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Efficiency of Latin American Container Seaports using DEA

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The literature on the performance of ports has typically centered on the advanced and the emerging markets. There is a dearth of studies on the performance of Latin American seaports. It is important to study the efficiency of seaports in this particular region which has experienced significant reforms since the mid-1980s.This study aims to benchmark the efficiency of Latin American Container seaports and investigate the changes in the pure technical efficiency, scale efficiency and nature of returns to scale using the Data Envelopment Analysis (DEA) method. Overall, the results show that the pure efficiency of the Latin American seaports have improved over the period 2000 to 2008, with the Central American seaports showing the best performance in the region. The source of inefficiency in the Central and South America is the pure technical efficiency, while the source of inefficiency in the Caribbean region is the scale inefficiency. The majority of the Latin American seaports exhibit increasing returns to scale while only a few are operating at optimal returns to scale. Hence, seaports that operate at increasing returns to scale could achieve significant efficiency gains by increasing its scale of operations through expansion and building alliances.

Field of Research: Economics

Keywords: DEA, technical efficiency, returns to scale, Latin America, container seaport

1. Introduction

Today, globalization has tremendously increased the volume of international trade among all the nations and regions. Hence, transportation of seaborne freight, which is known as the lower cost transport mode, is vital to support the supply chain for connecting different locations to allow worldwide production and consumptions of goods. According to United Nations Conference on Trade and Development (UNCTAD), the world seaborne freight accounts for four fifths of all traded goods amounting to 8.4 billion tons in 2010 (UNCTAD, 2011). This reflects seaports' significant role in transporting goods.

Latin America, which is rich in natural resources, has established ties with China, the world economic powerhouse, to boost the opportunity of trading, and in tandem Latin American seaports have experienced a growth in their volume of throughputs in recent years. However, there is a widespread perception that ports in Latin American countries are inefficient and most ports perform below international standards. Kimes (2010) noted that while Brazil is one of the world's biggest commodities producers, yet it has one of the weakest port systems and inadequate infrastructure. The insufficient ports' infrastructure is a serious problem in operating the ports as the port costs, cost of services and delays are

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the main concerns for the traders. Hence, there is a need not only to modernize but also to improve the efficiency of Latin American seaports in order to enhance their competitiveness in the world.

A review of previous studies shows that the majority of the studies focused on container port or terminals efficiency in developed countries such as Europe, Asia and other regions by using labor, capital and land input variables. However, there is a dearth of studies on the container port efficiency assessment in the Latin American region. Hence, it is important to study the Latin American seaports as this region is undergoing development and it is worth to know the evolution of the container seaports efficiency in this particular region which has experienced significant reforms since the mid-1980s.

This study will provide valuable guidance to port operators and policy makers in this region as port efficiency is a relevant determinant of a country's competitiveness. Port efficiency can be influenced by public policies, and there are big differences in efficiency among Latin American ports.

Cross-country comparison of port efficiency in developing countries is relatively lacking in the literature and there hasn't been any intensive work being done on cross-country efficiency comparisons for seaports in the Latin American region. This study aims to benchmark the efficiency of the Latin American container seaports using the Data Envelopment Analysis (DEA) method and investigate the changes in the pure technical efficiency, scale efficiency and nature of returns to scale, over the period 2000 to 2008, of seaports across countries. The following section will mainly review the literature on port efficiency. Next, the Data Envelopment Analysis (DEA) framework will be discussed. The empirical results and the analysis will be presented and discussed in the fourth section. The final section summarizes and concludes the study.

2. Literature Review

In 1993, Roll and Hayuth were the first researchers to assess port efficiency using the non-parametric method called Data Envelopment Analysis (DEA). Despite their study being purely a theoretical exploration, it has paved the path for numerous researchers to explore port efficiency using the DEA method. Since then there is an abundance of port performance studies applying DEA – for example, Martinez Budria (1999), Tongzon (2001), Valentine and Gray (2001, 2002), Barros (2003, 2006) and Barros and Athanassiou (2004), Turner, Windle and Dresnor (2004), Park and De (2004), Min and Park (2005), Culliane (2004, 2005, 2006), Cullinane and Wang (2006), Rios and Macada (2006), So et al. (2007), Liu, Liu and Cheng (2008), Mithun and Song (2009), Hung, Lu and Wang (2010), Munisamy and Singh (2011). Cullinane and Wang (2006) discovered that by using different DEA models on evaluating a similar sample of ports, the ports were operating on various technologies - there was a mixture of increasing returns to scale, decreasing returns to scale and constant returns to scale (CRS) technology.

There is an abundance of literature that focused on benchmarking the seaport performance in advanced and emerging markets. For instance, Liu (1995) benchmarked 28 British seaports; and Tongzon (2001) studied the port efficiency of Australasia with 16 ports; while Martines-Budria (1999) assessed the 26 Spanish ports' efficiency followed by Coto, Baños and Podriguez (2000) also targeted the Spanish seaports economics efficiency with 27 ports. Valentine and Gray (2001, 2002) selected 21 ports worldwide and Cullinane et al. (2004), and Cullinane, Ji and Wang (2005) also benchmarked the 25 worldwide seaports for two consecutive years and increased the sample size to 50 seaports in 2006 later in Cullinane et al. (2006). Turner, Windle and Dresner evaluated 26 North American seaports whereas Park and De (2004), Min and Park (2005) had targeted Korea seaports; Park and De (2004) studies 11 ports while Min and Park (2005) evaluated 11 container terminal. Barros and Athanassiou (2004) studied 6 ports from Greece and Portugal; Wang and Cullinane (2006) targeted 104 terminals' efficiency in Pan European countries; Barros (2006) studied 24 Italian ports while Munisamy and Singh (2011) extensively studied the technical and scale efficiency of 69 major Asian container ports. However, the efficiency studies on Latin American seaports are very limited. Estache, Gonzalez and Trujillo (2001) studied 14 Mexican ports whereas Rios and Macada (2006) evaluated 23 terminals in Brazil, Argentina, and Uruguay only.

