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# Influence of policy, operational and market conditions on seaport efficiency in newly emerging economies: the case of Vietnam

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**ABSTRACT**
Located in Southeast Asia as one of the most dynamic economic regions in the world and close to north-south shipping routes, Vietnam's seaports play a vital role in promoting its international trade and economic growth. And yet, most ports are small and owned by the public sector. Their performance is subject to various factors relating to government policy, operational and market conditions. Although the Government has been trying to improve the sector's performance through corporatization, its corporatization model is unique in many ways compared with reform models in other countries. This study seeks to analyse the effects of government policy, operational and market conditions among other factors, on Vietnamese seaports' efficiency. Double-bootstrap data envelopment analysis (DEA) and univariate and multivariate analyses were conducted using the data sample of 41 ports for years 2015 and 2016. The analysis results show that the factors of production, regional location and reform policy had a significant impact on port performance.

**KEYWORDS**
Microeconomic reform; port policy; port efficiency; bootstrapped DEA; Vietnam

**JEL CLASSIFICATION**
R53; R40; R38

## I. Introduction

Emerging economies contribute significantly to the world economic growth through enormous human resources and trade (Hanson 2012). Many countries have been successful in adopting the export-led model to expand their output and realized the importance of the transport and logistics sector in international trade promotion (Wu and Goh 2010). It is well known that the BRIC group (Brazil, Russia, India and China) represents the largest emerging economies in the world contributing 40% of the world population and 32% of the world's real GDP,[1] while the Next Eleven (N-11) group, including Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, Turkey, South Korea and Vietnam, is considered as the potential rivals of the former (O'neill et al. 2005). As a member of the Next 11 group and one of the most dynamic economies in East Asia, Vietnam has the economic growth rate of 6.3% over the last two decades. Its international trade contributes to 80% of the economic growth (Nguyen et al. 2016) and relies on seaports as transport hubs.

As non-landlocked country, Vietnam's seaports play a pivotal role in logistics supply chain operations (Pettit and Beresford 2009). The Vietnam's seaport sector has 68seaports of various sizes along the coastline of 3260 km, with the total 59,405 m berth length and a total capacity of 470–500 million tons per year (Vietnam Port Association 2019). However, the seaport system has small-scaled terminals scattered over the country's relatively long coastline. Most ports are general and bulk cargo ports; only about a third of them are container cargo ports. The average berth length is only 200–300 metres compared with the required length of 300–400 metres for the latest generation of containerships (Blancas et al. 2014). It is not surprising that most ports are not operating with economies of scale; 47% of the ports have the annual throughput less than one million tons and 93% have the annual throughput less than ten million tons.[2] Since 2009, the country has allowed for the state and private ownership of seaports following the Government Decision No. 2190/QĐ-TTg. This reflects the effort and policy to allow for public

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[1]Authors' calculation based on World Bank (2020).
[2]Authors' calculations based on Vietnam Seaports Association (2018).

and private ownership of not only port and terminal infrastructure but also other types of infrastructure such as access channels, breakwaters, land-based transport infrastructure, and power and water supply systems.

While port reform is not new in the literature, the case of Viet Nam is noteworthy for its unique so-called 'corporatization' model. In contrast to the fact that the most common reform model has undoubtedly been based on the landlord model, whereby a public port authority acts as both landlord and regulatory body and private companies carry out port operations under long-term lease agreements (Brooks, Cullinane, and Pallis 2017; Ferrari, Parola, and Tei 2015; Zhang 2016), Vietnam's port reform is based on its own 'corporatization' concept. Corporatization can be defined as 'the process in which a public sector undertaking, or part thereof, is transformed into a company under private corporate law' (World Bank 2007, 104). This means the port authority as a public entity or state-owned company (SOE) or its constituent parts, such as a cargo terminal is converted into a legally and financially independent legal entity with its own board of directors, while the government or public port authority retains the company's ownership. Unlike many other countries where port infrastructure remains under the state's ownership and management after reform (Brooks, Cullinane, and Pallis 2017; Lee and Lam 2017), Vietnam's corporatization model applies to port terminals as well as port and marine infrastructure, e.g. channels, breakwaters, land-based transport access, power and water supply systems for the port.

Another unique feature of the corporatization model is about land ownership. Under the current Constitution 2013 and Land Act 2013, private ownership of land is not allowed, and all land is owned by the State Government. Moreover, if a port has a permanent land use right before its corporatization, it will continue to have this right after corporatization. This is quite different from reform under the popular landlord model, full privatization in U.K., and long-term lease agreements in Australia, and a more decentralized port governance system in China (Brooks, Cullinane, and Pallis 2017; Wu et al. 2016).

This study seeks to evaluate the effects of various internal and external factors including port corporatization policy, operational and market conditions, on Vietnamese seaports' efficiency. We apply the double-bootstrap two-stage DEA proposed by Simar and Wilson (2007) and test efficiency disparity between groups using the method proposed by Simar and Zelenyuk (2006, 2007). The analysis makes use of the data of 41 seaports (93,6% of the Vietnamese seaport population) over the years 2015 and 2016, for which the most recent and complete data are available.

The next section presents an overview on the research of seaport performance in emerging economies and applications of DEA in studies of seaport efficiency. SectionsIII and IV explain the analysis methods and dataset, respectively. SectionV presents the analysis results and policy implications. SectionVI is conclusion.

## II. Review of the literature

Seaports are an important part of the transport and logistics system and are regarded as engines of regional economic development (Hesse 2018). Regarding their function as logistics nodes and provide infrastructure for the transport and logistics system, Venkatesh et al. (2017) found issues in port infrastructure, port procedures, and collaboration among the logistics and supply chain actors are among the main obstacles to multimodal transport. Ports need to take an important if not the leading role in improving the system's efficiency and extending its performance in the hinterland. As shown in Rodrigue and Notteboom (2005, 2010), an emerging trend in the transport and logistics system's development is 'regionalization' of ports' operations whereby more focus is given to inland distribution and connectivity through transport corridors and logistics nodes. This suggests that seaports' efficiency are critical to the performance of the transport and logistics system itself and performance of the other components in the system including inland container depots, transport infrastructure, and freight and logistics service providers (Ambrosino et al., 2018). Research into seaport efficiency and its determinants deserve attention in its own right.

Different efficiency evaluation methods have been used to evaluate port efficiency. Wu and Goh (2010) compared the efficiency of container ports in emerging markets including the BRIC and 'Next-11' groups with the group of seven advanced economies (G7). Andersen and Petersen (1993) found the outperformance of container port in emerging markets over those in G7. Serebrisky et al. (2016) applied the Stochastic Frontier Analysis (SFA) method to explore the determinants of port efficiency in Latin America and the Caribbean (LAC) using the 10-year panel data of 63 ports. The study found a positive link between private ownership and port efficiency.

Yuen, Zhang, and Cheung (2013) examine the impact of ownership, competition and hinterland on Chinese container port efficiency, using two-stage DEA and the data of 21 container ports. They found that state ownership influenced on container port performance. Sun et al. (2017) include the environmental factors in their study on Chinese port efficiency. Using the distance function, the study found that port size has a negative impact on environmental efficiency but a positive impact on operational efficiency. The number of berths has an adverse effect on port efficiency. Ports located in the north and the south have different levels of efficiency due to climate and industrial conditions.

