**IMPACT OF PRIVATIZATION ON PORT EFFICIENCY AND EFFECTIVENESS:
RESULTS FROM PANAMA AND US PORTS**

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ABSTRACT

Panama has five main ports: Balboa and PSA Panama International on the Pacific side 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 the period in which the Panamanian ports were privatized, there were a variety of ports in the US that have implemented some type of public-private partnership in port operations. When a port moves away from operating to non-operating, we observe more private sector involvement. 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 various types of privatizations.

Secondly, there have been a variety of studies measuring port efficiency, but few studies examining 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 that of the US in which there are degrees of privatization.

Key Words: Ports, Privatization, Efficiency, Effectiveness, Port Performance

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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 Shashikumar (1998) who examined the manner in which Indian ports are privatized, Cullinane, Song, and Gray (2002) who used a stochastic frontier model to estimate efficiency in different privatization schemes and Wang and Knox (2011) who also utilized a stochastic frontier model to estimate efficiency impacts of privatization on US ports. Cullinane and Song (2002) investigated the theoretical underpinnings and practical validity that private sector involvement in ports increases the efficiency of operations. Anderson, Park and Chang (2011) examined the privatization process in game theoretic terms. Pagano, Sanchez and Ungo (2012) developed a model of the privatization process for ports in Panama.

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, Daley and Dalenberg (1991) who developed a set of factors affecting port choice in order of importance to carriers. Pardali and Michalopoulos (2008) 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 (2008) used stated preference analysis to understand the importance of port service attributes. Ugboma, et al (2007) analyzed service quality in two Nigerian ports. They collected data on ports using a questionnaire, which was given to port users and was developed from focus groups and the literature. Finally, Rugman and Verbeke (1993) 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. 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.

Table 1. Alternative Port Privatization Approaches

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 Operate Port	Operate and Maintain

There are a variety of roles that the private sector can play in this type of PPP. The private sector can finance the facility, or financing can be done by the public sector. One important question is should the same or different firms perform these roles. Marimort and Pouyet (2008) analyze whether building infrastructure and managing assets should be bundled or not. They conclude that a technology driven reason is the basis for this decision.

A long-term lease of an existing facility, called a “Brownfield Concession,” is this fourth approach. While utilized in the US for roads and bridges, beginning with the Chicago Skyway lease in 2006, it has not been used in the US. 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 (1996). 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 of these cases, 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. (2000), Talley (2009), Wang and Knox (2011), and Wang, Knox and Lee (2012) discuss 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 equivalent levels of overall economic efficiency.

A central objective of port privatization and private sector involvement is stimulating efficiency (Cullinane and Song, 2003). 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.

Literature based on the DEA model includes Oum et al.(1992), Roll and Hayuth (1993), Thanassoulis (1993), Tongzon (2001), Barros and Athanassiou (2004), Turner, Windle, and Dresner (2004), Wang and Cullinane (2006), and thorough literature surveys by

Panayides et al. (2009) and Pantouvakis and Dimas (2010). Tongzon (2001) applies the DEA to rank efficiency among four Australian ports and twelve international container ports. Similarly, Barros and Athanassiou (2004) use the DEA to rank production efficiency of seaports in Greece and Portugal from 1998 to 2000. Turner, Windle, and Dresner (2004) measure infrastructure productivity, using the DEA, and present production efficiency under economies of scale in North American seaports from 1984 to 1997. Wang and Cullinane (2006) study 104 container terminals across 29 European countries and find that higher efficiency is obtained due to economies of scale.

Though the DEA approach generates multiple inputs and outputs at once, we use 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. (1977), Pitt and Lee (1981), Schmidt and Sickles (1984), Liu (1995), Cullinane et al. (2002), and Green (2003) are examples of the stochastic frontier model. Cullinane et al. (2002) find that transformation of ownership from the public to the private sector improves Asian ports' efficiency. Cullinane and Song (2003) note that private sector involvement and privatization improve productive efficiency of Korean container terminals. Tongzon and Heng (2005) conclude that private sector participation in the Asian, European, and American container terminals improves port operation efficiency.