Most of the previous studies widely accepted container throughput measured in twenty equivalent units (TEUs) as the most paramount indicator for a seaport or terminal performance measurement (see for e.g. Martinez-Budria (1999), Cullinane et al. (2004, 2005, 2006), Turner, Windle and Dresnor (2004), Cullinane and Wang (2006), Min and Park (2005)). Therefore, it is appropriate to use container throughputs to benchmark port efficiency because it is closely related to the need of cargo-related facilities and services.

Dowd and Leschine (1990) pointed out that the productivity of the container terminals relies upon the efficient use of the labor, land and equipment. There were many ways of defining labor input, for example, Martinez-Budria et al. (1999) utilized labour expenditures while Tongzon (2001) and Gonzalez and Trujillo (2008) used the number of port authority employees to represent labor input in their respective studies. Barros (2003) and Barros and Athanassiou (2004) collected the number of workers as labor inputs and Min and Park (2005) opted for labour force size. Marconsult (1994) pointed out that there is a fixed relationship between the number of cranes deployed and the labor factor input employed in production. Therefore, Tongzon and Wu (2005) adopted his idea by using the number of quay crane to indicate the labor resources. In terms of land input, the most common criteria for this are the container berth length and total terminal area. Cullinane et al. (2004), Cullinane, Ji and Wang (2005) defined the land input by using the total quay length and terminal area whereas Tongzon (2001) and Rios and Macada (2006) used the number of berth to indicate the land input. Wang, Cullinane and Song (2005) justified that total berth length are most suitable compared to counting the number of berths. This is because the quay within a port or terminal can be reconfigured and restructured in order to meet the market requirements.

From the review of the literature, studies on the performance of ports has typically centered on the advanced and the emerging markets. Hardly any studies focused on port efficiency across developing markets in the Latin American region. This study is an attempt to fill the gap by carrying out a cross country analysis of seaport efficiency in the Latin American region which consists of Central America, South America and the Caribbean.

3. Methodology

Farrell (1957) was the first to introduce the methodology of making evaluations by realizing deviations from an idealized production frontier using a single input and a single output. He defined efficiency as the ratio of output to input. Subsequently, Farrell and Fieldhouse (1962) constructed a measurement of multiple inputs and multiple outputs by using a hypothetical efficient unit as a weighted average of efficient units.

However, realizing the difficulty of getting a common set of weights to determine the relative efficiency, Charnes, Cooper and Rhodes (1978) proposed the DEA-CCR model and afterward it was further extended by Banker, Charnes and Cooper (1984) who introduced the DEA-BCC model. The difference between DEA-CCR model and DEA-BCC model is that the former is based on constant returns to scale technology while the latter relies on the variable returns to scale technology. Hence, these two models became the primary non-parametric linear programming models for efficiency assessment.

3.1 The Charnes, Cooper and Rhodes (CCR) Model

The basic idea of DEA-CCR model was initially proposed by Charnes, Cooper and Rhodes in 1978. In order to assess the decision making unit (DMU) efficiency, a virtual output and input is formed by unknown weights, $\mathcal{A}_n$and $\mathcal{B}_n$ attached to each output and input, respectively. The efficiency of the unit is provided by the ratio of a weighted sum of its outputs to a weighted sum of inputs as below:

$$\text{Efficiency} = \frac{\text{Virtual output}}{\text{Virtual input}} = \frac{\sum_{n=1}^{N} \mathcal{B}_n \mathcal{X}_n}{\sum_{m=1}^{M} \mathcal{A}_m \mathcal{Y}_m}$$

where $\mathcal{Y}$ is the output and $\mathcal{X}$ is the input of the DMU.

The linear programming equations below explain the output oriented DEA-CCR model where U_k is the *technical efficiency* score of the *k*-th DMU.

Minimize

$$U_k = \sum_{n=1}^{N} \mathcal{B}_n \mathcal{X}_{nk} \tag{3.1}$$

Subject to:

$$\sum_{m=1}^{M} \mathcal{A}_m \mathcal{Y}_{mk} = 1 \tag{3.2}$$

$$\sum_{m=1}^{M} \mathcal{A}_m \mathcal{Y}_{mk} - \sum_{n=1}^{N} \mathcal{B}_n \mathcal{X}_{nk} \leq 0 \quad (k = 1,2,3 \dots K) \tag{3.3}$$

$$\mathcal{A}_m \geq 0 \ \ (n = 1,2,3, \dots, M) \tag{3.4}$$

$$\mathcal{B}_n \geq 0 \ \ (m = 1,2,3, \dots, N) \tag{3.5}$$

From the formula above, one could assume that there are M outputs and N inputs for each of K units. For the *k*-th DMU that uses the N inputs is designated as $\boldsymbol{\mathcal{X}_{nk}}$ where n = 1, 2, 3…N. Similarly, for the *k*-th DMU that produce M outputs is designated as $\boldsymbol{\mathcal{Y}_{mk}}$ where m =

1, 2, 3…M. The DMU is considered an efficient unit if it achieves the efficiency score of 1 otherwise it will be considered as inefficient if its score is larger than 1.