Wanke (2013) used network DEA to measure Brazilian ports' efficiency. The author found a positive effect of private ownership, while physical efficiency, hinterland size and cargo diversity also positively affect cargo consolidation efficiency. Nguyen, Nghiem, and Chang (2018) examined the technical efficiency of Vietnamese seaports and their influential factors using metafrontier analysis. They found that cargo handling facilities and information technology are the most important inputs but their contribution to port performance varies across regions. Land is important to the efficiency of ports in the north, whereas the cargo storage capacity is important to ports in the Central, and information technology is important to ports in the south. Nguyen et al. (2016) applied the bootstrapped DEA method and show this method is more preferred over standard DEA because it provides consistent and bias-corrected estimates of efficiency scores. However, the study did not examine the factors causing the underperformance of Vietnam's seaports.

According to Wu and Goh (2010), the methodologies used in estimating port efficiency include DEA, SFA, Total Factor Productivity (TFP), and Free Disposal Hull (FDH). However, the most widely applied method is DEA due to a number of its advantages. First, it does not require large data sets to estimate efficiency scores. Second, it does not require *ad hoc* specifications of the production function as SFA does, and third, it can accommodate multiple inputs and outputs (Nguyen et al. 2016).

The applications of DEA in measuring seaport/terminal efficiency can be divided into different groups. The first group applies standard DEA proposed by Charnes, Cooper, and Rhodes (1978) and Banker, Charnes, and Cooper (1984) also known as CCR-DEA and BCC-DEA models under the assumptions of constant and variable returns to scale respectively (Bichou 2013; Wu and Goh 2010). The second group incorporates undesirable outputs, e.g. carbon dioxide into DEA models using Directional Distance Function (DDF) or Slack-based Measurement (SBM) (Na et al. 2017; Sun et al. 2017). In the third group, the production process of ports is divided into stages each with specific inputs and outputs. The efficiency of different stages is then evaluated using network DEA (Wanke 2013). The fourth group utilizes bootstrapping to make inferences of DEA estimates (Nguyen et al. 2016; Wanke 2013; Wanke and Barros 2015).

Given the recent developments in efficiency measurement, yet limited research on port efficiency and issues in emerging economies, this article aims to conduct efficiency evaluation and examine the effects of various factors on seaport efficiency in Vietnam as an emerging economy. Following Simar and Zelenyuk (2006, 2007), the study extends the application of bootstrapped DEA by using subsample bootstrapping to estimate and compare the efficiency of seaport groups. In addition, the double-bootstrap two-stage DEA proposed by Simar and Wilson (2007) is also applied to examine the impact of policy, and operational and market conditions on seaport performance.

## III. Methodology

### *Measuring technical efficiency*

Under the assumption of free disposability of inputs and outputs, and variable returns to scale, the DEA estimate of the production set can be defined as[3]

$$\hat{\wp} = \left\{ (x, y) \in_{+} \mathbb{R}_{+}^{p} \times_{+} \mathbb{R}_{+}^{q} : \sum_{k=1}^{n} z_k y_k^i \geq y^i,\ i = 1, \ldots, q; \right.$$
$$\left. \sum_{k=1}^{n} z_k x_k^j \leq x^j,\ j = 1, \ldots, p;\ \sum_{k=1}^{n} z_k = 1, z_k \geq 0 \right\}, \quad (1)$$

where $x \in \mathbb{R}_{+}^{p}$ denotes a $(1 \times p)$ vector of inputs and $y \in \mathbb{R}_{+}^{q}$ denotes a $(1 \times q)$ vector of outputs.

Farrell's measure of technical efficiency ($\delta$) is the reciprocal of the distance function (Simar and Wilson 2007). The DEA output-oriented estimator[4] of $\delta$ for variable returns to scale production can be written as:

$$\hat{\delta} = \delta(x,\ y \in \hat{\wp})$$
$$= max \left\{ \delta > 0 : \sum_{k=1}^{n} z_k y_k^i \geq \delta y^i,\ i = 1, \ldots, q; \right.$$
$$\left. \sum_{k=1}^{n} z_k x_k^j \leq x^j,\ j = 1, \ldots, p;\ \sum_{k=1}^{n} z_k = 1, z_k \geq 0 \right\}. \quad (2)$$

To measure the efficiency of groups, we can use aggregate or mean efficiency scores. Aggregate efficiency scores of a group or industry are computed by allocating weights to individual firms in the group based on their contribution to overall group output, while mean efficiency scores apply equal weighting to all firms irrespective of their contribution to group/industry output.

### *Simar and Zelenyuk (2007) test for differences in efficiency between two groups*

We use a bootstrap-based test proposed by Simar and Zelenyuk (2007) to investigate the efficiency difference between different seaport groups. In brief, if there are two seaport groups, say A and Z, we can state the following set of hypotheses: $H_0 : \overline{\delta^A} = \overline{\delta^Z}$ against $H_1 : \overline{\delta^A} \neq \overline{\delta^Z}$, where $\overline{\delta^A}$ and $\overline{\delta^Z}$ are the efficiency means of groups A and Z, respectively. Due to the multiplicative nature of efficiency values, Simar and Zelenyuk (2007) proposed an RD ratio and its DEA estimate as $RD_{A,Z} = \frac{\overline{\delta^A}}{\overline{\delta^Z}}$ and $\widehat{RD}_{A,Z} = \frac{\overline{\hat{\delta}^A}}{\overline{\hat{\delta}^Z}}$, respectively. The bootstrap confidence intervals of the RD statistics can be used to test the above hypotheses. $H_0$ is rejected if the confidence interval for $RD_{A,Z}$ does not overlap with unity. If the confidence interval lies above unity, then the efficiency score of group A is larger than that of group Z, $\overline{\delta^A} > \overline{\delta^Z}$, and group A is less efficient than group Z, and vice versa.

In this study, the difference in efficiency of seaport groups is tested using Simar and Zelenyuk (2007) test. As shown in Section IV, seaports are grouped into two or three groups before the comparison of the efficiency disparity between them is conducted using Simar and Zelenyuk (2007) testing method. For the case of three groups, we extend the testing method by further dividing the groups into three pairs and conducting three comparisons of efficiency with a unique computing process as shown in Le, Harvie, and Arjomandi (2017).

### *Li (1996) test for equality of efficiency densities*

In this study, Li (1996) test is also carried out to consider the difference in groups' efficiency densities. Suppose there are two random samples of efficiency values, $\{x_{A,i} : i = 1, \ldots, n_A\}$ and $\{x_{Z,i} : i = 1, \ldots, n_Z\}$, coming from potentially different distributions characterized by the density functions $f_A(x)$ and $f_Z(x)$, respectively. The two density functions are different if their values at any arbitrary point are different. At an arbitrary point $x^o$ the values of the density functions are $f_A(x^o)$ and $f_Z(x^o)$. Our interest is in testing the following hypotheses:

$H_0 : f_A(x^o) = f_Z(x^o)$ (The densities of two groups A and Z are equal)

$H_1 : f_A(x^o) \neq f_Z(x^o)$ (The densities of two groups A and Z are unequal)

[3]The constant-returns-to-scale assumption is only appropriate when all firms are operational at their optimal scale (Charnes, Cooper, and Rhodes 1978). In Vietnamese seaports vary substantially in size. Therefore, this study's analysis is conducted under the assumption of variable returns to scale.:

[4]Output-orientation is applied in our DEA model because some input variables, such as berth length or terminal area, are quasi-fixed and cannot adjust for a better performance.

