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MEASURING AND DECOMPOSING TOTAL FACTOR PRODUCTIVITY OF VIETNAMESE SEAPORTS

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Abstract: In this paper the total factor productivity of Vietnamese seaports is measured and decomposed into three main components, namely technical, scale and mix efficiency. The analysis results using the data of 40 seaports show that the seaport sector is underperformed, while seaports in the northern region are the most efficient group on any measures of efficiency, southern ports are the least efficient group if scale efficiency is utilised. It has also been found that container ports outperform non-container ports, and those belonging to logistics companies are overall more efficient than their partners operated by the local governments.

1 Introduction

Over the last three decades, the world has seen accelerating economic growth of emerging economies and their significant and active contribution to the global economy through international trade [1-3]. It is well known that more than 90 percent of international trade is carried by ships through ports. Being an emerging economy, Vietnam increasingly depends on maritime transportation and its seaport sector plays a pivotal role in connecting the country’s hinterland and sea [4]. However, Vietnamese seaports appear to be less competitive compared with other countries in ASEAN (the Association of Southeast Asian Nations) [5]. In terms of financial cost, port charges in Vietnam are 16% more than those in Shanghai, Ningbo, or Shenzhen (China), and 28% more than those in Hong Kong [6]. These raise concerns about the competitiveness of the seaport sector in particular and the country’s trade competitiveness in a broader sense. Accordingly, finding the causes behind the underperformance of Vietnamese seaports will be useful for relevant authorities.

There are numerous studies on seaport efficiency [7-9]. Most studies mainly focus on technical efficiency as a measure of seaport performance. However they do not provide comprehensive information on efficiency [10-12] with De [13] being one of a few exceptions; the only measure is overall technical efficiency without further information on how it is attributed to different types of efficiency. In fact, this issue is related to the total factor productivity (TFP) concept [14]; generally TFP comprises three main sources, namely technical efficiency, scale efficiency, and mix efficiency.

O’Donnell [12] (p. 873) noted on the decomposition of TFP in productivity and efficiency evaluate at both micro (firm and sectoral) and macro (national) levels:

“Several estimates of technical change and efficiency change are available e.g. [15,16] but they are not coherent in the sense that they do not combine to yield recognizable productivity indexes. And while several researchers have decomposed well-known productivity indexes into various components [17], not all of these components have unambiguous interpretations as measures of technical change or efficiency change.”

This implies that the incoherent knowledge of TFP components can be misleading to seaport management and policy makers, who face the challenge of finding the best approach to improve productivity.

Against this background, the current study seeks to extend the analysis of Vietnamese seaport efficiency to decompose it into technical efficiency, scale efficiency and mix efficiency, and based on this, proposes recommendations for management and policy makers. To this end, O’Donnell [12] approach is adopted to measure overall productive efficiency (to be further explained below) based on aggregating inputs and outputs. This approach has been chosen as it is less restrictive requiring no assumption on market structure, competition and production, i.e. constant versus variable returns to scale, and single versus multiple input, output cases. (For more detail about the literature on seaport efficiency analysis, see for example [18-20]).

Following the introduction section, Section 2 presents the methodology to estimate and analyse TFP and its components. Section 3 describes the data set and variables.

Section 4 presents the analysis results, and Section 5 provides the concluding remarks.

2 Methodology

2.1 Total factor productivity

The productivity of a one-output, one-input firm can intuitively be defined as the output-input ratio. This concept is generalized by O'Donnell [11] by defining the total factor productivity of a firm to be the ratio of an aggregate output to an aggregate input. Let $\boldsymbol{x}_{it} = (x_{it1}, x_{it2}, \dots, x_{itK})'$and $\boldsymbol{q}_{it} = (q_{it1}, q_{it2}, \dots, q_{itJ})'$ denote the input and output vectors of firm i $(i = 1, 2, \dots, n)$ in period t. Then the TFP of the firm can be defined as:

$$TFP_{it} = \frac{Q_{it}}{X_{it}}, \quad (1)$$

where $Q_{it} = Q(q_{it})$ is a scalar 'aggregate' output, $X_{it} = X(q_{it})$ is a scalar 'aggregate input', and $Q(.)$ and $X(.)$ are "aggregator" functions, which are assumed to be non-negative, non-decreasing and linearly homogenous.