The above model basically assumes the constant returns to scale technology whereby the increase of the inputs leads to a proportional increase of the outputs. Hence, it produces a linear relationship between inputs and outputs.

3.2 The Banker, Charnes and Cooper (BCC) Model

Since the nature of production does not always conform to the constant returns to scale (CRS) technology, Banker, Charnes and Cooper (1984) proposed another model which provides the ability of the variable returns to scale. Under the assumption of variable returns to scale, the linear programing model with output orientation is as follows:

Minimize

$$U_k = \sum_{n=1}^{N} \mathcal{B}_n \mathcal{X}_{nk} - \mathcal{C}_n \quad (3.6)$$

Subject to:

$$\sum_{m=1}^{M} \mathcal{A}_m \mathcal{Y}_{mk} = 1 \quad (3.7)$$

$$\sum_{m=1}^{M} \mathcal{A}_m \mathcal{Y}_{mk} - \sum_{n=1}^{N} \mathcal{B}_n \mathcal{X}_{nk} - \mathcal{C}_n \leq 0 \quad (k = 1,2,3 \ldots K) \quad (3.8)$$

$$\mathcal{A}_m \geq 0 \ \ (n = 1,2,3, \ldots, M) \quad (3.9)$$

$$\mathcal{B}_n \geq 0 \ \ (m = 1,2,3, \ldots, N) \quad (3.10)$$

The output oriented DEA-BCC model above differs from the DEA-CCR model only in that it includes a unit specific constant, $\mathcal{C}_m$, which prohibits extrapolation of scale of operation and allows for the variable returns to scale for production efficiency. U_k is termed the *pure technical efficiency* of DMU k, because is 'net' of any scale effects.

3.3 Returns to Scale

A DMU is said to operate at constant returns to scale (CRS) when there is a proportional increase or decrease of the output to input resources. If the DMU increase by less than proportional change, then it is deemed as operating at decreasing returns to scale (DRS). On the other hand, if the DMU increase by more than the proportional change, then it operates at the increasing returns to scale (IRS). Both of the DRS and IRS fall under the variable returns to scale (VRS).

Banker, Charnes and Cooper (1984) show that the efficiency score generated by the DEA-CCR model is a composite total efficiency score that can be broken up into two components: scale efficiency and pure technical efficiency. The DEA-BCC model generates the pure technical efficiency. Dividing the CCR score with the BBC score generates a measure of scale efficiency for each DMU as follows:

$$SE_k = \frac{U_{k\,CRS}}{U_{k\,VRS}}$$

whereby SE = 1 indicates scale efficiency and SE greater than 1 implies scale inefficiency, using the output orientated DEA model. A DMU is considered as scale inefficient if it is operating at increasing returns to scale or decreasing returns to scale. To determine whether a firm is at increasing returns to scale or decreasing returns to scale, one must calculate its non-increasing returns to scale (NIRS) DEA model. If the score of NIRS is equivalent to DEA-BCC score, then it implies that the DMU is operating at decreasing scale. If the score of NIRS varies from DEA-BCC score, then the DMU is operating at increasing returns to scale (Coelli et al., 1998).

3.4 Variable Selection and Sample

The container throughput in twenty foot equivalent units (TEU) is the most common and appropriate indicator in determining the port's production efficiency and is popularly used in the previous efficiency comparison studies as the sole output of port production. It is strongly related to the need for cargo-related facilities and services. This study uses container throughput as the single output.

In production theory, vital inputs are labor, land and equipment. Almost all previous studies, took into account the total berth length and the total terminal area as land input. However, only container berth and multipurpose berth will be taken into consideration in this study. Due to the difficulty in collecting data on labor, a labor proxy variable will be derived based on the suggestion of Notteboom et al. (2000) that highlights the close relationship between the number of gantry cranes and the number of dock workers in a container terminal. Thus, this study uses yard and quay equipment to proxy labor.

Table 1 provides a summary of the input and output variables definitions which will be used in the DEA-CCR and DEA-BCC models in the empirical part of this study. All the variables used in this study have been aggregated from each terminal to port level by summing up the quantity of the equipment from each terminal for a particular port.

Table 1: Definition of Output and Input Variables for DEA models

Variable	Description
Output	
Throughput	Total container seaport throughput (TEU)
Inputs	
Berth	Total berth length (m)
Terminal_Area	Total terminal area (m^2)
Quay_Equip	Total number of quayside cranes, mobile cranes, quay gantry, mobile gantry and the ship shore container gantry
Yard_Gantry	Total number of yard gantries
Soph_Yard_Equip	Total number of reach stackers, straddle carriers
Gen_Yard_Equip	Total number of forklifts and yard tractors

This study considers the container seaports in Latin American region for performance benchmarking. Latin American region consists of Central America, South America and the Caribbean. Data on container seaports from these regions are collected primarily based on the International Containerization Year Book for a period of 8 years spanning from 2000 to 2008. The total number of seaports analyzed in this study is 30. The ports are selected based on the available information within the observed time period, i.e. 2000 to 2008. By excluding all the seaports which have incomplete information or missing values and unrelated type of seaports such as general cargo ports, bulk cargo ports, RO-RO ports; a total of 8 container seaports were selected from Caribbean, 9 container seaports from Central America, and 13 ports were selected from South America for each year. The ports are located in 20 countries i.e. Bahamas, Barbados, Dominican Republic, Jamaica, Netherlands Antilles, Puerto Rico, St. Lucia, Trinidad &Tobago, Costa Rica, Guatemala, Honduras, Mexico, Argentina, Brazil, Chile, Ecuador, Uruguay and Venezuela (see Appendix 4 for the list of ports studied).