In order to conduct this test, Li (1996) proposes the Integrated Square Difference (ISD) criterion, which is computed as:

$$\begin{aligned} \mathrm{ISD} &= \int [f_A(x) - f_Z(x)]^2 dx \\ &= \int \left[f_A^2(x) + f_Z^2(x) - 2f_A(x)f_Z(x)\right] dx \\ &= \int f_A(x) dF_A(x) + \int f_Z(x) dF_Z(x) \\ &- \int f_A(x) dF_Z(x) - \int^{f_Z}(x) dF_A(x) \end{aligned} \quad (3)$$

Equation (3) satisfies the property that $\mathrm{ISD} \geq 0$, and $\mathrm{ISD} = 0$ if and only if $H_0$ is true $(f_A(x^o) = f_Z(x^o))$. Based on a joint sample for the two groups, a consistent and asymptotically normal estimator of ISD is obtained by replacing the unknown distribution function $(F_A(x)\,\mathrm{and}\,F_Z(x))$ by empirical distribution functions. An empirical distribution function can be defined as: $F_{l,n_l}(x) \equiv \frac{1}{n_l}\sum_{k=1}^{n_l} I\left(x_{l,k} \leq x\right), l = A,\ Z.$ I(X) is an indicator function. I(X) = 1 if the statement X is true, and zero otherwise. The unknown densities $(f_A(x)\,\mathrm{and}\,f_Z(x))$ are replaced by a Gaussian density function to obtain the asymptotic estimates of ISD. Based on these estimates Li (1996) test statistic can be formulated. Li (1999) shows that the bootstrap procedure can provide a better approximation than the asymptotic normal approximation. Simar and Zelenyuk (2006) also propose a bootstrapped-based statistical tool in DEA. Given the original Li test statistics and the bootstrap Li test statistics, the p-values for the respective Li tests will be computed. One difficulty when applying Li's test in DEA is the bound problem, where there is a 'spurious mass at unity'. Simar and Zelenyuk (2006) used the sample of DEA estimates where those with the unity score are 'smoothed' away from the boundary by adding a small noise $\left(\varepsilon^k\right)$:

$$\widetilde{\mathrm{TE}}^k = \begin{cases} \widehat{\mathrm{TE}}^k + \varepsilon^k, if\,\widehat{\mathrm{TE}}^k = 1 \\ \widehat{\mathrm{TE}}^k, otherwiswe \end{cases} \quad (4)$$

where: $\varepsilon^k = \mathrm{Uniform}\left(0, \min\left\{n^{-\frac{2}{M+N+1}}, \alpha - 1\right\}\right)$,$\alpha$ is the $\alpha -$ quantile (e.g. 5%) of the empirical distribution of $\left\{\widehat{\mathrm{TE}}^k : \widehat{\mathrm{TE}}^k > 1, k = 1, \ldots, n\right\}$.

### Double-bootstrap two-stage DEA

To explore the relationship between DEA inefficiency scores as dependent variables and environmental variables, we used the double-bootstrap two-stage DEA approach developed by Simar and Wilson (2007). Formally, a true model of regressing true efficiency scores on environmental variables is described as:

$$\delta_i = z_i\beta + \varepsilon_i \geq 1\ , \quad (5)$$

where $\beta$ *is* the vector of the parameters, and $\varepsilon_i \sim N\left(0, \sigma_\varepsilon^2\right)$ is a continuous *i.i.d* random variable, independent of the vector of environmental variables $z_i$. However, the true efficiency scores $(\delta_i)$ are replaced by DEA estimates from the first stage. Because output-oriented technical efficiency scores under the Farrell (1957) approach are larger than unity $(\delta_i \geq 1)$, $\varepsilon_i \geq 1 - z_i\beta$, for all $i = 1, \ldots, n$. Hence, to account for the boundary issue a truncated regression is conducted. A parametric bootstrap is also used to improve the accuracy of the coefficients $(\beta)$ and variance of random variable $(\sigma_\varepsilon^2)$ inference. The bootstrapping process is presented in the Appendix. It is worth noting that the negative sign of coefficient $(\beta)$ indicates a positive impact on seaport efficiency under Farrell (1957) output-oriented efficiency evaluation.

## IV. Data set

The main inputs of seaport production consist of labour, land, equipment and infrastructure (Wu and Goh 2010). The proxies for the labour input can be the number of employees (Tongzon 2001), number of port authority employees (González and Trujillo 2008) or total wages (Cullinane and Song 2003). Terminal area and workshop area are often chosen as proxies for land resources (Na et al. 2017; Nguyen, Nghiem, and Chang 2018; Nguyen et al. 2016; Wanke and Barros 2015). Capital stock is proxied by the number of quay cranes, yard cranes or pieces of equipment (Chang and Tovar 2014; Hung, Lu, and Wang 2010; Wu and Goh 2010), and infrastructure is proxied by the number of berths and the total length of terminals (Chang and Tovar 2017). This study uses four input variables, namely

Table 1. Input, output and environmental variables.

| Variables | Description | Studies |
|---|---|---|
| **Output variable** | | |
| Throughput/ output (O) | Annual total throughput | Chang and Tovar (2014), Bichou (2013), Panayides et al. (2009) |
| **Input variables** | | |
| Berth length (BL) | Total berth length in metre | Chang and Tovar (2017), Panayides et al. (2009) |
| Terminal area (TA) | Total terminal area in square metre | Nguyen, Nghiem, and Chang (2018), Na et al. (2017), Nguyen et al. (2016), Wanke and Barros (2015); Panayides et al. (2009) |
| Warehouse area (WA) | Total warehouse in square metre | Nguyen, Nghiem, and Chang (2018), Na et al. (2017), Nguyen et al. (2016), Wanke and Barros (2015), Panayides et al. (2009) |
| Equipment (Eq) | Total number of cranes, tractors, trucks | Wu and Goh (2010), Hung, Lu, and Wang (2010), Chang and Tovar (2014), Panayides et al. (2009) |
| **Environmental variables** | | |
| Located in the south (GS) | Dummy variable for seaports locating in the south | Nguyen, Nghiem, and Chang (2018) |
| Location in the central (GC) | Dummy variable for seaports locating in the central | Nguyen, Nghiem, and Chang (2018) |
| Container serving (CN) | Dummy variable for seaports serving container lines | Nguyen, Nghiem, and Chang (2018), Panayides et al. (2009) |
| Ownership (OWN) | Dummy variable for seaports operating under the corporation model | Boitani, Nicolini, and Scarpa (2013), Panayides et al. (2009) |
| Ship arrival/ departure procedure (ST) | Number of administrative steps in the procedure for ship arrival and departure | Venkatesh et al. (2017), Panayides et al. (2009) |

terminal area (TA), warehouse area (WA), the total number of pieces of equipment (Ep) and the total length of berths (BL), given the available data.

Table 1 presents the variables and relevant studies, and Table 2 presents variable statistics. For those ports that handle containers and non-container goods, the correlation between the total throughput and container throughput has a coefficient of 0.98. Thus, while it cannot be warranted that port throughputs are homogenous, total cargo throughput can be used as the main output variable (Bichou 2013; Nguyen, Nghiem, and Chang 2018). The data were collected from the Vietnam Seaport Association website (www.vpa.org.vn) and include 41 seaports located in the three regions, the north, the central and the south of the country, over the 2015–2016 period, the most recent period that the data are available.

To examine the effect of policy, operational and market conditions on seaport efficiency, various environmental variables are considered. The first and second environmental variables aim to evaluate variations in port performance across the north, the central and the south of Vietnam that are well known for their distinctive social and economic conditions (Nguyen, Nghiem, and Chang 2018) and are expected to influence seaport efficiency. Dummy variables GS and GC are used for seaports located in the south and central, respectively. The third environmental variable (CN) is used to differentiate ports handling containers from the rest.

