CHAPTER - VII

EFFICIENCY ANALYSIS OF THE CONTAINER HANDLING PORTS OF INDIA

Container ports play a pivotal role in the container transportation process. Container terminals, a place where containers are transferred among transport modes, form a central part of the transport infrastructure for freight transport. A container terminal is a seaport having facilities for berthing of container vessels, loading and discharge of containers on and from vessels, trucks or railway. It should also have area for storage of import and export containers as well as good land connection by way of roads / rail. A container terminal in general has two interface areas, heading to the land side and water side of the terminal. The waterside interface area connects the quay where vessels are berthed and the stacking area where containers are stored after being discharged. The landside interface area accommodates the flow of containers from the stacking yard to the hinterland by road and rail. Some containers are transhipped; therefore, they are transported back to the waterside and loaded to another vessel.

The performance of container terminal can be gauged by its ability to produce a maximum output (in TEUs) for given inputs or use minimal inputs for the production of a given level of output. A container terminal is inefficient if it is not able to produce maximum possible output (or at the minimum possible cost). To obtain efficiency for the whole handling operations in the terminal, there are several sub processes that can be investigated, namely gate efficiency (handling of trucks), stack efficiency, berth efficiency, container handling efficiency, and other forms of efficiency (for example train and barge handling efficiency). In order to measure container port performance, many operational and functional variables; such as total length of berths, stacking area of container yards, container handling equipments, number of terminal ground slots, ownership of container terminals, etc. can be selected.

The focus of this thesis is measuring technical efficiency, given the lack of comparable input prices across the ports in the country. In the present application, DEA refers to each port as a DMU, in the sense that each is responsible for converting inputs into outputs. As mentioned in chapter VI, compared with traditional approaches, DEA has the advantage that consideration can be given to multiple inputs and outputs. This accords with the characteristics of port production, so that there exists, therefore, the capability of providing an overall evaluation of port performance. We also employ the Malmquist total factor productivity (TFP) index to measure the impact of productivity change on the panel data. Comparison of measurement of productivity can be done by establishing certain indexes using non-parametric methods. Malmquist productivity index (MPI) index is one of them and is used in this study to examine the detailed productivity change. The Malmquist index estimates the total factor productivity (TFP) change of a DMU between two different time periods by calculating the ratio of the distances under a specific technology. As mentioned in chapter VI, the distance functions allow us to describe a multi-input, multi-output production technology without the need to specify the producer behaviour (such as cost minimization or profit maximization). There are many different methods that could be used to measure the distance function which make up the Malmquist TFP index. In this study a DEA-like linear programming method (DEAP, version 2.1) developed by Coelli (1996) is used to devise the indexes of which the empirical results are obtained.

1. SAMPLE SIZE

The estimated units in this study include the ports Kolkatta port, Mumbai port , Kandla port, Haldia Dock and Jawaharlal Nehru port and the terminals Visakaha Container Terminal Pvt. Ltd. (VCTPL, Visakahpatnam Port), Chennai Container Terminal Limited (CCTL, Chennai Port), India Gateways terminal Pvt. Ltd. (IGTPL, Kochi Port) and Nhava Sheva International Container Terminal (NSICT, JNP). These ports/terminals are all under the purview of major ports. There are two non-major ports also, which handle containers and have the same facilities as in the above mentioned ports/terminals. They are Mundra International Container Terminal Limited (MICTL, Gujarat Adani Ports Ltd, {GAPL}, Gujarat) and Port of Pipavav, Gujarat. Thus, the sampling frame for analysis is India's 12 container handling ports/terminals, i.e., this study has 12 DMU units. Annual data of three financial years from 2004-05 to 2006-07 are collected for each port/terminal. Thus, the sample for analysis comprises a total of 36 DMU observations. There are several possible ways to deal with the panel data within the context of DEA. One is to compute a frontier for each period (three cross-sectional analyses in this case) and compare these cross-sectional runs. In this way, one constructs a frontier in each year and can calculate the efficiency of each firm relative to the frontier in each period. Another possibility is to treat the panel as a single cross-section (each firm in each period being considered as an independent observation) and pool the observations. This way, a single frontier is computed, and the relative efficiency of each firm in each period is calculated by reference to this single frontier. In this study, the DEA models are based on cross-sectional data analyses for the three years.

2. INPUT AND OUTPUT VARIABLES

The first and probably most difficult step in efficiency evaluation is to decide which inputs and outputs data should be included. As the selection of inputs and outputs is directly related with the validity of the model, it requires close attention to maximize the discrimination power of the model with the selected inputs and outputs (Nyhan and Martin, 1999)[1] One of the strengths of DEA is the fact that inputs and outputs can be measured in different units for example dollars, square meters, number of staff, etc. The analysis can be run using one input and several outputs or vice versa estimating one output produced by multiple inputs. The literature on applying the DEA technique to container port evaluation shows various schemes of inputs and outputs sets. The input and output variables for measuring the efficiency of container ports or terminals industry tends to exhibit a kind of diversity in the literature, due to the lack of uniform performance evaluation criteria.

There are different opinions in the literature on choosing the input indicators. Chang (1978)[2] suggests that the inputs of a port should include the real monetary value of net assets in the port, the number of labourers per year, and the average number of employees per month each year. Dowd and Leschine (1990)[3] argue that the productivity of a container terminal depends on the efficient use of labour, land and equipment. They, as well as Cullinane and Song (2003)[4], also suggest that labour information should be included as one of the input indicators. On the other hand, Valentine and Gray (2001)[5] argue that labour information is difficult to obtain and there is a high potential of measurement error. Though, Notteboom et. al. (2000)[6] show that the number of gantry cranes and the number of dock workers are closely related. Besides this, Tongzon (2001)[7] and Cullinane and Song (2003) suggest using number of berths as one of the input indicators reflecting the berth side productivity, whereas Cullinane *et al.* (2002)[8] and Notteboom *et al.* (2000) define total berth length instead. As argued by Wang *et al.* (2005)[9], berth length is more reasonable because the number of berths can change easily. De Neufville and Tsunokawa (1981)[10], Notteboom *et al.* (2000) and Wang et al (2005) also suggest that information on unloading facilities, such as the number of quay cranes and yard cranes, should also be considered. When considering output indicators, that container throughput has been considered as the most appropriate indicator.

As suggested by Wang (2004)[11], the input and output variables should reflect the objective and process of container terminal production as accurately as possible. Now, in the process of container port/terminal production, the terminal's activity is to utilize the labour and equipment to accomplish the container loading or discharging missions. This production process depends crucially on the efficient use of labour, land and capital. In this process, the efficient transfer of containers across a quay between shore and ship is of fundamental importance in deciding the competitiveness of ports. For this quayside operation, the quayside gantry crane (QCs) is the most important equipment (Tongzon, 1995)[12]. The size of a ship is very frequently thousands of times the size of the land vehicles that carry the cargo to and from the port. As a result, storage space for containers, before being loaded or after being discharged, is needed. The container yard, as a storage area, acts as a buffer between sea and inland transportation or transhipment. Before the containers are loaded on board or after they are discharged, to effectively handle the containers and further serve for hinterland demand, the yard gantry cranes; viz., the rubber-tyred gantry cranes (RTGCs) and/or the rail-mounted gantry cranes (RMGCs) are essential equipment within the container yard. Thus, the QCs and the yard cranes approximated for the 'equipment' factor. The 'land' factor could be approximated by the total quay length (QL) and the container yard area of the port/terminal. Other input factors, such as berth working hours, geographical position, berth waiting time and other equipments, are not included from the consideration of both data availability and avoidance of the problem of multicollinearity as well in keeping with the DEA convention.

As to the labour input, the variable was not directly incorporated, following Cullinane et. al. (2006)[13] that "in the light of the unavailability or unreliability of direct data, information on labour inputs is derived from a pre-determined and highly correlated relationship to terminal facilities. Also, as pointed out by Notteboom et al. (2000), that since a fairly stable and close relationship exists between the number of gantry cranes and the number of dock workers in a container terminal, the labour input could be derived by a function of the facilities of the terminal. De Neufville and Tsunokawa (1981) also advocate this.

With regards to the output side, we selected the container throughput as the output index in accordance with the conventional treatment, since throughput is the most important and widely accepted indicator for comparing the ports and terminals and also the container is basic handling unit in the operation. Another consideration was that container throughput is the most appropriate and analytically tractable indicator of the effectiveness of the production of a port (Cullinane, Song and Wang, 2005)[14].

Thus, this study had initially selected three inputs including the total quay length measured in meters, container yard measured in hectares, number of equipments (container quay gantry cranes (QCs) and yard gantry cranes (RTGCs and RMGCs) were clubbed together in to a common input variable named equipments) and one single output of container throughput in number of TEUs. This is shown in the table: 7.1 below.

Table: 7.1 Description of the Selected Input and Output Variables

Variables	Unit	Description
Inputs	Quay Length X1 (meters)	Total length of container berths
	Container Yard X2 (Hectares)	Area of Container Yard
	Equipments X3 (Numbers)	Number of Quay and Yard Gantry Cranes (QCs, RTGCs and RMGCs)
Outputs	Container Throughput Y (Number of TEUs)	Annual container throughput

The relevant data for all the three years are give in the Appendix tables, A1, A2 and A3. The analysis in this study is based on these data.