As shown in O'Donnell [11], the aggregator function may take various forms depending on its parameters which can be vectors of input and output prices, vectors of representative prices and quantities, and Shephard [21] output/input distance functions. In this paper, Shephard's output and input distance functions, denoted as D_o and D_I respectively, are used as the output and input aggregator functions:

$$Q(.) = D_o(x_{it}, q) = min\left\{\delta > 0: \left(\boldsymbol{x}_{it}, \frac{q}{\delta}\right) \in P\right\}, \quad \text{(2-a)}$$
$$X(.) = D_I(x, q_{it}) = max\left\{\rho > 0: \left(\frac{x}{\rho}, \boldsymbol{q}_{it}\right) \in P\right\}, \quad \text{(2-b)}$$

where P is the production possibility set of the t period.

The distance functions can be estimated using the Data Envelopment Analysis (DEA) models developed by O'Donnell [12].

2.2 Measures of efficiency

The so called "total factor productivity efficiency" (TFPE) or overall productive efficiency of firm i for period t is defined as:

$$TFPE_{it} = \frac{TFP_{it}}{TFP^*} \leq 1, \quad (3)$$

where TFP^* is the maximum TFP that is possible using the technology available in period t.

The output-oriented overall productive efficiency can be decomposed into three main components:

$$TFPE_{it} = OTE_{it} \times OSE_{it} \times RME_{it}, \quad (4)$$

where:

- *output-oriented technical efficiency (OTE)* measures the difference between observed TFP and the maximum TFP that is possible while holding the input-output mix and input level fixed;
- *output-oriented scale efficiency (OSE)* measures the difference between TFP at the technically efficient point and TFP at the technically scale efficient point; and
- *residual mix efficiency (RME)* measures the difference between the maximum TFP subject to the fixed output-input mix and the optimal output-input mix.

Figure 1 illustrates the relationship between measures of efficiency. The curve passing through point D is referred as a mix-restricted frontier – it is the boundary of the set of all technically-feasible aggregate input-output combinations that have the same input-output mix as the firm operating at the point A. The curve passing through point E is an unrestricted production frontier – it is the upper boundary of the production possibility with variable input-output mix. O'Donnell [11] shows how different measures of efficiency of firm *i* for period *t* (point A in Figure 1) can be expressed in terms of slopes of rays in aggregate quantity space. Its TFP is $TFP_{it} = \frac{Q_{it}}{X_{it}} = slope(OA)$; the optimum TFP efficiency is defined as $TFP^* = \frac{Q_t^*}{X_t^*} = slope(OE)$; the TFP efficiency defined by equation (3) is $TFPE_{it} = \frac{slope(OA)}{slope(OE)}$; the output-oriented technical efficiency is $OTE_{it} = \frac{slope(OA)}{slope(OC)} = \frac{\frac{Q_{it}}{X_{it}}}{\frac{\bar{Q}_{it}}{X_{it}}} = \frac{Q_{it}}{\bar{Q}_{it}}$; the output-oriented scale efficiency is $OSE_{it} = \frac{slope(OC)}{slope(OD)} = \frac{\frac{\bar{Q}_{it}}{X_{it}}}{\frac{\tilde{Q}_{it}}{\tilde{X}_{it}}}$; and the residual mix efficiency, $RME_{it} = \frac{slope(OD)}{slope(OE)} = \frac{\frac{\tilde{Q}_{it}}{\tilde{X}_{it}}}{TFP^*}$.