The fourth environmental variable is the dummy variable (OWN) for ports corporatized under Vietnam's corporatization model as explained earlier. It takes the value of one if the

Table 2. Descriptive statistics of the variables.

| Variables | Unit | Min | Max | Mean | St. dev. |
|---|---|---|---|---|---|
| **Output variable** | | | | | |
| Throughput (O) | 1000 MT | 131 | 60,512 | 5,103 | 9,424 |
| **Input variables** | | | | | |
| Berth length (BL) | Metre | 110 | 3,567 | 678 | 784 |
| Terminal area (TA) | 1000 $m^2$ | 10,850 | 5,450,486 | 313,144 | 836,449 |
| Warehouse area (WA) | 1000 $m^2$ | 850 | 596,550 | 34,823 | 98,509 |
| Equipment (Eq) | Number | 5 | 355 | 64 | 74 |
| **Environmental variables** | | | | | |
| South (GS) | 1 or 0 | 0 | 1 | 0.3415 | 0.4742 |
| Central location (GC) | 1 or 0 | 0 | 1 | 0.3902 | 0.4878 |
| Container serving (CN) | 1 or 0 | 0 | 1 | 0.4634 | 0.4987 |
| Ownership (OWN) | 1 or 0 | 0 | 1 | 0.4390 | 0.4963 |
| Ship arrival/departure procedure (ST) | Step | 4 | 6 | 5.3537 | 0.8020 |

seaport is a corporatized port and zero otherwise. The fifth environmental variable (ST) pertains to seaport administrative policy, which is proxied by the number of steps required in the ship arrival and departure procedure that has a long history of the Government's management.

The descriptive statistics of the variables and the correlation matrix are presented in Tables 2 and 3 respectively. The figures in Table 2 indicate substantial variations among seaports in terms of their throughput/output, inputs and environmental factors. For example, the largest port has the throughput about 12 times larger than the smallest one, and the maximum berth length is 3,567 m, while the minimum value is only 110 m.

**Table 3.** Correlation matrix of the environmental variables.

| | GS | GC | CN | OWN | ST |
|---|---|---|---|---|---|
| GS | 1.0000 | | | | |
| GC | −0.5761 | 1.0000 | | | |
| CN | 0.2591 | −0.4426 | 1.0000 | | |
| OWN | 0.0885 | −0.4055 | 0.4591 | 1.0000 | |
| ST | −0.0289 | 0.2083 | −0.1963 | −0.2369 | 1.0000 |

## V. Analysis results and policy implications

### *Univariate analysis*

Figure 1 shows the Kernel estimates of the seaport efficiency distributions. The distribution of bootstrap seaport efficiency scores is shown in Figure 2. Table 4 provides results of Li test on the difference of efficiency distribution between groups. The test for efficiency difference between the government-owned and corporatized port groups has $t = 2.1723$ and p-value = 0.0160, indicating a significant difference between the two groups at the 0.05 significance level. Table 5 shows the aggregate and mean efficiency ratios of groups of 0.5802 and 0.5374 for conventional DEA or 0.5089 and 0.4545 for bootstrapped DEA, respectively. Their values less than one confirm the better performance of corporatized ports at the 0.01 significance level.

At the 0.01 significance level, the Li test result indicates significant efficiency disparity between container and non-container seaports, with the $t$ value and P-value of 2.919 and 0.0050, respectively.

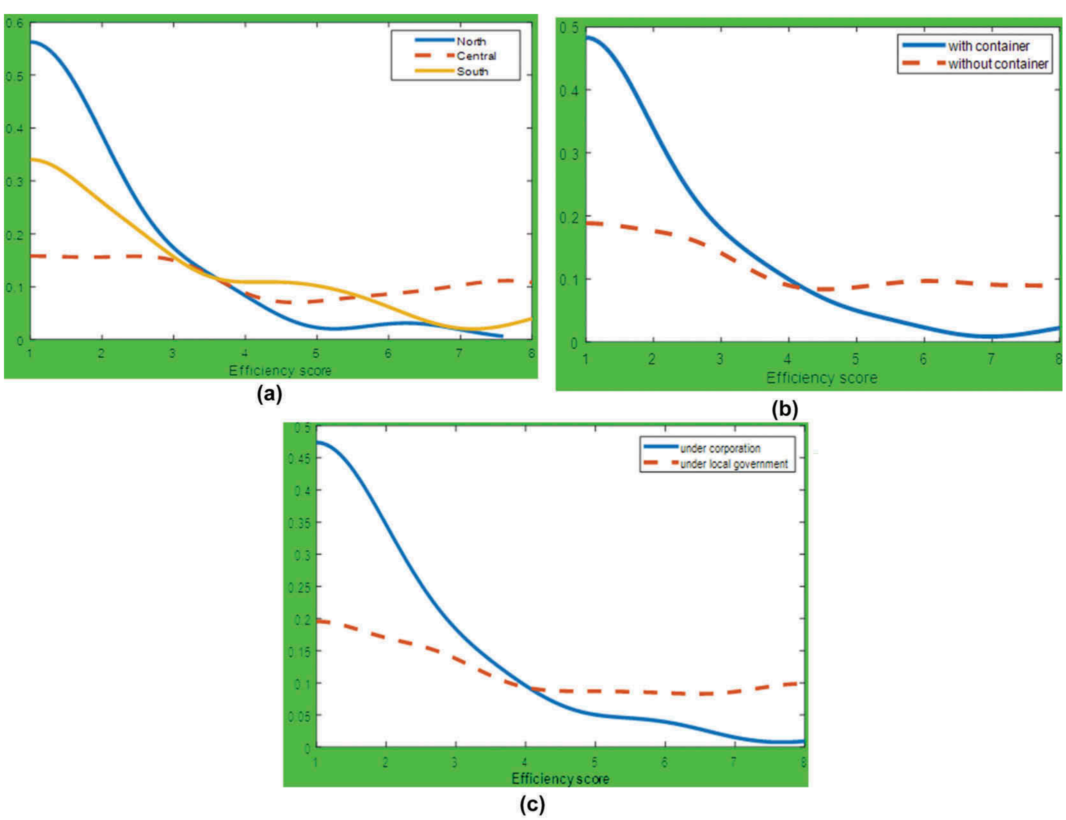


**Figure 1.** Kernel estimation densities of individual Vietnamese seaport efficiency.

Panel A: Efficiency density of ports by locations. Panel B: Efficiency density of ports with or without containerized cargo. Panel C: Efficiency density of ports by ownership.

