Determinants of Port Infrastructure Pricing*

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Contents

Abstract

Despite many theories on port pricing have been discussed in literature, empirical research on this topic remains very limited. This paper seeks to empirically analyse port infrastructure charges using the simultaneous equation regression method and data of 159 seaports. The analysis result indicates that seaport infrastructure pricing is primarily cost-based but other factors are also relevant. These include demand, the governance model, legal structure and geographical region. Given the exploratory nature of its research, the paper also discusses the limitations and implications for port authorities, policy makers and future research.

Key Words : Seaports, Port charges, Infrastructure Pricing, Simultaneous Equation Regression

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I. Introduction

External factors behind the changes in port operations and management have put pressures on port competition, which has increased to a level never seen in the past. These factors include globalisation of production, changing technology, shifting bargaining power to users, and changing distribution patterns, which have respectively resulted in changes in port operations and management structures as ports have become value adders, a need for improving port productivity, the emergence of mega carriers and global port logistics service providers influencing a port's bargaining power, and the arrival of hub ports creating more competition between ports.[1)] For ports to be efficient and competitive, port reforms have been undertaken worldwide with the private sector significant involvement in port operations, investments, development and management (e.g. ownership/ partnership). Although most ports still have substantial market power, it is undeniable that ports are now under more pressure to become more competitive and responsive to changes in market conditions. Port competitiveness depends on a number factors, such as port and terminal charges, geographical location, water draft, feeder and multimodal connectivity, service reliability and stability, client relationship management and communication.[2)] Port strategies should target these factors if they want to stay competitive or improve their competitiveness. Examples of such strategies include setting tariffs and charges, improving operational efficiency, accommodating high shipping frequency, investment in infrastructure and cargo handling, information and communication technology. The current paper examines port pricing as an effective tool used by management to address the above mentioned changes in the sector.

This paper's focus is on the determinants of seaport infrastructure tariffs as opposed to non-infrastructure tariffs. The main difference between these types of tariffs is that infrastructure charges are often managed by the port authority, while non-infrastructure charges, e.g. cargo handling charges, are often managed by terminal operators. For most ports (landlord ports), infrastructure is owned by the state sector and tends to be regarded as public goods. Therefore their charges necessarily take into account the social welfare effect. On the other hand, if terminal operators are partially or fully owned by the private sector, their charges would be subject to competition and profit

1) The World Bank(2007), p.1.
2) Tongzon(2007), Chang, Lee and Tongzon(2008).

oriented.

While pricing strategies are often influenced by the cost of production, market structure, demand and institutional factors,[3)] they are more complex for ports for various reasons. First, most ports nowadays operate as providers of multiple services, whose operations are interdependent. Therefore splitting production cost for pricing purposes can be very difficult if not infeasible. In addition, since port investments in ports are largely "irreversible" and therefore "sunk" costs and operational costs play an important role in short-term pricing. Second, as ports are regarded as both public assets and businesses, a port's pricing strategy can vary substantially depending on which role it wants to focus on. Third, port pricing is often subject to strong regulations, changes to port tariffs and charges require careful planning and justification. Fourth, because ports are logistics nodes, pricing should take into account both competition between ports and competition within the supply chain, which imply the equilibrium price can be even higher than the monopoly price level.[4)] This is particularly the case where port users are highly dependent on the ports within the total supply chain.[5)]

Despite there have already been many studies on port pricing, most studies mainly focus on only the theoretical or policy aspects. To the authors' best knowledge, little empirical research has been conducted on seaport infrastructure pricing. Therefore this study seeks to fill this gap in the literature. The study examines the infrastructure related charges of 159 seaports in the world and empirically examines the relationship between port charges and other factors using the simultaneous equation regression method. The analysis tries to cover as many factors as possible, where data are available, including those related to production, cost, market and institution. Because of the exploratory nature of the research, the focus is on the main port infrastructure tariffs imposed on vessels (i.e. marine charges), including channel and berth charges, whose data are available. Channel charge applies to the provision of navigation infrastructure including dredged channel and turning basins. For many ports this charge is also referred as port due. Berth charge is a charge for the occupancy of a berth and is also referred to as berth hire in some countries. The next section reviews port tariff structures and existing studies on port pricing, followed by Section 3, the analysis methods, and Section 4, the analysis results. Section 5 discusses the findings and

3) Tyndall(1951).
4) Nguyen(2011).
5) Robinson(2002).

implications, and section 6 is the conclusions.

