Impact of privatization on port efficiency and effectiveness: results from Panama and US ports

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Panama has five main ports: Balboa and PSA Panama International on the Pacific, and Cristóbal, Manzanillo and Colon Container Terminal (CCT) on the Caribbean side. The government of Panama originally operated the ports of Balboa and Cristóbal. After being transferred from the United States government, most of these ports were privatized in the late 1990s. During this period, some ports in the United States have moved away from operating to non-operating. There are more private sector involvements and public–private partnerships. However, in the US there are few full asset privatizations as was done in Panama. This range of privatizations provides the opportunity to study the effects of various types of privatization on port production. We use financial econometric techniques to assess port performance during government operation and private sector operation. The results of the study provide an estimate of the savings and effectiveness gains from privatizations. Few studies examine effectiveness, beyond questionnaires of users. However, especially for transshipment ports as are the case in Panama, service variables, along with price, are very important in determining demand for service. This study compares the effectiveness of Panama privatized ports with US ports in which there are degrees of privatization.

1. Introduction
Globalization and international trade are increasingly important functions for ports and maritime transportation. Port efficiency based on operational performance is crucial in maintaining advantage in a competitive environment. There have been a variety of papers that attempt to quantify the relationship between economic efficiency and port privatization. These include Cullinane et al. [1] who used a stochastic frontier model to estimate efficiency in different privatization schemes and Wang and Knox [2] who also utilized a stochastic frontier model to estimate efficiency impacts of privatization on US ports. Cullinane and Song [3] investigated the theoretical underpinnings and practical validity that private sector involvement in ports increases the efficiency of operations. Pagano, Sanchez and Ungo [4] developed a model of the privatization process in game theoretic terms for ports in Panama.

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Researchers appeared increasingly concerned about port efficiency and port performance. But few studies examine effectiveness, beyond questionnaires of users. There have been a variety of studies of port choice and service characteristics of ports. These include Murphy et al. [5] who developed a set of factors affecting port choice in order of importance to carriers. Pardali and Michalopoulos [6] used benchmarking analysis to ascertain the competitiveness of the Port of Piraeus compared to other Mediterranean ports in terms of services offered. Bergantino and Bolis [7] used stated preference analysis to understand the importance of port service attributes. Ugboma et al. [8] analyzed service quality in two Nigerian ports. They collected data on ports using a questionnaire, which was given to port uses and was developed from focus groups and the literature. Finally, Rugman and Verbeke [9] applied Porter’s diamond to the port industry, concluding that the port’s position in the market is determined by six main factors: (a) factor conditions; (b) demand conditions; (c) related and supporting industries; (d) the strategy of competitors; (e) chance; and (f) government.

2. Types of port privatizations
There are a variety of roles that the public and private sectors can play in a privatization scheme. Traditionally, ports have been considered either pure public, where all operations are performed by the public sector, mixed in which the public sector is a landowner and operations are performed by the private sector and pure private in which ownership and all functions are performed by the private sector. However, within these three categories, there are many variations. Some of these are shown in Table 1.

The first approach is pure public. In this case the public sector owns and operates the port. This approach is very prevalent in the US. Many ports in the US at some point in their history were of this approach. While the private sector plays no operating role, it is utilized extensively for the design and construction of the facility.

| Type                           | Public sector role                                      | Private sector operating role                           |
|--------------------------------|--------------------------------------------------------|--------------------------------------------------------|
| 1. Pure public                 | Public sector owns and operates port                    | None                                                   |
| 2. Landowner and regulator     | Public sector owns port and regulates private sector    | Operation – competition among terminals                 |
| 3. Build, operate transfer – BOT – Greenfield Concession | Negotiation with private companies, regulation          | Operation                                              |
| 4. Long-term lease of existing facility – Brownfield Concession | Negotiation with private companies, regulation          | Operation – competition among terminals                 |
| 5. Pure private                | None                                                   | Operation – competition among terminals                 |
| 6. Publicization               | Public sector owns and operates port                    | Operate and maintain                                    |
The second approach is very prevalent in the US. In this approach, the public sector, usually a public authority, owns the port. The private sector becomes a tenant and leases land from the port. In this approach, the private sector usually owns the equipment. Several private sector terminals can share the same port as tenants.

