0.33	1.00	1.00	0.50	1.00	1.00	0.57	0.00
1994	0.69	0.52	0.68	1.00	1.00	0.33	1.00	1.00	0.55	1.00	1.00	0.57	0.00
1995	0.64	0.59	0.62	1.00	1.00	0.30	1.00	0.98	0.49	1.00	1.00	0.57	0.00
1996	0.62	0.50	0.62	1.00	1.00	0.26	1.00	0.91	0.56	1.00	1.00	0.61	0.00
1997	0.71	0.55	0.61	1.00	1.00	0.23	1.00	0.86	0.74	1.00	1.00	0.61	0.00
1998	0.69	0.38	0.62	1.00	1.00	0.23	1.00	0.83	0.83	1.00	1.00	0.56	0.00
1999	0.55	0.34	0.63	1.00	1.00	0.22	1.00	0.67	0.78	1.00	0.93	0.59	0.00
2000	0.52	0.29	0.56	1.00	1.00	0.19	1.00	0.49	0.93	1.00	0.91	0.58	0.00
2001	0.60	0.33	0.65	1.00	1.00	0.12	1.00	0.30	0.95	1.00	0.73	0.75	0.00
2002	0.46	0.31	0.61	1.00	1.00	0.07	1.00	0.23	0.93	0.78	0.72	0.66	1.00
2003	0.40	0.38	0.65	1.00	1.00	0.08	1.00	0.18	1.00	0.75	0.62	0.64	1.00
2004	0.40	0.53	0.67	1.00	1.00	0.10	1.00	0.22	1.00	0.66	0.61	0.59	1.00
2005	0.45	0.48	0.66	1.00	1.00	0.11	1.00	0.23	1.00	0.68	0.61	0.55	1.00
2006	0.48	0.27	0.79	1.00	1.00	0.12	1.00	0.32	1.00	0.72	0.58	0.61	1.00
2007	0.72	0.50	0.78	1.00	1.00	0.41	1.00	0.35	1.00	0.83	0.68	0.60	1.00
2008	0.67	0.29	0.64	1.00	1.00	0.32	1.00	0.30	1.00	0.79	0.57	0.60	1.00
2009	0.70	0.31	0.58	1.00	1.00	0.33	1.00	0.27	1.00	0.80	0.57	0.54	1.00
2010	0.62	0.28	0.41	1.00	1.00	0.35	1.00	0.24	1.00	0.87	0.51	0.50	1.00
2011	0.73	0.33	0.42	1.00	1.00	0.33	1.00	0.30	1.00	0.83	0.55	0.52	1.00
2012	0.70	0.35	0.35	1.00	1.00	0.30	1.00	0.52	1.00	0.81	0.55	0.50	1.00
2013	0.68	0.35	0.37	1.00	1.00	0.31	1.00	0.58	1.00	0.85	0.58	0.48	1.00
Avg	**0.61**	**0.40**	**0.60**	**1.00**	**1.00**	**0.24**	**1.00**	**0.51**	**0.87**	**0.87**	**0.75**	**0.58**	**1.00**

Table 2: Input Oriented – Standard BCC

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	1.00	0.52	1.00	1.00	1.00	0.33	1.00	1.00	0.97	1.00	1.00	0.59	0.00
1994	1.00	0.53	1.00	1.00	1.00	0.33	1.00	1.00	0.99	1.00	1.00	0.90	0.00
1995	1.00	0.59	0.76	1.00	1.00	0.30	1.00	1.00	0.99	1.00	1.00	1.00	0.00
1996	1.00	0.53	0.76	1.00	1.00	0.28	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1997	1.00	0.56	0.70	1.00	1.00	0.27	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1998	1.00	0.51	0.69	1.00	1.00	0.27	1.00	1.00	1.00	1.00	1.00	0.56	0.00
1999	1.00	0.55	0.73	1.00	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.60	0.00
2000	1.00	0.52	0.69	1.00	1.00	0.28	1.00	0.52	1.00	1.00	1.00	0.59	0.00
2001	1.00	0.52	0.69	1.00	1.00	0.29	1.00	0.35	1.00	1.00	1.00	1.00	0.00
2002	0.63	0.55	0.64	1.00	1.00	0.29	1.00	0.24	1.00	0.91	1.00	1.00	1.00
2003	0.50	0.59	0.67	1.00	1.00	0.31	1.00	0.19	1.00	0.78	1.00	1.00	1.00
2004	0.56	0.60	0.67	1.00	1.00	0.31	1.00	0.24	1.00	0.71	1.00	1.00	1.00
2005	0.82	0.61	0.80	1.00	1.00	0.34	1.00	0.38	1.00	0.72	1.00	1.00	1.00
2006	0.79	0.60	0.97	1.00	1.00	0.35	1.00	0.48	1.00	0.73	1.00	1.00	1.00
2007	0.97	0.61	0.78	1.00	1.00	0.44	1.00	0.55	1.00	0.86	1.00	1.00	1.00
2008	0.76	0.62	0.68	1.00	1.00	0.41	1.00	0.39	1.00	0.84	1.00	0.68	1.00
2009	0.77	0.61	0.63	1.00	1.00	0.41	1.00	0.35	1.00	0.85	1.00	0.63	1.00
2010	0.68	0.66	0.61	1.00	1.00	0.43	1.00	0.30	1.00	0.91	1.00	0.56	1.00
2011	0.77	0.60	0.61	1.00	1.00	0.41	1.00	0.35	1.00	0.93	1.00	0.57	1.00
2012	0.72	0.60	0.63	1.00	1.00	0.42	1.00	0.57	1.00	0.94	1.00	0.54	1.00
2013	0.69	0.61	0.64	1.00	1.00	0.42	1.00	0.61	1.00	0.95	1.00	0.51	1.00
Avg	**0.84**	**0.58**	**0.73**	**1.00**	**1.00**	**0.34**	**1.00**	**0.60**	**1.00**	**0.91**	**1.00**	**0.80**	**1.00**

