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Hub Status and Indexation of Container Ports

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Contents

Abstract

Although ports play a traditional role as loading and connecting centers for cargo and passengers, container ports as intermodal junctions have undergone continuous and diverse changes since the late 1950s as a result of technological advancements and transport network expansion. In order to shed light on the port transformation process, the objective of the present paper is to develop a hub index for container ports to evaluate the hub status of container ports within shipping networks, inland networks, and various logistics services.

This study develops two sub-indexes of port classification and capacity, and combines cases of these two sub-indexes into various types in order to find a proper port hub index. The paper demonstrates how different types of port hub index are useful measurements for evaluating outputs and inputs of container ports. In a case analysis we show that the indexes of period variables and lagged variables have more explanatory power with regard to changes of port throughputs and high correlation with inputs.

Key words : Container Port, Hub, Measurement, Index, Network

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I. Introduction

The revolutionary concept of the internationally standardized iron box has instigated continuous, dynamic changes at nodes and links across transport networks (Levinson, 2006). The standardization of containers nowadays affects the design and shape of vessels, trucks, and railway flatcars. Transport facilities such as ports, truck terminals, railway stations, and warehouses have fully adapted their designs and structures to accommodate the container. Improvements in the safety and accountability of transport through the use of the container–to move cargo from origin to destination–currently promotes intermodal, multimodal and integrated services by combining different transport modes in a single liability.

In addition, the enlargement of container ships has continued steadily since the 1960s. The largest container vessel is now a ship of over 18,000 Twenty-foot Equivalent Units (TEUs), about eighteen times larger than the largest container vessel of the early 1960s (Imai et al., 2006; Veldman et al., 2011). Larger vessels tend to limit their calling ports in order to save turnaround time and voyage time, which has resulted in the development of hub and spoke networks (Hayuth, 1978; Slack, 2004; Lin and Tsai, 2014). Furthermore, myriad technical and network changes relating to container transport have also impacted firm behavior, regional economies, and trade patterns. Given these important changes, the analysis of the interrelation between a container port and its region must account for innovation in container transport as well as complexity in the interaction between a port and its region.

In order to accurately evaluate the role of a container port in the regional economy, a measurement of hub status of a container port would be useful. This paper aims to test a hub index for container ports to appraise the hub status of container ports in terms of shipping networks, inland networks, and various logistics services. The index uses key factors of port operations and activities, and measures the relationship between ports and their transport networks. The index has been developed to complement existing indexes for container ports, such as the Liner Shipping Connectivity Index (UNCTAD, 2005), the port accessibility index to world shipping networks (Cullinane and Wang, 2009), and the assessment index of hub status (Low et al., 2009). In the study we will test the hub index with a dataset on three Korean container ports (Busan, Gwangyang and

Incheon) and two European container ports (Rotterdam, the Netherlands and Felixstowe, U.K.).

The present paper is arranged as follows. Chapter II reviews the context of the hub-and-spoke network. The chapter also reconsiders the role of the hub in the container transport system and within intermodal transport. Chapter III explains our collection of the panel data of the Korean ports Busan, Gwangyang, and Incheon, and Rotterdam and Felixstowe ports, and describes different scales for calculating a hub index. In a regression analysis of cargo throughput, in Chapter IV we test the suitability of the scale of sub-indexes of a hub index in addition to other variables of port inputs, such as handling capacity of containers, length of berth, and area of container yard at a port. Chapter V suggests diverse types of hub index and illustrates the trend of hub indexes for the five ports. Chapter VI restates our findings and draws the paper to a close.

II. Context: Hub-and-Spoke

1. Hub-and-Spoke Network

In order to best use their limited capacity, transport companies among other things, have forged strategic alliances, shared services and concentrated services on just a few nodes (Alderighi et al., 2007). The hub-and-spoke network is a prime example. It consists of a few hubs that serve as connecting or central nodes with many feeders linked to other nodes, mainly through the hub: this point-to-point network offers direct links to other nodes and radiates from a base (Flemming and Hayuth, 1994; Wang and Slack, 2000; Low et al., 2009; Nishimura et al., 2009; Roso et al., 2009; Gelareh and Nickel, 2011).