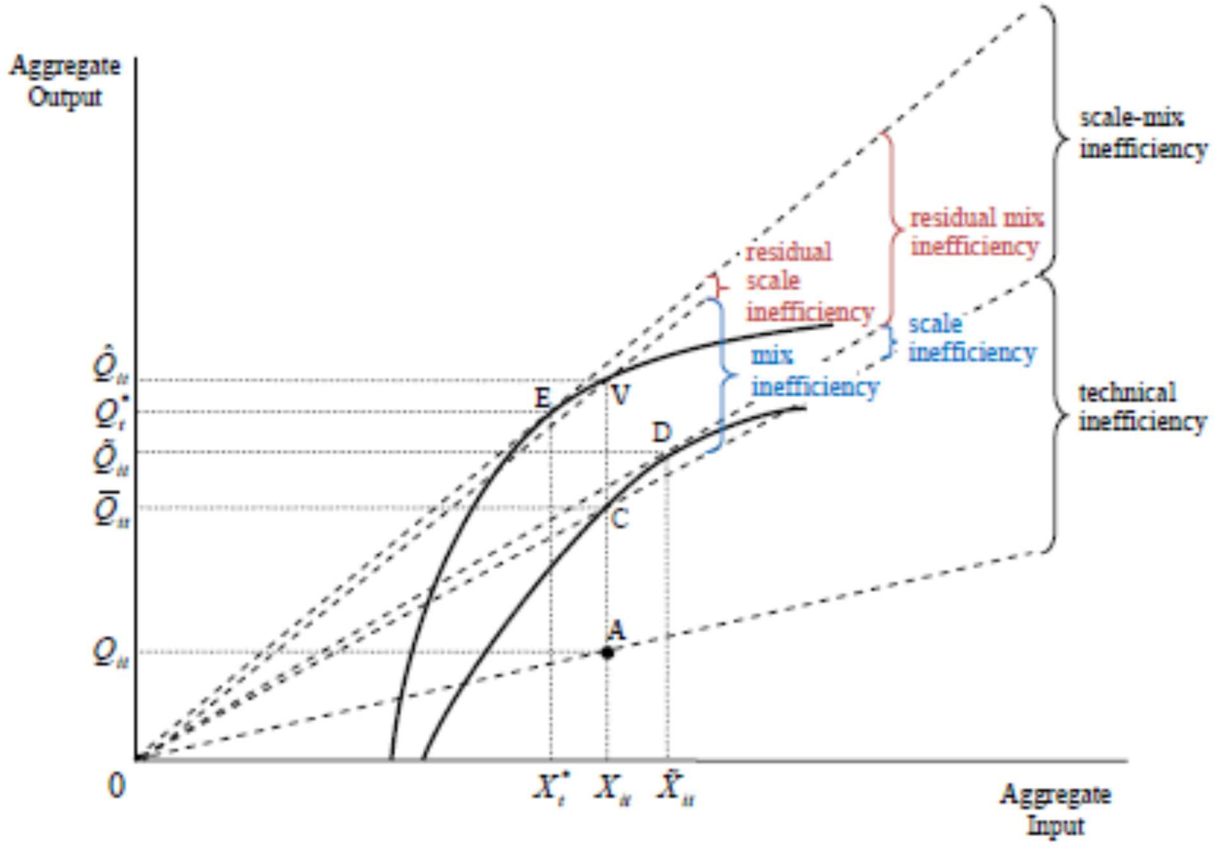

Figure 1 Output-oriented measures of efficiency for a multiple-input multiple-output firm
Source: Adapted from O'Donnell [11]

3 Data

A cross-sectional data set of Vietnamese seaports in 2016 is collected from Vietnam Seaport Association (VPA). The system consists of 44 seaports, located along the 3260 km coastline from the North to the South. Of which, the data of 40 seaports are available in the sample, which can be categorized into three groups locating in the northern, central and southern region. Due to the fact that the economic-social conditions of three regions are different, seaports in particular regions are significantly impacted by these conditions. In terms of ownership, these seaports can be owned either by provincial authorities or logistics companies. The latters are expected to manage seaports better because of their expertise and financial capability.