II. Literature Review

Port tariffs are the main source of income for ports. The design of the suitable tariff structure is a necessary and first step in port pricing. Tariff structures tend to differ substantially across countries and regions, because of the variations in the port governance model, national port policy, accounting and financing practices, and the view of port management. Among the main differences are those with the scale factor in channel dues and berth occupancy charges. For example, some countries use Net Registered Tonnage (NRT)[6] as the scale factor for charging channel due and berth hire, while others use Gross Tonnage (GT) or Gross Registered Tonnage (GRT) following the International Tonnage Certificate of vessels established by the London Tonnage Convention in 1969. This difference is partly due to the fact that NRT can be easily abused by a smaller change in the ship design, while GT or GRT relatively represents the volume of vessels.

Based on a sample of 118 seaports, the current study found 72% of the ports under study use GT/GRT as the scale factor for channel dues and about 53% adopt the same for berth dues. However, only 21% use Length Overall of the vessel (LOA) as the scale factor for berth charges. UNCTAD and ESCAP recommend that ports standardize their tariff structure as a way to improve business efficiency and transparency.[7]

Traditionally the principle of infrastructure pricing was to maximize social welfare, and the pricing of port infrastructure in most ports around the world was under the purview of public statutory bodies, in most cases port authorities. This practice has changed greatly as a result of the recent waves of port reforms and active participation of the private sector and transnational port operators in the sector. Initial reforms required cost-recovery pricing be taken to lessen the financial burden on the government. Subsequent reforms allowed for more competition and port financing using external funding, which put a further pressure on ports to come up with new pricing strategies that address the port's market position and enable it to achieve the corporate financial goals.

6) Net Registered Tonnage is the Gross Registered Tonnage (GRT) minus the spaces of the ship which do not provide earnings.
7) UNCTAD(1995) & ESCAP(2002).

Port pricing has been covered in many studies together with infrastructure pricing. However, with only few exceptions, most studies on this topic mainly concentrate on the theoretical and policy perspectives. Regarding the theoretical perspective, several approaches to port infrastructure pricing have been covered in the literature. One of the most popular pricing approaches is the cost-based approach. This includes marginal cost pricing,[8)] average cost pricing[9)] and cost-axiomatic pricing.[10)] Other pricing approaches include strategic pricing[11)] and congestion pricing, priority pricing and port slot auctions.[12)] Dowd and Fleming[13)] noted,

"Clearly there is no single pricing approach that is accepted and applied uniformly by all Ports. Nor can it be said that there is a 'best approach,' given the diversity in port characteristics, types of ownership, philosophies of management, specific goals, etc. These differences are reflected in the pricing approach or combination of approaches that they use, and, of course, there are always cases of mismanagement and misguided policies!".

Regarding the policy perspectives of port pricing, Gardner et al. examined how full cost recovery principle can be applied to three EU ports, Felixstowe, Dove and Dublin, and found evidence that the approach does not necessarily result in large increases in port charges. Their findings challenged the proposition earlier made by Baird[14)] that "full cost recovery for private ports, privatised ports, as well as for public ports, remains an elusive ideal". Haralambides and Meersman et al. studied efficient port prices and Perez-Labajos & Esteban Garcia[15)] developed a methodology to evaluate efficient tariffs for commercial port services. The latter proposed an objective function for all port services that can estimate the deviation of port tariffs from their optimal level. However their methodological framework does not cover infrastructure cost.

The literature also addresses various issues in port pricing practices. Dowd & Fleming[16)] provided a guide on port tariff design and identified the key factors influential to port tariffs. According to the authors, port tariffs can be designed in several stages. The first stage involves internal examination of historical

8) Button(1979), Goss & Stevens(2001), Haralambides(2002), Swahn(2002), Abbes(2007) & Meersman et al.(2007).
9) Gardner,Marlow & Pettit(2006).
10) Talley(1994).
11) Frankel(1987) & Ashar(2001).
12) Strandenes(2004).
13) Dowd & Fleming(1994), P.31.
14) Baird(1999), p.1.
15) Perez-Labajos & Esteban Garcia(2000).
16) Dowd & Fleming(1994).

costs, imputed costs and sensitivity analysis, the second stage is external examination, the third stage is to seek approval for new tariffs, and the last stage is to decide the actual tariffs which can be different from those approved by the authority. With regards to the tariff structure of European container ports, as analysed in terms of differentiation of charges from the port users' perspective, port infrastructure charge differentiation is viewed as a means to secure the port's position in the market driven by increased competition and differentiation of port services.[17] The research also highlighted the fact that seaports are required to be financially sustainable as ports now move towards a more independent of the government's financial support. In addition, the degree of port competition and the type port governance model have resulted in port infrastructure charge differentiation.