Since the introduction of standardized containers in shipping, the hub-and-spoke network has changed the geographical range of shipping services, from a region or a nation, to the global scale and now promotes transshipment activity at ports proximal to the intersection of main sea routes, or where the main flows of container traffic enter into feeder routes (Talley, 2002). Furthermore, the continuous enlargement of container vessels themselves has induced the division of container ports into hub and feeder ports (Yeo, 2010; Nam and Song, 2011).

Even though the hub-and-spoke network has stratified container ports into a few hubs and numerous feeder ports, the status of a container port can nevertheless be diversified from a peripheral to a global hub port in accordance with its status in shipping networks, inland networks, and logistics chains provided around the port. Nowadays, a container port in a feeder network, such as Chongqing port in China, can be a main player in inland networks and logistics chains (Trip and Bontekoning, 2002; Notteboom, 2012); and a pure transshipment port in main shipping routes similar to Tanjung Pelepas port in Malaysia, may function well without inland networks (Zeng and Yang, 2002; Nishimura et al., 2009; Petering, 2009). In addition, containerization of the transport system and the deregulation of transport industries has fostered intermodal transport of containers and diversification of shipping networks, inland networks, and logistics chains around container ports (Talley, 2002; Nam and Song, 2011).

2. Literature on the Measurement of Hub Status

Given that measurements of hub status for ports, airports, and railway stations mainly assume that the hub in transport networks plays the role of connecting junction between transport routes in the same transport modes, major measurements and indices also tend to focus on the evaluation of hub status of nodes within the same transport mode, which could be sea shipping network, air transport network, railway network, or personal communication network (Freeman et al., 1991; Burghouwt and Wit, 2005; Low et al., 2009). When analysts attempt to measure accessibility of a port or a transport node, they try to gauge the connection of a port or a transport node to its hinterland (Bergqvist and Tornberg, 2008; Bok, 2009; Thill and Lim, 2010). The accessibility evaluation is useful, for example, when assessing connectivity or centrality of single transport mode but is insufficient in the assessment of intermodal transport and in cases where a port has multiple transport networks in close proximity.

We find therefore that the accessibility evaluation cannot be used as an integral indicator for the hub status of a container port in the same way as the port accessibility index can be used to assess a single transport mode (Cullinane and Wang, 2009). Hence, if a node functions as a multiple role player, such as a container port in intermodal transport, a measurement and index can be more effective when considering and assessing the intermodal roles of a hub port.

III. Methodology of Indexation

1. Building Panel Data

The 21-year panel data period covers the years 1991 to 2011. Our main sources of data include Containerisation International Yearbook (Informa U.K., 1993-2013), governments, port authorities (Port of Rotterdam, 2013), port operators, maritime magazines and consulting companies, specifically. Outputs of a container port consist of general cargo and containers. Throughput of general cargo at a port is comprised by the movement of all cargo, excluding crude oil, ores, and coal. The measurement unit of general cargo is tonnage, and the measurement unit of containers is the twenty-foot equivalent unit (TEU).

The inputs of a container port are composed of three major elements: handling capacity of container, represented by the number of quay cranes and their mechanical characteristics, length of berths, and area of container yards. We use a measurement of handling capacity of container ports which counts the number of quay cranes and their yearly mechanical capacity, and the optimum utilization of mechanical capacity during one period when the installation of a port facility begins and ends (Rankine, 2003; Park and Medda, 2014).

2. Port Classification Sub-Index

Also in this study we develop a sub-index of port classification through taking the mean of two scales of shipping and inland networks.

1) Shipping Network Scale

This study adopts three categories of shipping networks: continental, regional, and feeder networks. A scale of shipping networks can be weighted by the slot size of a representative container ship in each shipping network, as shown in Table 1: Post-Panamax for a continental network; Panamax for a regional network; and around average size of world container ships for a feeder shipping network (Drewry, 2010). These sizes of container ships and their slot capacity represent the network potential of a container port (Lam, 2011). We use this size ship as a relative scale of each shipping network.

<Table 1> Shipping networks and representative ships

Item/Shipping network	***Continental network***	***Regional network***	***Feeder network***	***Total***
Type of a representative ship	Post-Panamax	Panamax	Average of container ships	
Slot capacity	8000TEU	4000 TEU	2700 TEU	14700
Scale of shipping network	8000/14700	4000/14700	2700/14700	1

Source: Author's elaboration

Therefore, if a container port has three shipping networks, it can service three sizes of container ships. We can evaluate the scale of shipping networks of each container port, as in Table 2.