Estimating the efficiency of seaports requires the information of inputs and outputs. The inputs consist of a number of seaports' resources, which include infrastructure and building proxied by the total length of berths; in terms of land resource the terminal and workshop area are chosen as input variables; and the capital stock of seaports is proxied by the total number of handling equipment. There are a number of output variables that can be utilized including containerized cargo (in TEUs or MT), bulk cargo (MT), general and rolling freight (MT) [6]. In case the sample includes both specific and general seaports the throughput variable is employed [6,22]. In this papers, two output variables are domestic and international throughput.

Table 1 describes input and output variables used to estimate seaport efficiency. In general, there is a difference in terms of the size of employed variables. For example, in terms of infrastructure input, the maximum berth length is 3,567 meter while the shortest is only 110 meter. A significant number of Vietnamese seaports have their berth length under international standard. According to World Bank [23], the required length of seaports should be at least 300 meter for containerships. Other seaports' resources including land and equipment also expose a substantial disparity. The information of outputs reveal a fact that the average export and import cargo volume through a Vietnamese seaport are approximately 3.5 times higher than domestic cargo throughput. This issue highlights the important role of international trade on Vietnam's economy.

Table 2 presents statistical description of input and output variables in different categories. While export-import cargo volume through a Southern seaport stands at 7.15 million MT, only 2.94 million and 0.84 million tons of cargo were transported through a seaport located in the

Northern or Central area respectively. Southern seaports use more land resource than their rivals in the Northern and Central area. Seaports managed by different entities including local government and logistics companies. Accordingly, seaports belonging to the former have significantly smaller inputs and outputs.

Table 1 Description of input and output variables
Source: [24]

Variables	Unit	Min	Max	Mean	Standard Deviation
Inputs					
Total berth length	Meter	110	3,567	689	791
Terminal area	1000 m2	10,850	5,450,486	317,516	846,378
Warehouse area	1000 m2	850	596,550	35,613	99,604
Total number of handling equipment	Number	5	355	65	75
Outputs					
Domestic cargo throughput	1000 MT	1,050	9,485,755	1,099,541	1,747,869
International cargo throughput	1000 MT	0	60,512,435	3,574,264	9,753,353

Table 2 Distribution of input and output variables by geographical, ownership and service factors
Source: [24]

Variables	No. of sea_ ports	Total berth length (in meter)		Terminal area (in m²)		Warehouse area (in m²)		No. of equipment		Domestic throughput (in 1000 MT)		International throughput (in 1000 MT)	
		Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Categories by geographical factor													
Northern seaports	10	949	1,117	136,246	72,160	48,418	76,537	64	78	1,586,339	2,762,067	2,941,034	3,258,182
Central seaports	16	433	306	142,885	208,715	9,517	8,537	49	44	586,463	717,812	841,423	1,690,981
Southern seaports	14	796	809	646,573	1,351,526	56,290	150,849	84	94	1,338,203	1,470,872	7,149,819	15,470,522
Categories by service factor													
Seaports with container services	19	718	739	231,762	193,514	20,392	43,581	75	65	1,194,848	1,075,884	3,626,858	4,311,277
Seaports without container services	21	663	834	395,103	1,148,012	49,384	129,536	56	82	1,013,311	2,180,871	3,526,680	12,820,854
Categories by ownership													
Seaports managed by logistic SOEs	18	981	950	545,136	1,206,503	47,521	134,026	103	95	1,261,787	1,291,098	6,773,999	13,703,706
Seaports managed by local government	22	451	522	131,282	185,480	25,869	55,949	34	25	966,794	2,037,551	956,300	2,020,306