Table 3: Input Oriented - Relative Efficiency Analysis

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	EFF	SIE	EFF	EFF	SIE	NA
1994	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	EFF	SIE	EFF	EFF	SIE	NA
1995	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1996	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1997	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1998	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	PTIE	NA
1999	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	SIE	PTIE	NA
2000	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	EFF	SIE	PTIE	NA
2001	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	EFF	SIE	SIE	NA
2002	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	PTIE	SIE	SIE	EFF
2003	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2004	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2005	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2006	SIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2007	SIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2008	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	PTIE	EFF
2009	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	PTIE	EFF
2010	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2011	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2012	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2013	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF

Note: SIE – Scale Inefficient, PTIE – Pure Technical Inefficient, EFF – Efficient, NA – Not Available

Table 4: Input oriented – DEA Additive CRS

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.62	0.51	0.51	1.00	1.00	0.22	1.00	1.00	0.39	1.00	1.00	0.45	0.00
1994	0.58	0.49	0.40	1.00	1.00	0.12	1.00	1.00	0.37	1.00	1.00	0.37	0.00
1995	0.56	0.54	0.41	1.00	1.00	0.14	1.00	0.85	0.34	1.00	1.00	0.37	0.00
1996	0.53	0.47	0.46	1.00	1.00	0.12	1.00	0.75	0.41	1.00	1.00	0.52	0.00
1997	0.55	0.53	0.32	1.00	1.00	0.11	1.00	0.75	0.63	1.00	1.00	0.39	0.00
1998	0.53	0.32	0.37	1.00	1.00	0.13	1.00	0.73	0.75	1.00	1.00	0.34	0.00
1999	0.48	0.31	0.40	1.00	1.00	0.15	1.00	0.52	0.60	1.00	0.86	0.45	0.00
2000	0.41	0.27	0.30	1.00	1.00	0.14	1.00	0.30	0.67	1.00	0.50	0.31	0.00
2001	0.46	0.31	0.34	1.00	1.00	0.11	1.00	0.28	0.83	1.00	0.60	0.18	0.00
2002	0.29	0.27	0.35	1.00	1.00	0.07	1.00	0.21	0.81	0.50	0.57	0.23	1.00
2003	0.35	0.32	0.35	1.00	1.00	0.07	1.00	0.16	1.00	0.38	0.51	0.23	1.00
2004	0.35	0.46	0.35	1.00	1.00	0.08	1.00	0.20	1.00	0.32	0.48	0.15	1.00
2005	0.39	0.46	0.37	1.00	0.80	0.09	1.00	0.22	1.00	0.34	0.53	0.18	1.00
2006	0.45	0.24	0.37	1.00	0.81	0.10	1.00	0.30	1.00	0.29	0.53	0.18	1.00
2007	0.98	0.36	0.49	1.00	1.00	0.22	1.00	0.32	1.00	0.54	0.52	0.20	1.00
2008	0.54	0.27	0.36	1.00	1.00	0.21	1.00	0.21	1.00	0.36	0.52	0.22	1.00
2009	0.51	0.26	0.32	1.00	1.00	0.18	1.00	0.20	1.00	0.33	0.49	0.20	1.00
2010	0.47	0.25	0.22	1.00	1.00	0.17	1.00	0.14	1.00	0.69	0.43	0.18	1.00
2011	0.49	0.26	0.24	1.00	1.00	0.16	1.00	0.21	1.00	0.66	0.45	0.21	1.00
2012	0.51	0.31	0.28	1.00	1.00	0.25	1.00	0.48	1.00	0.56	0.50	0.29	1.00
2013	0.51	0.33	0.28	1.00	1.00	0.24	1.00	0.36	1.00	0.66	0.53	0.27	1.00
Avg	**0.50**	**0.36**	**0.36**	**1.00**	**0.98**	**0.15**	**1.00**	**0.44**	**0.80**	**0.70**	**0.67**	**0.28**	**1.00**

Table 5: Input Oriented – DEA Additive – VRS

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	1.00	0.48	1.00	1.00	1.00	0.26	1.00	1.00	0.77	1.00	1.00	0.46	0.00
1994	1.00	0.49	1.00	1.00	1.00	0.24	1.00	1.00	0.87	1.00	1.00	0.38	0.00
1995	1.00	0.62	0.43	1.00	1.00	0.25	1.00	1.00	0.05	1.00	1.00	1.00	0.00
1996	1.00	0.45	0.47	1.00	1.00	0.25	1.00	1.00	0.00	1.00	1.00	1.00	0.00
1997	1.00	0.55	0.29	1.00	1.00	0.24	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1998	1.00	0.35	0.36	1.00	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.79	0.00
1999	1.00	0.31	0.39	1.00	1.00	0.23	1.00	1.00	1.00	1.00	1.00	0.49	0.00
2000	1.00	0.27	0.29	1.00	1.00	0.21	1.00	0.46	1.00	1.00	1.00	0.79	0.00
2001	1.00	0.28	0.50	1.00	1.00	0.15	1.00	0.58	1.00	1.00	1.00	1.00	0.00
2002	0.84	0.26	0.48	1.00	1.00	0.09	1.00	0.59	1.00	0.02	1.00	1.00	1.00
2003	0.75	0.31	0.51	1.00	1.00	0.08	1.00	0.16	1.00	0.02	1.00	1.00	1.00
2004	0.82	0.32	0.63	1.00	1.00	0.08	1.00	0.41	1.00	0.03	1.00	1.00	1.00
2005	0.92	0.31	0.71	1.00	1.00	0.10	1.00	0.71	1.00	0.02	1.00	1.00	1.00
2006	0.91	0.25	0.74	1.00	1.00	0.11	1.00	0.91	1.00	0.81	1.00	1.00	1.00
2007	0.92	0.37	0.65	1.00	1.00	0.27	1.00	0.94	1.00	0.51	1.00	1.00	1.00
2008	0.63	0.27	0.55	1.00	1.00	0.25	1.00	0.47	1.00	0.66	1.00	0.99	1.00
2009	0.64	0.26	0.22	1.00	1.00	0.23	1.00	0.47	1.00	0.57	1.00	0.49	1.00
2010	0.63	0.25	0.18	1.00	1.00	0.23	1.00	0.45	1.00	0.67	1.00	0.49	1.00
2011	0.64	0.27	0.20	1.00	1.00	0.22	1.00	0.56	1.00	0.71	1.00	0.51	1.00
2012	0.49	0.31	0.20	1.00	1.00	0.19	1.00	0.49	1.00	0.56	1.00	0.33	1.00
2013	0.47	0.31	0.20	1.00	1.00	0.21	1.00	0.56	1.00	0.67	1.00	0.36	1.00
Avg	**0.84**	**0.35**	**0.48**	**1.00**	**1.00**	**0.20**	**1.00**	**0.70**	**0.89**	**0.68**	**1.00**	**0.77**	**1.00**