To confirm the correlation between selected inputs and outputs, this study applies analysis of Pearson correlation coefficients at 5% significance level (two-tailed), the results of which are shown in the table: 7.2.

Table 7.2 Pearson Correlation Matrix of the Input and Output Variables, N=36

	TEUs	Quay Length	Equipments	Container Yard
TEUs	1			
Quay Length	0.317*	1		
Equipments	0.903	0.380	1	
Container Yard	0.733	0.160	0.738	1
*Not Significant at the level 0.05 (2-tailed)				

We find that output variable of container throughput (Y) highly correlates with inputs of container yard (X2) and equipments [container gantry cranes and yard gantry cranes, viz., the RTGCs/RMGCs] (X3), indicating their complementary nature in the production process. Container quay length (X1) is not significant with Pearson correlation coefficient of 0.317. Since the input of quay length is not significant, therefore it is eliminated and then this study finally selected two inputs (X2 and X3) and single output (Y).

2.1 Descriptive Statistics

The summary statistics for the above sampling frame are summarised and reported in Table 7.3.

Table: 7.3 Descriptive Statistics of Input and Output Variables in the Analysis

Descriptive Statistics	Output	Inputs	
	Throughput (TEUs)	Container Yard (hectares)	Equipments (number)
Mean	440574.6	14.66	13.64
Standard Deviation	447015.5	9.24	12.82
Minimum	46868	3.7	1
Maximum	1359125	35	40

Being a deterministic rather than statistical technique, DEA produces results that are particularly sensitive to measurement error. If one organisation's inputs are understated or its outputs overstated, then that organisation can become an outlier that significantly distorts the shape of the frontier and reduces the efficiency scores of nearby organisations. In regression–based studies, the presence of error terms in the estimation tends to discount the impact of outliers, but in DEA they are given equal weight to that of all other organisations. It is important to screen for potential outliers when assembling the data. One useful check is to scrutinise those organisations whose output-to-input ratios lie more than about two-and-a-half standard deviations from the sample mean.

DEA can be run with a very small data set, as is the case in this study. But, DEA scores are sensitive to input and output specification and the size of the sample. For a DEA-model to be able to provide reasonable results, attention must be paid to providing a sufficient amount of degrees of freedom for the model to distinguish efficient DMUs. Degrees of freedom are dependent upon the number of inputs and outputs and also the number of DMUs. Increasing the sample size will tend to reduce the average efficiency score, because including more organisations provides greater scope for DEA to find similar comparison partners. Conversely, including too few organisations relative to the number of outputs and inputs can artificially inflate the efficiency scores. Increasing the number of outputs and inputs included without increasing the number of organisations will tend to increase efficiency scores on average. This is because the number of dimensions in which a particular organisation can be relatively unique (and, thus, in which it will not have similar comparison partners) is increased. DEA gives the benefit of the doubt to organisations that do not have similar comparison organisations, so they are considered efficient by default. Thus, given a certain set of samples, this means that the addition of measures will reduce discriminatory power of the DEA model. Essentially, this is because it is possible that a DMU may dominate all the others on one measure, which in turn, makes it look equally efficient to other DMUs. To avoid this problem, the straightforward way is to guarantee that there will be a sufficient number of DMUs for comparison, regarding any of the measures. Although there is no optimal way to decide the number of inputs and outputs, there are different rules of thumb as to what the minimum number of organisations in the sample should be. The number of samples was checked against this several applicable rules of thumb to guarantee the sufficiency and meaningful interpretation.

Boussofiane, Dyson, Thanasoullis (1991)[15] recommend that the total number of DMUs be much greater than the number of inputs times the number of outputs. Compared to this analysis, where three inputs and one output are selected for analysis, the number of samples needs to be much more than 2 × 1 or 2 ports in order to reduce the chance that a port is too dominant compared to the others on a particular measure. According to the recommendation, the number of eleven ports under study is deemed satisfactory.

To avoid losing discriminatory power, Cooper, Seiford and Tone (2006, page 106)[16] recommend that the desired number of DMUs exceed the total of the number of input and output measures by several times. They suggest a more stringent rule of thumb in the following formula (Cooper, Seiford and Tone 2006, page 272):

$$n \geq \max\{\, m \times s,\ 3\,(m + s)\,\}$$

where n is the number of DMU observations/units, m is the number of inputs and s is the number of outputs. Substituting m and s in the above yields the minimum number of sample:

$$n \geq \max\{\, 2 \times 1, 3\,(2 + 1)\,\} = \max\{\, 2, 9\,\} = 9$$

Again, the number of ports under study, i.e., eleven ports/terminals, satisfies this recommendation. Thus, it can be concluded that the sample size is sufficient for the analysis.

3. DATA SOURCES

The required secondary data are mainly taken from the various issues of the annual Major Ports: A Profile published by the Indian Ports Association (IPA), and Basic Port Statistics of India, Transport Research Wing, Ministry of Shipping, Road Transport and Highways, Government of India as well as by email and telephonic enquiries with the concerned managers at the various ports and terminals. The latest data available on port/terminal throughput was for 2006-07 and this was chosen as the basis for the analysis. The third container terminal, Gateway Terminals India Pvt. Ltd. (GTIPL), at Jawaharlal Nehru Port is not included in this study because it became fully operational only from January 2007. Before that, it was on a trial run from March 2006 and so its data are not comparable.

4. MODEL ORIENTATION

In order to solve the DEA problem, we need to specify the following characteristics of the model: the input/output orientation system and the returns-to-scale. Now, the choice of an input or output-oriented DEA is based on the market conditions of the DMUs. As a general rule of thumb, in competitive markets, DMUs are output-oriented, assuming that inputs are under the control of the DMU, which aims to maximise its output, subject to market demand; something that is outside the control of the DMU. In monopolistic markets, the units analysed (DMU) are input-oriented, while output is endogenous. The concept of efficiency is intrinsically related to the firm's resource utilization performance. The efficient units use its mix of inputs better than inefficient ones or the efficient units manage to produce more outputs using a given mix of inputs. An input-oriented measure quantifies the input reduction, which is necessary for a DMU to become efficient, holding the output constant. Similarly, an output-oriented measure quantifies the necessary output expansion, holding the input constant. A non-oriented measure quantifies the improvements when both inputs and outputs can be modified simultaneously. Production is an act of transforming inputs into outputs. Since resources are limited, producing as large an output as possible with a specific quantity of input is a desirable objective.

Quoting from Cullinane *et. al.* (2005) "input-oriented ... is closely related to operational and managerial issues, whilst the output-oriented model is more related to port planning and strategies. As far as input-oriented models are concerned, the port industry is normally associated with long-lived infrastructure and facilities and with a long-term planning horizon that mean that once a port is built, its output is roughly fixed within a certain constrained range for some time to come. A port is normally able to approximately predict its container throughput for the ensuing year at least. This is because a container port has a fairly stable customer base of shipping lines. Over the fairly short-term, container terminals should even be able to predict impending dramatic changes.... A container terminal can also attempt to predict its future throughput by studying historic data or regional economic developments... On the other hand, with rapid expansion of globalisation and international trade, many container ports must frequently review their capacity in order to ensure that they can provide satisfactory services to port users and maintain their competitive edge. Sometimes, the need to build a new terminal or increase capacity is inevitable. However, before a port implements such a plan, it is of great importance for the port to know whether it has fully used its existing facilities and that output has been maximised given the output. From this perspective, the output-oriented model provides a more appropriate benchmark for the container industry."

For the purposes of this study, we choose the output-oriented models for the analysis. The reason for this choice is that the Indian ports are presently investing heavily in port infrastructure build-up, with more projects on the anvil. With more and more investment coming in this sector, it becomes imperative to know whether the existing infrastructure facilities are being fully and efficiently utilised and that there is no duplication and thus, a waste of the scarce investment resources. It is assumed that once a port has invested in the infrastructure, it is difficult for the managers to disinvest to save on costs. Consequently, port managers are more interested to know the probable levels of output, given the existing infrastructure. From this viewpoint, we use the output-oriented DEA models assuming the inputs to be endogenous and the outputs exogenous because of the public nature of seaports, which have to accept traffic as offered (Barros and Athanassiou, 2004)[17].

With regard to the returns-to-scale, these may be either constant or variable. Since precise information on the returns to scale of the port production function is not available, we calculate both forms (the CCR and the BCC model) for comparative purposes. Applying both DEA-CCR and DEA-BCC models to derive the efficiency of the container ports under study would also help to facilitate the exploration of returns to scale. As mentioned in chapter VI, in the VRS approach a convex hull of intersecting planes are formed which envelope the data points more tightly than under the constant returns to scale (CRS) convex hull.

It should also be mentioned here that the relative weights that may be placed on inputs and outputs in the objective function are subject to the inequality constraints mentioned in the model algorithms. Weights are endogenously defined by the algorithm and measure the distance between the DMU and the frontier.