According to Haralambides the difficulty in assessing port costs especially marginal costs and the identification of the costs associated with specific port operations is among the challenges in port pricing.[18] Existing studies on port pricing mainly focus on the theoretical and policy perspectives, while little has been done to analyse port infrastructure charges implemented by seaports, which is the focus of this paper.

III. Methodology

The methodology employed by the current study is characterized by econometric analysis of port infrastructure tariffs. Simultaneous equation regression is applied to explore the relationship between port infrastructure tariffs as the dependent variables, and a number of factors as the independent variables. Relevant diagnostics tests are also conducted to assist the data analysis. The test for simultaneity is conducted to see whether the different types of infrastructure tariffs are subject to simultaneous relationships, and the test for normality is also conducted to confirm whether the regression conditions are met. The analysis covers the effect of not only infrastructure-related costs but also other factors including port demand, legal structures, governance models and geographical regions.

The econometric model is mainly based on the cost-based approach to pricing. Because of the unavailability of data for port costs, port infrastructure

17) Wilmsmeier(2007).
18) Haralambides(2002).

specifications are used as proxies for port costs. Thus, the underlying assumption is that port infrastructure building and maintenance costs are strongly correlated with port physical specifications such as the depth, length and width of the access channel and berths.[19] Other variables are also covered in the data analysis including port service demand.

The analysis also takes into account the effect of various governance models, namely the service port, tool port, landlord port and privatized port models that are widely believed to govern the ways ports are managed. This is partly because the governance model reflects the level of port reform and especially the involvement of the private sector in port ownership and management. The study also considers the effect of the legal structures used by ports. The legal structure of a port reflects its specific view on and preference on its corporate responsibility as a legal entity.[20] Four legal structures adopted by seaports are covered in the analysis, including a public port authority, a port corporation, limited company, and local government. Majority of ports are overseen by a public port authority and takes a form of landlord ports. In the absence of a port regulatory mechanism, the sole authority over port investment, planning and financing and formulating and regulation of tariff regime is on a public port authority.[21] Yet, many ports conformed to the landlord or service model have the legal structure as public port corporations or limited companies. Thus, given the similarity existing in port governance, the level of corporatization of port business can vary depending on the legal structure. In addition, the study also considers the effect of the geographical location of the port. This is because, all else being the same, ports located in the same region tend to share similar business practices, culture and level of economic activities, which may affect the pricing regime.

The following regression equation system is used in econometric analysis :

$$lnTRF_{ci} = \alpha_0+\beta_2\, lnCHL_i+\beta_3\, lnCHW_i+\beta_1\, lnCHD_i+\beta_4\, lnPTP_i+\beta_5\, lnTF_i +\sum\beta_{6k}\, DPM_{ki}+\sum\beta_{7j}\, DPG_{ji}+\sum\beta_{8l}\, DPR_{li}+\beta_9\, lnTRF_{bi}+\varepsilon_{ci} \quad (1)$$

$$lnTRF_{bi} = \phi_0+\theta_2\, lnBL_i+\theta_1 lnBD_i+\theta_3 lnPTP_i+\theta_4\, lnTF_i +\sum\theta_{5k}\, DPM_{ki}+ \sum\theta_{6j}\, DPG_{ji} +\sum\theta_{7l}\, DPR_{li}+\theta_8\, lnTRF_{ci}+\varepsilon_{bi} \quad (2)$$

19) Kent & Ashar(2001).
20) Morris et al.(2005).
21) Trujillo & Nombela(1999).

where *i*=1,2,3…..*n*; $lnTRF_{ci}$ =Channel due; $lnTRF_{bi}$ =Berth due; $lnCHL_i$ =Channel lenght; $lnCHW_i$ = Channel width; $lnCHD_i$ =Channel depth; $lnBL_i$ =Berth lenght; $lnBD_i$ =Depth alongside; $lnPTP_i$ =Port throughput; $lnTF_i$=country' s trade value.