Contrary to these studies, Liu (1995) fails to identify ownership as a significant factor of production and efficiency in British ports. A similar outcome can be found in Notteboom et al. (2000) in studying a set of 36 European container terminals. Saundry and Turnbull (1997) note that deregulation rather than privatization, contributes to improving service to port users. Cullinane and Song (2002) show 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. (1977) are among the pioneers proposing the stochastic frontier model with the maximum likelihood estimators. Later, Kumbhakar and Lovell (2000) provide a detailed explanation.

We assume that each firm produces less than its optimal output due to a degree of inefficiency. Specially, $Y_{it} = f(X_{it}; \beta)\xi_{it}$, 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 $i = 1, \dots, N$, $t = 1, 2$. Taking the natural log on both sides of above equation and substituting $u_{it} \equiv -\ln(\xi_{it})$, we obtain

$$\ln Y_{it} = \beta_0 + \sum \beta_k \ln x_k + v_{it} - u_{it}$$

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 include 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 (1997) examine whether the United Kingdom's privatized ports out-perform the public ports. Pallis and Syriopoulos (2007) identify 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 assess 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 1 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. 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 and the World container traffic from the Containerization International Yearbooks.

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.

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 (1995) and Cullinane et al. (2002), port ownership can be divided into public, public/private, private/public, and purely private. Similarly, the port devolution matrix in Baltazar and Brooks (2001) provides 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. Three ratios are established to capture private sector involvement 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.

Figure 2. Private Sector Involvement for Selected Container Ports

Note: Pure private ratio is calculated by the number of terminals, docks, wharves, shipyards, and piers that are owned and also operated by private corporations accumulated over years. Source: The US Army Corps of Engineers.

Figure 3. Partial Private Sector Involvement for Selected Container Ports

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. Source: The US Army Corps of Engineers.

Figure 4. Public Sector Involvement for Selected Container Ports

Note: Pure public ratio is the percentage of the number of terminals, docks, wharves, shipyards, and piers that are owned and operated by public entities of a given port collected over years. Source: The US Army Corps of Engineers.

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.

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

$$\ln \text{Profit} = \beta_0 + \beta_1 \ln(\text{AR}) + \beta_2 \ln(\text{CapInt}) + \beta_3 \ln(\text{Public}) + v - u \quad (2)$$

In eq(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.

Table 2: Definition of Variables

Variable	Definition
Profit	Profit per ton = Operating income/ Tons of Cargo
TEUs	Container traffic in thousands of TEUs

AR	Average revenue per ton = Operating Revenue/ Tons of Cargo
CapInt	Net Investment in Plant, Property & Equipment/ Employees
Operating	1 if an operating port; 0 otherwise
Landlord	1 if a landlord port; 0 otherwise
Public	the percentage of the number of terminals, docks, wharves, shipyards, and piers that are owned and operated by public entities

Source: Accounting variables are obtained from the US Maritime Administration Public Port Finance Survey. TEUs are from the America's Container Ports by RITA Bureau of Transportation Statistics. Terminal level of public private partnership is calculated by the ownership and operating status provided by US Army Corps of Engineers.

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 2 thousand and 4 hundred dollars. The average container traffic is above 2 million TEUs.

Table 3. Descriptive Statistics (Mean)

Variable	Mean	Min	Max
Profit	2.4363 (14.1661)	-0.7544	94.0803
TEUs	2318.522 (2.61.134)	175.957	8469.853
AR	6.0879 (34.1559)	0.0010	227.5312
Cap_int	2410.903 (1902.518)	4.6313	9094.369
Public ratio	0.4012 (0.2190)	0.1268	0.9091
Mix ratio	0.2571 (0.2301)	0.02272	0.6620
Private ratio	0.3416 (0.2165)	0	0.6447

Note: Descriptive statistics of mean, minimum, and maximum of a panel data of 10 selected container ports in the period of 1997-2006 are reported with standard errors in the parentheses.