Approach three is Build Operate Transfer (BOT) or Design Build Operate Transfer (DBOT). In this approach, the private sector builds, operates, finances, maintains the facility and then over a period of years transfers the facility to the public sector. This is called a “Greenfield Concession” since a brand new facility is built. This type of concession has been implemented in Panama.

A long-term lease of an existing facility, called a “Brownfield Concession,” is this fourth approach. This type of concession has been utilized in Panama to privatize the government run ports. Both the Brownfield and Greenfield concessions are similar to approach/type 2 above. In these two cases, however, an initial payment is made to the port and a payment related to revenue is made on a continuing basis.

In the pure private alternative, the private sector builds and operates its own port, or the public sector sells an existing port to the private sector. This latter approach is used to privatize State Owned Enterprises. The private sector takes the role of financing, operating, and maintaining the facility. The public sector role is either to negotiate a sales price with private companies or to have no role. There are two types of asset sales. One is a Citizen Share Purchase in which the asset is sold to an individual company or shares are sold in the marketplace. In this approach, the government keeps all the proceeds from the sale. The privatization of Conrail in the US was done in this manner. The second approach is called “Voucher Privatization” by Pool [10]. In this approach, the SOE is privatized by distributing shares to citizens of the country. Citizens are free to sell or keep their shares. In this case, the proceeds from the sale accrue to individuals rather than to the government. British Columbia used this approach in the privatization of its state owned forest products and natural gas companies. Pool notes that the Czech Republic in privatizing its SOE’s also used this approach. Asset sales are similar to “Brownfield Concessions,” except the facility is permanently transferred to the private sector.

The last PPP approach can be called “Publicization.” In this approach, the public sector becomes involved in what was an exclusive private operation. Publicization is not nationalization, since there is a very large role played by the private sector. An example in a port setting is the Alameda Corridor project in Southern California, where the railroads and the ports created a public entity to service the ports of Long Beach and Los Angeles. In each case, the public sector has become involved in what has traditionally been a strictly private sector endeavor to build, maintain and operate a transportation infrastructure.

3. Efficiency and port privatization

Academic research has largely used the concept of efficiency to assess performance. In port literature, Coto-Millán et al. [11], Talley [12], Wang and Knox [2], and Wang et al. [13] discussed three types of efficiency: technical, allocative, and overall efficiency. Technical efficiency is defined as achieving the highest productivity given available inputs or production at the least possible cost per unit of output. The concept refers to the production possibility frontier and the isocost curve.
Firms produce on the production possibilities frontier when the right mix of resources is used and no resource is idle. Allocative efficiency is defined as producing the goods and services that consumers want. Firms are considered to operate with this form of efficiency if the value of the next unit of output produced equates with the value of the inputs used ($MR = MC$). Overall efficiency exists when a firm maximizes both technical and allocative efficiency and can be examined using the profit function.

Using the profit function, we evaluated the overall efficiency of ports. This enables a comprehensive examination of efficiency and is necessitated by the nature of US port authorities and our use of financial data. Differences in operating status result in differences in mission and output. Ports may differ in allocative or technical efficiency based on operating objectives yet exhibit the equivalent levels of overall economic efficiency.

A central objective of port privatization and private sector involvement is stimulating efficiency, e.g., Cullinane and Song [14], Chang and Lee [15]. To measure efficiency, most studies use data envelopment analysis (DEA) or the stochastic frontier model (SFM). The former focuses on non-parametric linear programming without assuming a specific distribution of the error terms. The latter is a statistical method with concise production structures that can be estimated. Both methods have been extensively applied in the port literature.