Table 6: Input Oriented – A & P Super Efficiency

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.74	0.51	0.72	6.45	1.48	0.33	1.73	1.06	0.50	3.73	2.90	0.57	0.00
1994	0.69	0.52	0.68	5.19	1.42	0.33	1.84	1.07	0.55	3.56	3.18	0.57	0.00
1995	0.64	0.59	0.62	6.06	1.29	0.30	1.41	0.98	0.49	4.29	4.37	0.57	0.00
1996	0.62	0.50	0.62	7.04	1.51	0.26	1.58	0.91	0.56	4.36	3.39	0.61	0.00
1997	0.71	0.55	0.61	6.95	1.76	0.23	1.23	0.86	0.74	4.68	2.56	0.61	0.00
1998	0.69	0.38	0.62	7.82	1.76	0.23	1.49	0.83	0.83	3.77	1.91	0.56	0.00
1999	0.55	0.34	0.63	10.00	2.26	0.22	1.23	0.67	0.78	4.36	0.93	0.59	0.00
2000	0.52	0.29	0.56	10.00	2.16	0.19	1.02	0.49	0.93	4.49	0.91	0.58	0.00
2001	0.60	0.33	0.65	10.00	1.54	0.12	1.73	0.30	0.95	5.07	0.73	0.75	0.00
2002	0.46	0.31	0.61	10.00	1.44	0.07	2.14	0.23	0.93	0.78	0.72	0.66	10.00
2003	0.40	0.38	0.65	10.00	1.41	0.08	2.43	0.18	1.04	0.75	0.62	0.64	10.00
2004	0.40	0.53	0.67	10.00	1.12	0.10	2.89	0.22	1.19	0.66	0.61	0.59	10.00
2005	0.45	0.48	0.66	10.00	1.10	0.11	2.20	0.23	1.71	0.68	0.61	0.55	10.00
2006	0.48	0.27	0.79	8.39	1.00	0.12	2.24	0.32	1.67	0.72	0.58	0.61	10.00
2007	0.72	0.50	0.78	8.83	1.21	0.41	2.71	0.35	1.18	0.83	0.68	0.60	9.37
2008	0.67	0.29	0.64	10.00	1.30	0.32	2.13	0.30	1.43	0.79	0.57	0.60	5.83
2009	0.70	0.31	0.58	10.00	1.33	0.33	2.42	0.27	1.22	0.80	0.57	0.54	5.37
2010	0.62	0.28	0.41	10.00	1.34	0.35	2.78	0.24	1.02	0.87	0.51	0.50	3.54
2011	0.73	0.33	0.42	10.00	1.41	0.33	2.96	0.30	1.09	0.83	0.55	0.52	3.34
2012	0.70	0.35	0.35	10.00	1.58	0.30	1.04	0.52	1.59	0.81	0.55	0.50	4.17
2013	0.68	0.35	0.37	10.00	1.22	0.31	1.12	0.58	2.00	0.85	0.58	0.48	6.51
Avg	0.608	0.399	0.601	8.891	1.459	024	1.92	0.519	1.06	2.270	1.334	0.580	4.196