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, 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.

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 (0.221)***	1.038 (0.022)***	1.0354 (0.0241)***	1.036 (0.024)***
ln CapInt	0.3797 (0.237)	0.619 (0.136)***	0.0273 (0.2593)	0.146 (0.332)
Operating	-0.7666 (0.223)***			
Landlord		0.460 (0.148)***		
ln Public			-0.3549 (0.1944)*	-0.293 (0.237)
Cons	-3.6465 (1.949)*	-6.006 (0.999)***	-1.3069 (1.9527)	-2.153 (2.430)
Obs	69	69	69	69
N	10	10	10	10
σ_v^2	0.1795	0.207	0.1897	0.193
σ_μ^2	4.2677	8.833	1.0985	0.957

Note: 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, $u_{it} = u_i$ belong to truncated normal distribution, $N^+(\mu, \sigma_\mu^2)$. We report the maximum likelihood estimates of panel frontier models with standard errors in the parentheses. ***, **, * are significant at the 1%, 5%, and 10% level.

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.

Table 6. Time-Varying Efficiency Scores for the Selected US Container Ports

Ports	Year	Scores	Ports	Year	Scores
PORT OF LOS ANGELES (CA)	1997	0.97187	PORT OF LOS ANGELES (CA)	2005	0.825021
PORT OF LOS ANGELES (CA)	1998	0.964305	PORT OF HOUSTON (TX)	2002	0.816912
PORT OF SEATTLE (WA)	1997	0.962563	PORT OF MIAMI (FL)	2001	0.813018
PORT OF LONG BEACH (CA)	1997	0.958609	PORT OF TACOMA (WA)	2002	0.807207
PORT OF LOS ANGELES (CA)	1999	0.954779	PORT OF OAKLAND (CA)	2003	0.800849
PORT OF SEATTLE (WA)	1998	0.952599	PORT EVERGLADES (FL)	2003	0.799176
PORT EVERGLADES (FL)	1997	0.948299	PORT OF LONG BEACH (CA)	2004	0.798039
PORT OF LONG BEACH (CA)	1998	0.947577	PORT OF LOS ANGELES (CA)	2006	0.784994
PORT OF OAKLAND (CA)	1997	0.947291	PORT OF HOUSTON (TX)	2003	0.773788
PORT OF LOS ANGELES (CA)	2000	0.942826	PORT OF MIAMI (FL)	2002	0.769094
PORT OF HOUSTON (TX)	1997	0.941141	PORT OF TACOMA (WA)	2003	0.763768
PORT OF TACOMA (WA)	1997	0.936518	PORT EVERGLADES (FL)	2004	0.753018
PORT EVERGLADES (FL)	1998	0.934607	PORT OF LONG BEACH (CA)	2005	0.752256
PORT OF LONG BEACH (CA)	1999	0.933744	PORT OF SEATTLE (WA)	2006	0.729237
PORT OF OAKLAND (CA)	1998	0.933504	PORT OF HOUSTON (TX)	2004	0.722786
PORT OF LOS ANGELES (CA)	2001	0.927901	PORT OF MIAMI (FL)	2003	0.717212
PORT OF HOUSTON (TX)	1998	0.925623	PORT EVERGLADES (FL)	2005	0.699018
PORT OF SEATTLE (WA)	2000	0.92455	PORT OF LONG BEACH (CA)	2006	0.698997
PORT OF MIAMI (FL)	1997	0.923951	PORT OF HOUSTON (TX)	2005	0.663655
PORT OF TACOMA (WA)	1998	0.92002	PORT EVERGLADES (FL)	2006	0.637235
PORT EVERGLADES (FL)	1999	0.917496	PORT OF NEW ORLEANS (LA)	1997	0.62475
PORT OF LONG BEACH (CA)	2000	0.916484	PORT OF HOUSTON (TX)	2006	0.596761
PORT OF OAKLAND (CA)	1999	0.916373	PORT OF NEW ORLEANS (LA)	1998	0.550597
PORT OF HOUSTON (TX)	1999	0.906269	PORT OF MIAMI (FL)	2006	0.515119
PORT OF MIAMI (FL)	1998	0.904182	PORT OF NEW ORLEANS (LA)	1999	0.469683
PORT OF TACOMA (WA)	1999	0.899585	PORT OF NEW ORLEANS (LA)	2000	0.384898
PORT EVERGLADES (FL)	2000	0.896231	PORT AUTHORITY OF NY & NJ	1999	0.18736
PORT OF LONG BEACH (CA)	2001	0.895082	PORT AUTHORITY OF NY & NJ	2000	0.119536
PORT OF LOS ANGELES (CA)	2003	0.88654			
PORT OF HOUSTON (TX)	2000	0.882285			
PORT OF MIAMI (FL)	1999	0.879694			
PORT OF TACOMA (WA)	2000	0.874472			
PORT EVERGLADES (FL)	2001	0.869997			
PORT OF LONG BEACH (CA)	2002	0.868748			
PORT OF LOS ANGELES (CA)	2004	0.858664			
PORT OF HOUSTON (TX)	2001	0.852798			