Though the DEA approach generates multiple inputs and outputs at once, we used the Stochastic Frontier Model estimated through panel regressions rather than DEA because of our interest in a concise representation of the industry’s profit function through production and costs. Aigner et al. [16], Pitt and Lee [17], Schmidt and Sickles [18], Liu [19], Cullinane et al. [20], and Greene [21] are examples of the stochastic frontier model. Cullinane et al. [20] found that transformation of ownership from the public to the private sector improves Asian ports’ efficiency. Cullinane and Song [14] noted that private sector involvement and privatization improve productive efficiency of Korean container terminals. Tongzon and Heng [22] concluded that private sector participation in the Asian, European, and American container terminals improves port operation efficiency.

Contrary to these studies, Liu [19] failed to identify ownership as a significant factor of production and efficiency in British ports. A similar outcome can be found in Notteboom et al. [23] in studying a set of 36 European container terminals. Saundry and Turnbull [24] noted that deregulation rather than privatization, contributes to improving service to port users. Cullinane and Song [3] showed that privatization only partially improves economic efficiency and financial and operational performance. Thus, research on this subject is far from settled.

Review of the literature points to a research gap. Existing studies focusing on Asian and European ports provide mixed results to support the argument that private sector involvement improves economic efficiency. Thus, the principal contribution of this paper is to add to the literature from a perspective that examines the financial performance of privatized and non-privatized ports in the US, using the stochastic frontier profit function and panel data regression analysis. Further, this paper explains the efficiency determinants of port profitability. This analysis is extended by examining the impact of privatization on port effectiveness. This is examined by incorporating Panama ports into the analysis.
4. Methodology and data

4.1. Theoretical framework

Production frontier models indicate maximum production capacity given the combination of available resources. Inefficiency is measured by the extent that a firm deviates from the production possible frontier. Thus, the OLS regression is biased because firms may fall short of the production frontier but cannot go beyond it. Likewise, symmetric distribution around the production frontier cannot be guaranteed. To fix it, Aigner et al. [16] were among the pioneers proposing the stochastic frontier model with the maximum likelihood estimators. Later, Kumbhakar and Lovell [25] provided a detailed explanation.

We assumed that each firm produces less than its optimal output due to a degree of inefficiency. Specifically, \( Y_{it} = f(X_{it}; \beta)\xi_{it} \), where \( Y_{it} \) and \( X_{it} \) are the appropriate form of output and the combination of inputs respectively in the production function with \( i \) denoting ports and \( t \) denoting time. \( \xi_{it} \in (0, 1) \) is the level of technical efficiency. The production function is subjected to random and uncontrolled factors by adding the stochastic components. These effects are described by \( \exp(v_{it}) \).

\[
Y_{it} = f(X_{it}; \beta)\xi_{it}\exp(v_{it})
\]

where \( t = 1, 2 \). Taking the natural log on both sides of above equation and substituting \( u_{it} = -\ln(\xi_{it}) \), we obtain

\[
\ln Y_{it} = \beta_0 + \sum_k \ln x_k + v_{it} - u_{it}
\]

where \( v \) is the idiosyncratic component that captures statistical noise. It is assumed to be independently and identically \( N(0, \sigma_v^2) \) distributed. \( u \) indicates the unobservable efficiency shortfall that could potentially be avoided. Different specifications of the inefficiency \( u \) studied are half-normal, exponential, and truncated normal with the log-transformed variables to estimate the maximum likelihood function.

Since we included only 10 container ports in the study, panel data rather than cross-sectional analysis is used. For the panel data study, technical and cost efficiency were estimated based on the assumption of whether the inefficiency is time invariant or time-varying decay. The former reports fixed efficiency scores throughout the study period; the latter shows efficiency scores which vary over time.

4.2. Data specification

In the port efficiency literature, the empirical study of a port’s financial appraisal is surprisingly sparse. Saundry and Turnbull [24] examined whether the United Kingdom’s privatized ports out-perform the public ports. Pallis and Syriopoulos [26] identified efficiencies of port performance in Greece and examine whether port privatization improves the key financial indicators. Neither study provides a clear conclusion about whether private ports live up to expectations. To fill this gap, we assessed the influence of administrative and operating status on port efficiency and examine whether privatization exerts a direct impact on financial performance.