5. EMPIRICAL RESULTS AND ANALYSIS

As discussed previously, the DEA empirical analysis uses one output measure: TEUs handled (the number of twenty foot container equivalent units handled) and two input measures: equipments {quay cranes (QCs) and yard cranes (RTGCs and RMGCs)} and container yard. The model is based on output oriented model in that whether the existing facilities have been fully utilised and that output has been maximised given the input is the main examining purpose of this study. The ranking analysis of container ports using the super-efficiency model is also undertaken. We also employ the Malmquist total factor productivity (TFP) index to measure the impact of productivity change. The softwares DEAP 2.1 (Coelli, 1996)[18] and EMS (H. Scheel, 2000)[19] are employed to derive the solutions to the models.

5.1 The DEA Efficiency Analysis

Initially, in order to explore the overall technical efficiency (OTE), pure technical efficiency (PTE), and scale efficiency (SE), both the CCR and BCC models are used to evaluate all the 12 container ports/terminals in each years 2004-05, 2005-06 and 2006-07 respectively. For these ports, then ranking was undertaken, again for all the three years. The results as per the super-efficiency model showed Kandla having a super-efficiency score of 0.00% for all the three years. Now, as we mentioned in chapter VI, a very low score in the output oriented perspective may indicate that a DMU is highly specialized and therefore not comparable to other DMUs. Hence the concept of super-efficiency helped to identify Kandla as incomparable to the other ports/terminals and so was dropped from the data set. When we take into consideration the fact that Kandla didn't have any of the equipments that we have included in our study, viz. QCs, RTGCs and RMGCs, the result doesn't come as a surprise. At Kandla, containers are handled using shore and ship cranes only. Thus, we then proceeded with the analysis using just 11 ports/terminal. This data set of 11 ports is also in compliance with the earlier mentioned recommendations regarding the number of DMUs and the input and output measures {(n=) **11 ≥ max 9** (=3[m+s])}

The three efficiency scores calculated are given in table: 7.4.

Table: 7.4 Efficiency of Ports/Terminals under CCR and BCC Models

Port/ Terminal	2004-05				2005-06				2006-07			
	OTE	PTE	SE	RTS	OTE	PTE	SE	RTS	OTE	PTE	SE	RTS
Kolkata	0.504	0.746	0.676	DRS	1	1	1	CRS	1	1	1	CRS
Haldia	1	1	1	CRS	0.652	1	0.652	IRS	0.56	1	0.56	IRS
Visakhapatnam	0.091	0.181	0.502	DRS	0.174	0.185	0.94	DRS	0.233	0.233	1	CRS
Chennai	0.593	0.81	0.732	DRS	0.684	0.905	0.756	DRS	1	1	1	CRS
Tuticorin	1	1	1	CRS	1	1	1	CRS	0.898	0.982	0.914	IRS
Cochin	0.563	0.866	0.65	DRS	0.45	0.463	0.973	DRS	0.657	0.734	0.896	IRS
Mumbai	0.566	0.737	0.768	DRS	0.517	0.526	0.982	DRS	0.507	0.515	0.983	IRS
JNPCT	0.685	1	0.685	DRS	0.931	1	0.931	DRS	1	1	1	CRS
NSICT	0.691	1	0.691	DRS	0.711	1	0.711	DRS	1	1	1	CRS
MICT	0.571	1	0.571	DRS	0.219	0.289	0.758	DRS	0.53	0.533	0.993	IRS
GPPL	0.168	0.3	0.56	DRS	0.432	0.432	1	CRS	0.371	0.395	0.939	IRS
Mean	0.585	0.785	0.712		**0.615**	**0.709**	**0.882**		**0.705**	**0.763**	**0.935**	

It is clear from table: 7.4 above that for all the three years taken for analysis, as one would expect, the DEA-BCC model yields higher average efficiency estimates than the DEA-CCR model, where an index value of 1.00 equates to perfect (or maximum) efficiency. This is not surprising since, as observed in chapter VI, a DEA model with an assumption of constant returns to scale provides information on technical and scale efficiency taken together, while a DEA model with the assumption of variable returns to scale identifies technical efficiency alone.

In 2004-05, the average OTE score is 0.585, suggesting that a considerable proportion of the inputs are wasted in the Indian port/terminal industry dealing with the handling of containers. For example, the average efficiency of container ports derived from applying the DEA-CCR model was 0.585, meaning that, in theory, the ports under study could have, on an average, increased the level of their outputs to 1.7 (=1/0.585) times as much as what they had handled, using the same inputs. The overall technical efficiency (OTE) in the CCR model can be classified into pure technical (PTE) and scale efficiency (SE). This helps us to find whether the cause of the inefficiency is from technical inefficiency or from scale inefficiency. When the OTE (CCR) was decomposed into the PTE and SE, the average scores were 0.785 and 0.712 respectively. This result indicated that the ports/terminals needed to be improved through better management[20] as well as the scale of operations needed to looked into. In the year 2004-05, only Haldia and Tuticorin were identified as efficient when the DEA-CCR model was applied and with the BCC model, three more ports, JNPCT, NSICT and MICT were identified as efficient. Since Haldia and Tuticorin were exhibiting scale efficiency, they are considered to have operated at the most productive scale size (MPSS). The rest 6 ports/terminals had shown both technical as well as scale inefficiency. On the basis of the BCC results, which measures PTE, due to management skills, more than half of the Indian ports were badly managed during 2004-05, the most noteworthy of them being Visakhapatnam and GPPL, with extremely low efficiency scores. Table 7.4 also reports the returns to scale properties of port production yielded by DEA. Out of the 11 terminals/ports, with the exception of Haldia and Tuticorin, which had exhibited constant returns to scale (CRS), the rest all had shown decreasing returns to scale (DRS). Now, ports with DRS are too large in dimension for their production results. Therefore, doubling inputs would less than double the output. Scale dimension should decrease if DRS prevail. Similarly, seaports with IRS are too small in dimension for their production results. Therefore, doubling inputs would more than double the output. Scale dimension should increase if IRS prevail. Going by this principle, for majority of the Indian ports, showing scale inefficiency and DRS, it meant that the scale of operations, relative to the output that they had handled, was high.

The results for the year 2005-06 throw up some interesting facts. During this year, the average OTE score had accrued to 0.615 which was slightly more than the previous year, indicating that the inefficient use of inputs had decreased during this year. The PTE, though, had decreased to 0.709, indicating that there had been a down-turn in the management practice of the whole industry. The scale efficiency had, on the other hand, increased substantially to average at 0. 882. Thus, it had been this increase in SE that had pulled up the OTE score during 2005-06.

During this year also, only two ports/terminals had been efficient under CCR whereas under the BCC model five ports/terminals displayed efficiency. Haldia, which had been both CCR as well as BCC efficient in 2004-05, became CCR inefficient in 2005-06. Since it still was BCC efficient, it can be concluded that the inefficiency had crept in due to scale effect, as borne out by the quite low SE score of 0.652. The port underwent a change from CRS to IRS. This was inspite of the scale expansion that had taken place in the port. The port had commissioned two more equipments (2 quay cranes), which became operational half-way in 2005-06. Tuticorin port had maintained its position in this year too. At the same time, Kolkata, had transformed itself into a CCR as well as BCC-efficient port, indicating a better usage of its inputs as well as better management practices. Thus, during 2005-06, Kolkata had operated at MPSS along with Tuticorin. Going by the BCC results, Haldia, JNPCT and NSICT had maintained their position of being BCC-efficient whereas MICT showed a drastic deterioration in its managerial handling of the operations as compared to the previous year when it had been BCC-efficient. This could have been due to the fact that the then terminal operator, P&O Ports, Australia and the present operator, Dubai Ports (World) were in strategic talks regarding merger. Chennai and GPPL had both shown themselves to be better and more efficiently managed, with their PTE score increasing, as compared to the previous year. The rest of the ports/terminals, in fact, had shown a reduction in their PTE scores from the previous year. All the ports/terminals, with the exception of Haldia, had shown an increase in their scale efficiency. This could have been due to the fact that the respective ports were beginning to make better utilisation of their operation facilities, by handling increased cargo. Though, the industry, for a majority part, still exhibited DRS, meaning thereby that the scale of operations was still higher as compared to the throughput handled. Of course, during this year, Cochin Chennai and MICT had undertaken massive additions to their equipments, which had enlarged their scale of operations. If we analyse the increased scale efficiency in light of the fact that major scale expansions had taken place in these ports, then we can construe that these three ports had done extremely well. In Cochin, 5 new RTG cranes had been added. As for Chennai, 1 QC and 8 RTGCs were added. A massive scale expansion in terms of a large increase in the number of equipments commissioned and operated during the year (addition of four QCs, twelve RTGCs and two RMGCs – a whopping 18 pieces of equipment in one year!) had been undertaken by MICT in 2005-06. We can thus say that MICT had just started its new phase II of development:

the number of quay cranes increased 66.7 per cent and the number of yard cranes also increased by 66.7 per cent in 2005-06. In spite of this, the scale efficiency had, in fact, showed a large increase. One expects the productivity to drop as the inputs increase, but rather, MICT got a higher scale efficiency score, as compared to the previous year. Therefore we can conclude that MICT did an extremely good job compared to the other ports in 2005-06. If we look at the increase in scale efficiencies of all the ports in absolute terms, then Visakhapatnam stands out. From the port with the lowest scale efficiency in the previous year, it showed the highest increase in efficiency. Mumbai and JNPCT also showed higher scale efficiencies, showing that the inputs had been better utilised during that particular year by these ports/terminals. GPPL, though not so very well managed as indicated by its quite comparatively low PTE score, had shown 100 per cent utilisation of its operating resources, as signified by its SE score of 1. GPPL, in 2005-06, had been operating at its MPSS. Any further utilisation of the then present resources would have meant that scale inefficiency would start creeping in. This implied that the scale of operations would have to be augmented if there is a further increase in throughput.