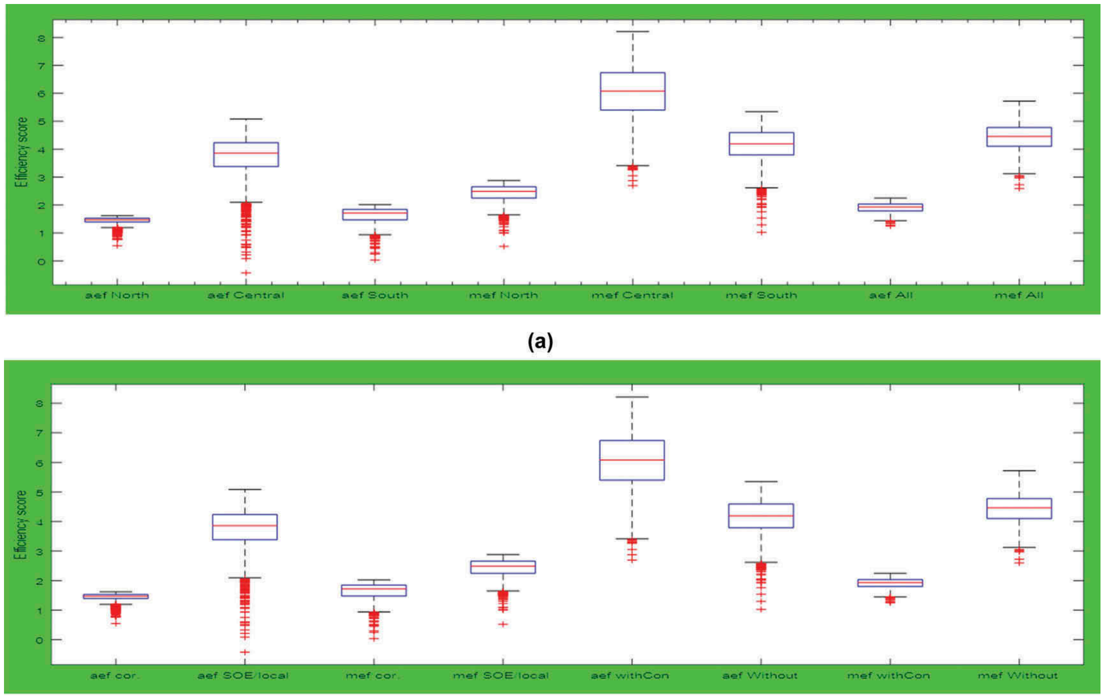


**Figure 2.** Boxplots of bootstrap aggregate and mean technical efficiency of seaports by group.

**Table 4.** Li test for difference in technical efficiency between groups.

| | Ho (f is density) | Li test (*t* stat [P-value]) | Decision on Ho |
|---|---|---|---|
| **Seaport location** | | | |
| North vs central | f(North) = f(Central) | 3.8629 [0.0015] | Reject Ho |
| North vs south | f(North) = f(South) | 0.7277 [0.1775] | Accept Ho |
| Central vs south | f(Central) = f(South) | 0.4368 [0.5285] | Accept Ho |
| **Container serving** | | | |
| With vs without serving container | f(with) = f(without) | 2.9219 [0.0050] | Reject Ho |
| **Ownership** | | | |
| Corporatized vs SOE/local government owned | f(cor) = f(SOE/l. gov) | 2.1723 [0.0160] | Reject Ho |

Ho: 'densities of two seaport groups are equal'.

The aggregate and mean efficiency ratios of container and non-container seaports do not provide consistent results; while the former value is 0.9510 and supports an equality of efficiency, the latter (standing at 0.4428) does not. This shows how the analysis result changes when the analysis accounts for the relative importance of seaports.

The Li test result indicates a significant difference between seaports in the north and the central (P-value of 0.0015). However, there is insignificant difference inefficiency density between the north and south (P-value of 0.1775), and between the central and the south (P-value of 0.5285). The aggregate and mean efficiency ratios (AER and MER) of seaports in the north and central are 0.3394 and 0.3708, respectively, using bias-corrected criteria. These ratios are under unity and significant at 99% of significance level, supporting the outperformance of seaports locating in the north.

The AER and MER for seaports in the north and the south give different results on their performance. The AER is 0.8549 and its interval overlaps unity, indicating insignificant efficiency difference between the two seaport regions. Meanwhile, the value of MER of 0.5269 supports the outperformance of seaports in the north at 0.01 significance. Regarding the test result for the central and the south, the AER obtained from the bootstrapped DEA is 2.2629 indicating that seaports in the south are more efficient at the .10 significance level. However, this is not supported by the MER with the value of 1.3438.

**Table 5.** Simar–Zelenyuk test for difference in technical efficiency between groups.

| | DEA efficiency score | Standard error | Bias correction estimation | Confidence interval 90% | | 95% | | 99% | |
|---|---|---|---|---|---|---|---|---|---|
| **Pair A: Seaports with vs without container serving** | | | | | | | | | |
| Agg.Eff. with container | 1.5857 | 0.1446 | 1.8440 | 1.5829 | 2.0466 | 1.5063 | 2.0723 | 1.3452 | 2.1135 |
| Agg.Eff. without container | 1.7608 | 0.5819 | 1.8138 | 1.0350 | 2.3861 | 0.7995 | 2.4108 | 0.5151 | 2.4548 |
| M.Eff. with container | 2.3874 | 0.4159 | 2.9348 | 2.1743 | 3.5217 | 1.9425 | 3.5829 | 1.5266 | 3.6758 |
| M.Eff. without container | 4.4008 | 0.7795 | 5.8816 | 4.4948 | 7.0821 | 4.2379 | 7.2225 | 3.8106 | 7.4662 |
| AER with/without container | 0.9006 | 0.2474 | 0.9510 | 0.5605 | 1.3397 | 0.4832 | 1.3886 | 0.3069 | 1.4710 |
| MER with/without container | 0.5584 | 0.2328 | 0.4428 | 0.3185 | 0.7424 | 0.2309 | 0.7707 | 0.2141 | 0.8317 |
| **Pair B: Corporatised vs government-owned ports** | | | | | | | | | |
| Agg.Eff. under corporation | 1.4388 | 0.1347 | 1.6299 | 1.3687 | 1.8081 | 1.3208 | 1.8247 | 1.2388 | 1.8475 |
| Agg.Eff. under SOE/local government | 2.4798 | 0.5586 | 2.9275 | 1.8763 | 3.6043 | 1.5542 | 3.6636 | 0.6028 | 3.7530 |
| M.Eff. under corporation | 2.4032 | 0.3414 | 3.0742 | 2.4655 | 3.5542 | 2.3424 | 3.6188 | 2.0035 | 3.7110 |
| M.Eff. under SOE/local government | 4.3008 | 0.7723 | 5.6405 | 4.3287 | 6.7945 | 4.0053 | 6.9432 | 3.4186 | 7.1750 |
| AER under cor./SOE and local gov. | 0.5802 | 0.1590 | 0.5089 | 0.2495 | 0.7590 | 0.1835 | 0.7971 | 0.0716 | 0.8777 |
| MER under cor./SOE and local gov. | 0.5374 | 0.1871 | 0.4545 | 0.3104 | 0.7004 | 0.2075 | 0.7291 | 0.1552 | 0.7871 |
| **Pair C: Seaports locating in the south, the central and the north** | | | | | | | | | |
| Agg.Eff. for the north | 1.3094 | 0.1224 | 1.4441 | 1.2066 | 1.5816 | 1.1133 | 1.5924 | 0.9141 | 1.6122 |
| Agg.Eff. for the central | 3.1483 | 0.7404 | 3.7350 | 2.2854 | 4.6950 | 1.8877 | 4.8246 | 0.8411 | 4.9836 |
| Agg.Eff. for the south | 1.5174 | 0.2699 | 1.6399 | 1.1231 | 1.9465 | 0.9923 | 1.9720 | 0.6790 | 1.9967 |
| M.Eff. for the north | 1.9426 | 0.3084 | 2.4256 | 1.8268 | 2.8070 | 1.6985 | 2.8384 | 1.4069 | 2.8726 |
| M.Eff. for the central | 4.7420 | 0.9291 | 6.0276 | 4.4182 | 7.4308 | 4.0748 | 7.6250 | 3.3863 | 7.9106 |
| M.Eff. for the south | 3.2098 | 0.6069 | 4.1429 | 3.0795 | 5.0110 | 2.8135 | 5.1341 | 2.2125 | 5.2967 |
| AER the north/central | 0.4159 | 0.1365 | 0.3394 | 0.1761 | 0.5402 | 0.1003 | 0.5732 | 0.0891 | 0.6215 |
| AER for the north/south | 0.8629 | 0.1793 | 0.8549 | 0.5679 | 1.1323 | 0.4788 | 1.1828 | 0.2622 | 1.2481 |
| AER for the central/south | 2.0748 | 0.6095 | 2.2629 | 1.1182 | 3.0626 | 0.9281 | 3.1663 | 0.0698 | 3.3046 |
| MER for the north/central | 0.4097 | 0.1375 | 0.3708 | 0.2189 | 0.5473 | 0.1417 | 0.5702 | 0.1028 | 0.6012 |
| MER for the north/south | 0.6052 | 0.2293 | 0.5269 | 0.3147 | 0.8092 | 0.2060 | 0.8378 | 0.1468 | 0.9032 |
| MER for the central/south | 1.4773 | 0.5970 | 1.3438 | 0.9180 | 2.0692 | 0.7115 | 2.1911 | 0.5938 | 2.3114 |
| **Aggregate and mean efficiency of all seaports** | | | | | | | | | |
| Agg.Eff. All | 1.6666 | 0.1637 | 1.9088 | 1.6141 | 2.1471 | 1.5452 | 2.1705 | 1.4415 | 2.2123 |
| M.Eff. All | 3.4677 | 0.4707 | 4.4367 | 3.6404 | 5.1904 | 3.4785 | 5.2874 | 3.1400 | 5.4724 |