4.2.1. Definition of privatization for selected ports. Based on the maritime container cargo handled by the America’s Container Ports, our sample includes 14 leading US container ports across three major geographic regions, Atlantic, Pacific, and Gulf. After filtering out the ports where there is missing data, nine ports remain
in the unbalanced panel study, five on the West Coast, three on the East Coast, and one on the Gulf Coast. To investigate regional competition and collaboration, we added the Port of New Orleans. Figure 1 shows container traffic for the selected ports. The leading container ports in the US are published by the Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics [27], and the Maritime Administration [28]. When discussing the effectiveness of container ports, we obtained total Twenty-Foot Equivalent Units (TEUs) for North America from the American Association of Port Authorities (AAPA) Surveys [29] and the World container traffic from the Containerization International Yearbooks [30].

Given the unique structure of the US ports, the first proxy to define privatization is a port’s operating status. Based on a port’s regulatory, landowner, and operator functions, as mentioned in Baird [31] and Cullinane et al. [20], port ownership can be divided into public, public/private, private/public, and purely private. Similarly, the port devolution matrix in Baltazar and Brooks [32] provided guidance for landlord and operator ports based on port governance and operations. According to the Public Port Finance Survey published by the Maritime Administration, ports can be categorized as operating, limited-operating, and non-operating. Operating ports provide all services except stevedoring. Non-operating ports basically are landlord ports with all facilities leased; limited-operating ports are between operating and non-operating ports. In this study, we define privatization as the transition from operating to non-operating (Landlord) status. The financial data is accessible through Public Port Finance Survey published by the US Department of Transportation Maritime Administration. Annual data were collected for the 10-year period from 1997 to 2006.

The second proxy used to quantify private sector involvement is the public-private ratio (Figures 2–4). Three ratios are established to capture private sector involvement

**Figure 1. Container traffic in million of TEUs for selected ports.**
Source: The America’s Container Ports published by the Research and Innovative Technology Administration (RITA) Bureau of Transportation Statistics.
Figure 2. Private sector involvement for selected container ports.  
Source: The US Army Corps of Engineers.  
Note: Pure private ratio is calculated by the number of terminals, docks, wharves, shipyards, and piers that are operated and owned by private corporations to total facilities ratio accumulated over years.

Figure 3. Partial private sector involvement for selected container ports.  
Source: The US Army Corps of Engineers.  
Note: Partial private ratio is calculated by the number of publicly owned terminals, docks, wharves, shipyards, and piers that are operated by private corporations to total facilities ratio accumulated over years.
at a terminal level. Pure private ratio indicates the percentage of terminals, docks, wharves, shipyards, and piers in a given port owned and operated by private corporations. Mixed ratio represents the percentage of terminal, docks, wharves, and piers that are public owned but operated by the private sector. Pure public is percentage of terminals and facilities in a port that are owned and operated by a public entity. The information on port facilities at the terminal level is available from the US Army Corps of Engineers [33].

4.2.2. Definition of other variables. Financial performance in terms of profitability of a port is (a) positively related to the price of output measured by average revenue earned, (b) positively related to the level of capital intensity measured by resources devoted to capital such as plant, property & equipment, and (c) uncertain about the operating status that represents privatization. The advantage of privatization comes from strengthened managerial incentives and better capital utilization. Fiscal and labor constraints will be tightened without government subsidy. Thus, whether private operating status improves port’s financial performance depends on which effect outweighs the other.

\[
\ln Profit = \beta_0 + \beta_1 \ln(AR) + \beta_2 \ln(CapInt) + \beta_3 \text{Operating} + v - u \tag{1}
\]

\[
\ln Profit = \beta_0 + \beta_1 \ln(AR) + \beta_2 \ln(CapInt) + \beta_3 \ln(Public) + v - u \tag{2}
\]
In Equation (1), a dummy variable, Operating, is included as a control for ports categorized as operating. In addition, we define a quantitative measure of privatization in Equation (2); Public identifies the percentage of terminals that are owned and operated by public entities. For simplicity, we drop panel subscriptions i and t, which represent port i at time t. A quantitative measure tests the hypothetical scenario that increasing the private sector involvement will enhance a port’s financial performance and profit. Table 2 summarizes the definition of variables. Table 2 reports descriptive statistics of key variables included in the study.