<Table 2> Shipping networks and scale of each network

Items	***Continental network***	***Regional network***	***Feeder network***	***Shipping network scale***
A port	√	√	√	14700/14700
B port	√	√		(8000+4000)/14700
…	…	…	…	…
P port			√	2700/14700

Source: Author's elaboration

<Table 3> Inland networks and scale of each network

Port/Item	***Road***	***Freight railway***	***Inland waterway and/or short sea shipping***	***Logistics facilities FTZ and/or logistics park***	***International airport***	***Inland network scale***
Scale	0.2	0.2	0.2	0.2	0.2	
A port	√	√	√	√	√	1
B port	√	√	√	√		0.8
C port	√	√	√			0.6
…	…	…	…	…	…	…
P port	√	…				0.2

Source: Author's elaboration

2) Inland Network Scale

Usually inland modes can be placed into four categories: truck, rail, barge and/or short sea shipping, and districpark (Ottjes et al. 2006). We add an additional mode: international airport. We put the same weight on each inland transport mode as shown in Table 3, as in the cases of evaluation of transport infrastructure and service of each country by the World Economic Forum and the case of logistics performance evaluation by the World Bank (World Bank, 2010; World Economic Forum, 2010a; World Economic Forum, 2010b). In Table 3 we can observe different types of inland transport modes around a container port and their scales.

3) Port Classification Sub-Index

By taking an arithmetic mean of shipping network scale and inland network scale, we are able to calculate the sub-index of port classification (PCI). The assumption here is that each network of inland and shipping can equally affect the economic role of a container port, and that their range of economic effects will be decided by different components of shipping and inland networks.

$$PCI_p = (SS_p + IS_p)/2 \quad (1)$$

Where,

PCI_p: classification sub-index of port p, $0 < PCI_p \leq 1$

SS_p: shipping network scale of port p, $0 < SS_p \leq 1$

IS_p: inland network scale of port p, $0 < IS_p \leq 1$

3. Port Capacity Sub-Index

Since the handling capacity of container ports can represent the status and efficiency of ports very well, two indexes are developed in this paper: one is calculated by absolute value of capacity and the other by relative value of capacity.

1) Port Capacity Sub-Index 1

We use the container throughput record of the highest ranking port worldwide in the previous year, and the optimum utilization ration of mechanical capacity. The port capacity sub-index of a container port is as follows,

$PSI1_p$ = *Mechanical handling capacity of port p / Estimated optimum capacity of the port in world rank one* (2)

Where,

Estimated optimum capacity of the port in world rank one

= (1/0.781) x (container throughput of the port in world rank one)

0.781: the utilization ratio of mechanical capacity of container ports (Park and Medda, 2014)

We cap the upper value of the port capacity sub-index at 1.

Therefore,

$0 < PSI1_p \leq 1$

2) Port Capacity Sub-Index 2

While considering the wide range of expansion and shrinkage of handling capacity of container ports, we can develop a relative value of changes of handling capacity. We assume that the capacity of extreme expansion becomes twice that of the previous capacity; and the capacity of extreme shrinkage becomes half of the previous capacity.

$$PSI2_p = (0.5) / c \quad (3)$$

$c = (Capacity_{t-1} / Capacity_t)$

Where,

$Capacity_t$: handling capacity of present year t

The value of c ranges from 0.5 in the case of extreme expansion, to 2 in the case of extreme shrinkage of capacity.

Therefore,

$1/4 \leq PSI2_p \leq 1$

We assess the changes of handling capacity of container ports by PSI2: in expansion of capacity with PSI2 exceeds 0.5; and in shrinkage of capacity with PSI2 is below 0.5.

A Hub Index of a container port is formulated by combining two sub-indexes: port classification sub-index and port capacity sub-index. Port classification sub-index is based on the shipping, inland networks, and logistics services of a container port. Port capacity is counted as an indicator for handling capacity or status of a container port.

4. Panel Regression Method

Two methods are developed in terms of dependent variables. Method I seeks suitable variables to impact the throughput of general cargo during the study period 1991 to 2011. Method II focuses on container throughput during the same period. In this panel regression, the port of Gwangyang is excluded in order for us to collect our 21-year dataset, 1991 to 2011.