PORT OF MIAMI (FL)	2000	0.849607
PORT OF TACOMA (WA)	2001	0.843919
PORT OF OAKLAND (CA)	2002	0.838136
PORT EVERGLADES (FL)	2002	0.837929
PORT OF LONG BEACH (CA)	2003	0.83666

Note: 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.

Table 7 Average Time-Varying Efficiency Scores Cross Time

Ports	Model 2	Min	Max	Obs
Port of Los Angeles (CA)	0.902 (0.067)	0.785	0.972	9
Port of Seattle (WA)	0.892 (0.110)	0.729	0.963	4
Port of Oakland (CA)	0.887 (0.064)	0.801	0.947	5
Port of Tacoma (WA)	0.864 (0.063)	0.764	0.937	7
Port of Long Beach (CA)	0.861 (0.088)	0.699	0.959	10
Port of Everglades (FL)	0.829 (0.105)	0.637	0.948	10
Port of Houston (TX)	0.808 (0.117)	0.597	0.941	10
Port of Miami (FL)	0.796 (0.133)	0.515	0.924	8
Port of New Orleans (LA)	0.507 (0.103)	0.385	0.625	4
Port Authority of NY & NJ	0.153 (0.048)	0.120	0.187	2

Table 7 summarizes efficiency coefficients from Table 6. 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 8 reports the 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.

Table 8. Fixed Effect Efficiency Determinants for the Selected US Container Ports

	Model 1	Model 2	Model 3	Model 4
Total	-0.002 (0.001)***		-0.002 (0.001)***	-0.002 (0.001)***
Containerratio		-0.00 (0.00)	-0.000 (0.000)	
Dryratio				0.000 (0.000)
Liquidratio				-0.000 (0.000)
Cons	1.148 (0.093)***	0.806 (0.013)***	1.155 (0.097)***	1.151 (0.117)***
Obs	69	64	64	54
N	10	10	10	9
R^2	0.406	0.011	0.405	0.439

Note: We report the fixed effect panel regression models with standard errors in parentheses. The dependent variable is the time-varying efficiency score obtained from model 2 in Table 4. The efficiency determinants included as independent variables are the total number of terminals, docks, wharves, shipyards, and piers and variables representing the cargo mix of selected ports – container, dry bulk, and liquid bulk to total cargo handled. ***, **, * are significant at the 1%, 5%, and 10% level.

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 (2006) 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 9. 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.