The year 2006-07 can be considered to be a water-shed in many ways for the container port sector in India. First of all, the average efficiency scores for all three, OTE, PTE and SE, have gone up. Secondly, the number of ports/terminals demonstrating CCR-efficiency increased to four in 2006-07. Kolkatta maintained its position from the previous year, displaying both CCR and BCC-efficiency, whereas Tuticorin lost its position. Chennai, JNPCT and NSICT were the new three entrants. The number of BCC-efficient ports remained the same as in 2005-06, i.e. 5 ports, with the only change being the replacement of Tuticorin by Chennai.

With the information about the returns to scale properties of the individual terminal production, in 2004-05, it can be figured out that all the ports/terminals in the sample, with the exception of Haldia and Tuticorin who had exhibited constant returns to scale, had showed decreasing returns to scale. In 2005-06 also, the majority of the ports/terminals had exhibited decreasing returns to scale, as mentioned above. The year 2006-07, however, showed a complete reversal of the pattern exhibited during the earlier years with over half the ports/terminals in the sample (6 out of 11) exhibiting increasing returns to scale and the rest 5 showing constant returns to scale. The industry can be said to have evolved from a (mainly) decreasing returns to scale stage to an increasing returns to scale stage. In 2006-07, the throughput increased to such an extent that the scenario changed from one of where the scale of operations needed to be scaled down by the majority of the ports/terminals to that where it now needed to be scaled up, relative to output. The implications of this result are extremely important and an eye-opener.

Tuticorin, as compared to the previous two years, when it had presented both CCR and BCC-efficiency, showed inefficiency on all fronts this year. Not only did managerial inefficiency creep in a little, scale inefficiency also reared itself. Together, both brought down the OTE-efficiency. The terminal has gone in for scale enhancement by increasing the number of quay cranes by 33.3 per cent and yard cranes (RTGCs) by 50 per cent. It also doubled the area of its container yard. Nonetheless, it showed IRS. This leads us to surmise that the relative increase in output is much greater that that in the inputs, which in turn explains the scale-inefficiency.

The other ports/terminals which went in for scale augmentation in 2006-07 include Haldia Dock, JNPCT and GPPL. Notwithstanding this expansion, apart from JNPCT, which is exhibiting CRS, the rest two are exhibiting IRS.

Despite the fact that in 2006-07 also, Haldia Dock has gone in for a further expansion with the addition of 4 new RTGCs, it still is exhibiting IRS implying that there is a need for still further expansion, if it has to handle the output efficiently. Not only that, the throughput handled in 2006-07 is actually slightly lower as compared to that handled in 2005-06. Keeping both these facts in mind, the still lower scale efficiency as compared to the previous year bears out that even for handling the present scale of output, Haldia's operational capacity is woefully inadequate, when compared to the other ports/terminals in the sample.

On the other hand, the throughput at GPPL in 2006-07 has nearly doubled as compared to that handled during 2005-06. As a result, regardless of it expanding its scale of expansion, it still shows IRS. In other words, the operations need to be scaled up still further. GPPL, which had only 3 quay cranes, added yard cranes (8 RTGCs) too to their equipments.

Chennai port propelled itself into the MPSS region by recording an increase in scale efficiency, implying perfect utilisation of its resources vis-à-vis its output. As mentioned above, Chennai had augmented substantially to its equipments in 2005-06. CRS in 2006-07 signifies that the additional equipments were also utilised to their fullest. It also brought about a further efficiency in its management practice – scoring a perfect efficiency score this particular year.

Visakhapatnam still exhibits low managerial efficiency, albeit slightly higher than the previous year, which can be termed to be a cause of major concern. One of the reasons that could explain its consistently low PTE could be the fact that though the port handles the highest cargo among all the major ports of India, the majority of cargo passing through it is in the form of bulk/break-bulk and the management might be concentrating more on the cargo that the port is specialising in. In fact, Visakhapatnam has handled the least throughput among all the eleven ports/terminals under study. It has not only been handling the lowest cargo, its CCR and BCC-efficiencies are also the lowest amongst all. Of course, its scale efficiency has been increasing through the years to reach the score of "1" in 2006-07, thereby displaying CRS. In the previous two years, the port had been displaying DRS, as mentioned above. Keeping in mind the fact that there had been no addition to the capacity, we can safely surmise that in the previous two years, the throughput at this port was so low that the extant operational capacity was not being utilised to its fullest and it is only this year that the output has reached the level where the facilities could be utilised to the maximum.

Cochin has brought about changes in its managerial practices from the previous year, which has got reflected in its higher PTE score in 2006-07. The scale efficiency has reduced in this year. Now, as we saw above, Cochin had undertaken augmentation of its facilities in 2005-06, and had exhibited high scale efficiency, though with DRS. Now, the scale efficiency has reduced, along with change in scale of operations to IRS. In face of these facts, what is being shown by the results is that within a span of 1 year, the output increased to such an extent that from under-utilisation of facilities, the scenario changed to one of over-utilisation, resulting into a need for extension of the present facilities.

Mumbai port need to revamp its management practices to a great extent, as reflected by its low PTE score. The scale efficiency has remained unchanged from the previous year. The fact that the throughput through the port in 2006-07 has decreased as compared to 2005-06 and the scale of operations has changed from DRS to IRS leads to interesting connotations. We need to recall here that DEA gives relative efficiency scores, relative to other ports/terminals within the sample. Since some of the other ports have gone in for capacity augmentation as well as the fact that increase in throughput has also been quite large for some of them, the reference ports on the frontier would change and Mumbai would now be compared to these new reference ports on the new frontier. Given the actuality of no capacity enhancement, and being weighed against the new virtual standard, could reason behind Mumbai displaying IRS despite the decrease in throughput from the earlier year.

Though MICT still exhibited a low BCC-efficiency score, indicating thereby that a lot more still needs to be done on management issue, its increase over the previous year is significant. What grabs the attention more is the fact scale issue. Not only has the scale changed from DRS to IRS, the scale inefficiency has come down to very low levels. In other words, the SE score shows a considerable improvement over the previous two years. We look at this fact bearing in mind two very important pieces of data: the scale expansion of 2005-06 to the tune of 18 pieces of equipments, which translates into a 225 per cent increase - the largest among all the ports/terminals during all the years under study and the increase in throughput in 2006-07 as compared to 2005-06 – a colossal 75 per cent. Analysing this two together provides us the answer to increased scale efficiency and the change in returns to scale. Now, MICT already had 8 cranes, on top of which came the above mentioned massive increase. So, inspite of the huge increase in throughput, the facilities were not fully utilised, though the scale efficiency has increased over the previous year and is the highest amongst all the inefficient ports. In other words, the scale inefficiency of MICT in this year is very low, just 0.7 per cent. The shift from DRS to IRS shows that there is still scope for further expansion of scale, relative to output. The other explanation for the results could also be that this huge expansion resulted into technology change which reflected into the results. This would be checked when we undertake Malmquist productivity study in later paragraphs.

What all this boils down to is the fact that an increasingly larger amount of container cargo is passing through the Indian ports/terminals and the infrastructure facilities available at the majority of these ports/terminals are not enough. Thus, in spite of the large scale construction of the port infrastructure that has and is taking place in India, there is a need for still further expansion, keeping in mind the increasingly larger output being handled. This fact is also borne out by the fact that compared to previous years, alongwith an increase in the average scale efficiency, which stood at 0.935 as against 0.882 and 0.712 during 2005-06 and 2004-05 respectively, majority of the ports are exhibiting IRS.

Although the CCR and BCC models provide a method to dichotomize container handling ports/terminals into efficient and inefficient DMUs, it is impossible to determine the relative rankings among the efficient DMUs. When there are several efficient ports like in this study, it is difficult to tell which port is more efficient and to what extent than the other efficient ports. To overcome this limitation, we attempt the ranking analysis of the ports/terminals using the super-efficiency model.

5.2 Ranking Using Super-Efficiency Model

With a small set of cases, many DMUs can be efficient. DEA assigns a score of one to efficient DMUs. So, it is not possible to distinguish between the efficient DMUs. To allow a ranking of efficient DMUs Andersen and Petersen (1993) introduced the concept of super-efficiency. Theoretically, the super-efficiency model differentiates between efficient cases by excluding the DMU under observation from the constraints. The basic idea is to compare the DMU under evaluation with a positive linear combination of all other DMUs in the sample. The super-efficiency measure examines the maximal radial change in input, and outputs for an observation to remain efficient. Therefore, it provides a means of distinguishing between efficient observations, which would otherwise seem identical, i.e. DMU under evaluation itself is excluded. The efficiency score of an inefficient DMU does not change, since an inefficient DMU cannot be a reference DMU of itself. In order to decide the rank of each container port in view of overall technical efficiency, we attempt to measure super-efficiency scores in output-oriented CCR model. This model is also chosen because, as mentioned in chapter VI, infeasibility cannot arise in an output-oriented CCR super-efficiency model. Output directed CCR application model solutions are obtained by the EMS (Efficiency measurement systems, version 1.3, Scheel, 2000) decision supporter system. Table: 7.5 presents the ranking of the ports/terminals for all the three periods. 2004-05 to 2006-07.