IV. Panel Data and Regression Results

1. Panel Data

In the panel data, tonnage of general cargo ranges from 16 million tons up to 258 million tons; container throughput of the ports from 113thousand TEU to 13 million TEU; port-classification sub-index from 0.43 to 1; container handling capacity of the ports from 789 thousand TEU to 30 million TEU as listed in Table 4. The length of berths in the ports records 493 m in minimum and 18 km in maximum. The area of container yards ranges from 28 thousand m^2 to 6.9 million m^2.

<Table 4> Summary of the panel data

Variable	*Obs*	*Mean*	*Std. Dev.*	*Min*	*Max*
Ttlg (thousand ton)	84	112556.9	72295.4	16126	258331
Cth (thousand TEU)	84	4540.7	3544.2	113	12963
Class	84	.71	.18	.43	1
Cca (thousand TEU)	84	9304.4	7028.5	788.7	30296.9
Length (m)	84	6950.9	5199.6	493	18091
Area (thousand m^2)	84	2442.1	1971.3	28	6933

Note: ttlg: throughput of general cargo; cth: container throughput; class: port classification sub-index; cca: container handling capacity; length: length of berths; area: area of container yards

2. Tests of Suitability of Models

Before estimating the coefficients of our variables, we test the characteristics of the error term in the fixed effects model, conduct a significance test of the random effects model, and perform a serial auto-correlation, contemporaneous correlation between panels, and Sargan test of over-identifying restrictions in order to find our suitable models, as shown in Table 5.

<Table 5> Summary of searching for suitable models and suitability tests

Test/Method	***I***	***II***
Variables	Dependent: total throughput Independent: classification sub-index, handling capacity	Dependent: container throughput Independent: classification sub-inde x, handling capacity
Characteristics of error term in fixed effects model	F(2, 78)=122.65 prob> F = 0.000	F(3. 78)=4.15 prob> F = 0.009
Significance test of random effects model	$chi^2(1)$ = 442.24 prob > chi^2 = 0.0000	F(3. 79)=3.75 prob > F = 0.0142
Tests for serially auto-correlation	Serial correlation: LM(ρ =0)= 75.43 prob >$chi^2(1)$ = 0.0000 ALM(ρ =0)= 6.48 prob >$chi^2(1)$ = 0.0109	Serial correlation: LM(ρ =0)= 60.98 prob >$chi^2(1)$ = 0.0000 ALM(ρ =0)= 60.82 prob >$chi^2(1)$ = 0.0000
Tests for contemporaneous correlation	$chi^2(6)$ = 34.31, prob> chi^2 = 0.0004	$chi^2(6)$ = 24.66 prob> chi^2 = 0.0004
Sargan test	$chi^2(189)$ = 73.43, Prob > chi^2 = 1.000	$chi^2(170)$ = 165.23, Prob > chi^2 = 0.8931

Note: Prob is the abbreviation of Probability.

After having conducted the tests, we find that the fixed effects model and random effects model are more suitable than panel generalized least squares. There is serial auto-correlation in error term e_{it}. In addition, the Sargan test for over-identifying restrictions tells us that over-identifying of the dynamic panel model is appropriate. Dynamic panel modelling can also be efficient.

3. Panel Regression

1) Panel Regression on Throughput of General Cargo from 1991-2011

In the regression analysis as shown in Table 6, independent variables include classification sub-index, handling capacity of containers, length of berths, and area of container yard (Yeo, 2010).