4 Empirical results

Table 3 presents the estimated efficiency measures of individual Vietnamese seaports, including output-oriented overall productive efficiency (TFPE), output-oriented technical efficiency (OTE), output-oriented scale efficiency (OSE), and output-oriented residual mix efficiency (ORME). There are only two efficient seaports if using the overall productive efficiency measure, including Chan May and Tan Cang Sai Gon port. The variation of efficiency level among Vietnamese seaports is significant. While having five seaports with TFPE index higher than 90%, there are 17 seaports under 10%. Output-oriented technical efficiency reveals the capability of seaport operators in terms of exploiting their scarce inputs to generate as much output as possible. Under this criterion five of ten Northern seaports (Quang Ninh, Cam Pha, Transvina, Dinh Vu and Nam Hai Dinh Vu port), four of 16 Central seaports (Quang Binh, Cua Viet, Chan May, and Vung Ro port) and seven of 14 Southern seaports (Binh Duong, Tan Cang Sai Gon, Sai Gon, Tan Thuan Dong, Ben Nghe, TCIT and My Tho port) are the best-practice operators. Obviously, there is a difference when using TFPE and OTE for benchmarking seaport system in the context that most of previous researches on seaport efficiency are preferred in the latter measure.

Output-oriented scale efficiency identifies the gap between temporary and optimal scale of seaports' inputs and is a roof for adjusting the seaport size to raise the benefit of scale effect. For example, the OSE score of Quang Ninh port is 0.8002 and its operator, accordingly, can reduce/increase the size of the port's inputs to obtain a nearly 20% increase of its TFPE. The number of seaports achieving the scale effect is eight. Of which, four ports locate in the northern area, three in the southern area and only one operating in the Central of Vietnam.

Table 3 Efficiency measures of individual Vietnamese seaports
Source: Author's calculations