5. Results
Table 3 presents the descriptive statistics for efficiency and effectiveness. We estimated the stochastic frontier models using profitability and TEU ratio as dependent variables. On average, profit per ton measured by operating income
divided by total short tons of cargos is around $2400. The average container traffic is above 2 million TEUs.

5.1. Efficiency

Table 4 is the results for stochastic profit function. The efficiency scores for the time-invariant model and the time varying model are presented in Tables 5 and 6,

| Table 4. Panel frontier model for efficiency. |
|-----------------------------------------------|
| Model 1 | Model 2 | Model 3 | Model 4 |
| Time-invariant | Time-varying | Time-invariant | Time-varying |
| ln AR | 1.0428 | 1.038 | 1.0354 | 1.036 |
| (0.221)*** | (0.022)*** | (0.024)*** | (0.024)*** |
| ln CapInt | 0.3797 | 0.619 | 0.0273 | 0.146 |
| (0.237) | (0.136)*** | (0.2593) | (0.332) |
| Operating | -0.7666 | 0.460 | -0.3549 | -0.293 |
| (0.223)*** | (0.148)*** | (0.1944)* | (0.237) |
| Landlord | | | | |
| ln Public | | | | |
| Cons | -3.6465 | -6.006 | -1.3069 | -2.153 |
| (1.949)* | (0.999)*** | (1.9527) | (2.430) |
| Obs | 69 | 69 | 69 | 69 |
| N | 10 | 10 | 10 | 10 |
| σ² | 0.1795 | 0.207 | 0.1897 | 0.193 |
| σ²ₚ | 4.2677 | 8.833 | 1.0985 | 0.957 |

Notes: Models 1 and 2 report binary dummy variables Operating and Landlord to represent a port’s operating structure; Models 3 and 4 use a quantitative ratio Public to quantify public private partnership. In the time invariance models 1 and 3, ui = w belong to truncated normal distribution, N(μ, σ²). We report the maximum likelihood estimates of panel frontier models with standard errors in the parentheses. *** and * are significant at the 1% and 10% levels, respectively.

| Table 5. Time-invariant efficiency scores for the selected US container ports. |
|-----------------------------------------------|
| Ports | Model 1 | Model 3 |
| Port of Oakland (CA) | 0.8984 | 0.8378 |
| Port of Long Beach (CA) | 0.8951 | 0.8522 |
| Port of Los Angeles (CA) | 0.8642 | 0.7485 |
| Port of Seattle (WA) | 0.7862 | 0.4040 |
| Port of Miami (FL) | 0.7666 | 0.5889 |
| Port of Everglades (FL) | 0.7263 | 0.8561 |
| Port Authority of NY &NJ | 0.6630 | 0.7032 |
| Port of New Orleans (LA) | 0.6370 | 0.4787 |
| Port of Tacoma (WA) | 0.5137 | 0.5403 |
| Port of Houston (TX) | 0.3800 | 0.2459 |

Note: Time-invariant efficiency scores from Models 1 and 3 are reported in Table 4. Model 1 studies port efficiency by introducing a binary dummy Operating to evaluate privatization while Model 3 provides a quantitative measure Public to analyze how private sector involvement impact port profitability.
respectively. Models 1 and 2 report the binary dummy variables *Operating* and *Landlord* to represent a port’s operating structure; Models 3 and 4 use a quantitative ratio *Public* to quantify public private partnership.