DPMs are dummy variables for legal structures, including port authority (DPM_1ºDPMPA), port corporation (DPM_2ºDPMPCR), port public/limited company (DPM_3ºDPMLC) or local government as the bench mark. DPGs are dummy variables for governance models, including landlord (DPG_1ºDPGLL), service (DPG_2ºDPGS), service-landlord (DPG_3ºDPGSL) or private port as the bench mark.

DPRs are dummy variables for geographical regions, including Africa (DPR_1ºDPRAF), Australia (DPR_2ºDPRAU), East Asia (DPR_3ºDPREA), North America (DPR_4ºDPRNA), North West Europe (DPR_5ºDPRNWE), South Asia (DPR_6ºDPRSA), West-Middle East region (DPR_7=DFRWME) and the rest of the word as the bench mark.

Cluster sampling was applied in data collection. In particular, ports were divided into eight (8) clusters including Africa, Australia, East Asia, South Asia, North America, North West Europe, West-Middle East, and the rest of the word. There were totally 159 ports identified covering all the seaports whose data[22] are available from Lloyd's Register-Fairplay's database.[23] Port tariffs were quoted on the basis of US$(PPP) per 100 GT/GRT. Port infrastructure specifications are in meters (m). Port infrastructure tariff, channel/port dues and berth occupancy charge, and port throughput in metric tons are mainly obtained from official web sites of port authorities and, where no tariffs are published, tariffs were obtained by requesting port authorities.

Data are collected from various sources. Port infrastructure data which includes port channel and berth specifications are obtained from Ports and Terminal Guide published by Lloyd's Register-Fairplay and ports' official web sites. Data on external trade, the sum of export and import, of each port country are obtained from the web site of the World Trade Organization. Since many ports quote their charges in their local currencies, their tariffs are converted to universally comparable common currency using purchasing power parity index (PPPI) published by the World Bank. Port data on ports' legal structure, port governance model and geographical region are also

22) Only seaports whose port infrastructure tariffs based on Dead Weight Tonnage (DWT), Gross Tonnage (GT), Gross Registered Tonnage (GRT), Net Tonnage (NT) were included in the analysis.

23) Lloyd's Register-Fairplay(2011).

collected mainly from port websites and analysed using dummy variables in the regression analysis.

The regression model is estimated using Ordinary Least Square (OLS) estimation, two-stage least square (2SLS) estimation, and three-stage least square (3SLS) estimation methods with different functional specifications. In addition to the OLS estimation, 2SLS and 3SLS is used to test for simultaneity relationship between channel dues and berth occupancy charge. Jarque-Bera (JB) normality test and the Hausman test for simultaneity are also conducted.

IV. Analysis Results

The analysis includes 153 observations out of 159 observations after removing the outliers from the sample. Tables 1 and 2 provide the descriptive statistics and correlation matrix for the variables in natural log. As can be seen from Table 1, the values of the standard deviation for all the variables are small relative to their means. Table 2 shows the two types of port infrastructure tariffs, ($lnTRF_c$) and ($lnTRF_b$), are positively correlated. The correlation between channel/port dues and berth occupancy charge is 0.39. The correlation is positive because of two main reasons. First, ports are consistent in their tariff setting; ports with high channel dues tend to have higher berth occupancy rates. Second, these two charges are affected by the same factors, e.g. competition, geographical region, the governance model and legal structure. The positive correlation between the channel due ($lnTRF_c$) and length (*lnCHL*) of 0.29 could be due to the fact that the maintenance cost of a channel depends on its length. The negative correlation between the channel due ($lnTRF_c$) and depth (*lnCHD*) of 0.20 might be because deeper channels require less maintenance. Port throughput (*lnPTP*) is positively correlated with berth length (*lnBL*), berth depth (*lnBD*) and channel depth (*lnCHD*) with the correlation coefficients of 0.55, 0.47 and 0.22, respectively. These imply that ports with deep channels, deeper and longer berths can accommodate larger ships and therefore have larger throughput.