Seaports	Q	X	TFP	TFP*	TFPE	OTE	OSE	ORME
Quang Ninh	1.0000	1.0000	1.0000	2.4505	0.4081	1.0000	0.8002	0.5100
Cam Pha	1.0000	1.0000	1.0000	1.0539	0.9489	1.0000	1.0000	0.9489
Hai Phong	0.9585	1.3883	0.6904	2.1776	0.3170	0.9585	0.8914	0.3710
Đoan Xa	0.0911	1.2208	0.0747	1.2518	0.0596	0.0911	0.9700	0.6745
Vat Cach	0.7670	1.2876	0.5957	0.8092	0.7362	0.7670	1.0000	0.9598
Cua Cam Hai Phong	0.3047	1.0000	0.3047	2.0826	0.1463	0.3047	0.5595	0.8582
Transvina	1.0000	1.0000	1.0000	11.73	0.0853	1.0000	0.1645	0.5185
Đinh Vu	1.0000	1.0000	1.0000	1.0004	0.9996	1.0000	1.0000	0.9996
Nam Hai Đinh Vu	1.0000	1.0000	1.0000	1.3175	0.7590	1.0000	1.0000	0.7590
Tan Cang 128 – Hai Phong	0.7668	2.2424	0.3420	1.3463	0.2540	0.7668	0.5655	0.5858
Thanh Hoa	0.0675	2.3804	0.0284	0.5872	0.0483	0.0675	0.9222	0.7759
Nghe Tinh	0.5276	5.1247	0.1030	0.7625	0.1350	0.5276	0.3174	0.8062
Vung Ang Viet Lao	0.3542	2.3991	0.1476	3.5460	0.0416	0.3542	0.8433	0.1393
Quang Binh	1.0000	1.0000	1.0000	117.86	0.0085	1.0000	0.0542	0.1568
Cua Viet	1.0000	1.0000	1.0000	52.4547	0.0191	1.0000	0.0408	0.4681
Thuan An	0.1187	1.1988	0.0990	1.9862	0.0498	0.1187	0.6813	0.6158
Chan May	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Đa Nang	0.8772	1.4962	0.5863	2.9832	0.1965	0.8772	0.5781	0.3875
Hai Son	0.0254	1.5608	0.0163	1.1498	0.0142	0.0254	0.8305	0.6732
Ky Ha	0.0676	1.3774	0.0491	3.5983	0.0136	0.0676	0.7316	0.2750
Ky Ha – Quang Nam	0.0440	1.0772	0.0408	6.1617	0.0066	0.0440	0.7190	0.2086
Quy Nhon	0.6547	2.0864	0.3138	2.3584	0.1331	0.6547	0.6634	0.3065
Thi Nai	0.5336	1.3862	0.3850	0.8760	0.4395	0.5336	0.8742	0.9422
Vung Ro	1.0000	1.0000	1.0000	63.8482	0.0157	1.0000	0.0366	0.4290
Nha Trang	0.1653	2.7911	0.0592	0.5434	0.1090	0.1653	0.9770	0.6749
Cam Ranh	0.1585	4.9738	0.0319	0.7732	0.0412	0.1585	0.3195	0.8136
Đong Nai	0.9455	1.5849	0.5966	117.59	0.0051	0.9455	0.6565	0.0082
Binh Duong	1.0000	1.0000	1.0000	3.2816	0.3047	1.0000	1.0000	0.3047
Tan Cang Sai Gon	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Sai Gon	1.0000	1.0000	1.0000	10.6078	0.0943	1.0000	0.3367	0.2801
Tan Thuan Đong	1.0000	1.0000	1.0000	5.5094	0.1815	1.0000	0.2755	0.6588
Ben Nghe	1.0000	1.0000	1.0000	7.2012	0.1389	1.0000	0.5099	0.2724
Bong Sen (Lotus)	0.2676	2.3342	0.1147	1.2353	0.0928	0.2676	0.9059	0.3828
Rau qua	0.0892	1.0000	0.0892	2.8689	0.0311	0.0892	0.4033	0.8645
Phu My	0.4751	2.4569	0.1934	0.9603	0.2014	0.4751	0.8455	0.5014
TCIT	1.0000	1.0000	1.0000	1.3283	0.7528	1.0000	1.0000	0.7528
CMIT	0.9776	1.0199	0.9586	1.0684	0.8972	0.9776	0.9956	0.9218
My Tho	1.0000	1.0000	1.0000	3.5642	0.2806	1.0000	0.5177	0.5420
Vinh Long	0.0617	1.5471	0.0399	4.7440	0.0084	0.0617	0.9320	0.1461
Can Tho	0.5047	3.0122	0.1676	0.9064	0.1849	0.5775	0.3201	1.0000
GeoMean	***0.4382***	***1.4136***	***0.3100***	***2.7207***	***0.1139***	***0.4397***	***0.5470***	***0.4738***

Notes: X is aggregate input, Q is aggregate output, TFP is total factor productivity index, TFP* is the maximum TFP, TFPE is TFP efficiency (overall productive efficiency), OTE is output-oriented technical efficiency, OSE is output-oriented scale efficiency, and ORME is output-oriented residual mix efficiency.

Output-oriented residual mix efficiency determines the ability of firms to composite different outputs and inputs for generating the maximum ratio of aggregate output and aggregate input. In this paper, we classify Vietnamese seaports' outputs into domestic and international cargo throughput. ORME in this case measures the seaports' capability to maximize the aggregate cargo throughput from given two mentioned outputs. However, due to the Vietnamese maritime regulations, there are seaports serving only domestic cargoes and a limited number of seaports capable to serve both types of outputs. As a result, they are impossible to achieve maximal mix efficiency. Increasing ORME via better compositing adjustable inputs (warehouse area, cargo handling equipment) can be a feasible solution. Empirical results show that three seaports achieve the maximum level of mix efficiency, including Chan May, Tan Cang Sai Gon and Can Tho port.