Even though the ports selected in this research grew in terms of container traffic from 1997 to 2006, the driving force behind the growth is different across regions. Ports on the west side benefit from increased US trade with Pacific countries while the growth on the Gulf Coast relies on the expansion of traffic with Latin America. Overall, from Table 5, the container ports on the West, such as Ports of Oakland, Long Beach, and Los Angeles, and ports on the East such as Ports of Everglades, New York & New Jersey, dominate the ports in the Gulf, the ports of New Orleans and Houston. The results could reflect that West Coast ports handled the most container trade compared to ports on the East Coast and the Gulf coast.

Time-varying efficiency scores from Models 2 are reported in Table 6. Model 2 studies port efficiency by introducing a binary dummy *Landlord* to evaluate privatization. The efficiency coefficients for Model 4 are available based on request.

The efficiency ranking is consistent with the time-invariance estimates presented in Table 5. The only exception is the Port Authority of NY&NJ. Only two observations are available across the study period of 1997 to 2006 for the Port Authority of NY&NJ. The outcome could result from data deficiency.

5.2. Efficiency determinants

Once we located the efficiency scores, our next step was to identify efficiency determinants that can explain why a certain port has higher efficiency in terms of profitability than others. The hypotheses tested are (1) whether economics of scale improves port efficiency in terms of profitability in Model 1 and (2) whether product diversification enhances operating efficiency in Models 2 to 4. Table 7 reports the

| Ports                  | Model 2 | Min   | Max   | Obs |
|------------------------|---------|-------|-------|-----|
| Port of Los Angeles (CA)| 0.902   | 0.785 | 0.972 | 9   |
|                        | (0.067) |       |       |     |
| Port of Seattle (WA)   | 0.892   | 0.729 | 0.963 | 4   |
|                        | (0.110) |       |       |     |
| Port of Oakland (CA)   | 0.887   | 0.801 | 0.947 | 5   |
|                        | (0.064) |       |       |     |
| Port of Tacoma (WA)    | 0.864   | 0.764 | 0.937 | 7   |
|                        | (0.063) |       |       |     |
| Port of Long Beach (CA)| 0.861   | 0.699 | 0.959 | 10  |
|                        | (0.088) |       |       |     |
| Port of Everglades (FL)| 0.829   | 0.637 | 0.948 | 10  |
|                        | (0.105) |       |       |     |
| Port of Houston (TX)   | 0.808   | 0.597 | 0.941 | 10  |
|                        | (0.117) |       |       |     |
| Port of Miami (FL)     | 0.796   | 0.515 | 0.924 | 8   |
|                        | (0.133) |       |       |     |
| Port of New Orleans (LA)| 0.507  | 0.385 | 0.625 | 4   |
|                        | (0.103) |       |       |     |
| Port Authority of NY &NJ| 0.153  | 0.120 | 0.187 | 2   |
|                        | (0.048) |       |       |     |
fixed effect panel regressions with the $R^2$ from the highest, 0.439, in Model 4 to the lowest, 0.011, in Model 2. Surprisingly, the number of terminals, docks, wharves, shipyards, and piers in a given port may create a negative impact on efficiency scores. The results are consistent when we control for product mix. No matter whether a port is concentrated in containerization or specializes in bulk services, the greater the number of terminals and facilities, the greater the probability of a lower efficiency score.

6. Effectiveness

Rather than port service variables, we used TEUs to represent effectiveness of ports. Either profitability or throughput seems to be a reasonable measure of effectiveness. If a port increases its throughput and is able to do so efficiently, effectiveness is enhanced. See Talley [29] for an elaboration. As a first step, we obtained TEU information for the World, for the US, and for Panama. All ports in Panama have been privatized, while the US ports have mixed management structures. This is shown in Table 8. The first three columns of the table show that container traffic in TEUs in all three steadily increased. Much of the growth in US and Panama traffic can be explained by the overall growth worldwide. Thus, US and Panama TEUs adjusted for world traffic growth are reported in the last four columns. Adjusted Panama TEUs continued to rise, except for two years, while adjusted US TEUs have actually fallen throughout the series. This is seen explicitly in the last two columns in which adjusted growth rates are calculated. While a variety of factors can affect effectiveness as measured by TEUs, one factor stands out, and that is the presence of privatization in Panama.