Table 5 also provides estimates of technical efficiency for all the seaports and individual groups. The last two rows present the aggregate and mean efficiency scores of all seaports, estimated by standard DEA, which are 1.666 and 3.4677, respectively. However, the bias-corrected values of these estimates are 1.9088 and 4.4367. Even though the methods applied provide different results, the results indicate that Vietnamese seaports appear to underperform. The disparity between aggregate and mean criteria reveals that taking into account the relative importance of seaports according to their revenue can result in different outcomes. Using the sub-sampling bootstrap method, the confidence intervals of aggregate and mean efficiency scores can be obtained. Their .95 confidence intervals are [1.5452; 2.1705] and [3.4785; 5.2874], respectively.

## *Multivariate analysis*

Table 6 shows the results of double-bootstrap two-stage DEA. The coefficients of GS and GC variables are positive and significant at 1% across different models, suggesting the stronger performance of ports in the north compared with the central and the south. There is a significant positive effect of the corporatization variable (OWN) at 5% and 1% significance levels in Models 1 and 3, respectively. The coefficient of the variable representing container handling ports (CN) is consistently positive at 1%, indicating that seaports handling containers tend to be more efficient than those not.

Administrative reform has been seen as a key factor to improve the efficiency of the public

**Table 6.** Regression results on the effect of policy, operational and market conditions on port efficiency.

| | Model 1 | Model 2 | Model 3 | Model 4 |
|---|---|---|---|---|
| Intercept | −54.3986*** | −73.6031*** | −83.9545*** | −80.8247*** |
| | (3.7967) | (1.0014) | (2.7576) | (4.7081) |
| GS | 4.1317*** | 5.4340*** | | |
| | (0.8548) | (0.3171) | | |
| GC | 4.2748*** | 7.9393*** | | |
| | (0.8971) | (0.2997) | | |
| OWN | −1.1678** | | −4.9367*** | |
| | (0.4852) | | (0.5311) | |
| CN | −2.7092*** | | | −4.8201*** |
| | (0.6879) | | | (0.6780) |
| ST | 9.6749*** | 12.1983*** | 15.0904*** | 14.5990*** |
| | (0.5882) | (0.0748) | (0.2820) | (0.6804) |

The coefficients with ** and *** are significant at 5 and 1% respectively. Standard errors are included in parentheses.

sector in general and the maritime sector in particular (Mishra 2011). Variable ST representing the effect of administrative policy on port efficiency is 1% significantly positive across different models indicating the simplification and improvement of the ship arrival and departure procedures has contributed to the improvement of seaport efficiency.

### *Implications*

A number of implications can be drawn from the analysis results. First, the results of univariate and multivariate analysis show that corporatized ports have better performance than SOE/local government-owned ports. This indicates that although Vietnam's corporatization model has helped to improve port performance. To date, however, only eleven of Vietnamese seaports have been corporatized representing about 16% of the total number of seaports. Therefore, the model needs to be applied more extensively to the entire sector. More extensive corporatization not only helps to improve the competitiveness of ports and but also reduces the burden on the State's budget. Alternative models such as BOT (build-operate-transfer), BOOT (build-own-operate-transfer), and BOO (build-own-operate) may also be considered to allow ports to benefit from technology transfer and investment from global operators.

Unlike the complete privatization of ports in other countries, corporatization in Vietnam provides flexibility for the Government to maintain influence on the ports after reform while still taking advantage of the private sector's participation. This helps to avoid the risk of losing control (Schubert 2017). The analysis results indicate that the Government can improve the performance of the port sector through corporatization.

Until now, the main seaports in Vietnam are managed by Vinalines, a state-owned conglomerate. At the time of writing this article, it is undergoing the process of initial public offering (IPO) to be listed in the stock market. However, the completion of Vinalines' corporatization will create a chain of State's control of its seaports. This means the State's ability to manage seaports through Vinalines could potentially be compromised as the company is now under the ownership of both the State Government and the private sector. Complication could arise when the same private company becomes a shareholder of both Vinalines and its subsidiary seaports and therefore gains more control over the latter.

The significance of the port administrative policy variable implies that ports need to improve their administrative procedure. Ports need to be more customer oriented. This can be achieved through the investment and application of information and communication technologies (ICT) in ship and cargo information management, development of a more user-friendly administrative procedure, human resource training, port logistics integration, and upgrading cargo handling facilities.

The landside efficiency of seaports can be improved with dry ports especially with rail connection (Black et al. 2018; Garcia-Alonso, Monios, and Vallejo-Pinto 2019). Given the large hinterlands in north and south, development of inland/dry ports is important to the efficient operations of seaports and economic development. There are currently five dry ports and seven inland custom warehouses with similar functions as dry ports in the north, one dry port and nine inland custom warehouses in the south, but none in the central (Minh Hanh 2019). The Government has announced a specific plan for the development of the dry ports and dry port clusters for all regions (Ministry of Transport 2018). However, the plan mainly refers to the allocation of land areas; there was no detail on infrastructure development and connection with seaports and within the proposed dry port clusters themselves that are important to the efficiency of seaports' landside operations (Roso 2008, 2009). The Government's plan only allows for the proposed dry ports to be financed by the private investors, without its financial support. Therefore, it will be difficult for the Government to ensure the timely development of the proposed dry ports. Thus, the public–private partnership (PPP) approach may be applied instead, especially where businesses and government from municipalities can develop their inland ports based on 'a clear and shared vision' (Witte, Wiegmans, and Ng 2019). To address these issues, Vietnam can learn about the experience and lessons in seaport and dry port development from other countries/regions such as Australia (Black et al. 2018; Roso 2008), China (Beresford et al. 2012; Zeng et al. 2013), Europe (Bask et al. 2014; Kramberger et al. 2018); Mexico (Wilmsmeier, Monios, and Rodrigue 2015), Pakistan (Alam 2016), Portugal (Santos and Soares 2017) and Spain (Garcia-Alonso, Monios, and Vallejo-Pinto 2019).

## VI. Conclusion

As one of the fastest-growing economies in Southeast Asia, Vietnam relies heavily on the seaport sector for its exports and imports. Despite there is a relatively large number of seaports, their operations are subject to various environmental factors depending on the policy, operational and market conditions. This study applied the double-bootstrapped DEA method to evaluate port efficiency under the effect of various environmental factors and conducted Simar and Zelenyuk (2007) and Li (1996) tests to compare the performance levels of ports located in the three regions, the north, central, and south of the country.

The result of analysis using the data for the 2015–2016 period found seaports' efficiency not only varied across the regions and type of ports but was also constrained by the administrative procedures, types of ownership, and management models. Seaports locating in the north appeared to have a higher level of performance compared with those in the central and the south. Those seaports that offer container cargo services tend to be more efficient than those do not offer them. Corporatization and port administrative reform appear to have had positive effects on port performance.

