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STRUCTURAL CHANGES IN PORT CARGO FLOW DISTRIBUTION IN ASIAN CONTAINER PORT SYSTEMS

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ABSTRACT

This study discusses the structural changes in port cargo flow distribution in Asia and traffic inequality in Asian container port systems, by conducting an inequality decomposition analysis of the Gini index. Specifically, port systems considered here comprise 229 container ports, which were classified into fifteen port ranges according to their geographic locations and annual port container traffic data from 1980 to 2009. The results confirmed the trend of shrinking inequality all in all. Progress in port development in Asia allowed us to confirm similar trends for each port range from a time series estimation. The result also revealed the trend of expanding inequality between pairs of port ranges, such as those of China and Southeast Asia. The following structural changes were observed: **(a)** the trend of shrinking inequality within/between port ranges due to regional port developments in Japan, **(b)** the trend of slightly shrinking inequality within/between port ranges in South Korea and Taiwan due to policy-concentrated investments at limited container ports, and **(c)** the changes in the center of gravity of container movements and inter-port competition within Chinese and Southeast Asian port range groups, owing to the increase in container handling volumes at all ports for specific port ranges. As a result, the comparative differences in the pace of economic growth and port investments in Asia have produced changes in inequalities.

Key Words: traffic inequality, container handling volumes, port cargo flow distribution, Asian port systems, Gini coefficient, decomposition analysis

1. INTRODUCTION²

Between 1990 and 2008, world maritime cargo transport volumes increased by 1.96 times owing to Asian economic growth focused primarily in China, and the rise in international and intra-industry specialization and trade in developed countries. Especially, international container cargo handling volumes have increased by 3.57 times over the past 15 years. For example, the cargo handling volumes between Asia and Europe increased by 4.98 times from 1990 to 2005, and the volumes between Asia and North America expanded to 3.44

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² All statistics in this paper, with the exception of the database used in the empirical analysis, have been sourced from the internal documents of the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT), the press releases of Mitsui O.S.K. Lines, Doi (ed.) (2003), and Kuroda *et al.* (eds.) (2010).

times over the same period. However, the volumes between Europe and North America expanded to only 1.62 times from 1990 to 2005. Moreover, the Asian inter-regional cargo volumes increased by 3.61 times from 1990 to 2005. International container cargo moves with a central focus on Asia.

Figure 1 shows the international container cargo flow in 2007. The trade volumes between East Asia and North America and between East Asia and Europe in 2007 were 23.87 and 26.96 million twenty-foot equivalent units (TEUs), respectively. As compared to these trade volumes, the inter-regional container movements within East Asia were 45.56 million TEUs in 2007. We can confirm the impact of inter-regional industrialization and consuming markets in East Asia on the world economy and container movements.

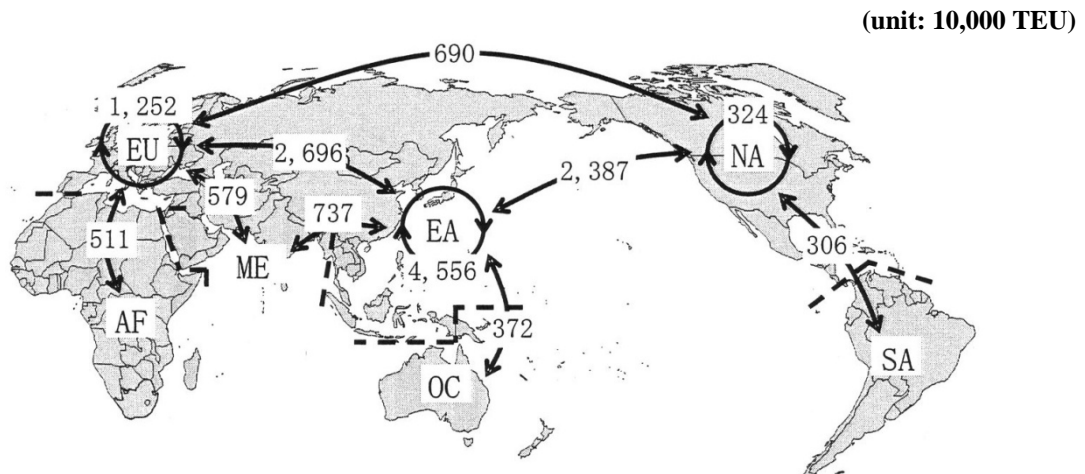


Figure 1: International container cargo flow in 2007

(Source: National Institute for Land and Infrastructure Management (2009), The analysis of container cargo flow and container ship movements, No. 538. (in Japanese))