<Table 1> Variable's descriptive statistics

VARIABLE	N	MEAN	ST. DEV	VARIANCE	MINIMUM	MAXIMUM
InTRFc	153	2.3	1.3	1.9	-3.9	4.5
InTRFb	153	1.9	1.4	2.1	-4.6	4.9
InBL	153	8.3	0.9	0.8	6.1	10.4
InBD	153	2.3	0.2	0.05	1.5	2.9
InCHL	153	8.5	1.5	2.4	3.2	12.3
InCHW	153	5.5	0.7	0.5	3.8	8.2
InCHD	153	2.6	0.3	0.09	1.6	3.5
InPTP	153	16.2	1.4	2.1	10.4	19.5
InTF	153	26.1	1.7	3	16.5	28.5

<Table 2> Correlation matrix of the study variables

	InTRFc	InTRFb	InBL	InBD	InCHL	InCHW	InCHD	InPTP	InTF
InTRFc	1.00								
InTRFb	1.39*	1.00							
InBL	-0.14	-0.08	1.00						
InBD	-0.08	-0.15	0.21*	1.00					
InCHL	0.29*	0.02	019	0.10	1.00				
InCHW	-0.08	0.02	0.14	0.23*	0.02	1.00			
InCHD	-0.2*	-0.09	-0.05	0.39*	-0.18	0.43*	1.00		
InPTP	0.01	-0.11	0.55*	0.47*	0.36*	0.03	0.22*	1.00	
InTF	*0.07	0.19	0.37*	0.19	0.19	0.10	-0.03	0.28*	1.00

Table 3 presents the results of the stepwise regression analysis using both the ordinary least square (OLS), two-stage least square (2SLS) and three-stage least square (3SLS) methods with different functional specifications. For each model specification (from I to XI), there are two lines of regression results for equations (1) and (2) respectively.

The Hausman test for the dependent variables suggests that ($lnTRF_{bi}$) and ($lnTRF_{ci}$) are endogenous. Thus a simultaneous equation system (SES) is appropriate. As shown below, the results obtained from the 2SLS and 3SLS methods are highly consistent with those provided by the OLS method. The over identification restrictions of both regression equations are considered using Hausman Specification test statistic. The test statistics for both simultaneous equations $lnTRF_{ci}$ (H=11.29 p= 0.0007) and $lnTRF_{bi}$ (H= 8.27 p= 0.0040) are significant at 1% significance level. Thus, the null hypothesis that some instruments used in both simultaneous equations, $lnTRF_{ci}$ and $lnTRF_{bi}$ are not valid, is rejected. Since the analysis used cross-sectional data, the heteroskedasticity correction covariance matrix is also used to address the heteroskedasticity problem.

As can be seen from Table 3, the analysis result identifies several factors that have a significant effect on port infrastructure charges. Especially, berth occupancy charge, channel length, channel depth and trade flow of the port's country are highly significant. Channel depth is however not highly significant in the model except in *MODELs III* and *VII* with the coefficient of channel depth being -0.51 and -0.55 respectively, only significant at 10%. The berth length and depth variables, representing the cost of berth maintenance, are however insignificant.