This study has contributed to the literature on seaport performance management in a number of ways. It considered the effect of various reform measures including administrative procedure reform and corporatization on port efficiency in the context of Vietnam as a transitional economy that has not previously been considered in the literature. Furthermore, the study examined the variations in port performance across the three regions of the country. In addition, it has applied various methods to obtain extensive analysis results, including univariate and multivariate analysis, double bootstrapped DEA, and comparison of the aggregate and mean efficiency and its densities.

## Disclosure statement

No potential conflict of interest was reported by the authors.

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## References

Alam, J. 2016. "Role of Effective Planning Process in Boosting Dry Port Effectiveness: A Case Study of Central Pakistan." *International Journal of Supply Chain Management* 5: 153–164.

Ambrosino, D., C. Ferrari, A. Sciomachen, and A. Tei. 2018. "Ports, External Costs, and Northern Italian Transport Network Design: Effects for the Planned Transformation." *Maritime Policy & Management* 45 (6): 803–818. doi:10.1080/03088839.2018.1448475.

Andersen, P., and N. C. Petersen. 1993. "A Procedure for Ranking Efficient Units in Data Envelopment Analysis." *Management Science* 39 (10): 1261–1264. doi:10.1287/mnsc.39.10.1261.

Banker, R. D., A. Charnes, and W. W. Cooper. 1984. "Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis." *Management Science* 30 (9): 1078–1092. doi:10.1287/mnsc.30.9.1078.

Bask, A., V. Roso, D. Andersson, and E. Hämäläinen. 2014. "Development of Seaport–dry Port Dyads: Two Cases from Northern Europe." *Journal of Transport Geography* 39: 85–95. doi:10.1016/j.jtrangeo.2014.06.014.

Beresford, A., S. Pettit, Q. Xu, and S. Williams. 2012. "A Study of Dry Port Development in China." *Maritime Economics & Logistics* 14 (1): 73–98. doi:10.1057/mel.2011.17.

Bichou, K. 2013. "An Empirical Study of the Impacts of Operating and Market Conditions on Container-port Efficiency and Benchmarking." *Research in Transportation Economics* 42 (1): 28–37. doi:10.1016/j.retrec.2012.11.009.

Black, J., V. Roso, E. Marušić, and N. Brnjac. 2018. "Issues in Dry Port Location and Implementation in Metropolitan Areas: The Case of Sydney, Australia." *Transactions on Maritime Science* 7 (1): 41–50. doi:10.7225/toms.v07.n01.004.

Blancas, L. C., J. Isbell, M. Isbell, H. J. Tan, and W. Tao. 2014. *Efficient Logistics: A Key to Vietnam's Competitiveness*. Washington, DC: World Bank.

Boitani, A., M. Nicolini, and C. Scarpa. 2013. "Do Competition and Ownership Matter? Evidence from Local Public Transport in Europe." *Applied Economics* 45 (11): 1419–1434. doi:10.1080/00036846.2011.617702.

Brooks, M. R., K. P. Cullinane, and A. A. Pallis. 2017. "Revisiting Port Governance and Port Reform: A Multi-country Examination." *Research in Transportation Business & Management*, no. 22: 1–10. doi:10.1016/j.rtbm.2017.02.005.

Chang, V., and B. Tovar. 2014. "Efficiency and Productivity Changes for Peruvian and Chilean Ports Terminals: A Parametric Distance Functions Approach." *Transport Policy* 31: 83–94. doi:10.1016/j.tranpol.2013.11.007.

Chang, V., and B. Tovar. 2017. "Metafrontier Analysis on Productivity for West Coast of South Pacific Terminals." *Transportation Research Part A: Policy and Practice* 103: 118–134.

Charnes, A., W. W. Cooper, and E. Rhodes. 1978. "Measuring the Efficiency of Decision Making Units." *European Journal of Operational Research* 2: 429–444. doi:10.1016/0377-2217(78)90138-8.

Cullinane, K., and D.-W. Song. 2003. "A Stochastic Frontier Model of the Productive Efficiency of Korean Container Terminals." *Applied Economics* 35 (3): 251–267. doi:10.1080/00036840210139355.

Farrell, M. J. 1957. "The Measurement of Productive Efficiency." *Journal of the Royal Statistical Society. Series A (General)* 120 (3): 253–290. doi:10.2307/2343100.

Ferrari, C., F. Parola, and A. Tei. 2015. "Governance Models and Port Concessions in Europe: Commonalities, Critical Issues and Policy Perspectives." *Transport Policy* 41: 60–67. doi:10.1016/j.tranpol.2015.03.012.

Garcia-Alonso, L., J. Monios, and J. Á. Vallejo-Pinto. 2019. "Port Competition through Hinterland Accessibility: The Case of Spain." *Maritime Economics & Logistics* 21 (2): 258–277. doi:10.1057/s41278-017-0085-5.

González, M. A. M., and L. Trujillo. 2008. "Reforms and Infrastructure Efficiency in Spain's Container Ports." *Transportation Research Part A: Policy and Practice* 42 (1): 243–257.

Hanh, M. 2019. "Ministry of Transport Announces the Dry Port System." https://www.msn.com/vi-vn/news/national/b%E1%BB%99-giao-th%C3%B4ng-v%E1%BA%ADn-t%E1%BA%A3i-c%C3%B4ng-b%E1%BB%91-h%E1%BB%87-th%E1%BB%91ng-c%E1%BA%A3ng-c%E1%BA%A1n/ar-AAC5ckP

Hanson, G. H. 2012. "The Rise of Middle Kingdoms: Emerging Economies in Global Trade." *Journal of Economic Perspectives* 26 (2): 41–64. doi:10.1257/jep.26.2.41.

Hesse, M. 2018. "Approaching the Relational Nature of the Port-City Interface in Europe: Ties and Tensions between Seaports and the Urban." *Tijdschrift Voor Economische En Sociale Geografie* 109 (2): 210–223. doi:10.1111/tesg.2018.109.issue-2.

Hung, S.-W., W.-M. Lu, and T.-P. Wang. 2010. "Benchmarking the Operating Efficiency of Asia Container Ports." *European Journal of Operational Research* 203 (3): 706–713. doi:10.1016/j.ejor.2009.09.005.

Kramberger, T., J. Monios, G. Strubelj, and B. Rupnik. 2018. "Using Dry Ports for Port Co-opetition: The Case of Adriatic Ports." *International Journal of Shipping and Transport Logistics* 10 (1): 18–44. doi:10.1504/IJSTL.2018.088319.

Le, P. T., C. Harvie, and A. Arjomandi. 2017. "Testing for Differences in Technical Efficiency among Groups within an Industry." *Applied Economics Letters* 24 (3): 159–162. doi:10.1080/13504851.2016.1173172.

Lee, P. T.-W., and J. S. L. Lam. 2017. "A Review of Port Devolution and Governance Models with Compound Eyes Approach." *Transport Reviews* 37 (4): 507–520. doi:10.1080/01441647.2016.1254690.

Li, Q. 1996. "Nonparametric Testing of Closeness between Two Unknown Distribution Functions." *Econometric Reviews* 15 (3): 261–274. doi:10.1080/07474939608800355.

Li, Q. 1999. "Nonparametric Testing the Similarity of Two Unknown Density Functions: Local Power and Bootstrap Analysis." *Journal of Nonparametric Statistics* 11 (1–3): 189–213. doi:10.1080/10485259908832780.

Ministry of Transport. 2018. *Decision No. 1201/QĐ-BGTVT: Plan for the Development of the Vietnamese Dry Port System Upto Year 2020, with Orientation to Year 2030 (Quyết Định Số: 1201/QĐ-BGTVT: Phê Duyệt Quy Hoạch Chi Tiết Phát Triển Hệ Thống Cảng Cạn Việt Nam Giai Đoạn Đến Năm 2020, Định Hướng Đến Năm 2030)*. Hanoi: Ministry of Transport.