Table: 7. 5 Ranking of the Ports/Terminals by Super-efficiency Scores

Port/Terminal	2004-05		2005-06		2006-07	
	Eff. Score*	S. Eff.Score@ (Ranking)	Eff. Score*	S. Eff.Score@ (Ranking)	Eff. Score*	S. Eff.Score@ (Ranking)
Kolkata	198.42%	198.42% (8)	100.00%	78.96% (2)	100.00%	75.20% (1)
Haldia	100.00%	48.03% (1)	153.28%	153.28% (6)	178.69%	178.69% (7)
Visakhapatnam	1097.51%	1097.51% (11)	573.88%	573.88% (11)	429.33%	429.33% (11)
Chennai	168.50%	168.50% (5)	146.24%	146.24% (5)	100.00%	88.51% (2)
Tuticorin	100.00%	67.10% (2)	100.00%	67.99% (1)	111.41%	111.41% (5)
Cochin	177.62%	177.62% (7)	222.07%	222.07% (8)	152.15%	152.15% (6)
Mumbai	176.67%	176.67% (6)	193.46%	193.46% (7)	197.36%	197.36% (9)
JNPCT	145.97%	145.97% (4)	107.46%	107.46% (3)	100.00%	95.21% (3)
NSICT	144.62%	144.62% (3)	140.67%	140.67% (4)	100.00%	97.38% (4)
MICT	410.68%	410.68% (9)	456.37%	456.37% (10)	188.85%	188.85% (8)
GPPL	594.32%	594.32% (10)	231.39%	231.39% (9)	269.85%	269.85% (10)

* CCR-Efficiency Scores; @ Super-efficiency Scores

With an output-orientation, higher scores indicate lower efficiency. The scores indicate by how much the output needs to be increased to become efficient. A score of 2.69 (GPPL, Super-efficiency model, 2006-07) indicates that GPPL must increase its output by a factor of 2.69 to become DEA-efficient. In other words, GPPL falls massively short in creating outputs in relation to other ports/terminals with similar inputs (e.g., NSICT or JNPCT). For input-oriented models, the score indicates how much inputs must be decreased to become efficient, with higher scores indicating higher efficiency.

The results in the table: 7.5 above show that according to the super-efficiency scores, the ranking of the ports/terminals have shown a high volatility in the three years under study. It is only Visakhapatnam which has been consistent - remaining at the last position in all the three years. Since super-efficiency scores basically work as tie-breaker among the efficient ports, we first deal with those. In 2004-05, only Haldia and Tuticorin were efficient. Haldia ranked first and Tuticorin second. In 2005-06, it had been Kolkatta and Tuticorin which had been efficient. In that year, Tuticorin ranked first and Kolkata came second. In 2006-07, four ports, namely Kolkata, Chennai, JNPCT and NSICT showed efficiency. The order of ranks was as follows: Kolkata ranked first; Chennai came second followed by JNPCT and NSICT at the third and fourth positions respectively. Chennai attained CCR-efficiency only in 2006-07 and came at the fourth position, after JNPCT. Tuticorin and Haldia, which had featured among the efficient ports in the earlier in 2005-06 and 2004-05 respectively, lost their positions due to reasons already discussed above. On the other hand, as the super-efficiency scores of the inefficient ports/terminals are the same as the efficiency indices in the CCR model, Visakhapatnam port, which shows the highest score, is the most inefficient. The rankings of the rest of the ports can be seen from the table. While the inefficiency on inputs and outputs in efficient ports/terminals are all zero, there are too much inputs or too little output in inefficient container ports.

An analysis of variance (ANOVA) of the efficiency for the DEA-BCC and DEA-CCR analyses for all the 3 years under the study showed that the calculated value of F is very less than the critical value, indicating that the efficiency measures calculated using these two different approaches were not significantly different at the 5% level (with a critical value of 4.35).

Table: 7.6 Analysis of Variance and Spearman's Rank Correlation

Year	Test	
	ANOVA*	Spearman's Rank Correlation
2004-05	$F = 2.71$ ($F_{crit} = 4.35$)	0.8696
2005-06	$F = 0.50$ ($F_{crit} = 4.35$)	0.9270
2006-07	$F = 0.24$ ($F_{crit} = 4.41$)	0.9076
*At 5% level of significance		

Spearman's rank order correlation coefficient between the efficiency rankings derived from DEA-BCC and DEA-CCR analyses for 2004-05, 2005-06 and 2006-07 were 0.8696, 0.927 and 0.9076 respectively. Hence, there is a high degree of positive correlation for all the three years. This positive and high Spearman's rank order correlation coefficient indicated that the rank of each firm derived from applying the two different models was similar. The results of ANOVA and Spearman correlation are summarised in the table: 7.6.

The combination of the two, ANOVA and Spearman's rank order correlation coefficient leads us to conclude that the efficiency estimates yielded by the two approaches are similar and follow a similar pattern across the ports/terminals.

We now undertake comparison of measurement of productivity of the different ports/terminals. Malmquist productivity index (MPI) is used in this study to examine the detailed productivity change. The concept of Malmquist productivity index was first introduced by Malmquist (1953) to compare the input of a production unit at two different points in time in terms of the maximum factor by which the input in one period could be decreased such that the production unit could still produce the same output level of the other time period. The idea leads to the Malmquist input index. It has further been studied and developed in the non-parametric framework by several authors, for example, among others, Caves, Christensen and Diewert (1982)[21], Färe et. al. (1994)[22], etc. It is an index representing the Total Factor Productivity (TFP) growth of a decision making unit (DMU), in that it reflects progress or regress in efficiency along with progress of the frontier technology over time under multiple inputs and multiple outputs framework.

5.3 The Malmquist Productivity Index

We employ the Malmquist productivity index (MPI) developed by Caves et al., (1982). In this study, following the method developed by Fare et. al., (1994), Total Factor Productivity (TFP) growth is considered as a joint effect of the shift in the production frontier (technological progress) and a movement towards the frontier (technical efficiency) by using the data envelopment analysis (DEA). In other words, given panel data, the Malmquist index evaluates the productivity change of a port between two time periods. It is defined as the product of "Catch-up" and "Frontier-shift" terms. The catch-up (or recovery) term relates to the degree that a port attains for improving its efficiency, while the frontier-shift (or innovation) term reflects the change in the efficient frontier surrounding the port between the two time periods.

As mentioned in chapter VI, with the help of MPI, it is possible to obtain the following indexes:

(a) Technical efficiency change (effch), a ratio of two distance functions which measures the change in the technical efficiency between the periods of change.

(b) Technological change (techch), a measure of the technological change in the production technology, an indicator of the distance covered by the efficient frontier from one period to another.

Considering the hypothesis of variable returns to scale technology, the technical efficiency change (effch) index may be further decomposed into two components, the pure technical efficiency change (pech), and the scale efficiency change (sech).

(c) Pure technical efficiency change (pech), a component of the technical efficiency change and obtained by re-computing efficiency change under the variable return to scale.

(d) Scale efficiency change (sech), the ratio of efficiency under constant return to scale and the same efficiency under variable return to scale.

Both sech and pech are components of effch.

5.3.1 Results in Terms of Means

Table: 7.7 summarises the mean of TFP – of the whole sample of firms – and its components per year and displays the calculated productivity changes in the ports/terminals over the period 2004-05 to 2006-07, as represented by the Malmquist output-based productivity index. We also show the average productivity change for each port and period. As noted earlier, a greater-than-one Malmquist index denotes improvement in the relevant performance. The last row shows the average annual cumulative indices. Here we observe that TFP has decreased by 10.1 per cent over this 3-year period, corresponding to at an average annual rate of over 3.3 per cent per year.

Table: 7.7 Malmquist Index Summary of Annual Means

Firm	Effch	Techch	Pech	Sech	Tfpch
2004-05 to 2005-06	1.101	0.766	0.879	1.252	0.843
2005-06 to 2006-07	1.189	0.805	1.123	1.06	0.958
Mean	**1.144**	**0.785**	**0.994**	**1.152**	**0.899**

Among the TFP components, technical change shows the worst, and a very high one at that, average performance rate of 21.5 per cent decrease. On the other hand, technical efficiency increased at a yearly average growth rate of 14.4 per cent in the period. In this turn, the simple average results showed that the productivity deterioration of the sample ports/terminals in the whole period was the result of the negative frontier shift (i.e., technical change) - due, for instance, to technological regress.

In addition to this, we have a 0.6 per cent reduction from pure technical efficiency suggesting thereby that the Indian ports/terminals need to go in for slightly better management practices. There has also been a 15.2 per cent increase in scale efficiency change, implying that the scale of operations have increased over this period. This is borne out by the fact that the ports/terminals have undertaken scale expansion over the period.