4.2. Output Oriented Models

Table 7: Output Oriented – Standard CCR

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.74	0.51	0.72	1.00	1.00	0.33	1.00	1.00	0.50	1.00	1.00	0.57	0.00
1994	0.69	0.52	0.68	1.00	1.00	0.33	1.00	1.00	0.55	1.00	1.00	0.57	0.00
1995	0.64	0.59	0.62	1.00	1.00	0.30	1.00	0.98	0.49	1.00	1.00	0.57	0.00
1996	0.62	0.50	0.62	1.00	1.00	0.26	1.00	0.91	0.56	1.00	1.00	0.61	0.00
1997	0.71	0.55	0.61	1.00	1.00	0.23	1.00	0.86	0.74	1.00	1.00	0.61	0.00
1998	0.69	0.38	0.62	1.00	1.00	0.23	1.00	0.83	0.83	1.00	1.00	0.56	0.00
1999	0.55	0.34	0.63	1.00	1.00	0.22	1.00	0.67	0.78	1.00	0.93	0.59	0.00
2000	0.52	0.29	0.56	1.00	1.00	0.19	1.00	0.49	0.93	1.00	0.91	0.58	0.00
2001	0.60	0.33	0.65	1.00	1.00	0.12	1.00	0.30	0.95	1.00	0.73	0.75	0.00
2002	0.46	0.31	0.61	1.00	1.00	0.07	1.00	0.23	0.93	0.78	0.72	0.66	1.00
2003	0.40	0.38	0.65	1.00	1.00	0.08	1.00	0.18	1.00	0.75	0.62	0.64	1.00
2004	0.40	0.98	0.67	1.00	1.00	0.10	1.00	0.22	1.00	0.66	0.61	0.59	1.00
2005	0.45	0.88	0.66	1.00	1.00	0.11	1.00	0.23	1.00	0.68	0.61	0.55	1.00
2006	0.48	0.27	0.79	1.00	1.00	0.12	1.00	0.32	1.00	0.72	0.58	0.61	1.00
2007	0.72	0.50	0.78	1.00	1.00	0.41	1.00	0.35	1.00	0.83	0.68	0.60	1.00
2008	0.67	0.29	0.64	1.00	1.00	0.32	1.00	0.30	1.00	0.79	0.57	0.60	1.00
2009	0.70	0.31	0.58	1.00	1.00	0.33	1.00	0.27	1.00	0.80	0.57	0.54	1.00
2010	0.62	0.28	0.41	1.00	1.00	0.35	1.00	0.24	1.00	0.87	0.51	0.50	1.00
2011	0.73	0.33	0.42	1.00	1.00	0.33	1.00	0.30	1.00	0.83	0.55	0.52	1.00
2012	0.70	0.35	0.35	1.00	1.00	0.30	1.00	0.52	1.00	0.81	0.55	0.50	1.00
2013	0.68	0.35	0.37	1.00	1.00	0.31	1.00	0.58	1.00	0.85	0.58	0.48	1.00
Avg	**0.61**	**0.44**	**0.60**	**1.00**	**1.00**	**0.24**	**1.00**	**0.51**	**0.87**	**0.87**	**0.75**	**0.58**	**1.00**

Table – 8: Output Oriented – Standard – BCC

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	1.00	0.61	1.00	1.00	1.00	0.33	1.00	1.00	0.85	1.00	1.00	0.94	0.00
1994	1.00	0.61	1.00	1.00	1.00	0.34	1.00	1.00	0.97	1.00	1.00	0.99	0.00
1995	1.00	0.68	0.65	1.00	1.00	0.31	1.00	1.00	0.61	1.00	1.00	1.00	0.00
1996	1.00	0.60	0.64	1.00	1.00	0.29	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1997	1.00	0.65	0.63	1.00	1.00	0.27	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1998	1.00	0.44	0.64	1.00	1.00	0.31	1.00	1.00	1.00	1.00	1.00	0.93	0.00
1999	1.00	0.42	0.65	1.00	1.00	0.32	1.00	1.00	1.00	1.00	1.00	0.88	0.00
2000	1.00	0.36	0.58	1.00	1.00	0.32	1.00	0.95	1.00	1.00	1.00	0.85	0.00
2001	1.00	0.39	0.71	1.00	1.00	0.23	1.00	0.76	1.00	1.00	1.00	1.00	0.00
2002	0.92	0.35	0.72	1.00	1.00	0.15	1.00	0.67	1.00	0.79	1.00	1.00	1.00
2003	0.82	0.42	0.76	1.00	1.00	0.18	1.00	0.63	1.00	0.77	1.00	1.00	1.00
2004	0.85	0.75	0.83	1.00	1.00	0.20	1.00	0.67	1.00	0.73	1.00	1.00	1.00
2005	0.96	0.76	0.92	1.00	1.00	0.22	1.00	0.76	1.00	0.85	1.00	1.00	1.00
2006	0.95	0.33	0.98	1.00	1.00	0.22	1.00	0.52	1.00	0.88	1.00	1.00	1.00
2007	0.99	0.53	0.88	1.00	1.00	0.44	1.00	0.96	1.00	0.83	1.00	1.00	1.00
2008	0.92	0.33	0.69	1.00	1.00	0.33	1.00	0.88	1.00	0.79	1.00	1.00	1.00
2009	0.85	0.32	0.64	1.00	1.00	0.34	1.00	0.72	1.00	0.80	1.00	0.89	1.00
2010	0.83	0.30	0.47	1.00	1.00	0.36	1.00	0.69	1.00	0.87	1.00	0.82	1.00
2011	0.82	0.33	0.48	1.00	1.00	0.34	1.00	0.67	1.00	0.86	1.00	0.83	1.00
2012	0.74	0.37	0.36	1.00	1.00	0.31	1.00	0.63	1.00	0.89	1.00	0.64	1.00
2013	0.73	0.37	0.38	1.00	1.00	0.31	1.00	0.66	1.00	0.97	1.00	0.66	1.00
Avg	**0.92**	**0.47**	**0.70**	**1.00**	**1.00**	**0.29**	**1.00**	**0.82**	**0.97**	**0.91**	**1.00**	**0.93**	**1.00**

Table – 9, Output Oriented DEA - Relative Efficiency Analysis

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	EFF	SIE	EFF	EFF	SIE	NA
1994	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	EFF	SIE	EFF	EFF	SIE	NA
1995	SIE	PTIE	SIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1996	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1997	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	SIE	NA
1998	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	EFF	PTIE	NA
1999	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	SIE	SIE	EFF	SIE	PTIE	NA
2000	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	EFF	SIE	PTIE	NA
2001	SIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	EFF	SIE	SIE	NA
2002	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	SIE	PTIE	SIE	SIE	EFF
2003	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2004	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2005	PTIE	PTIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2006	SIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2007	SIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	SIE	EFF
2008	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	PTIE	EFF
2009	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	PTIE	SIE	PTIE	EFF
2010	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2011	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2012	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF
2013	PTIE	SIE	PTIE	EFF	EFF	PTIE	EFF	PTIE	EFF	SIE	SIE	PTIE	EFF

Note: SIE – Scale Inefficient, PTIE – Pure Technical Inefficient, EFF – Efficient, NA – Not Available

With a view to acquire information to identify the relative efficient and inefficient ports in India during 1993-2013, study adopted different DEA models. Table 7, shows the results of output oriented DEA- CCR model has been used to measure the technical efficiency of the ports under study. The results show that the port of JNPT, Kandla, Mormugao, and Ennore proved their operational efficiency throughout the study period. The port of Chennai, Cochin, Haldia, Kolkata and Visakhapatnam were found to be inefficient all through the period. Mumbai port showed efficiency in the first two years but slipped down to inefficiency later. The port of New Mangalore showed efficiency only during 2003 – 2013, and for the remaining period it was observed to be inefficient. The port of Tuticorin and Paradip were marked efficient during initial years, later were found to be inefficient. From the results in table, it is observed that four major ports (30.76%) showed technically efficiency, while remaining eight major ports (69.23%) were found to be technically inefficient during the study period.