4. Results

4.1 Descriptive Statistics

Table 3 displays the descriptive statistics for the input and output variables used to calculate the efficiency scores. On average, all the input and output variables are showing an upward trend from 2000 to 2008. This indicates that container seaports in Latin America are developing and expanding within the observed periods. Besides, the enhancement and development of the ports' capacity have improved the total container throughputs.

4.2 DEA Results

The result of the technical and scale efficiency within the observed period, from year 2000 to 2008, of each container seaport in Latin America is presented in the Appendix Table 4. The DEA CRS scores indicate the overall technical efficiency and can be decomposed into pure technical efficiency (represented by the VRS score) and scale efficiency (SE). The efficiency score of 1 signifies the best efficient frontier while values of efficiency score greater than 1 indicates inefficient performance of the port. The port of Puerto Limon in

Central America, Cartagena and La Guairá in South America and San Juan in Caribbean have achieved the best overall technical efficiency (DEA-CCR score) of 1.0 across 9 years of the observed periods, 2000 to 2008, and are considered the most efficient ports in the Latin American region. It can be seen that most of the ports that perform poorly are found to be located in the Caribbean region. The weakest port in 2008 was port Castries which suffered mainly from scale inefficiency. It is worth noting that the results of this study are different from the previous studies as this study carries out a cross country analysis on a greater number of ports from twenty countries in the Latin American region.

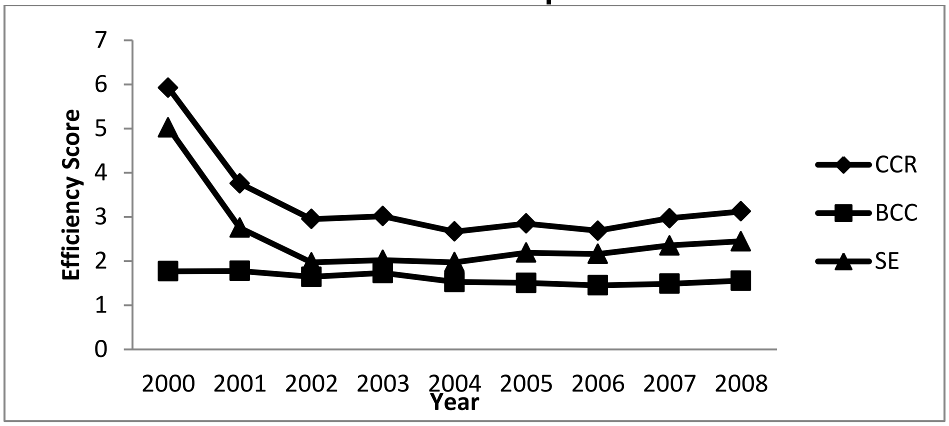
Figure 1 displays the trend in the CRS, VRS and SE scores over the period of analysis using the sample average results. The figure depicts sharp improvements in overall technical and scale efficiency at the initial period, between 2000 and 2002, and subsequently efficiency levels remained stable for the next four years before a slight deterioration towards the end of the period. In contrast, the pure technical efficiency of the seaports shows an improvement, albeit slight, and was at the highest level (close to 1). The trend shows that, in general, Latin America container seaports suffer more from scale inefficiency than the technical inefficiency. Overall, the Latin American container seaports do not perform well in terms of scalability.

Next, we review the regional trend in overall technical efficiency (Figure 2), pure technical efficiency (Figure 3) and scale efficiency (Figure 4) over the period. Overall, the results show that the pure technical efficiency of the Latin American seaports have improved over the period 2000 to 2008, with the Central American seaports showing the best performance in the region (see Figure 3). The source of inefficiency in the Central and South America is the pure technical efficiency, while the source of inefficiency in the Caribbean region is the scale inefficiency (see Figure 4). In fact, the scale efficiency of Caribbean seaports has generally deteriorated over the period of the study.

Table 3 : Descriptive Statistics for Input-Output Variables, Latin America Container Seaports, 2000 - 2008