In 2008, world container cargo handling volumes reached a record 509.44 million TEU. However, after the fall of the global financial services firm Lehman Brothers, international cargo transport volumes slumbered because of the economic slowdown in Western countries. Consequently, world container cargo handling volumes dropped by 10.0% over a year ago. In contrast, between 2000 and 2005, the rate of handling volumes in China increased by 20% annually. Moreover, in 2010, China became the second-largest country in the world in current GDP terms (US dollar). However, over a year ago, container handling volumes in China also witnessed a drop by 8.9%. Notwithstanding this, the Yangshan deepwater port in Shanghai (China) surpassed the port of Singapore to become the top container port in the world in 2010. This fact seems all the more remarkable given that operations at the Shanghai port (situated about 30 km offshore) were initiated as recently as December, 2006. It recorded container cargo handling volumes of 29.07 million TEU in 2010.³

On the other hand, after the early 1990s, the ports of Busan in South Korea and Shenzhen in China including the ports of Singapore and Hong Kong, which strongly compete with each other, have been actively promoting their own port development for becoming hub ports in Asia. For example, Busan New port began its operations in 2006, and Da Chan Bay container terminal in Shenzhen also initiated its operations in 2007. Moreover, Tanjung Pelepas in Malaysia also initiated its operations at the end of 1999, etc. Container cargo handling volumes rapidly increased at the Tanjung Pelepas port because it had captured the transshipment cargo share of the Taiwanese shipping company, Evergreen,

³ See, World Shipping Council's HP (<http://www.worldshipping.org>).

from the port of Shanghai against the backdrop of cheaper port charges.⁴

In Japan, the target of the high-standard central port policy, which indicates the change in policy from quantitative expansion to qualitative expansion for port investments, is the formation of the logistics hub function and the use of some deregulation for attracting industries. Specifically, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) had designated three port groups—the Keihin port, the ports of Nagoya and Yokkaichi, and the ports of Osaka and Kobe—as “super-center ports” in July 2004. Nevertheless, export container cargos were shipped via the ports of Busan and Shanghai from Japanese regional ports to Western countries, because of rapidly escalating container cargo transport from the Asian region, with the central focus being on China. However, domestic hub container ports continue to play an important role in maintaining industrial competitiveness, and hence, serve as the main ports for European/North American routes. As a result, in August 2010, MLIT designated the Keihin port and the Hanshin port as “international container strategic ports,” which received focused investments and support.

In this situation, wherein international container cargo moves with a central focus on Asia, it is rather interesting to discuss the changes in the flow of port cargo. This research aims to confirm the structural changes in the international container cargo flow in Asia by focusing on the transition of freight container handling volumes. In particular, this research focuses on the structural changes of container cargo flow distribution in the main Asian economic zones such as the Japanese ports group, which had a high ranking in terms of the volumes handled in Asia until 1990, the East Asia ports group, which included the Chinese ports following the rapid economic growth after 1990, and the Southeast Asia ports group, which included the port of Singapore that traditionally handled numerous cargo transshipments.

The aim of this paper is two-fold: one, to evaluate traffic inequality dynamics or handling concentration, and two, to observe the structural changes in port cargo flow distribution in Asian container port systems, by conducting an inequality decomposition analysis of the Gini index. The latter was proposed by Dagum (1997), and evaluated the contribution of each inequality index (component) to the (original) Gini index. Specifically, Asian container port systems considered in this study comprise 229 container ports in all, which are classified into fifteen port ranges according to their geographic locations. Further, the study uses annual container traffic data at ports from 1980 to 2009.

This paper is structured in the following manner: Section 2 explains port hinterlands and the decomposition analysis of the Gini coefficient, which was applied in this paper for the inequality index or the degree of concentration of container traffic. Section 3 examines the port cargo flow structure in the Asian region, which is the focus of this empirical study, and compares this paper’s perspectives with those of previous related papers. Subsequently, Section 4 reviews the framework of this empirical study, and discusses the results of the decomposition analysis for Asian port systems, wherein the data period between 1980 and 2009 has been considered, and has implications on the main findings of this analysis. Finally, Section 5 summarizes this paper and outlines the challenges for future research.

⁴ The Denmark shipping giant Maersk Sealand also shifted their port of transshipment cargo from Singapore to Tanjung Pelepas in 2000.

2. PORT HINTERLAND AND INEQUALITY INDEX OF HANDLING VOLUMES

2.1 Port hinterland

Port hinterland analysis serves as the most important and universal research topic in the field of transport geography, specifically maritime cargo transport. “Port hinterland” refers to the market area of the port handling the cargo, i.e., the origin or destination area.

For example, Itoh *et al.* (2003) analyzed port service areas by conducting fuzzy clustering for 47 prefectures in Japan.⁵ This paper discussed clusters of shippers’ utilization of ports, i.e., shippers’ groups based on export/import handling cargo data in monetary terms as well as on the basis of weight, cross section, and time series. This result showed that there were different groups of shippers. One shippers’ group used the ports of Osaka as well as Kobe in the Osaka Bay area, while another used the port of Kobe while avoiding that of Osaka. There was also a mono-shippers’ group that used both the ports of Tokyo and Yokohama in the Tokyo Bay area.