In general, the estimated mean of TFPE is extremely low at 0.1139, pointing out that the seaport system is underperformed and inputs are employed substantially inefficient. This underperformance can be due to a number of factors which are found via decomposing the overall productive efficiency. First, a low level of technical efficiency at 0.4397 provides evidence of poor management quality of Vietnamese seaports' operators, while there is a potential to increase the temporary outputs by 56.03%. In fact, the Vietnamese seaports are mostly a cluster of many small terminals operated by different entities and not connected via either contiguous wharf or road links. Subsequently, additional land-side infrastructure is required to connect multiple marine terminals and more dredging and channel maintenance expenses are also required for facilitating vessel navigation to various port locations. Another subsequence is the difficulties in setting up transshipment hubs due to a lack of inter-terminal connections and dispersion of cargo volumes.

Second, scale effect is not well utilized with the low mean value of OSE standing at 0.5470. The fragmentation of Vietnam's current port system makes individual ports unable to leverage economies of scale and duplicates their operating costs due to congestion at certain terminals and under-utilization in other terminals.

Third, mix efficiency, recorded at a value of 0.4738, is the last factor contributing to the overall underperformance of Vietnamese seaport sector. There is a substantial room to increase this criterion through coordinating properly output and input variables.

Figure 2 demonstrates the variation of overall productive efficiency and its components including technical, scale and mix efficiency. Seaports in the sample are organized in their increasing TFPE score order. The figure exposes a significant disparity of performance among Vietnamese seaports.

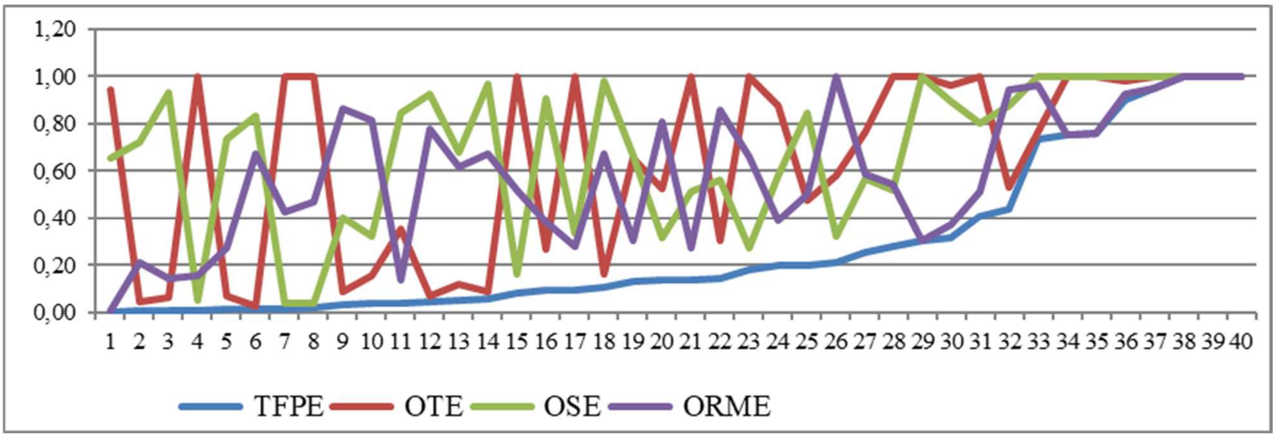

Figure 2 Distribution of individual Vietnamese seaports' efficiency measures

Notes: TFPE is output-oriented overall productive efficiency, OTE is output-oriented technical efficiency, OSE is output-oriented scale efficiency, and ORME is output-oriented residual mix efficiency.