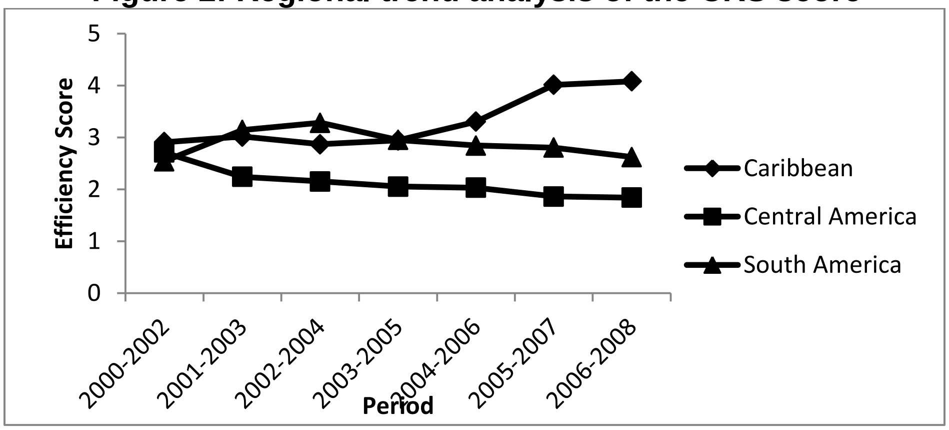
		Year								
		2000	2001	2002	2003	2004	2005	2006	2007	2008
Berth Length	N	30	30	30	30	30	30	30	30	30
(m)	Minimum	152	152	152	152	152	238	238	238	238
	Maximum	2690	4319	4324	4324	4439	4642	4577	4577	4577
	Mean	**845.87**	**974.03**	**1024.43**	**1094.73**	**1168.03**	**1213.00**	**1247.67**	**1240.57**	**1285.17**
	SD	698.423	927.912	971.643	953.859	995.439	1021.329	997.634	1002.827	1064.649
Terminal Area	Minimum	10,000	10,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
(m^2)	Maximum	950,000	1,240,000	1,240,000	1,240,000	1,270,500	1,270,500	1,270,500	1,270,500	1,280,000
	Mean	**213,101.83**	**240,388.17**	**295,448.17**	**317,014.83**	**337,146.67**	**346,613.37**	**348,980.03**	**353,342.03**	**393,942.03**
	SD	242,340.27	292,705.24	294,393.14	290,964.68	308,835.15	309,857.39	310,905.93	306,840.95	355,278.50
No of Quay	Minimum	1	1	1	1	1	1	1	1	1
Equipment	Maximum	37	37	38	38	38	38	38	38	38
	Mean	**6.37**	**6.77**	**7.03**	**7.20**	**8.00**	**8.37**	**8.63**	**8.87**	**8.90**
	SD	7.609	8.080	8.143	8.075	8.052	8.152	8.369	8.435	8.531
No of Yard Gantry	Minimum	0	0	0	0	0	0	0	0	0
	Maximum	36	42	42	42	42	43	144	144	144
	Mean	**4.07**	**4.63**	**5.00**	**5.33**	**5.90**	**6.07**	**9.77**	**10.00**	**10.00**
	SD	8.944	10.659	10.625	10.659	10.993	10.935	27.233	27.202	27.202
No of General Equipment										
	Minimum	0	0	0	0	0	0	0	0	0
	Maximum	177	177	177	177	177	181	181	181	181
	Mean	**31.87**	**33.97**	**39.57**	**44.60**	**47.77**	**55.87**	**60.20**	**59.90**	**58.73**
	SD	41.873	43.806	42.992	43.225	44.925	52.631	55.342	55.568	54.960
No of Sophisticated Equipment										
	Minimum	0	0	0	0	0	0	0	0	0
	Maximum	187	187	194	191	191	191	194	194	194
	Mean	**20.33**	**21.57**	**23.13**	**24.23**	**25.43**	**25.90**	**26.23**	**26.53**	**28.23**
	SD	37.157	37.418	39.013	38.510	38.785	38.830	38.867	39.410	40.935
Total Container Throughputs (TEU)										
	Minimum	3,721	13,550	23,003	22,792	24,956	29,647	29,955	33,492	35,950
	Maximum	1,884,494	1,830,125	1,393,627	1,665,765	1,667,868	1,727,389	2,150,408	2,016,792	2,167,700
	Mean	**393,336.80**	**400,824.17**	**404,424.17**	**468,830.17**	**537,248.53**	**575,593.67**	**649,439.76**	**705,433.90**	**731,622.30**
	SD	406,356.90	372,489.79	328,095.66	403,803.45	437,822.36	496,438.42	566,268.71	599,521.47	638,622.44

Figure1: Trend analysis of the CRS, VRS, and SE scores in Latin America Container Seaports



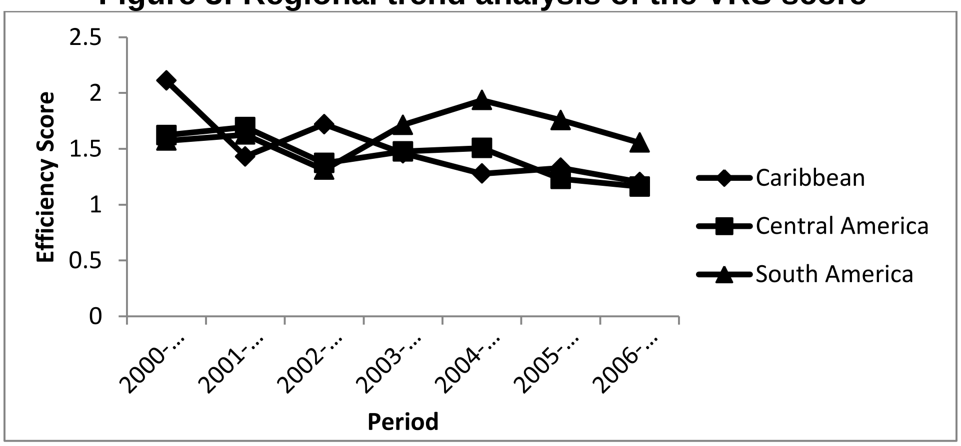
Note: lower scores represent increased efficiency