Table - 8 presents the results of output oriented DEA-BCC model that is used to measure the pure technical efficiency of major ports in India during 1993 – 2013. The results reveal that the ports of JNPT, Kandla, Mormugao, Tuticorin and Ennore were rated efficient all through the study period. The port of Cochin and Kolkata were indicated inefficient throughout the period of time. The other ports like Chennai, Haldia, Mumbai, New Mangalore, Paradip and Visakhapatnam showed mixed performance during the study period. Compared to the results of DEA-CCR and DEA-BCC models, it is observed that the scores obtained under the DEA – BCC model were rated high, may be because DEA – CCR measures constant return to scale efficient whereas DEA – BCC measures the efficiency through variable return to scale.

Table - 8 reveal that 38.46% of the ports i.e. five ports, were efficient while remaining 61.54% of the ports i.e. eight ports, showed inefficiency during the study period.

Table - 9 presents the output oriented relative efficiency of the major ports of India during 1993 to 2013. It is observed that JNPT, Kandla, Mormugao, and Ennore were more efficient as compared to the remaining major ports of India. The ports of New Mangalore, Tuticorin and Visakhapatnam were observed to be scale-inefficient in most of the study periods. This shows that these ports need to improve their utilization of resources through modernization. The Ports like Cochin, Haldia, Kolkata, Mumbai and Paradip were observed to be pure technically inefficient in most of the years. This suggests that these ports are technologically lagging behind the other ports. Thus, technological upgradation should be under taken to make them efficient.

Output oriented DEA – Additive model measures the performance of ports with regard to utilization of resources, and Table - 10 presents the efficiency scores of major ports in India obtained from DEA – Additive mode under CRS. The results reveal that JNPT, Kandla, Mormugao, and Ennore to be efficient during the study period, while the other major ports like Chennai, Cochin, Haldia, Kolkata and Visakhapatnam were found to be inefficient throughout the study period. The Mumbai port was efficient in the first two years, but later on showed inefficiency. The New Mangalore port showed efficiency during the period 2003 – 2010, while for the rest of the period it was found to be inefficient. The port of Paradip and Tuticorin showed efficiency during the initial years, but later were observed as inefficient units.

Table 10: Output Oriented – Additive CRS

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.62	0.51	0.51	1.00	1.00	0.22	1.00	1.00	0.39	1.00	1.00	0.45	0.00
1994	0.58	0.49	0.40	1.00	1.00	0.12	1.00	1.00	0.37	1.00	1.00	0.37	0.00
1995	0.56	0.54	0.41	1.00	1.00	0.14	1.00	0.85	0.34	1.00	1.00	0.37	0.00
1996	0.53	0.47	0.46	1.00	1.00	0.12	1.00	0.75	0.41	1.00	1.00	0.52	0.00
1997	0.55	0.53	0.32	1.00	1.00	0.11	1.00	0.75	0.63	1.00	1.00	0.39	0.00
1998	0.53	0.32	0.37	1.00	1.00	0.13	1.00	0.73	0.75	1.00	1.00	0.34	0.00
1999	0.48	0.31	0.40	1.00	1.00	0.15	1.00	0.52	0.60	1.00	0.86	0.45	0.00
2000	0.41	0.27	0.30	1.00	1.00	0.14	1.00	0.30	0.67	1.00	0.50	0.31	0.00
2001	0.46	0.31	0.34	1.00	1.00	0.11	1.00	0.28	0.83	1.00	0.60	0.18	0.00
2002	0.29	0.27	0.35	1.00	1.00	0.07	1.00	0.21	0.81	0.50	0.57	0.23	1.00
2003	0.35	0.32	0.35	1.00	1.00	0.07	1.00	0.16	1.00	0.38	0.51	0.23	1.00
2004	0.35	0.46	0.35	1.00	1.00	0.08	1.00	0.20	1.00	0.32	0.48	0.15	1.00
2005	0.39	0.46	0.37	1.00	0.80	0.09	1.00	0.22	1.00	0.34	0.53	0.18	1.00
2006	0.45	0.24	0.37	1.00	0.81	0.10	1.00	0.30	1.00	0.29	0.53	0.18	1.00
2007	0.98	0.36	0.49	1.00	1.00	0.22	1.00	0.32	1.00	0.54	0.52	0.20	1.00
2008	0.54	0.27	0.36	1.00	1.00	0.21	1.00	0.21	1.00	0.36	0.52	0.22	1.00
2009	0.51	0.26	0.32	1.00	1.00	0.18	1.00	0.20	1.00	0.33	0.49	0.20	1.00
2010	0.47	0.25	0.22	1.00	1.00	0.17	1.00	0.14	1.00	0.69	0.43	0.18	1.00
2011	0.49	0.26	0.24	1.00	1.00	0.16	1.00	0.21	1.00	0.66	0.45	0.21	1.00
2012	0.51	0.31	0.28	1.00	1.00	0.25	1.00	0.48	1.00	0.56	0.50	0.29	1.00
2013	0.51	0.33	0.28	1.00	1.00	0.24	1.00	0.36	1.00	0.66	0.53	0.27	1.00
Avg	**0.50**	**0.36**	**0.36**	**1.00**	**0.98**	**0.15**	**1.00**	**0.44**	**0.80**	**0.70**	**0.67**	**0.28**	**1.00**