If we analyse the annual means for each biennium, we find that in the biennium 2004-2005 to 2005-06 the total factor productivity reduced by 15.7 per cent. This extensive negative performance is mainly and largely explained by the contraction of production frontier, that is, 23.4 per cent reduction in technical change. On the other hand, the positive performance of 10.1 per cent in technical efficiency owes itself to the fact that the scale efficiency change has been very high – 25.2 per cent. This high sech bears out the huge scale expansion that took place in 2005-06, by MICT, Cochin, Chennai and Haldia. Together these ports invested in 34 additional equipments. Of the three years under study, 2005-06 is the year which has seen the highest amount of investments pour into inputs. This has got reflected in the scale efficiency change. In keeping with the DEA results, this biennium also saw a 12.1 fall in pure efficiency – probably due to management problems. The reason behind this fall in managerial efficiency could be due to two factors. Firstly, as we mentioned earlier, there was a change in the ownership with the then terminal operators, P&O Ports, changing hands with Dubai Ports (World), the present operators. Secondly, the increase in scale would also bring with it management issues, because initially the new equipment would have to be not only put in place but also issues such as the scheduling and routing of the cranes involving sequencing of jobs and their assignment to the respective crane, optimisation of crane operations, etc. need to addressed by the management, which in turn, takes time to smoothen out. Thus, a fall in pech during this biennium is not surprising. But this fall in pech was outweighed by the sizeable increase in scale efficiency change, resulting in an increased technical efficiency.

The biennium 2005-06 to 2006-07 also presented a falling performance in term of TFP, but to a lesser extent. The TFP decreased by 4.2 per cent during this period, again mainly due to a technical regress of 19.5 per cent. On the other hand, 18.9 per cent increase due to technical efficiency of the ports/terminals was indicative of their getting nearer to the frontier. Decomposing this increase in technical efficiency it is possible to highlight that the increase in pure efficiency by 12.3 per cent –due to efficient management handling - is the main factor behind this considerable positive performance. The scale efficiency has also increased again this year by 6 per cent, reflecting the further scale expansion that has been undertaken in 2006-07 by Kolkata, Haldia, Tuticorin, JNPCT and GPPL. This expansion, though, was not to the scale of the year 2005-06 (an additional 22 equipments and 5 hectares added to the container yard area by Tuticorin) and hence a lower scale efficiency change as compared to the previous biennium.

There has also been a diminution in the negative index of TFP and technical change from the earlier period – probably due to technological progress to some extent. Also, the technical efficiency has seen a higher positive growth, mainly due to better management handling of the operations during 2006-07.

The main conclusion thus borne out by the above cumulative average results is that Indian container handling ports/terminals need to upgrade their technology on a massive scale. At the same time, the ports/terminals need to bring about slight changes in their management policies, as borne out by increased pure technical efficiency. The scale of operations is quite high, as indicated by the scale efficiency.

Table: 7.8 shows the mean of TFP and its components for each of the firm during the whole 2004-2007 period.

Table: 7.8 Malmquist Index Summary of Firm Means

Port/Terminal	effch	techch	pech	sech	tfpch
Kolkata	1.409	0.769	1.158	1.216	1.083
Haldia	0.748	0.751	1	0.748	0.562
Visakhapatnam	1.599	0.682	1.133	1.411	1.091
Chennai	1.298	0.928	1.111	1.169	1.205
Tuticorin	0.947	0.851	0.991	0.956	0.807
Cochin	1.08	0.769	0.92	1.174	0.831
Mumbai	0.946	0.84	0.837	1.131	0.795
JNPCT	1.208	0.842	1	1.208	1.017
NSICT	1.203	0.873	1	1.203	1.05
MICT	0.963	0.724	0.73	1.319	0.698
GPPL	1.484	0.655	1.146	1.294	0.971
Mean	**1.144**	**0.785**	**0.994**	**1.152**	**0.899**

Considering all the sample firms, 45 per cent of them (5 in 11) showed an increase in TFP rates. Chennai presented the highest average yearly growth rate, 20.5 per cent. For this port, technical efficiency, especially the scale efficiency change, is the main component influencing the productivity performance. The performance of Kolkatta and Visakhapatnam are also worth noting, both recording yearly growth rates of 8.3 and 9.1 per cent respectively.

The other 6 of the 11 ports/terminals (Haldia, Tuticorin, Cochin, Mumbai, MICT and GPPL) presented a negative TFP performance, with an annual average decrease of 22.3 per cent. Haldia showed the poorest performance, an annual negative growth rate of a whopping 43.8 per cent whereas GPPL showed the lowest negative performance at 2.9 per cent.

For those port/terminals with negative performance, with the exception of Haldia, the falling productivity is largely and mainly explained by the technical change component. This indicates that the frontier shift was not favourable for them. For Haldia, the key component behind the drop in productivity is both, technical change as well as technical efficiency, denoting that it also got far away from the production frontier. By decomposing technical efficiency into pure technical efficiency and scale change, it becomes clear that it is scale change that has influenced its negative evolution of technical change.

5.3.2 Detailed Firm-wise Break-up of the Results

We now look at the productivity and its decomposed indexes period-wise and firm-wise both.

Table: 7.9 displays the calculated productivity changes in the port/terminals over the period 2004-05 to 2006-07, as represented by the Malmquist output-based productivity. As noted earlier, a greater-than-one Malmquist index denotes improvement in the relevant performance.

Although in the period 2004-05 to 2005-06 there are only 4 ports/terminals who have recorded a negative TFP. They are Haldia, Cochin, Mumbai and MICT, with MICT showing the worst performance as its TFP had decreased by 72.2 per cent. Amongst those recording a positive TFP, GPPL shows the best performance at 36.5 per cent. In 2005-06 to 2006-07 biennium, the scenario underwent a reversal. Now the number of ports/terminals for which the TFP decreased went up to 6. Inspite of this, as compared to 2005-06 to 2006-07, the average TFP change is higher than that in the previous period. In this period, it is MICT which shows the highest TFP growth, a massive 74.9 per cent. Thus, MICT, from showing a mammoth decrease in its TFP change in the previous period, shows an increased TFP of an even larger magnitude over the period 2005-06 to 2006-07. Thus, it can be safely deduced from here that it is MICT which lifted up the average TFP change in this period as compared to the previous year. Tuticorin, which had shown a positive performance in the preceeding period 2004-05 to 2005-06, regressed badly in this period, recording a negative performance (-37.7 per cent). MICT showed the highest growth between the two periods, from a negative record of 72.2 per cent to a positive one of 74.9 per cent – an increase of a mind-boggling 147.1 per cent totally, from one period to the other.

Table: 7.9 Annual TFP Change

Port/Terminal	2004-05 to 2005-06	2005-06 to 2006-07
Kolkata	1.278	0.917
Haldia	0.452	0.699
Visakhapatnam	1.009	1.18
Chennai	1.204	1.206
Tuticorin	1.045	0.623
Cochin	0.61	1.133
Mumbai	0.714	0.885
JNPCT	1.176	0.88
NSICT	1.074	1.027
MICT	0.278	1.749
GPPL	1.365	0.691
Mean	**0.843**	**0.958**

On decomposing the TFP index of each port/terminal into its components technical efficiency and technical change, we get clearer insights as to how each port/terminal functioned over the three-year period under study. We first look at technological or technical change and then the technical efficiency.

Table: 7.10 presents annual technical progress or regress.

Table: 7.10 Annual Technical Change

Port/Terminal	2004-05 to 2005-06	2005-06 to 2006-07
Kolkata	0.644	0.917
Haldia	0.693	0.815
Visakhapatnam	0.528	0.883
Chennai	1.045	0.825
Tuticorin	1.045	0.694
Cochin	0.763	0.776
Mumbai	0.782	0.903
JNPCT	0.865	0.818
NSICT	1.045	0.73
MICT	0.725	0.724
GPPL	0.532	0.806
Mean	**0.766**	**0.805**

For the time period, 2004-05 to 2005-06, only Chennai, Tuticorin and NSICT which showed technical progress, and that too of the same magnitude of 4.5 per cent. The worst technical regress was shown by Visakhapatnam (-47.2 per cent) followed closely by GPPL (-46.8 per cent). In the biennium 2005-06 to 2006-07, none of the ports/terminals showed any increase in the technical change component of the TFP index. In other words, over the period 2005-06 to 2006-07, all the ports/terminals experienced technical regress, the worst being in Tuticorin (-30.6 per cent). As we can understand from table: 7.10, the magnitude of regress is comparatively lesser in the later period, which has led to its having a higher average as compared to the former period.

Table: 7.11 shows the annual efficiency change. An industry, which has been efficient at time t and t+1, will naturally show no change in relative efficiency, i.e. efficiency scores in Table: 7.11 would be equal to 1.