Table 9. World, US and Panama Container Traffic TEUs

	TEUs (000s)			Normalized For World Traffic			
	World	US	Panama	US	Panama	US	Panama
2010	517,364	42,283				Growth Rate	
2009	459,003	37,528	4,234	18,420	2,078	(2.41)	1.37
2008	511,182	42,827	4,652	18,875	2,050	(9.22)	8.92

2007	487,652	45,008	4,074	20,794	1,882	(9.93)	19.56
2006	433,253	44,396	3,028	23,086	1,574	(4.31)	(1.30)
2005	391,883	41,964	2,775	24,125	1,595	(2.75)	2.33
2004	351,060	38,655	2,429	24,807	1,559	(6.34)	5.29
2003	303,109	35,634	1,992	26,486	1,480	(4.27)	4.63
2002	266,300	32,703	1,672	27,667	1,415	(5.20)	(6.60)
2001	236,700	30,664	1,591	29,186	1,515	(3.98)	11.40
2000	225,294	30,396	1,360	30,396	1,360		

Source: AAPA Survey, Containerization International Yearbook, and Autoridad Maritima de 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 eq(3), a dummy variable, Operating $\square$, is included to control for ports categorized as operating, and a quantitative measure of privatization is used in eq(4). Public $\square$ identifies the percentage of terminals that are owned and operated by public entities. The estimated results for effectiveness are in Table 10, followed by the fixed effect panel regression in Table 11.

$$\ln \text{TEU ratio} = \beta_0 + \beta_1 \ln(\text{AR}) + \beta_2 \ln(\text{CapInt}) + \beta_3 \text{Operating} + v - u \quad (3)$$

$$\ln \text{TEU ratio} = \beta_0 + \beta_1 \ln(\text{AR}) + \beta_2 \ln(\text{CapInt}) + \beta_3 \ln(\text{Public}) + v - u \quad (4)$$

Table 10. Panel Frontier Model for Effectiveness

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	Time-invariant	Time-varying	Time-invariant	Time-varying	Time-invariant	Time-varying
ln AR	0.0167 (0.0082)**	0.0093 (0.0054)*	0.0150 (0.0078)*	0.0094 (0.0054)*	0.0184 (0.0085)**	0.0107 (0.0056)*
ln CapInt	-0.0136 (0.0067)	0.0200 (0.0154)	-0.1237 (0.0214)	0.0191 (0.0154)	-0.0149 (0.2307)	0.0183 (0.0158)
Operating	0.0946 (0.0874)	0.0821 (0.0576)				
Landlord			-0.1945 (0.0626)***	-0.0681 (0.0460)		
ln Public					-0.1317 (0.2986)	-0.1857 (0.1640)
Cons	-1.7939 (0.2086)***	-2.1187 (0.1272)***	-1.6192 (0.2099)***	-2.0402 (0.1358)**	-1.9609 (0.3982)***	-2.3134 (0.2175)***
Obs	83	83	83	83	83	83
N	10	10	10	10	10	10
σ_v^2	0.0255	0.0112	0.0227	0.0111	0.0260	0.0114
σ_u^2	1.6500	2.4876	1.6176	2.4007	1.6970	2.3540

Note: 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, $u_{it} = u_i$

belongs to truncated normal distribution, $N^+(\mu, \sigma_u^2)$. We report the maximum likelihood estimates of panel frontier models with standard errors in the parentheses. ***, **, * are significant at the 1%, 5%, and 10% level.

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 conclude 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, Daley and Dalenberg (1991) who concluded that price is low on the list of important factors affecting port choice.

Table 11. Panel Fixed Effect Model for Effectiveness

	Model 1	Model 2	Model 3	Model 4
ln AR	0.0160 (0.0085)*	0.0159 (0.0086)*	0.0144 (0.0081)*	0.0165 (0.0086)*
ln CapInt		-0.0162 (0.0233)	-0.0146 (0.0220)	-0.0153 (0.02357)
Operating		0.0986 (0.0901)		
Landlord			-0.2027 (0.0642)***	
ln Public				0.0399 (0.3961)
Cons	-3.1184 (0.0325)***	-3.0110 (0.1798)***	-2.8920 (0.1730)***	-2.9609 (0.4445)***
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 Model 4 uses a quantitative ratio Public to quantify public private partnership. We reported standard errors in the parentheses. ***, **, * are significant at the 1%, 5%, and 10% level.

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 effective than publicly run operations. Further research is needed to investigate these relationships.

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