Table 11: Output oriented – Additive VRS

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	1.00	0.48	1.00	1.00	1.00	0.26	1.00	1.00	0.77	1.00	1.00	0.46	0.00
1994	1.00	0.49	1.00	1.00	1.00	0.24	1.00	1.00	0.87	1.00	1.00	0.38	0.00
1995	1.00	0.62	0.43	1.00	1.00	0.25	1.00	1.00	0.45	1.00	1.00	1.00	0.00
1996	1.00	0.45	0.47	1.00	1.00	0.25	1.00	1.00	0.40	1.00	1.00	1.00	0.00
1997	1.00	0.55	0.29	1.00	1.00	0.24	1.00	1.00	1.00	1.00	1.00	1.00	0.00
1998	1.00	0.35	0.36	1.00	1.00	0.28	1.00	1.00	1.00	1.00	1.00	0.79	0.00
1999	1.00	0.31	0.39	1.00	1.00	0.23	1.00	1.00	1.00	1.00	1.00	0.49	0.00
2000	1.00	0.27	0.29	1.00	1.00	0.21	1.00	0.46	1.00	1.00	1.00	0.79	0.00
2001	1.00	0.28	0.50	1.00	1.00	0.15	1.00	0.58	1.00	1.00	1.00	1.00	0.00
2002	0.84	0.26	0.48	1.00	1.00	0.09	1.00	0.59	1.00	0.20	1.00	1.00	1.00
2003	0.75	0.31	0.51	1.00	1.00	0.08	1.00	0.16	1.00	0.22	1.00	1.00	1.00
2004	0.82	0.35	0.63	1.00	1.00	0.08	1.00	0.41	1.00	0.32	1.00	1.00	1.00
2005	0.92	0.34	0.71	1.00	1.00	0.10	1.00	0.71	1.00	0.16	1.00	1.00	1.00
2006	0.91	0.25	0.74	1.00	1.00	0.11	1.00	0.91	1.00	0.81	1.00	1.00	1.00
2007	0.97	0.37	0.65	1.00	1.00	0.27	1.00	0.94	1.00	0.51	1.00	1.00	1.00
2008	0.63	0.27	0.55	1.00	1.00	0.25	1.00	0.47	1.00	0.66	1.00	0.99	1.00
2009	0.64	0.26	0.22	1.00	1.00	0.23	1.00	0.47	1.00	0.57	1.00	0.49	1.00
2010	0.63	0.25	0.18	1.00	1.00	0.23	1.00	0.45	1.00	0.67	1.00	0.49	1.00
2011	0.64	0.27	0.20	1.00	1.00	0.22	1.00	0.56	1.00	0.71	1.00	0.51	1.00
2012	0.49	0.31	0.20	1.00	1.00	0.19	1.00	0.49	1.00	0.56	1.00	0.33	1.00
2013	0.47	0.31	0.20	1.00	1.00	0.21	1.00	0.56	1.00	0.67	1.00	0.36	1.00
Avg	**0.84**	**0.35**	**0.48**	**1.00**	**1.00**	**0.20**	**1.00**	**0.70**	**0.93**	**0.72**	**1.00**	**0.77**	**1.00**

Table 12: Output Oriented – A & P Super Efficiency – CRS

	Chennai	Cochin	Haldia	JNPT	Kandla	Kolkata	Mormugao	Mumbai	New Mangalore	Paradip	Tuticorin	Vizag	Ennore
1993	0.74	0.51	0.72	6.45	1.48	0.33	1.73	1.06	0.50	3.73	2.90	0.57	0.00
1994	0.69	0.52	0.68	5.19	1.42	0.33	1.84	1.07	0.55	3.56	3.18	0.57	0.00
1995	0.64	0.59	0.62	6.06	1.29	0.30	1.41	0.98	0.49	4.29	4.37	0.57	0.00
1996	0.62	0.50	0.62	7.04	1.51	0.26	1.58	0.91	0.56	4.36	3.39	0.61	0.00
1997	0.71	0.55	0.61	6.95	1.76	0.23	1.23	0.86	0.74	4.68	2.56	0.61	0.00
1998	0.69	0.38	0.62	7.82	1.76	0.23	1.49	0.83	0.83	3.77	1.91	0.56	0.00
1999	0.55	0.34	0.63	10.00	2.26	0.22	1.23	0.67	0.78	4.36	0.93	0.59	0.00
2000	0.52	0.29	0.56	10.00	2.16	0.19	1.02	0.49	0.93	4.49	0.91	0.58	0.00
2001	0.60	0.33	0.65	10.00	1.54	0.12	1.73	0.30	0.95	5.07	0.73	0.75	0.00
2002	0.46	0.31	0.61	10.00	1.44	0.07	2.14	0.23	0.93	0.78	0.72	0.66	10.00
2003	0.40	0.38	0.65	10.00	1.41	0.08	2.43	0.18	1.04	0.75	0.62	0.64	10.00
2004	0.40	0.98	0.67	10.00	1.12	0.10	2.89	0.22	1.19	0.66	0.61	0.59	10.00
2005	0.45	0.88	0.66	10.00	1.10	0.11	2.20	0.23	1.71	0.68	0.61	0.55	10.00
2006	0.48	0.27	0.79	8.40	1.00	0.12	2.24	0.32	1.67	0.72	0.58	0.61	10.00
2007	0.72	0.50	0.78	8.83	1.21	0.41	2.71	0.35	1.18	0.83	0.68	0.60	9.37
2008	0.67	0.29	0.64	10.00	1.30	0.32	2.13	0.30	1.43	0.79	0.57	0.60	5.83
2009	0.70	0.31	0.58	10.00	1.33	0.33	2.42	0.27	1.22	0.80	0.57	0.54	5.37
2010	0.62	0.28	0.41	10.00	1.34	0.35	2.78	0.24	1.02	0.87	0.51	0.50	3.54
2011	0.73	0.33	0.42	10.00	1.41	0.33	2.96	0.30	1.05	0.83	0.55	0.52	3.34
2012	0.70	0.35	0.35	10.00	1.58	0.30	1.04	0.52	1.59	0.81	0.55	0.50	4.17
2013	0.68	0.35	0.37	10.00	1.22	0.31	1.06	0.58	2.00	0.85	0.58	0.48	6.51
Avg	0.608	0.440	0.601	8.892	1.459	0.240	1.917	0.519	1.064	2.270	1.334	0.580	4.196