Moreover, port selection behaviors of exporters and importers have also been evaluated separately. Itoh (2007) compared the port cargo flow structures between Japan and China by applying the estimated discrete choice functions used in early studies. This paper discusses the elasticity of port market share and marginal effects affecting the underlying factors on port choice in discrete choice models. The results of this study indicate that the port of Shanghai and other recent emerging ports in China have the potential for the growth of port influence. On the other hand, the regional ports in Kita Kanto need improvements not only in port upgrades but also in logistics facilities for the growth of port influence because of uncompetitive port market condition in Japan. The results of this paper also indicated that compared to exporters, importers are flexible towards changing their utilization port because of the limitation of port calls on main routes, and that Chinese ports have the competitive potential compared to Japanese ports.

Furthermore, Ducruet (2006) focused his empirical analysis on commodity composition, characteristics of port handling cargo, and economic characteristics of the surrounding area; i.e., the port hinterland. Specifically, this paper discussed the relationship between port-related variables and socioeconomic variables. As the port hinterland on Europe is more extensive compared to the hinterland for the Asian region, the importance of value-added logistics facilities, like distribution centers and warehouses in Europe was shown to be high. Therefore, improvements in logistics facilities were the focal strategy used to enhance regional economic development in Europe. On the other hand, the hinterland of Asian ports is limited because of geographical factors (there are many islands and peninsulas in Asia), and major Asian ports have their hinterlands located behind the ports. Therefore, access to Asian ports and their port handling functions assumed greater strategic significance for the growth of port influence in Asia.

Ducruet *et al.* (2012) identified mutual influences between the specialization of traffics passing through seaports and the socioeconomic characteristics of their surrounding regions. While the contemporary era is marked by the fading spatial fix of value chains (as notably seen in the dereliction of a port’s local linkages), there continues to be a lack of systematic and comparative empirical analyses. One main reason is the absence of internationally harmonized data on the precise spatial distribution of port-related hinterland flows as well as inadequacies between the volumes and the value of freight. This research proposed to overcome such difficulties based on a common set of 21 traffic and

⁵ This analysis appears as Chapter 2 in Doi *et al.* (2003).

socioeconomic indicators covering 189 port regions in Europe, Japan, and the United States. The main results underlined invariants as well as local specificities in the functional and spatial affinity between certain traffics and certain types of regions. While large urban and financial centers tend to polarize the most valued, diversified, and weighty traffics, rural regions generally concentrate agricultural goods and minerals, and industrial regions, combustibles and metals. Beyond the simple reflection of local demand, such results confirm the path-dependency of the association between material flows and regional economic development. A typology of port regions was proposed in order to map the distribution of port regions and to zoom in on specific local conditions.

Many previous studies discussing handling concentration for port systems focused on the relationship between maritime cargo transport and port hinterland, and evaluated inequality coefficients using the Gini index.⁶ Because the method of the Gini index involves descriptive statistics, it does not indicate the factors of concentration/inequality applicable to container handling volumes themselves. For example, various factors will affect the growth of port influence, namely, the location of the supply center of raw materials, the location of the factory, the economic state of the final consuming region and port facility, the number and frequency of ship calls, load/unload efficiency, and the neighboring value-added center, and their networks. Therefore, a discussion of inequality coefficients is insufficient for the analysis of port hinterlands. However, it is possible to quantitatively understand the degrees of and changes in container handling concentration by applying the Gini index.

Therefore, the current study estimates not only inequalities for all port systems, but also inequalities within each port group and those between port groups, by conducting a decomposition analysis of the Gini index. Then, it discusses the changes in port cargo flow structure (or geographical distribution) in Asia. While many academic papers have evaluated traffic inequality by applying index analysis (like the Gini index), most do not discuss the relative structural changes between ports or port groups.

2.2 Decomposition analysis of the Gini index

In this part, we introduce the concept of Gini coefficient as the inequality index and the decomposition analysis of the Gini coefficient by Dagum (1997).⁷

The Gini coefficient was developed to measure the degree of concentration or inequality of a variable in a distribution of its elements.⁸ A general formulation of the Gini index for a single group (port region) is expressed in the following equation.

$$G = \frac{1}{2\mu n} \sum_{i=1}^n \left(\frac{1}{n} \sum_{j=1}^n |t_i - t_j| \right) \quad (1)$$

where t_i is the i -th port in a single group ($i = 1, 2, \dots, n$), and n and μ are the number of ports and the container throughput average in a single group, respectively. The closer the coefficient is to 1.0, the more unequal the distribution. Conversely, the closer the coefficient is to 0, the more equal the distribution. In other words, all ports in the same area

⁶ For example, Lago *et al.* (2001) and Notteboom (1997) applied the Gini index to container port systems for the US and Europe, respectively.