Table: 7.11 Annual Technical Efficiency

Port/Terminal	2004-05 to 2005-06	2005-06 to 2006-07
Kolkata	1.984	1
Haldia	0.652	0.858
Visakhapatnam	1.912	1.337
Chennai	1.152	1.462
Tuticorin	1	0.898
Cochin	0.8	1.46
Mumbai	0.913	0.98
JNPCT	1.358	1.075
NSICT	1.028	1.407
MICT	0.384	2.417
GPPL	2.568	0.857
Mean	**1.101**	**1.189**

We find Visakhapatnam, Chennai, JNPCT and NSICT showing an increase in their technical efficiency in both the time periods. Out of the rest of the 7 Ports/Terminals in the country, we find that Kolkatta and GPPL show a positive performance over the period 2004-05 to 2005-06 whereas Haldia, Cochin, Mumbai and MICT show a negative performance. GPPL shows the utmost increase (156.8 per cent) amongst all the ports/terminals whereas MICT showed the poorest performance, an annual negative growth rate of 61.6 per cent. The reasons behind the results of this company regarding technical efficiency would come to light when we decompose it further into scale and pure technical efficiency in later paragraphs. Tuticorin, with its score equal to 1, shows no change in its efficiency over this period.

As for the period 2005-06 to 2006-07, it is Cochin and MICT this biennium which record a positive performance, over and above the four ports/terminals which are positive in both the periods. Kolkatta shows no change in its efficiency this period, as witnessed by its score of 1. It is MICT this period which increased its technical efficiency the greatest (141.7 per cent). Haldia and GPPL both show the same worst negative performance of 14.2 per cent. Thus, the magnitude of negative performance was lower this time, which could be one of the reasons behind the higher average during this period.

Allowing variable-returns-to-scale technology, we further decomposed the technical efficiency into pure technical efficiency and scale efficiency change, respectively, as shown in Tables 7.12 and 7.13.

Haldia, Cochin, Mumbai and MICT had a negative performance with respect to technical efficiency in the period 2004-05 to 2005-06. From the tables 7.12 and 7.13, it is possible to highlight in case of Cochin, Mumbai and MICT that the fall in pure efficiency – probably due to management problems - was the main factor behind their negative performance. The latter had a very high negative pure efficiency score (-71.1 per cent). In case of Haldia, it was the woefully low scale efficiency (-34.8 per cent) – lower scale of operations in relation to output – that was the main culprit. It showed no change in it pure technical efficiency change. Amongst those posting a positive performance, GPPL was the one with the highest positive change at 44 per cent in case of pure technical efficiency, which in turn led to its getting the highest positive technical efficiency score. It implies that over this period, amongst all the ports/terminals, GPPL was the one who had brought about the highest and substantive change in its managerial policies. As for scale efficiency change, it was Visakhapatnam with a mammoth 87.1 per cent increase. This high scale efficiency explained the high increase of 91.2 per cent (though, it was not the highest) in its technical efficiency change. What this implies is that, relative to all the ports/terminals and output, the scale efficiency change of Visakhapatnam is the highest. Now, Visakhapatnam has made no additions to its scale of operations in any of the three years under study. In light of this fact, what the above result says is that, relative to all the ports/terminals, the change in the level of output at Visakhapatnam over the period 2004-05 to 2005-06 was extremely low vis-à-vis its scale of operations.

Table: 7.12 Annual Pure Technical Efficiency

Port/Terminal	2004-05 to 2005-06	2005-06 to 2006-07
Kolkata	1.341	1
Haldia	1	1
Visakhapatnam	1.022	1.257
Chennai	1.117	1.105
Tuticorin	1	0.982
Cochin	0.534	1.585
Mumbai	0.715	0.979
JNPCT	1	1
NSICT	1	1
MICT	0.289	1.846
GPPL	1.44	0.913
Mean	**0.879**	**1.123**

Table: 7.13 Annual Scale Efficiency

Port/Terminal	2004-05 to 2005-06	2005-06 to 2006-07
Kolkata	1.479	1
Haldia	0.652	0.858
Visakhapatnam	1.871	1.064
Chennai	1.032	1.323
Tuticorin	1	0.914
Cochin	1.497	0.921
Mumbai	1.278	1.001
JNPCT	1.358	1.075
NSICT	1.028	1.407
MICT	1.328	1.309
GPPL	1.784	0.939
Mean	**1.252**	**1.06**

In the next biennium, 2005-06 to 2006-07, as we saw previously, it was Haldia, Tuticorin, Mumbai and GPPL which had recorded a decline in their technical efficiencies. For Haldia, it is once again the scale efficiency which is the only cause behind its negative technical efficiency, with pure technical efficiency showing no change. Tuticorin and GPPL are beset by a negative performance of both, pure technical efficiency change as well as scale efficiency change whereas Mumbai faces a problem only with its negative pure technical efficiency. In case of Tuticorin, it is scale efficiency which has a higher negative impact whereas for GPPL, it is the pure technical efficiency. In case of pure technical efficiency, it was MICT which recorded the highest increase at 84.6 per cent (thus explaining its 141.7 per cent increase in technical efficiency), implying that the management policies have got an overhauling, resulting in an increased managerial efficiency, which is borne out by the DEA results too.

Now, we are in a better position to understand the TFP indices of all the ports/terminals. As indicated earlier, the multiplication of efficiency change and technical change leads to the productivity growth. Therefore, we can tell from the tables: 7.9, 7.10, 7.11, 7.12 and 7.13 whether the productivity growth came from efficiency improvement or technical progress, or both. For example, during the biennium 2004-05 to 2005-06, Haldia, Cochin, Mumbai and MICT all owed their negative TFPs to both, negative technical change as well as negative technical efficiency change. On decomposing the latter we find that, for Mumbai, Cochin and MICT, the reason for negative technical efficiency was a decrease in pure technical efficiency change. On the other hand, for Haldia it was a decrease in scale efficiency, with no change in pure technical efficiency. In the next biennium 2005-06 to 2006-07, of Haldia, Tuticorin, Mumbai, JNPCT and GPPL, with the exception of JNPCT which had a negative TFP due only to a decrease in technical change, the reason behind the negative TFPs for the rest all was a decrease in both technical change as well as technical efficiency. Once again, for Haldia, it was just scale efficiency whereas for Mumbai it was just pure technical efficiency change that was the culprit behind their negative performance in technical efficiency change. In case of Tuticorin, it was both, a negative pure technical efficiency change as well as a negative scale efficiency change that played the part in its recording a decrease in technical efficiency change.

Thus, the overall picture that emerges here is that technology-wise the Indian ports are not up to the mark, i.e. they are all suffering from technical regress. If they have to increase their productivity, they would have to upgrade the technology in use. Secondly, the management practices of some ports/terminals leave a lot to be desired. An efficient management is a necessity for efficient use of inputs so as to maximise the productivity and get the maximum returns. The scale of operations also needs to be augmented in some ports, specially keeping in mind the traffic projections.

Having established the operating efficiency as well as the productivity of the container handling ports/terminals in India, we now try to detect and estimate if there is any correlation between the ports'/terminals' operating efficiency and the administrative structure. We divide the samples into two groups: ports/terminals under the control of the state and ports/terminals operated by private entities. This division can reflect whether the reforms and opening up in the port industry have improved the operational efficiency.

Of the eleven container handling ports/terminals under this study, four, viz., Kolkatta, Haldia, Mumbai and JNPCT are under public administrative organisation in 2006-07. The rest seven, viz. Chennai, Visakhapatnam, Cochin, Tuticorin, NSICT, MICT and GPPL are under private administrative organisation. Thus, the eleven ports/terminals are divided into two groups. To test statistically the difference between these two groups in terms of efficiency, and since the theoretical distribution of the efficiency score in DEA is usually unknown, we use non-parametric statistics for which the distribution of the DEA scores are statistically independent. The rank-sum test developed by Wilcoxon-Mann-Whitney test is used to identify whether the efficiency scores of DEA_{CCR} and DEA_{BCC} models in the year 2006-07for these two groups are significant.

5.4 The Rank-Sum Test[23]

The rank-sum test, developed by Wilcoxon-Mann-Whitney, is used to identify whether the differences between two groups are significant. In order to perform it, we take the sequence of ordered efficiencies C of all firms (i. e. in both groups), obtained as described in the previous sections, and rank them to get the sequence R. If two or more firms exhibit identical efficiencies their rank is determined by the sum of their position in C divided by the number of tied firms. So, for example, if C = {1, 1, 0.89, 0.67, 0.67, 0.56, . . .} the corresponding ranks are R = {1.5, 1.5, 3, 4.5, 4.5, 6, . . .}. Following that, we calculate the rank-sum S of one of the two groups. This statistic, S, is approximately normally distributed with mean m(m+n+1)/2 and variance mn(m+n+1)/12, where m is the number of firms of the chosen group and n is the number of firms in the other group. By normalizing S, we have

$$T = \frac{S - m(m+n+1)/2}{\sqrt{mn(m+n+1)/12}}$$

where T has an approximately standard normal distribution. Using T, we can check the null hypothesis that the two groups have the same population at a level of significance α. We will reject this hypothesis if $T \leq -T_{\alpha/2}$ or $T \geq T_{\alpha/2}$, where $-T_{\alpha/2}$ corresponds to the lower percentile of the standard normal distribution and $T_{\alpha/2}$ to the upper percentile. This test, attributed to Wilcoxon, is essentially equivalent to the Mann-Whitney test. Having specified our methodology, we can now proceed to the empirical part.

I propose the hypothesis as under:

H_0: There is no significant difference between the operating efficiency scores of state-run ports/terminals versus the ports/terminals operated by private companies.