<Table 6> Regression results of general cargo and container throughputs

Variable/Model	*Dependent: General Cargo*						*Dependent: Container Throughput*					
	M-1	*M-2*	*M-3*	*M-4*	*M-5*	*M-6*	*M-7*	*M-8*	*M-9*	*M-10*	*M-11*	*M-12*
Constant	-847	87285	-152453	143858	4433	-	-4726	29	-2449	-8092	-1695	-
Classification sub-index	84125*** (2.85)	167343	273543*** (5.1)	42073 (0.74)	115949** (2.14)	13974 (0.5)	8318*** (7.05)	19.84	5262 (1.20)	14859*** (2.80)	5845** (2.03)	7959*** (5.59)
Handling capacity of containers	6.08*** (10.5)	2.6e-06	5.82*** (4.1)	1.45** (2.3)	2.54*** (4.0)	0.47 (0.9)	0.32*** (10.9)	0.01	0.36*** (3.10)	0.19*** (3.01)	0.24*** (3.7)	0.27*** (10.5)
Length			-1.56 (-0.9)						-0.18 (-1.27)			
Area			10.8 (1.5)						0.46 (0.77)			
$Throughput_{t-1}$						0.93*** (17.0)						0.27*** (6.28)
Sample Size	84	84	84	80	84	76	84	84	84	80	84	76
R^2	-	λ=2.45***	0.55	0.56	0.55	-	-	λ=0.69***	0.73	0.84	0.50	-
F	-	ϑ=0.95***	62.1	3.0	-		-	θ=0.29***	20.9	10.1	-	-
Wald χ^2	188.0 Prob. > χ^2 = 0.000				22.3 Prob.> χ^2 = 0.000	-	395 Prob.>χ^2 = 0.000				36.90	-

Note: 1) * significant at 9% level; ** significant at 5% level; *** significant at 1% level
2) M-1 & M-7: Panel GLS Model; M-2 & M-8: Box-cox transformation; M-3 & M-9: Fixed Effects Model; M-4 & M-10: Fixed Effects Model with auto-correlation; M-5 & M-11: Random Effects Model with auto-correlation; and M-6 & M-12: Dynamic Model

In the dynamic model we also use lagged values of general cargo. We can state that in general, the panel GLS model with heteroscedasticity, fixed effects models and random effects model with auto-correlation as in Models 1, 3 and 5, have better explanatory power with higher t-statistics. In all the models the signs of the coefficients of classification sub-index and handling capacity of containers are positive, consonant with our intuition. Model 2 in Box-cox transformation shows a very elastic coefficient of classification sub-index. The dynamic model of general cargo in Model 6 does not have a significant estimator of classification sub-index. This seems to be caused by the various effects of different variables on the fluctuation of general cargo in a port.

Linear regression models explaining container throughput from 1991 to 2011 show positive effects of classification sub-index and handling capacity of containers on container throughput, as presented in Table 6. However, the possibility of correlation among handling capacity of containers, length of quays, and area of container yards seems to give the similar value of estimators of handling capacity in Models 7, 9, and 12. Model 8 with Box-cox transformation lessens the sensitivity of coefficient of classification sub-index. The dynamic model, Model 12, also has statistically significant coefficient of lagged container throughput at 1 percent significance level, as shown in the regression of general cargo.

From the main results of the regressions we can conclude that the models having the classification sub-index and the lagged variables of container throughput and handling capacity of containers have better explanatory power.

V. Indexation and Analysis

1. Indexation of Hub Status of a Container Port

When we combine the Port Classification Sub-index and two Port Capacity Sub-indexes: Port Capacity sub-index 1 and 2, we are able to measure the hub status of a container port. The sub-index of port capacity is evaluated, as shown in Equations 2 and 3. Sometimes researchers adopt the method of moving average weight of elements to make an index less sensitive to the specific year, and in order to widen the available information, as suggested by the World Economic Forum (World Economic Forum, 2010a).

That is,

$$\text{Moving Average of } X_t = \{(0.6 \times X_t) + (0.4 \times X_{t-1})\} \qquad (4)$$

1) Port Classification Sub-Index and Port Capacity Sub-Index 1

Nine types of hub indexes are shown in Table 7 which combine differently *Port Classification Sub-index* and *Port Capacity Sub-index 1*. The types of WS3-1 and WS4-1 use the present sub-indexes of port classification and port capacity; types of WS3-2 and WS4-2 mix the present sub-index of port classification and the moving average of port capacity sub-index. WSP-1 and WSP-2 adopt the average values of port classification and port capacity of five years from the fourth previous year to the present. WSL-1, WSL-2 and WSL-3 use the lagged values of port classification and port capacity.