<Table 3> Regression analysis results

	MODEL (153 Observations)	R SQUARE	VARIABLES																					
			lnTRFc	lnTRFb	lnBL	lnBD	lnCHL	lnCHW	lnCHD	lnPTP	lnTF	DPMPA	DPMPCR	DPMLC	DPGLL	DPGS	DPGSL	DPRAF	DPRAU	DPREA	DPRNA	DPRNWE	DPRSA	DPRWME
I	OLS - lnTRFc	0.28		0.38***			0.26***	-0.07	-0.45	0.01	- 0.13**													
	OLS - lnTRFb	0.21	0.42***		-0.002	-0.6				-0.12	0.15**													
II	OLS - lnTRFc (DPM)	0.32		0.35***			0.27***	-0.14	-0.46	0.03	- 0.148***	- 1.06*	- 1.13*	-0.4										
	OLS - lnTRFb (DPM)	0.21	0.40***		0.009	-0.6				-0.12	0.15**	0.24	-0.06	0.5										
III	OLS - lnTRFc (DPG)	0.34		0.39***			0.28***	-0.07	- 0.51*	0.04	- 0.09*				- 1.06***	-0.33	-0.5							
	OLS - lnTRFb (DPG)	0.25	0.44***		-0.02	-0.7				- 0.15*	0.11				-0.05	- 0.83***	-0.3							
IV	OLS - lnTRFc (DPG,DPM)	0.38		0.37***			0.28***	-0.14	-0.46	0.05	- 0.11**	- 0.98*	-0.94	-0.4	-0.54	0.16	0.07							
	OLS - lnTRFb (DPG,DPM)	0.26	0.43***		-0.09	-0.6				- 0.16*	0.11	0.37	-0.04	0.5	-0.06	- 0.86**	-0.3							
V	OLS - lnTRFc (DPR)	0.36		0.36***			0.24***	-0.06	-0.49	0.03	- 0.11**							-0.3	0.82**	-0.33	-0.37	0.05	0.66**	0.4
	OLS - lnTRFb (DPR)	0.35	0.40***		-0.04	-0				-0.05	0.06							-0.2	-0.15	-0.39	0.04	0.94*	-0.02	- 0.87*
VI	OLS - lnTRFc (DPM,DPR)	0.39		0.35***			0.25***	-0.11	-0.5	0.04	- 0.12***	- 1.06**	- 1.14*	-0.6				-0.3	0.71*	-0.32	-0.28	-0.08	0.58*	0.41
	OLS - lnTRFb (DPM,DPR)	0.35	0.40***		-0.03	0.01				-0.07	0.06	0.37	0.53	0.4				-0.2	-0.19	-0.38	0.07	0.97*	0.01	- 0.87*
VII	OLS - lnTRFc (DPG,DPR)	0.40		0.37***			0.26***	-0.06	- 0.55*	0.06	- 0.09*				- 0.87***	-0.29	-0.4	-0.5	0.68*	-0.37	-0.31	-0.08	0.39	0.23
	OLS - lnTRFb (DPG,DPR)	0.37	0.41***		-0.06	-0.1				-0.06	0.04				0.13	-0.44	-0.1	-0.1	0.01	-0.32	0.03	0.97*	0.01	-0.68
VIII	OLS - lnTRFc (DPM,DPG,DPR)	0.42		0.37***			0.26***	-0.12	-0.49	0.07	- 0.10**	- 1.05**	- 1.06*	-0.6	-0.39	0.18	0.14	-0.4	0.57	-0.35	-0.19	-0.14	0.38	0.24
	OLS - lnTRFb (DPM,DPG,DPR)	0.37	0.41***		-0.05	-0.1				-0.08	0.04	0.43	0.45	0.4	0.01	-0.55	-0.2	-0.1	0.001	0.3	0.03	0.99*	0.02	-0.69
IX	2SLS-lnTRFc	0.27		0.44***			0.26***	-0.08	-0.43	0.02	- 0.13**													
	2SLS-lnTRFb	0.21	0.45***		0.004	-0.6				-0.12	0.15***													
X	2SLS-lnTRFc (DPM,DPG,DPR)	0.29		0.76			0.22**	-0.18	-0.27	0.09	-0.1	-1.06	-1.09	-0.6	-0.29	0.43	0.25	-0.3	0.46	-0.11	-0.14	-0.56	0.28	0.54
	2SLS-lnTRb(DPM,DPG,DPR)	0.36	0.35*		-0.06	-0.1				-0.07	0.04	0.38	0.4	0.4	0.004	-0.54	-0.2	-0.1	0.05	-0.33	0	0.99	0.05	-0.68
XI	3SLS-lnTRFc/lnTRFb(Sy R sq= 0.77)	0.11		0.97			0.19	-0.08	-0.37	0.12	-0.1	-1.08	-1.1	-0.8	-0.3	0.5	0.25	-0.2	0.38	-0.35	-0.17	-0.81	0.2	0.67
		0.36	0.33*		-0.05	-0.2				-0.06	0.04	0.36	0.38	0.4	-0.01	-0.55	-0.2	-0.1	0.07	-0.35	-0.01	0.98	0.07	-0.67

Significance levels : *10%, **5%, ***1

The dummy variables show the impact of port managerial and spatial aspects on port infrastructure tariffs. The coefficients for the port legal structure are significant but only for the channel due, showing that the port authority and port corporation models do not have the same pricing system as the other legal structures, i.e. limited company and local government. The port governance model also has a significant impact on port pricing in some of the functional specifications. The result is however inconclusive. In addition, port infrastructure pricing methods used in Australia and northwest European countries tend to be significantly different from each other and from the rest of the word.