An econometric analysis of the stochastic frontier model and panel data regressions are performed on the US data only. The dependent variable for
effectiveness is the log of TEUs of a specific port to total North America TEUs ratio. Similar to the efficiency study, in Equation (3), a dummy variable, Operating, is included to control for ports categorized as operating, and a quantitative measure of privatization is used in Equation (4). (Public) identifies the percentage of terminals that are owned and operated by public entities. The estimated results for effectiveness are in Table 9, followed by the fixed effect panel regression in Table 10.

\[
\ln \text{TEUratio} = \beta_0 + \beta_1 \ln(AR) + \beta_2 \ln(CapInt) + \beta_3 \ln(\text{Public}) + v - u
\]

\[
\ln \text{TEUratio} = \beta_0 + \beta_1 \ln(AR) + \beta_2 \ln(CapInt) + \beta_3 \ln(\text{Public}) + v - u
\]

The price elasticity of demand can be expressed as follows:

\[
e_p = \frac{d(\log p)}{d(\log q)} = \frac{p \cdot dQ}{q \cdot dP}
\]

where \( p \) is the price of commodities or services and \( q \) is the quantity demanded. The ratio of TEUs to total North America TEUs represents the volume of maritime services, and the average revenue indicated the price of output for selected container ports. Given the relative small price elasticity, from 0.0144 to 0.0165, with 10% significant level, from Table 10, we concluded that the demand of maritime shipping and the use of port services are unresponsive to price changes. This is consistent with studies of port service variables such as Murphy et al. [5] who concluded that price is low on the list of important factors affecting port choice.

7. Conclusions
While the econometric results show important relationships of port efficiency to a variety of variables, those that represent the type of operation indicate that privatization can have a positive impact on port efficiency. The results concerning effectiveness, while not definitive, indicate a tendency for privatized ports to be more

### Table 8. World, US, and Panama container traffic TEUs.

|               | TEUs (000s) | Normalized for world traffic |
|---------------|-------------|------------------------------|
|               | World | US | Panama | US | Panama | US | Panama | Growth Rate |
| 2010          | 517,364 | 42,283 | 4,234 | 18,420 | 2,078 | (2.41) | 1,37 |
| 2009          | 459,003 | 37,528 | 4,373 | 18,875 | 2,050 | (9.22) | 8.92 |
| 2008          | 511,182 | 42,827 | 4,652 | 20,794 | 1,882 | (9.93) | 19.56 |
| 2007          | 487,652 | 45,008 | 4,074 | 23,086 | 1,574 | (4.31) | (1.30) |
| 2006          | 433,253 | 44,396 | 3,028 | 24,125 | 1,595 | (2.75) | 2.33 |
| 2005          | 391,883 | 41,964 | 2,775 | 24,807 | 1,559 | (6.34) | 5.29 |
| 2004          | 351,060 | 38,655 | 2,429 | 26,486 | 1,480 | (4.27) | 4.63 |
| 2003          | 303,109 | 35,634 | 1,992 | 27,667 | 1,415 | (5.20) | (6.60) |
| 2002          | 266,300 | 32,703 | 1,672 | 29,186 | 1,515 | (3.98) | 11.40 |
| 2001          | 236,700 | 30,664 | 1,591 | 30,396 | 1,360 |       |       |
| 2000          | 225,294 | 30,396 | 1,360 | 30,396 | 1,360 |       |       |

Source: AAPA Survey, Containerization International Yearbook, and Autoridad Maritima de Panama.
Table 9. Panel frontier model for effectiveness.