<Table 7> Hub Indexes of container ports by Port Capacity Sub-index 1

Index		*Type*	*Content*	*Index range*
Hub Index : $\sqrt{(a \times b)}$		WS3-1		0 < Index ≤ 1
		WS3-2	b: moving average of Port Capacity Sub-index I	0 < Index ≤ 1
Hub index: $\sqrt{\frac{(a+b)}{2}}$		WS4-1		0 < Index ≤ 1
		WS4-2	b: moving average of Port Capacity Sub-index I	0 < Index ≤ 1
Hub index	$\sqrt{(\bar{a} \times \bar{b})}$	WSP-1	$\bar{a}$: average of classification sub-indexes from 4th previous year to this year $\bar{b}$: average of Port Capacity Sub-indexes from 4th previous year to this year	0 < Index ≤ 1
	$\sqrt{\frac{(\bar{a} + \bar{b})}{2}}$	WSP-2		0 < Index ≤ 1
Hub index	$(a_{t-1}+b_{t-1})/2$	WSL-1		0 < Index ≤ 1
	$\sqrt{(a_{t-1} \times b_{t-1})}$	WSL-2		0 < Index ≤ 1
	$\sqrt{\frac{(a_{t-1} + b_{t-1})}{2}}$	WSL-3		0 < Index ≤ 1

Note: a: classification sub-index; b: capacity sub-index

$\bar{a} = (a_{t-4} + a_{t-3} + a_{t-2} + a_{t-1} + a_t) /5$

a_{t-n}: n^{th} previous year's classification sub-index

$\bar{b} = (b_{t-4} + b_{t-3} + b_{t-2} + b_{t-1} + b_t) /5$

b_{t-n}: n^{th} previous year's capacity sub-index

Source: Author's elaboration

2) Port Classification Sub-Index and Port Capacity Sub-Index 2

Table 8 lists nine types of hub indexes combining differently *Port Classification Sub-index* and *sub-index of Port Capacity sub-index II.*

<Table 8> Hub Indexes of container ports by Port Capacity Sub-index 2

Index	*Type*	*Content*	*Index range*
Hub Index : $\sqrt{(a \times b)}$	CS3-1		$0 < \text{Index} \leq 1$
	CS3-2	b: moving average of Port Capacity Sub-index II	$0 < \text{Index} \leq 1$
Hub index: $\sqrt{\frac{(a+b)}{2}}$	CS4-1		$0 < \text{Index} \leq 1$
	CS4-2	b: moving average of Port Capacity Sub-index II	$0 < \text{Index} \leq 1$
Hub index $\sqrt{(\bar{a} \times \bar{b})}$	CSP-1	$\bar{a}$: average of classification sub-indexes from 4th previous year to this year $\bar{b}$: average of Port Capacity Sub-indexes from 4th previous year to this year	$0 < \text{Index} \leq 1$
Hub index $\sqrt{\frac{(\bar{a}+\bar{b})}{2}}$	CSP-2		$0 < \text{Index} \leq 1$
Hub index $(a_{t-1}+b_{t-1})/2$	CSL-1		$0 < \text{Index} \leq 1$
Hub index $\sqrt{(a_{t-1} \times b_{t-1})}$	CSL-2		$0 < \text{Index} \leq 1$
Hub index $\sqrt{\frac{(a_{t-1}+b_{t-1})}{2}}$	CSL-3		$0 < \text{Index} \leq 1$