As mentioned, normality and simultaneity tests are also conducted. As shown in Table 4, the Jarque-Bera (JB) normality test statistic[24] for channel/port dues is 6.9 indicating that the null hypothesis of normality of the distribution of channel/port due data cannot be rejected at 1% significance level. The normality test conducted for berth occupancy charges also suggests the similar distribution.

<Table 4> Jarque-Bera normality test results

	JB STATISTIC	*P-VALUE*	*α*	*CRITICAL VALUES*
InTRFc	*6.9*	*0.03*	*0.01*	*9.21*
			0.05	*5.99*
			0.1	*4.61*
InTRFb	*1*	*0.6*	*0.01*	*9.21*
			0.05	*5.99*
			0.1	*4.61*

V. Discussion and Implications

The result of regression analysis presented in the previous section shows that sea-port pricing is significantly affected by a number factors, namely channel length, channel depth, trade flow, various business structure and governance models, geographical region, as well as the relationship between port charges themselves. This section discusses and interprets the results obtained from the regression analysis presented in section 4.

First, the analysis found a *two-way* relationship between channel dues and

24) The null hypothesis of normality is rejected if the calculated test statistic exceeds the critical value, in our case 5.99, from the Chi-Square, $\chi2$, distribution with 2 degrees of freedom.

berth dues. The analysis result shows that the average value of the coefficient for berth due (in natural log) is about 0.38. This means that, all else remaining the same, an increase in berth charge by 1% is associated with an increase in channel due by 0.38%. Similarly, the average value of the coefficient for the channel due variable (in natural log) of 0.40 indicates that an increase in channel due by 1% is associated with an increase in berth due by 0.4%. The significance of the channel length variable with the average value of its coefficient of 0.26 indicates that an increase in channel length by 1% would increase the channel/port due by 0.26%.

Berth infrastructure specifications, berth length and depth are found to have insignificant effect on berth occupancy charges. This may be due to the fact that there are other factors affecting berth occupancy charge. Moreover, in some ports, this charge tends to be incorporated into wharfage that is associated with terminal cargo handling service.[25]

The result does not indicate a significant effect of channel width ($lnCHW_i$) on channel dues, while channel depth ($lnCHD_i$) is found to have a negative effect on channel dues. Although this variable is only significant in two regression models, its coefficient is consistent with the value of about -0.53, suggesting that a 1% increase in channel depth would decrease channel due by 0.53%. As explained earlier, the negative effect channel depth ($lnCHD_i$) on channel due ($lnTRF_c$) could be due to the fact that channels with sufficient natural depth require less maintenance and dredging costs. This interpretation is based on the assumption that the available data reflect the natural depth of the channel rather than the artificial depth achieved through dredging. The analysis result provides evidence on the relevance of costs in port infrastructure charges. For example, longer and shallower channels require more maintenance cost that in turn affects their respective charges.

Some countries have a common policy towards port infrastructure maintenance. For instance, the financial burden of channel maintenance in the U.S. has resulted in a change in the port authority's responsibility for infrastructure maintenance, which has subsequently led to the imposition of the channel due by the port authorities as a way to cover the dredging costs.

It is interesting to note that trade flow has a significant but *negative* impact on channel dues, while the effect on berth due is insignificant. The negative relationship between trade flow and channel due could be because the

25) As noted earlier, this variable could not be included in the current study due to the unavailability of its data.

former is strongly correlated with the port's output, which often exhibits the economies of scale in port operations. This could also be because of the *demand effect*, whereby the lower the channel due, the higher the demand for port services. The value of the coefficient for the trade flow variable indicates that, all else being the same, an increase in total trade value by 1% is associated with a decrease in channel dues by 0.11% on average.