Table 4 illustrates the figures of seaport efficiency in groups categorized by geographical factor, types of services and ownership. It is clear that seaports in different areas of Vietnam reveal a distinction. While those located in the North reach the highest level of overall productive efficiency (0.3245), their partners in the central area are the least efficient (0.0513). Central seaports obtain the lowest technical efficiency at 0.2722, exposing the poor management quality of the operators in one hand. On the other hand, the small volume of cargo transported through these hubs is another cause when the central area contributes only three percents of the total national throughput [23]. Inspire of having better overall performance, southern seaports are less efficient in terms of scale efficiency if compared with the central ones (0.2790 versus 0.4094). This fact can be explained by the oversupply of southern maritime terminals resulted from the concession granting for new terminal building projects [23,25].

Seaports serving container ships are more overall efficient due to their better technical and scale performance. Containerization technology can be seen as the main factor contributing to the outperformance of container terminals if compared with those only server traditional cargoes (bulk and general cargoes). Over the last 10 years, the container cargo has increased at a rapid speed at 20 percent annually, while on average, a 16 percent growth rate is recorded for all types of cargo through Vietnamese seaports [24].

Ownership is also found as a significant factor that differentiates the performance of Vietnamese seaport system. Those under the management of logistics SOEs attain an overall efficiency score at 0.1899, while their rivals owned by local governments have their efficiency value equivalent to less than a half (0.0755). Technical efficiency is the cause of this substantial disparity, exposing the low quality of business administration of local governments. Logistics companies with superior experience in their specified businesses are the better operators.

Table 4 Decomposing Vietnamese seaports' overall productive efficiency
Source: Author's calculations

Efficiency measures	No. of sea_ ports	Overall productive efficiency		Technical efficiency		Scale efficiency		Residual mix efficiency	
		GeoMean	S.D	GeoMean	S.D	GeoMean	S.D	GeoMean	S.D
Categories by geographical factor									
Northern seaports	10	0.3245	0.3405	0.6599	0.3121	0.7172	0.2672	0.6857	0.2086
Central seaports	16	0.0513	0.2458	0.2722	0.3841	0.4094	0.3281	0.4599	0.2738
Southern seaports	14	0.1358	0.3206	0.5691	0.3561	0.2790	0.2790	0.3319	0.3319
Categories by service factor									
Seaports with container services	19	0.1721	0.2981	0.6350	0.3135	0.6593	0.2649	0.4111	0.2904
Seaports without container services	21	0.0790	0.3450	0.3153	0.4060	0.4620	0.3352	0.5422	0.2864
Categories by ownership									
Seaports managed by logistic SOEs	18	0.1899	0.3190	0.6272	0.3057	0.6068	0.2801	0.4989	0.2913
Seaports managed by local government	22	0.0755	0.3210	0.3288	0.4194	0.5024	0.3270	0.4570	0.2821

5 Conclusion

Using the data set of Vietnamese seaports in 2016 and following the method of O'Donnell [11,12], we measure overall productive efficiency of these ports and decompose into a number of efficiency measures, including technical, scale and mix efficiency. In general, the results point out the underperformance of Vietnamese seaport system, using the overall or any component measures of efficiency.

Particularly, ports locating in different regions reveal a disparity of performance. Northern ports are the most efficient ones compared with their partners in the Central and the South. While having better overall productive efficiency, southern ports are the least efficient if using scale efficiency measure. Seaports providing containership services are more efficient due to their better technical and scale efficiency. Ownership is also effective to seaports' production when ports operated under the logistics companies perform better than those under local government.

This study contributes to the literature of port performance via applying a complete measure of efficiency following the work of O'Donnell [11,12] in the context of an emerging economy like Vietnam. This measure is believed to be more comprehensive than the common measure of efficiency, technical efficiency that is mostly used in the literature.

Further studies on Vietnamese seaport performance can be conducted if the time series data is available; accordingly, technical progress of these seaports can be observed. While many Vietnam's seaports are conducting "Green port" strategy, integrating environmental factors such as carbon dioxide emission from ships in Total Factor Productivity models could improve the results and make researches of Vietnamese seaports more comprehensive.

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Review process

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