Note: a: classification sub-index; b: capacity sub-index

$\bar{a} = (a_{t-4} + a_{t-3} + a_{t-2} + a_{t-1} + a_t) /5$

a_{t-n}: n^{th} previous year's classification sub-index

$\bar{b} = (b_{t-4} + b_{t-3} + b_{t-2} + b_{t-1} + b_t) /5$

b_{t-n}: n^{th} previous year's port capacity sub-index

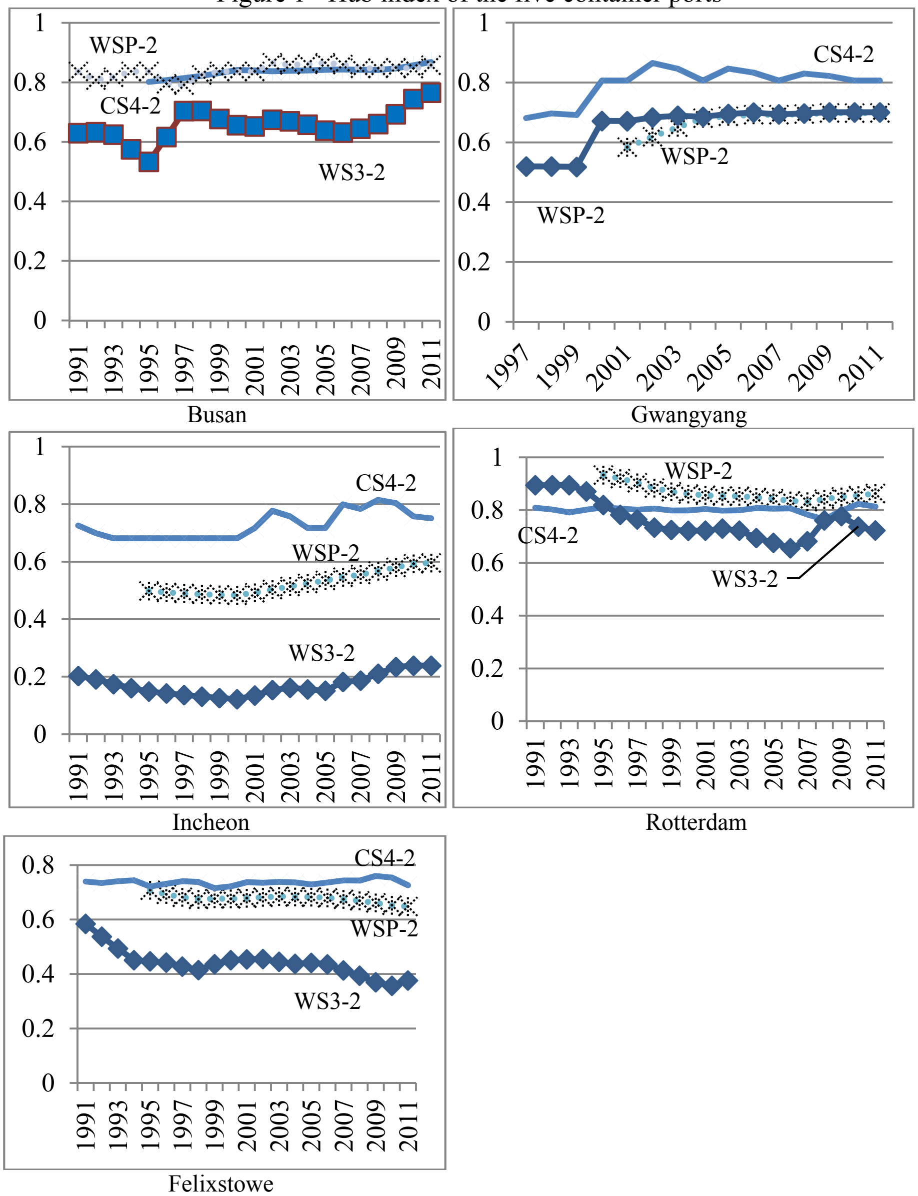
Source: Author's elaboration

2. Case Analysis of Five Container Ports

Next in our case analysis we test different types of hub indexes and exemplify the three indexes in superiority of correlation with outputs, total general cargo throughput, and container throughput. While all hub indexes show positive correlation with throughput of general cargo and throughput of containers in the three Korean ports, only three indexes, CSL-1, CSL-2, and CSL-3, indicate weak correlation with the throughput of general cargo in Rotterdam; the other indexes illustrate negative correlation with the throughput of general cargo in Rotterdam and in Felixstowe, as shown in Appendix 1. The indexes CS3-1, CS3-2, CS4-1, CS4-2, CSP-1, CSP-2, CSL-1, CSL-2 and CSL-3 show weak positive correlation with the throughput of containers in Felixstowe.

We illustrate and examine three hub indexes at each port: WS3-2, WSP-2, and CS4-2 listed in Figure 1, have relatively high correlation with container throughput. For example, Busan port has upgraded its position from a gateway port in Korea to a hub port in North East Asia through the uninterrupted expansion of its shipping and inland networks, and the enlargement of its container handling capacity. Therefore, the indexes of hub status show cyclical change in accordance with the development of container terminals and changes in the handling capacity of containers, as depicted in Figure 1.

<Figure 1> Hub index of the five container ports



VI. Conclusion

This study has investigated the essential roles of container ports in cargo transport networks and carried out an analysis of the fundamental factors and inputs of hub ports. The literature on the measurement of hub status for ports is scarce and does not focus on the different transport networks; papers tend not to consider shipping, inland and logistic services simultaneously, but instead focus mainly on shipping services.