Figure 2: Regional trend analysis of the CRS score



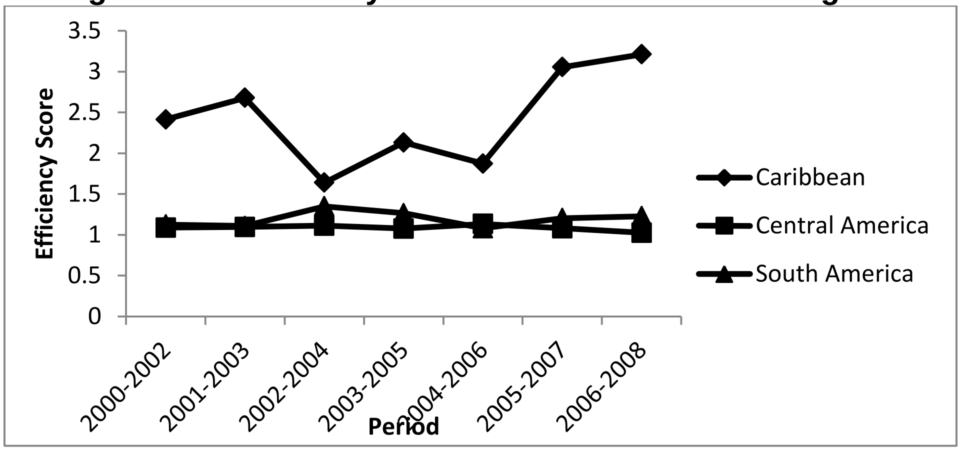
Note: lower scores represent increased efficiency

Figure 3: Regional trend analysis of the VRS score



Note: lower scores represent increased efficiency

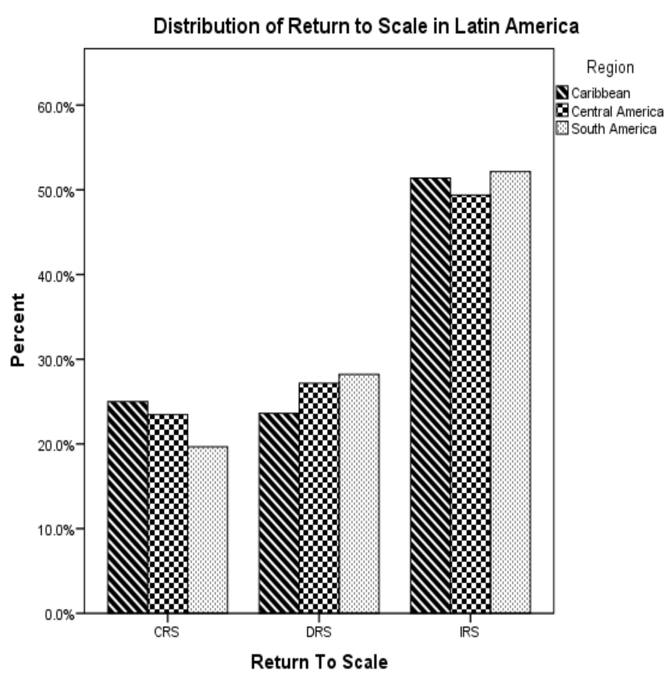
Figure 4: Trend analysis of the SE score across regions



Note: lower scores represent increased efficiency

Figure 5 depicts that more than 50% of the container seaports in each of the three regions in Latin America exhibit increasing return to scale (IRS), close to 30% operate under decreasing returns to scale, whereas only a few of the container seaports achieved constant return to scale (CRS). Hence, the port authorities should look into their management practices. For the container seaports with increasing return to scale, they should allocate more budgets on expanding the input capacity in order to increase the productivity and for those that suffer from decreasing return to scale, they may need to outsource part of the operation in order to operate at the optimum scale.

Figure 5: Distribution of Returns to Scale in Latin America Container Seaports



5. Summary and Conclusion

This study conducts a cross country analysis of Latin American seaports and analyses the changes in the seaport's pure technical efficiency, scale efficiency and nature of returns to scale, over the period 2000 to 2008, using the linear programming Data Envelopment Analysis (DEA) method. The results of this study are different from the previous studies as this study carries out a cross country analysis of ports from twenty countries in the Latin American region.

The DEA analysis shows that, overall the average technical, pure technical and scale efficiency levels have all improved over the period 2000 to 2008, with a significant improvement especially in the average technical and scale efficiency. The container seaports in Central America were the best performers as they achieved the best score in terms of overall efficiency. On the other hand, the Caribbean ports generally did not perform well, more because of its scale inefficiency rather than its technical inefficiency. Ports in the Caribbean region must focus on improving their scale efficiency first before moving on to pure technical efficiency. The findings reveal that the majority of the seaports in Latin America are operating under variable returns to scale (VRS) and very few are operating optimally under constant returns to scale (CRS). This means that the port authorities should take the scalability into consideration when expanding or enhancing port facilities and resources. Hence, seaports that operate at increasing returns to scale could achieve significant efficiency gains by increasing its scale of operations. These ports should increase its scale of operations via expansion though input capacity growth and building alliances with other ports and shipping organizations. For the container seaports that suffer from decreasing return to scale, they may need to outsource part of the operation in order to operate at the optimum scale.

This study is critical as it can provide insights and can help the management to make better decision on operating a seaport to enhance its efficiency, performance and competitiveness. An efficient seaport may escalate the economic activities and boost the country's GDP as the seaport has the potential to become a hub port in that particular region.