Table - 11 depicts the results of output oriented DEA-Additive model under VRS of the major ports in India in terms of their efficiency in utilization of resources during 1993-2013. The operations of JNPT, Kandla, Mormugao, Tuticorin and Ennore ports were indicated efficient all through, while New Mangalore port was found to be efficient only during 1997 – 2010. The ports like Chennai, Haldia, Mumbai, Paradip and Visakhapatnam showed mixed efficiency over the period of time. The operations of other ports like Cochin and Kolkata were observed inefficient throughout the study period. From this analysis, it is stated that the ports like JNPT, Kandla, Mormugao, Tuticorin and Ennore were found to be utilizing their resources satisfactorily, while Chennai, Cochin, Haldia, Kolkata, Mumbai, New Mangalore, Paradip and Visakhapatnam were found to be inefficient in resource utilization. This suggests that these ports must improve their utilization of capacity to become efficient units.

Finally, Table - 12 presents the results of DEA – A & P super efficiency model of the major ports in India during 1993-2013. The larger the value of the super efficiency measure, the higher an observation is ranked among the efficient units. Super efficiency values can be used for both inefficient and efficient observations. In the case of inefficient observations, the values of the efficiency measure do not change, while the efficient observations may obtain higher values. Table - 12 reveal that JNPT had the highest efficiency throughout the study period with an average efficiency level of 8.892 and thus acquired the top position among the major ports of India, followed by Ennore showing higher efficiency than the remaining ports over the study period with an average value of 4.196. Mormugao port was also categorized as superefficient ports and acquired third position with an average of 1.917. The port of Kandla, occupied fourth position and was the last among the superefficient ports with an average efficiency score of 1.459. The other ports like Chennai, Cochin, Haldia, Kolkata, Mumbai, New Mangalore, Paradip, Tuticorin and Visakhapatnam were observed as inefficient units.

5. Concluding Remarks

The most widely used tool for measuring and analyzing efficiency in DEA. Thus analyzing the efficiency of ports through data envelopment analysis we thought appropriate for the present study. The present study used both input and output oriented DEA models for measuring the relative efficiency of major ports in India during 1993 – 2013. The selection of input and output variables are based on the variable having close relationship with the efficiency of ports. The input variables selected for this study are number of berth, berth length, number of equipment's and number of employees whereas output variables considered in this study are container throughput and total traffic. Based on the results, the ports like JNPT, Kandla, Mormugao, and Ennore rated as efficient ports under both input and output oriented DEA-CCR, BCC and DEA – Additive – CRS and VRS methods. The study shows that compared to input oriented results, through output oriented results are with bit higher values but no efficiency difference should be identified among the results. Thus can be concluded that there is no difference in efficiency identification of DMUs i.e. major ports in India under either of the input and output oriented DEA models. The results also indicates that some of the ports reported inefficiency, thus it call s for necessary steps to be taken to strengthen the operation of those ports, more specifically to upgrade of infrastructure in the ports.

For improving technical efficiency the technological up gradation should be given priority for the particular ports who are identified as technical inefficient. However, the caution should be taken while interpreting the efficient ports like JNPT, Kandla, Mormugao, and Ennore. They may be better in comparison to the other ports in India but may not be the same, when compared with world ports. They should strive for still better operational to be at par with efficient ports in rest parts of the world.

Acknowledgement

The authors would like to grateful to Indian Council for Social Science Research (ICSSR) for providing the financial support through the ICSSR – Major Research Project – 2013 -14 grant.

References

Al-Eraqi A.S. Mustaffa A. Khader A.T. and Barros C.P. (2008), Efficiency of middle Eastern and East African seaports: application of DEA using Window analysis, European Journal of Scientific Research, Vol. 23, No. 4, pp. 597–612.

Andersen P. and Petersen N.C. (1993), A procedure for ranking efficient units in data envelopment analysis. Management Science, Vol. 39, pp. 1261-1264.

Barros C.P. and Athanassiou M. (2004), Efficiency in European seaports with DEA: Evidence from Greece and Portugal. Maritime Policy and Management, Vol. 6, No. 2, pp. 122-140.

Charnes A. Cooper W.W. and Rhodes E. (1978), Measuring the efficiency of decision making units, European Journal of Operational Research, Vol. 2, No. 6, pp. 119-140.

Cullinane K. Song D.W. and Wang T.F. (2004), An application of DEA window analysis to container port production efficiency, Review of Network Economics, Vol. 3, No. 2, pp. 184-206.

Cullinane K. Song D.W. and Wang T.F. (2005), The application of mathematical programming approaches to estimating container port production efficiency, Journal of Productivity Analysis. Vol. 24, pp. 73–92.

Cullinane K. and Song D.W. (2006), Estimating the relative efficiency of European container ports: A stochastic frontier analysis, Port Economics. Vol. 16, pp. 85 – 115.

Cullinane K. and Song D.W. (2002), Port privatization policy and practice, Transportation Review. Vol. 22, No. 1, pp. 55 – 75.