After examining the relationships among outputs and inputs of a container port and valid inputs which vary the throughputs of general cargo and containers in panel regressions, this study has set out to develop a port hub index to evaluate the hub status of container ports. The findings reported here demonstrate that the indexes which take lagged variables and period values have more explanatory power and show high correlation with the throughput of a container port.

In the case analysis, we have observed that each container port has specific characteristics and style of operation. Busan expanded its container facilities swiftly and widely in the early 1990s, and later faced a short recession around 1998 when the Korean economy endured a drop in its foreign exchange market. Busan nevertheless recovered well from the recession and proceeded to sustain and enlarge its role as hub. With regard to Gwangyang, when port hub indexes of Gwangyang in CS4-2 began to fall gradually after 2005, showing excess capacity compared with its cargo throughput, it became clear that the port would need to develop an innovative strategy to catch shippers in Northeast Asia. Incheon currently also faces a deficiency of container throughput. The two European ports show relatively stable trends in their indexes, indicating a steady but slow growth in container throughput in Europe; dull competition and entry barriers for newcomer port may be impacting factors in the European case.*

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<Appendix 1> Correlation table between hub indexes and throughputs

	Throughput of general cargo						Throughput of containers					
	Bs	Gw	In	Rot	Fel	Mean	Bs	Gw	In	Rot	Fel	Mean
WS3-1	0.53	0.76	0.49	-0.46	-0.54	0.16	0.6	0.94	0.67	-0.62	-0.77	0.16
WS3-2	0.54	0.79	0.46	-0.5	-0.63	0.13	0.61	0.96	0.63	-0.67	-0.81	0.14
WS4-1	0.71	0.63	0.72	-0.46	-0.56	0.21	0.75	0.85	0.91	-0.62	-0.77	0.23
WS4-2	0.73	0.64	0.72	-0.5	-0.65	0.19	0.78	0.86	0.91	-0.67	-0.81	0.21
WSP-1	0.61	0.77	0.7	-0.57	-0.16	0.27	0.71	0.96	0.78	-0.7	-0.86	0.18
WSP-2	0.86	0.67	0.75	-0.57	-0.17	0.31	0.91	0.88	0.97	-0.7	-0.86	0.24
WSL-1	0.64	0.7	0.7	-0.54	-0.72	0.16	0.69	0.89	0.89	-0.7	-0.81	0.19
WSL-2	0.42	0.8	0.35	-0.54	-0.7	0.07	0.49	0.94	0.49	-0.71	-0.82	0.08
WSL-3	0.64	0.69	0.69	-0.54	-0.72	0.15	0.68	0.89	0.88	-0.71	-0.81	0.19
CS3-1	0.42	0.35	0.51	-0.05	-0.25	0.19	0.42	0.58	0.69	-0.12	0.06	0.32
CS3-2	0.49	0.79	0.55	-0.02	-0.29	0.3	0.47	0.96	0.78	-0.11	0.14	0.45
CS4-1	0.62	0.41	0.51	-0.03	-0.25	0.25	0.61	0.64	0.69	-0.11	0.06	0.38
CS4-2	0.7	0.46	0.55	-0.01	-0.29	0.28	0.67	0.72	0.78	-0.1	0.15	0.44
CSP-1	0.8	0.33	0.68	-0.68	-0.28	0.17	0.69	0.6	0.95	-0.64	0.53	0.43
CSP-2	0.91	0.4	0.68	-0.68	-0.28	0.21	0.82	0.66	0.95	-0.64	0.53	0.46
CSL-1	0.59	0.5	0.42	0.03	-0.13	0.28	0.54	0.73	0.65	-0.02	0.18	0.42
CSL-2	0.35	0.48	0.44	0.01	-0.14	0.23	0.32	0.7	0.67	-0.04	0.16	0.36
CSL-3	0.58	0.52	0.43	0.02	-0.13	0.28	0.53	0.75	0.66	-0.03	0.17	0.42

Note: Bs: Busan; Gw: Gwangyang; In: Incheon; Rot: Rotterdam; Fel: Felixstowe
Source: Author’s elaboration