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Appendix

Table 4: DEA Efficiency Results of Latin America Container Seaports, Central America

Central America		2000	2001	2002	2003	2004	2005	2006	2007	2008
Altamira	CRS	1.0000	6.0273	4.2057	6.3090	3.2044	3.2812	3.1029	3.0555	5.7033
	VRS	1.0000	5.8297	3.9600	5.0980	3.1612	3.2323	3.0834	2.9131	5.5842
	SE	1.0000	1.0339	1.0620	1.2375	1.0137	1.0151	1.0063	1.0489	1.0213
	RTS	CRS	IRS	IRS	DRS	IRS	IRS	IRS	IRS	IRS
Balboa	CRS	6.0847	1.0574	2.2984	2.0978	1.0000	1.0000	1.0986	1.0000	1.0000
	VRS	1.0000	1.0000	1.8294	1.6933	1.0000	1.0000	1.0737	1.0000	1.0000
	SE	6.0847	1.0574	1.2564	1.2389	1.0000	1.0000	1.0232	1.0000	1.0000
	RTS	IRS	IRS	DRS	DRS	CRS	CRS	IRS	CRS	CRS
Ensenada	CRS	13.2854	13.4867	5.7752	7.2989	7.6503	4.3612	2.5842	2.8590	4.5554
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	13.2854	13.4867	5.7752	7.2989	7.6503	4.3612	2.5842	2.8590	4.5554
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Manzanillo	CRS	1.0000	1.0000	1.0000	1.0000	2.1978	2.2344	1.4599	1.2310	1.2231
	VRS	1.0000	1.0000	1.0000	1.0000	2.0076	1.9765	1.4410	1.2026	1.1951
	SE	1.0000	1.0000	1.0000	1.0000	1.0947	1.1305	1.0131	1.0236	1.0234
	RTS	CRS	CRS	CRS	CRS	DRS	DRS	DRS	DRS	DRS
Puerto Cortes	CRS	2.6669	2.6998	2.0000	2.0998	1.8966	1.9780	1.9164	1.7124	1.6498
	VRS	2.3270	2.4319	1.0000	1.0000	1.8129	1.7934	1.4422	1.3557	1.3086
	SE	1.1461	1.1102	2.0000	2.0998	1.0462	1.1029	1.3288	1.2631	1.2607
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Puerto Limon	CRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	RTS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS
Puerto Manzanillo	CRS	1.6849	1.9100	1.9714	1.8030	1.0443	1.1197	1.4385	2.4248	2.2927
	VRS	1.4265	1.6608	1.3396	1.3206	1.0000	1.0000	1.3367	1.4728	1.3548
	SE	1.1811	1.1500	1.4716	1.3653	1.0443	1.1197	1.0762	1.6464	1.6923
	RTS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS
Santo Tomas De Castilla	CRS	6.7410	5.1624	3.4815	2.9891	2.2877	3.0146	3.1152	2.6557	2.6371
	VRS	5.8118	5.1029	3.4510	2.8003	2.1436	2.5317	2.4942	2.1660	2.1309
	SE	1.1599	1.0117	1.0088	1.0674	1.0672	1.1907	1.2490	1.2261	1.2376
	RTS	DRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Veracruz	CRS	1.0747	1.5585	2.0068	2.1471	1.0042	1.1901	1.0000	1.3204	1.5800
	VRS	1.0000	1.2997	1.4133	1.5403	1.0000	1.1432	1.0000	1.1261	1.3434
	SE	1.0747	1.1991	1.4199	1.3939	1.0042	1.0410	1.0000	1.1725	1.1761
	RTS	DRS	DRS	DRS	DRS	IRS	IRS	CRS	IRS	IRS

Table 4 (cont.): DEA Efficiency Results of Latin America Container Seaports, South America

South America		2000	2001	2002	2003	2004	2005	2006	2007	2008
Antofagasta	**CRS**	4.7407	4.8851	2.1455	1.8625	5.0459	5.3531	4.2760	3.6408	3.5587
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	4.7407	4.8851	2.1455	1.8625	5.0459	5.3531	4.2760	3.6408	3.5587
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Barranquilla	**CRS**	4.1850	5.3002	2.5808	3.7831	1.0000	3.5322	3.0476	2.9685	3.9910
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	4.1850	5.3002	2.5808	3.7831	1.0000	3.5322	3.0476	2.9685	3.9910
	RTS	IRS	IRS	IRS	IRS	CRS	IRS	IRS	IRS	IRS
Buenos Aires	**CRS**	3.4619	8.9285	13.1521	6.0670	4.2367	4.1674	3.2551	3.8007	4.0108
	VRS	1.6726	2.8144	2.8868	1.4784	1.4650	1.2609	1.3057	1.1702	1.2171
	SE	2.0698	3.1724	4.5559	4.1038	2.8919	3.3051	2.4930	3.2479	3.2954
	RTS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS
Cartagena	**CRS**	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	RTS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS
Guayaquil	**CRS**	1.5120	1.4681	1.5607	1.7324	1.1788	1.1505	1.1108	1.1931	1.4357
	VRS	1.1341	1.1627	1.5455	1.6806	1.0000	1.0000	1.0000	1.0000	1.1399
	SE	1.3332	1.2627	1.0098	1.0308	1.1788	1.1505	1.1108	1.1931	1.2595
	RTS	IRS	IRS	DRS	IRS	IRS	IRS	IRS	IRS	IRS
La Guaira	**CRS**	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	RTS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS
Montevideo	**CRS**	2.6513	2.1783	1.7909	1.8394	1.5978	1.5446	1.5326	1.3146	1.2388
	VRS	2.6214	1.9908	1.0442	1.0000	1.4474	1.1979	1.0805	1.1334	1.0843
	SE	1.0114	1.0942	1.7151	1.8394	1.1039	1.2894	1.4184	1.1599	1.1425
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Paranagua	**CRS**	1.0337	1.0000	3.6088	4.6228	2.6663	2.9095	2.3071	2.3272	2.4265
	VRS	1.0000	1.0000	2.8939	3.1212	2.3288	2.1914	2.1406	2.1830	2.3965
	SE	1.0337	1.0000	1.2470	1.4811	1.1449	1.3277	1.0778	1.0661	1.0125
	RTS	IRS	CRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS
Puerto Cabello	**CRS**	1.0000	1.0000	2.5199	4.4139	3.2704	2.8766	2.7387	3.1467	3.2682
	VRS	1.0000	1.0000	1.7828	3.3860	2.1865	1.8439	1.6949	1.8106	1.9371
	SE	1.0000	1.0000	1.4135	1.3036	1.4957	1.5601	1.6158	1.7379	1.6872
	RTS	CRS	CRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS

Rio Grande	**CRS**	2.4462	2.0871	3.1305	3.0363	2.8309	2.6090	2.6005	2.9292	2.0081
	VRS	2.0415	1.7321	3.0644	3.0054	2.6997	2.5587	2.5311	2.7914	1.9510
	SE	1.1982	1.2050	1.0216	1.0103	1.0486	1.0197	1.0274	1.0494	1.0293
	RTS	IRS	IRS	DRS	DRS	DRS	DRS	DRS	DRS	IRS
Salvador	**CRS**	2.9399	2.5001	1.6502	1.4617	1.3233	1.2643	1.2358	1.2728	1.1381
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	2.9399	2.5001	1.6502	1.4617	1.3233	1.2643	1.2358	1.2728	1.1381
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
San Antonio	**CRS**	1.1003	1.1583	1.0000	2.3558	1.7931	1.7491	2.1239	2.3219	2.2900
	VRS	1.0000	1.0000	1.0000	2.2629	1.7375	1.6995	2.1193	2.2939	2.2605
	SE	1.1003	1.1583	1.0000	1.0411	1.0320	1.0292	1.0022	1.0122	1.0131
	RTS	IRS	IRS	CRS	DRS	IRS	DRS	DRS	IRS	IRS
Zarate	**CRS**	73.8070	19.6836	7.7057	4.6719	6.6001	9.3015	10.0993	8.3875	7.1727
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	73.8070	19.6836	7.7057	4.6719	6.6001	9.3015	10.0993	8.3875	7.1727
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS

Table 4 (cont.): DEA Efficiency Results of Latin America Container Seaports, Caribbean

Caribbean		2000	2001	2002	2003	2004	2005	2006	2007	2008
Rio Haina	CRS	1.0000	1.0000	1.0000	1.4209	1.9858	3.2634	3.4165	3.5398	3.0883
	VRS	1.0000	1.0000	1.0000	1.0000	1.1097	2.1480	2.2466	2.4319	2.1074
	SE	1.0000	1.0000	1.0000	1.4209	1.7895	1.5193	1.5207	1.4556	1.4655
	RTS	CRS	CRS	CRS	IRS	IRS	IRS	IRS	IRS	IRS
San Juan	CRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	VRS	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	RTS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS	CRS
Willemstad	CRS	10.0438	7.0692	5.4376	6.3006	6.2882	5.9422	6.2257	5.5759	5.3342
	VRS	9.3816	6.1681	3.9950	3.2225	2.8764	1.9471	1.0000	1.4730	1.4005
	SE	1.0706	1.1461	1.3611	1.9552	2.1861	3.0518	6.2257	3.7854	3.8088
	RTS	DRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Bridgetow n	CRS	5.2830	3.6989	2.9792	3.3495	3.0752	4.4966	4.3359	6.0857	6.9020
	VRS	3.5665	1.8896	1.5240	1.4203	1.5454	1.0000	1.0000	1.0000	1.0000
	SE	1.4813	1.9575	1.9549	2.3583	1.9899	4.4966	4.3359	6.0857	6.9020
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS
Castries	CRS	19.3665	7.5849	5.9245	6.9907	6.5198	6.3979	6.2440	13.3090	13.3977
	VRS	1.4265	1.6608	1.3396	1.3206	1.0000	1.0000	1.3367	1.4728	1.3548
	SE	13.5762	4.5670	4.4225	5.2935	6.5198	6.3979	4.6712	9.0365	9.8890
	RTS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS	DRS
Freeport	CRS	1.0000	1.0000	1.0000	1.0981	1.0065	1.0158	1.0000	1.0000	1.0000
	VRS	1.0000	1.2997	1.4133	1.5403	1.0000	1.1781	1.0000	1.1883	1.4198
	SE	1.0000	.7694	.7075	.7129	1.0065	.8622	1.0000	.8415	.7043
	RTS	CRS	DRS	DRS	DRS	IRS	IRS	CRS	IRS	IRS
Kingston	CRS	2.0522	2.8866	2.1211	2.3425	2.2842	2.1471	1.7999	1.8859	2.5306
	VRS	1.0000	10.4968	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	SE	2.0522	.2749	2.1211	2.3425	2.2842	2.1471	1.7999	1.8859	2.5306
	RTS	DRS	DRS	IRS	IRS	DRS	IRS	IRS	IRS	IRS
Port of Spain	CRS	2.6117	2.4057	2.4790	3.3222	2.9760	3.5049	3.4783	4.1090	4.2311
	VRS	2.6323	2.0576	1.4416	1.4720	1.5380	1.4796	1.4525	1.2506	1.1963
	SE	.9921	1.1691	1.7196	2.2569	1.9349	2.3688	2.3946	3.2856	3.5368
	RTS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS	IRS

CRS: constant return to scale using DEA-CCR model
VRS: variable returns to scale using DEA-BCC model
SE: Scale Efficiency
RTS: Returns to Scale
RTS: Returns to Scale