| Model | Time-invariant | Time-varying | Time-invariant | Time-varying | Time-invariant | Time-varying |
|-------|----------------|--------------|----------------|--------------|----------------|--------------|
| ln AR | 0.0167         | 0.0093       | 0.0150         | 0.0094       | 0.0184         | 0.0107       |
|       | (0.0082)**     | (0.0054)*    | (0.0078)*      | (0.0054)*    | (0.0085)**     | (0.0056)*    |
| ln CapInt | −0.0136       | 0.0200       | −0.1237        | 0.0191       | −0.0149        | 0.0183       |
|       | (0.0067)       | (0.0154)     | (0.0214)       | (0.0154)     | (0.2307)       | (0.0158)     |
| Operating | 0.0946        | 0.0821       |                 |              |                |              |
|       | (0.0874)       | (0.0576)     |                |              |                |              |
| Landlord | −0.1945       | −0.0681      |                 |              |                |              |
|       | (0.0626)***    | (0.0460)     |                |              |                |              |
| ln Public | −1.7939       | −2.1187      | −1.6192        | −2.0402      | −1.9609        | −2.3134      |
|       | (0.2086)***    | (0.1272)***  | (0.2099)***    | (0.1358)***  | (0.3982)***    | (0.2175)***  |
| Cons | 0.0399         | 0.0312       | 0.0227         | 0.0111       | 0.0260         | 0.0114       |
|       | (0.3961)       | (0.1798)***  | (0.0233)       | (0.0220)     | (0.4445)***    |              |
| σ_u^2 | 0.0255         | 0.0112       | 0.0227         | 0.0111       | 0.0260         | 0.0114       |
|       | (0.0235)       | (0.0257)     | (0.0220)       | (0.0220)     | (0.4445)***    |              |
| σ_v^2 | 1.6500         | 2.4876       | 1.6176         | 2.4007       | 1.6970         | 2.3540       |

Notes: Dependent variable is the log of TEUs of a specific port to total North America TEUs ratio. Models 1 to 4 use binary dummy variables Operating and Landlord to represent a port’s operating structure while Models 5 and 6 use a quantitative ratio Public to quantify public private partnership. In the time invariance models 1, 3, and 5, u_t = u_t belongs to truncated normal distribution, N^+(μ, σ^2_u). We report the maximum likelihood estimates of panel frontier models with standard errors in the parentheses. *** and * are significant at the 1%, 5%, and 10% levels, respectively.

Table 10. Panel fixed effect model for effectiveness.

| Model | Model 1 | Model 2 | Model 3 | Model 4 |
|-------|---------|---------|---------|---------|
| ln AR | 0.0160  | 0.0159  | 0.0144  | 0.0165  |
|       | (0.0085)*| (0.0086)*| (0.0081)*| (0.0086)*|
| ln CapInt | −0.0162 | −0.0146 | −0.0153 | −0.0153 |
|       | (0.0233) | (0.0220) | (0.02357)|         |
| Operating | 0.0986  | 0.0901  |         |         |
| Landlord | −0.2027 | −0.2027 |         |         |
|       | (0.0642)***| (0.0642)***|         |         |
| ln Public | −3.1184 | −3.0110 | −2.8920 | −2.9609 |
|       | (0.0325)***| (0.1798)***| (0.1730)***| (0.4445)***|
| Cons | 0.0399 | 0.0399 | 0.0399 | 0.0399 |
|       | (0.3961) | (0.3961) | (0.3961) | (0.3961) |
| Obs | 83 | 83 | 83 | 83 |
| N | 10 | 10 | 10 | 10 |
| R^2 | 0.1963 | 0.0638 | 0.0003 | 0.0284 |

Note: Dependent variable is the log of TEUs of a specific port to total North America TEUs ratio. Models 2 and 3 use binary dummy variables Operating and Landlord to represent a port’s operating structure while Models 4 uses a quantitative ratio Public to quantify public private partnership. We reported standard errors in the parentheses. *** and * are significant at the 1% and 10% levels, respectively.
effective than publicly run operations. Further research is needed to investigate these relationships.

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