The effect of various legal structures and governance models can be evaluated through the coefficients of the dummy variables. The dummy variable for the *port authority* legal structure is significant with the average value of the coefficient of -1.0375. This indicates that, all else being the same, channel dues charged by ports with the *port authority* legal structure are only 35% ($=e^{-1.0375}$ x100%) of those charged by ports with the *local government* legal structure.[26] Similarly, the value of the coefficient for the *port corporation* dummy of -1.11 indicates that the channel dues for the *port corporation* business structure is only 33% of those charged by ports under the *local government* legal structure. While these values of the coefficients appear to be large and therefore maybe questionable, their negative sign statistically indicates that ports under this legal structure charge less than those under the *local government* legal structure. While this statistical result, as it turned out to be, may not necessarily reflect the true characteristic of the seaport population, it might be due to the fact that the *local government* legal structure is typically preferred by small ports that face demand constraints and diseconomies of scale and therefore have to rely on higher tariffs to stay in business.[27] Higher tariffs of some ports could be due to high local input costs, trade unions and labour/employment policies. On the other hand, lower channel dues are due to the public goods nature of port infrastructure of which tariffs are formulated to achieve optimal social welfare.

The dummy variables for governance models can be interpreted in the same way as those for legal structures. The average value of the coefficient for the landlord model dummy variable, DPGLL, is -0.965, indicating that, under the same conditions, the average channel due of landlord ports is only 38% of that of private ports. The average value of the coefficient for the service port model of -0.84 shows that the average berth occupancy charge of service ports is only 43% of private ports, while the infrastructure charges of service-

26) This way of interpreting the numeral results follows the log linear form of the regression equation (1) used in the study.
27) Heaver(1995).

landlord (mixed model) ports are not significantly different from those of private ports. This finding is consistent with the fact that private ports are profit driven rather than social welfare driven and tend to charge higher than landlord and service ports.

The significance of the dummy variables for the Australian ports with the value of 0.73 means that, all else remaining the same, their channel dues tend to be about twice higher than those of ports in other regions. This could be due to two main reasons. First, following the government's public enterprise policies, Australian ports are under pressure to be profitable or at least to ensure cost recovery.[28)] Together with relatively high input costs, this tends to result in comparatively higher port infrastructure tariffs. Second, because of the country-specific factors, most Australian ports have some market power and are allowed to price their services independently.[29)] The average value of the coefficient for the northwest European region dummy variable of 0.9675 indicates that berth occupancy charges of ports in this region are 2.63 times higher than the bench marking region. This ratio is 1.59 for the channel dues of ports in south Asia and 0.41 for the berth occupancy charges of ports in the West-Middle East region.

VI. Conclusions

This paper examines port infrastructure charges using the data of 159 sea-ports. The result of simultaneous equation regression with channel due and berth occupancy charge as two dependent variables representing port infrastructure charges indicates a two-way relationship between channel due and berth occupancy charge. Channel due is positively related to channel length. Trade flow appears to have a negative effect on channel due but a positive effect on berth occupancy charges.

The study also found statistical evidence that channel dues charged by ports under the *port authority* and *port corporation* legal structures are lower than those under the *local government* entity legal structure. Furthermore, *landlord* ports and *service* ports tend to charge less than *private ports*, implying that the former are supposed to play dual role, while the latter are more profit driven.

28) Everett and Robinson(1998).

29) Menezes, Pracz and Tyers(2007) ; Pettitt (2007).

In addition, infrastructure charges of Australian and northwest European ports are significantly higher than the rest of the world.

The findings of the research have some implications for port policy, pricing committees, port authorities, operators and managers. Efficient pricing is a prerequisite for efficient infrastructure investments[30). While public ports should aim to maximize user welfare, given the growth in demand for port services, they may need to re-evaluate the pricing approach in order to reduce the financial burden and consider the competition with private ports. Port management bodies may be required to consider a suitable mechanism to establish cost-based infrastructure tariffs, especially those of self-financing port management bodies. The result of analysis strongly indicates that the cost-based approach plays a key role in port pricing but actual charges remain substantially different across port business structures, governance models and geographical regions in the word. In addition, very high charges of private ports may also mean their charges need to be monitored.

The study is subject to limitations that could be considered for future research. First, because of data unavailability, port infrastructure dimensions were used as proxies for port infrastructure costs. The inclusion of data on dredging cost in future research would help to reduce complexities related to the difference between natural depth and artificial depth of the channel. Second, due to its exploratory nature, the study only considered channel charges and berth charges, while other charges especially terminal charges were not considered. Thus, future study can extend the empirical framework and include additional charges, especially terminal charges to cargo owners/ shippers and charges for other services such as pilotages. Finally, future research can also incorporate the role of competition, vertical relationship along the supply chain and port-regional development.*

30) Winston (1991).

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