Guzowska M. and Strak T. (2010), DEA method in examining the efficiency of polish courts, Transformation in Business and Economics, Vol. 9, No. 1, pp. 1-12.

Hoang V.N. and Alauddin M. (2012), Input-orientated Data Envelopment Analysis framework for measuring and decomposing economic, environmental and ecological efficiency: An application to OECD agriculture, Environmental and Resource Economics, Vol. 51, pp. 431–452.

Itoh H. (2002), Efficiency changes at major container ports in Japan: A window application of data envelopment analysis, Review of Urban Regional Development, Vol. 14, No. 2, pp. 133–152.

Kordrostami S. and Noveiri M. (2012), Evaluating the efficiency of decision making units in the presence of flexible and negative data, Indian Journal of Science and Technology, Vol. 5, No. 12, pp. 3776 – 3782

Liu C. (2008), Evaluating the operational efficiency of major ports in the Asia-Pacific region using data envelopment analysis. Applied Economics, Vol. 40, pp. 1737-1743.

Loyds M.I.U. (2007), Seaborne trade accounts for 77% of total world trade, IOP Publishing http://www.lloydsmiu.com/lmiu/article/20017485999/index.htm, accessed 14 September 2010.

Martinez B. Armas D. Ibanez N. and Mesa R. (2003), A study of the efficiency of Spanish port authorities using data envelopment analysis. International Journal of Transportation Economics, Vol. 26, No. 2, pp. 237–253.

Micajkova V. and Poposka K. (2013), Efficiency of Macedonian banks: A DEA approach, Research Journal of Finance and Accounting, Vol. 4, No. 12, pp. 141 – 149.

Nasiripour A.A. Tabibi S.J. Mokhtari R. (2014), The Relationship between Head-Nurse’s Managerial Skills and Nurses’ Turnover Intention in Private Hospitals. Health Care Current Reviews Vol. 2, No. 1, pp. 2 – 5, DOI: 10.4172/hccr.1000117

Coto – Millan P. Banos - Pino J. and Rodriguez - Alvarez A. (2000), Economic efficiency in Spanish ports some empirical evidence, Maritime Policy and Management, Vol. 27, No. 2, pp. 169-174.

Rajasekar T. and MalabikaDeo (2014), Does Size Influence the Operational Efficiency of Major Ports in India, The IUP Journal of Operations Management, Vol. 13, No. 1, pp. 20 – 38.

Rajasekar T. and MalabikaDeo (2014), Measurement of Efficiency of Major Ports in India – A Data Envelopment Analysis Approach, Asian Journal of Management Research, Vol. 4, No. 3, pp. 606 – 616.

Rajasekar T. and MalabikaDeo (2013), Measuring the operational efficiency of selected Major Ports in India, Mexican Journal of Operations Research, Vol. 2, No. 2, pp. 29 – 41.

Rajasekar T. and MalabikaDeo (2012), The Size Effect of Indian Major Ports on its Efficiency Using DEA – Additive Models, International Journal of Advances in Management and Economics, Vol. 1, Issue. 5, pp. 12 – 18.

Razzaque M.A. (1997), Challenges to logistics development: the case of a third world country –Bangladesh, International Journal of Physical Distribution & Logistics Management, Vol. 27, No. 1, pp. 18-38.

Rios L.R. and Maçada, A.C.G. (2006), Analyzing the relative efficiency of container terminals of MERCOSUR using DEA, Maritime Economics & Logistics, Vol. 8, pp. 331–346.

Roll Y. and Hayuth Y. (1993), Port Performance Comparison Applying Data Envelopment Analysis, Maritime Policy and Management, Vol. 20, No. 2, pp. 21 – 30.

Sohn J.R. and Jung C. (2009), the size effect of a port on the container handling efficiency level and market share in international transshipment flow, Maritime Policy and Management, Vol. 36, No. 2, pp. 117-129.

Susila M. and Gurcharan S. (2011), Benchmarking the efficiency of Asian container ports, African Journal of Business Management, Vol. 5, No. 4, pp. 1397 – 1407.

Tongzon J. and Heng W. (2005), Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (terminal), Transportation Research Part A, Vol.39, pp. 405 – 424.

Tongzon, J. (2001), Efficiency measurement of selected Australian and other International Ports using data envelopment analysis, Transportation Research Part A, Vol. 35, No. 2, pp. 107–122.

Tongzon J.L. (2005), Port privatization, efficiency and competitiveness: Some empirical evidence from container ports (Terminals), Transportation Research Part A – Policy and Practice, Vol. 39, pp. 405–424.

Turner H. Windle R. Dresner M. (2004), North American container port productivity 1984–1997. Transportation Research Part E - Logistics and Transportation Review. Vol. 40, No. 4. Pp. 339–356.

Ujjainwala K. (2008), India logistics and supply chain market dynamics, Supply Chain Asia.

Valentine V.F. and Gray R. (2000), The measurement of port efficiency using data envelopment analysis, Special Interest Group on Maritime Transport and Ports a member of the WCTR Society, International Workshop, Genoa.

Wang T.F. and Cullinane K. (2006), The efficiency of European Container terminal and implications for supply chain management, Maritime Economics and Logistics, Vol. 8, pp. 82 – 99.

Wang T.F. Cullinane K. Song D.W. (2003), Container port production efficiency: A comparative study of DEA and FDH approach, Journal of the Eastern Asia Society for Transportation Studies, Vol. 5, pp. 698–713.

Wu J. and Lin C. (2008), National port competitiveness: Implications for India, Management Decisions, Vol. 46, No. 10, pp. 1482 – 1507.

Xueping X. Jie T. Hongxin R. (2011), A DEA model evaluation of the efficiency of peasant household credit investigation system in rural credit cooperatives, China Agricultural Economic Review, Vol. 3, No. 1, pp. 54 - 66