Table: 7.14 presents the results of the Mann-Whitney test, which was calculated using Richard Lowry's VassarStats Mann-Whitney calculator. Now, if either group/sample is of a size smaller than 5, it is not meaningful to calculate a z-ratio for the Mann-Whitney. Instead, one must refer the observed value of the measure U[24] directly to the sampling distribution of U.

Table: 7.14 Mann-Whitney Test Results

Model	Mann-Whitney U Test	Level of Significance*	
		Lower Limit	Upper Limit
DEA_{CCR}	17	5	23
DEA_{BCC}	20	5	23

*Significance at a 5% level.

As seen in the above table, for the CCR model, observed values of U fall within the range bounded by the upper and lower limits. Therefore, we can conclude from the U-value that there is no significant difference between the operating efficiency scores of state-run and privately-operated ports/terminals under constant returns to scale.

Similarly, for the BCC model, the value of U is 20, which is once again within the range of 5 and 23. For this model too, the null hypothesis cannot be rejected and we can conclude that even under variable returns to scale, the state-run and the privately-operated ports/terminals operate with no significant difference.

6. SUMMARY AND CONCLUSIONS

Indian economy has successfully moved out of its precarious position of 1991 and moved into a higher growth trajectory, displaying strong dynamism in its various sectors, specially its foreign trade. Noted economists and research organisations are enthusiastic and highly optimistic about India. Trade is one of the key growth accelerators for economic expansion. With the Government of India targeting a yearly 10 per cent GDP growth, a simultaneous growth in international trade would have to take place. With the aim of realizing a trade figure to the tune of $500 billion, the Government is enthusiastically pushing through rapid measures. Now, with 95 per cent of India's foreign trade by volume and about 77 per cent by value passing through India's seaports, any growth in international trade would place on the port sector significant challenges. The prevalent conditions regarding the capacity and handling of cargo at the Indian ports would need to be taken into consideration. Efficient movement of cargo through the ports lowers export costs, thereby directly affecting a country's competitiveness in the international market.

The three most important criteria for success in international Trade are prices, Quality and In-Time delivery. To meet these criteria is not possible without a proper logistics and multimodal system. International trade would not grow without the facilities afforded by modern and efficient infrastructure. New and innovative methods are being discovered and developed on a regular basis so as to bring about improvisations in the quality of products, while simultaneously lowering the costs. One of the important methods of lowering costs is by lowering the inventory levels by introducing the just in time concepts. As we saw in earlier chapters, this can be brought about with the help of containers. Containerisation forms an integral part of any logistics and supply chain.

Containerisation has lot of advantages, but need special cranes at berth and container yards, container freight station, internal container depots, trained personnel for equipment handling, etc. The diffusion and the increasing importance of the container business have required large investments. Containerisation of world trade is accompanied by an increase in the size of vessels. These large ships are the key to port development. The larger vessel size calls for investments in greater depth of port waters, increased infrastructure and better equipment in quays and terminals.

With the Indian economy booming and with no signs of China's growth abating, huge movement of containers is being foreseen in South Asia. In India too, the share of containerised cargo in general cargo has been increasing. Taking into consideration the volume of container traffic that would be generated in India over the next few years, India would need to develop its own hub operations as transhipment translates into additional costs for the shippers. India is taking steps to bolster its container handling capacity by pouring in massive amounts of investments. Under these circumstances, Indian ports need to go in for performance appraisal in an attempt to improve on the efficient use of their inputs.

This study has proposed a simple framework for the comparative evaluation of Indian container handling seaports and the rationalisation of their operational activities. The analysis was based on DEA models as well as the Malmquist Index which both allow for the incorporation of multiple inputs and outputs in determining relative efficiencies. The fundamental properties of DEA and the definitions of input and output variables in keeping with the characteristics of container handling ports/terminals have been methodically discussed. Data for three years, 2004-05, 2005-06 and 2006-07 for the twelve container handling ports/terminals were taken into consideration for the appraisal of individual efficiency scores of each port/terminal. We also undertook the ranking of the entire sample of container handling ports/terminals considered in this study by using the super-efficiency model.

The primary finding of this work is that significant inefficiency generally pervades most of the ports/terminals and can improve the level of their outputs substantially using the present set of inputs that they possess. According to the results of the CCR model, during the first two years under study, there were just two ports/terminals, which turned out to be relatively efficient, compared to the others. In the last year, this number of efficient ports/terminals increased to four. We also applied the BCC model to figure out the causes of inefficiency and found that, during 2004-05, it was scale inefficiency that played a bigger role whereas during 2005-06 and 2006-07, on an average, it is the managerial inefficiency that afflicts the Indian seaports to a greater extent than the inefficiency emerging from scale.

We not only evaluated the relative efficiency of the 11 container handling ports using DEA models but also the ranking of all the container ports considered in this study with the help of the CCR out-oriented super-efficiency model. This model worked as a tie-breaker between the efficient ports. The latest ranking, i.e., ranking for the year 2006-07, showed Kolkata at the first position, followed by Chennai, then JNPCT and lastly, it was NSICT. This was for the CCR-efficient ports.

In this study we next derive detailed information on the total factor productivity (TFP) growth. The TFP measures were calculated using a Malmquist DEA TFP methodology, which provided detailed information on TFP change (tfpch), technological change (techch), technical efficiency change (effch), pure technical efficiency change (pech) and scale efficiency change (sech) for each port/terminal between each pair of adjacent periods. The MPI shows progress or regress in efficiency along with progress of the frontier technology over time. The results indicated a decrease in TFP by 10.1 per cent over the 3-year period, i.e., a negative average annual rate of tfpch of 3.3 per cent per year, with most of this being due to the very high negative rate of techch (or frontier shift) of 21.5 per cent, indicating thereby that the Indian port sector need upgrade its technology on a massive scale. The splitting up of the technical efficiency change (effch) into scale efficiency change and pure technical efficiency change shows that the Indian ports/terminals need to tone up their management slightly, owing to 0.6 per cent decrease due to pure technical efficiency. On the other hand, the average scale efficiency change was a positive 15.2 per cent.

Considering all the sample firms, 45 per cent of them (5 in 11) showed an increase in TFP rates. 50.0 per cent of them (6 in 12) showed an increase in TFP rates, with Chennai presenting the highest yearly growth rate, 20.5 per cent. For this group of ports/terminals technical efficiency is the main component influencing the productivity performance. They all show a technology regress. On the other hand, the rest 6 ports/terminals (Haldia, Tuticorin, Cochin, Mumbai, MICT and GPPL) presented a negative TFP performance, with an annual average decrease of 22.3 per cent, with Haldia showing the poorest performance, an annual negative growth rate of 43.8 per cent.

This work next hypothesises that that here is no significant difference between the operating efficiency scores of state-run ports/terminals versus the privately operated ports/terminals. This hypothesis is upheld by the Mann-Whitney U-test results.

The general conclusion that can thus be drawn is that Indian ports suffer from a severe technological regress. This needs to be taken care of on a priority basis, if they have to compete at the international level with other ports. Not only to compete, but also to efficiently handle its own cargo, it is important that the technology should be up-to-date. This, specially in keeping with the throughput that is being forecasted and projected. The management of the ports/terminals differs from port-to-port, with some being very efficiently managed, while the others not. So, management is also an issue. Same is the case with the scale of operations. Those ports/terminals suffering from these two issues would have to up their operations on those counts so as to better manage their handling of the cargo, which in turn, would result into higher returns for them.

This research was totally an exploratory study. The basic intention was to draw the attention towards the need and importance of efficiency analysis and benchmarking. In no way can we assume here to have reached definite results. A small set of variable and DMUs as well as limited years of study place their own restrictions with regards to conclusions. In order to generalise, a larger panel data set would be necessary. Further research as mentioned below could be undertaken to study the Indian ports:

1. Other cargo types being handled by the Indian ports also can be included in the analysis.

2. Incorporation of wide-ranging asset values as well as maintenance expenditures can be an additional matter to look into.

3. DEA-window analysis with time-series data could put a new perspective on the efficiency study of the Indian ports.

4. International comparisons could be undertaken

5. Parametric and free-disposal hull analysis can also be used to assess the efficiency scores.

6. Fourrier frontiers as well non-traditional DEA models such as Cone-ratio DEA Model and Assurance Region DEA model could also be experimented with.

Endnotes

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[20] The rationale for interpreting BCC model is based on the difference between the CCR and BCC models: the CCR model identifies OTE, while BCC differentiates between TE and SE. Based on this differentiation, the ratio between CCR and BCC allows the estimation of scale efficiency. Assuming efficiency is due to managerial skills and scale effects, the BCC is interpreted as *managerial skills.* (Barros, C. P. (2006), "A Benchmark Analysis of Italian Seaports using Data Envelopment Analysis", *Journal of Maritime Economics and Logistics*, 8, pp. 347-365).

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[24] For either sample/group, U is equal to the difference between the maximum possible value of T for the sample versus the actually observed value of T. Suppose we have two samples/groups A and B. Then,

$$U_A = T_{A[max]} - T_A$$

$$= n_a n_b + \frac{n_a(n_a+1)}{2} - T_A$$

Where n_a =size of group A and n_b = size of group B and T_A = the sum of the n_a ranks in group A. (**Source:** VassarStats website).