Mishra, D. 2011. *Vietnam Development Report 2012: Market Economy for a Middle-income Vietnam*. Washington DC: Worldbank.

Na, J.-H., A.-Y. Choi, J. Ji, and D. Zhang. 2017. "Environmental Efficiency Analysis of Chinese Container Ports with CO2 Emissions: An Inseparable Input-output SBM Model." *Journal of Transport Geography* 65: 13–24. doi:10.1016/j.jtrangeo.2017.10.001.

Nguyen, H.-O., H.-S. Nghiem, and Y.-T. Chang. 2018. "A Regional Perspective of Port Performance Using Metafrontier Analysis: The Case Study of Vietnamese Ports." *Maritime Economics and Logistics* 20 (1): 112–130. doi:10.1057/s41278-017-0061-0.

Nguyen, H.-O., H.-V. Nguyen, Y.-T. Chang, A. T. H. Chin, and J. Tongzon. 2016. "Measuring Port Efficiency Using Bootstrapped DEA: The Case of Vietnamese Ports." *Maritime Policy & Management* 43 (5): 644–659. doi:10.1080/03088839.2015.1107922.

O'neill, J., D. Wilson, R. Purushothaman, and A. Stupnytska. 2005. "How solid are the BRICs?" *Global Economics Paper* 134.

Panayides, P. M., C. N. Maxoulis, T.-F. Wang, and K. Y. A. Ng. 2009. "A Critical Analysis of DEA Applications to Seaport Economic Efficiency Measurement." *Transport Reviews* 29 (2): 183–206. doi:10.1080/01441640802260354.

Pettit, S. J., and A. K. C. Beresford. 2009. "Port Development: From Gateways to Logistics Hubs." *Maritime Policy & Management* 36 (3): 253. doi:10.1080/03088830902861144.

Rodrigue, J.-P., and T. Notteboom. 2005. "Port Regionalisation: Towards a New Phase in Port Development." *Maritime Policy & Management* 32 (3): 297–313. doi:10.1080/03088830500139885.

Rodrigue, J.-P., and T. Notteboom. 2010. "Comparative North American and European Gateway Logistics: The Regionalism of Freight Distribution." *Journal of Transport Geography* 18 (4): 497–507. doi:10.1016/j.jtrangeo.2010.03.006.

Roso, V. 2008. "Factors Influencing Implementation of a Dry Port." *International Journal of Physical Distribution & Logistics Management* 38 (10): 782–798. doi:10.1108/09600030810926493.

Roso, V. 2009. "Emergence and Significance of Dry ports–The Case of the Port of Göteborg." *World Review of Intermodal Transportation Research* 2 (4): 296–310. doi:10.1504/WRITR.2009.026209.

Santos, T. A., and C. G. Soares. 2017. "Development Dynamics of the Portuguese Range as a Multi-port Gateway System." *Journal of Transport Geography* 60: 178–188. doi:10.1016/j.jtrangeo.2017.03.003.

Schubert, S. 2017. "NT Government Confirms Negotiations Underway to Retain Stake in Darwin's Port." *ABC News*, April 18.

Serebrisky, T., J. M. Sarriera, A. Suárez-Alemán, G. Araya, C. Briceño-Garmendía, and J. Schwartz. 2016. "Exploring the Drivers of Port Efficiency in Latin America and the Caribbean." *Transport Policy* 45: 31–45. doi:10.1016/j.tranpol.2015.09.004.

Simar, L., and P. W. Wilson. 2007. "Estimation and Inference in Two-stage, Semi-parametric Models of Production Processes." *Journal of Econometrics* 136 (1): 31–64. doi:10.1016/j.jeconom.2005.07.009.

Simar, L., and V. Zelenyuk. 2006. "On Testing Equality of Distributions of Technical Efficiency Scores." *Econometric Reviews* 25 (4): 497–522. doi:10.1080/07474930600972582.

Simar, L., and V. Zelenyuk. 2007. "Statistical Inference for Aggregates of Farrell-type Efficiencies." *Journal of Applied Econometrics* 22 (7): 1367–1394. doi:10.1002/()1099-1255.

Sun, J., Y. Yuan, R. Yang, X. Ji, and J. Wu. 2017. "Performance Evaluation of Chinese Port Enterprises under Significant Environmental Concerns: An Extended DEA-based Analysis." *Transport Policy* 60: 75–86. doi:10.1016/j.tranpol.2017.09.001.

Tongzon, J. 2001. "Efficiency Measurement of Selected Australian and Other International Ports Using Data Envelopment Analysis." *Transportation Research Part A: Policy and Practice* 35 (2): 107–122.

Venkatesh, V. G., A. Zhang, S. Luthra, R. Dubey, N. Subramanian, and S. Mangla. 2017. "Barriers to Coastal Shipping Development: An Indian Perspective." *Transportation Research Part D*. doi:10.1016/j.trd.2017.03.016.

Vietnam Seaports Association. 2019. *Statistics 2017*. http://www.vpa.org.vn/.

Vietnam Seaports Association. 2018. *VPA - Summary of Throughput in 2017*. http://www.vpa.org.vn/.

Wanke, P. F. 2013. "Physical Infrastructure and Shipment Consolidation Efficiency Drivers in Brazilian Ports: A Two-stage network-DEA Approach." *Transport Policy* 29: 145–153. doi:10.1016/j.tranpol.2013.05.004.

Wanke, P. F., and C. P. Barros. 2015. "Public-private Partnerships and Scale Efficiency in Brazilian Ports: Evidence from Two-stage DEA Analysis." *Socio-economic Planning Sciences* 51: 13–22. doi:10.1016/j.seps.2015.06.002.

Wilmsmeier, G., J. Monios, and J.-P. Rodrigue. 2015. "Drivers for Outside-In Port Hinterland Integration in Latin America: The Case of Veracruz, Mexico." *Research in Transportation Business & Management* 14: 34–43. doi:10.1016/j.rtbm.2014.10.013.

Witte, P., B. Wiegmans, and A. K. Ng. 2019. "A Critical Review on the Evolution and Development of Inland Port Research." *Journal of Transport Geography* 74: 53–61. doi:10.1016/j.jtrangeo.2018.11.001.

World Bank. 2007. *Port Reform Toolkit*. 2nd ed. Washington, DC: World Bank.

World Bank. 2020. *World Development Indicators*. Washington, DC: World Bank.

Wu, S., K. X. Li, W. Shi, and Z. Yang. 2016. "Influence of Local Government on Port Investment: Implications of China's Decentralized Port Governance System." *Maritime Policy & Management* 43 (7): 777–797. doi:10.1080/03088839.2016.1163431.

Wu, Y.-C. J., and M. Goh. 2010. "Container Port Efficiency in Emerging and More Advanced Markets." *Transportation Research Part E: Logistics and Transportation Review* 46 (6): 1030–1042. doi:10.1016/j.tre.2010.01.002.

Yuen, A. C.-L., A. Zhang, and W. Cheung. 2013. "Foreign Participation and Competition: A Way to Improve the Container Port Efficiency in China?" *Transportation Research Part A: Policy and Practice* 49: 220–231.

Zeng, Q., M. J. Maloni, J. A. Paul, and Z. Yang. 2013. "Dry Port Development in China: Motivations, Challenges, and Opportunities." *Transportation Journal* 52 (2): 234–263. doi:10.5325/transportationj.52.2.0234.

Zhang, J. 2016. "Quasi-landlord Port Financing in China: Features, Practice and a Contract Theory Analysis." *Transportation Research Part A: Policy and Practice* 89: 73–88.