⁷ Theil (1967) also proposed a decomposition approach dealing with the disaggregation and economic interpretation of the subgroup's inequality. Theil's inequality between subgroups is similar to G_{gb} in Eq. 7 in this paper. See Dagum (1997) for details.

⁸ For example, Rodrigue *et al.* (2006) explained the inter-port competition by using the concept of port hinterland and foreland, and the relationship between port competition and the Gini coefficient, or the Lorenz curve, in Chapter 5.

are at the same handling level.

Dugum (1997) extended the general formulation of the Gini index for a single subgroup (seen in Eq. 1) to that for many subgroups, as follows.

$$G = \frac{1}{2n^2 \mu} \sum_{j=1}^k \sum_{h=1}^k \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |t_{ji} - t_{hr}|. \quad (2)$$

Here, we assume a container port system, P , which is classified in k port ranges (subgroups). t_{ij} is the container throughput of the i -th port in the j -th port range.

By using the above formulation, the Gini ratio *within* the j -th port range is

$$G_{jj} = \frac{1}{2n_j^2 \mu_j} \sum_{i=1}^{n_j} \sum_{r=1}^{n_j} |t_{ji} - t_{jr}|. \quad (3)$$

Moreover, the extended Gini ratio *between* the j -th and the h -th port ranges is

$$G_{jh} = \frac{1}{n_j n_h (\mu_j + \mu_h)} \sum_{i=1}^{n_j} \sum_{r=1}^{n_h} |t_{ji} - t_{hr}|. \quad (4)$$

The Gini ratio G of the number of ports n portioned into k port ranges of size $n_j, j = 1, 2, \dots, k$, can be expressed as the average of the Gini ratio within each subgroup G_{jj} , and the extended Gini ratio *between* subgroups G_{jh} , weighted by the product of the j -th port range share (relative port size) p_j times the h -th port range handling share s_h , such that

$$G = \sum_{j=1}^k \sum_{h=1}^k G_{jh} p_j s_h. \quad (5)$$

The decomposition analysis by Dagum (1997) helps this paper prove that the “simple” and total Gini ratio G of the number of ports n partitioned in k port ranges of size $n_j, j = 1, 2, \dots, k$ is

$$G = G_w + G_b + G_t \quad (6)$$

with

$$G_{gb} = G_b + G_t. \quad (7)$$

In other words, a simple Gini ratio G is additively decomposed into the following three components: **(i)** the Gini inequality *within* subgroups (G_w), **(ii)** the Gini inequality *between* subgroups net of trans-variation (G_b), and **(iii)** the intensity of trans-variation between subgroups (the so-called *overlapping effects* between port groups) or G_t . Moreover, Dagum (1997) denoted the last two components in Eq. 6 as the *gross* contribution, G_{gb} , of the extended Gini inequality between port groups to the total Gini ratio in Eq. 7.

Here, each component of the Gini index is expressed by the following three equations.

(i) The inequality *within* subgroups (port ranges):

$$G_w = \sum_{j=1}^k G_{jj} p_j s_j \quad (8)$$

(ii) The inequality *between* subgroups (port ranges):

$$G_b = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} D_{jh} (p_j s_h + p_h s_j) \quad (9)$$

(iii) The trans-variation or the *overlapping effects* between subgroups (port ranges)

$$G_t = \sum_{j=2}^k \sum_{h=1}^{j-1} G_{jh} (1 - D_{jh}) (p_j s_h + p_h s_j) \quad (10)$$

where $(1 - D_{jh})$ is the measure of the intensity of trans-variation.⁹ In other words, D_{jh} is a

⁹ See Section 3 in Dagum (1997) for details. Dagum (1997) also illustrated this decomposition approach with

normalized index (Relative Economic Affluence or REA¹⁰) that indicates the “distance” between the structures of two port ranges, the j -th port range and h -th port range. For example, $D = 1$ implies that port structure discrimination between the two port ranges is perfect.

Moreover, G_b is the inequality between port ranges, which focuses on the “differential” parts of the distributions of port handling volumes for the two port ranges. In contrast, G_t is the inequality between port ranges, which focuses on the “similar” parts, i.e., overlapping of the distributions of port handling volumes of the two port ranges. In other words, the following interpretation becomes possible. Consider an empirical analysis by time series data; even if G_{gb} does NOT change over time, should G_t increase and G_b decrease, the cargo flow structures of the two port ranges becomes “similar.” On the other hand, should G_t decrease and G_b increase, these structures would become “dissimilar.”

2.3 Numerical example of decomposition analysis of the Gini index

This section provides a simple numerical example (**Table 1**) in order to help the reader appreciate the decomposition analysis conducted by Dagum (1997). This example presents cases 1, 2, and 3. Each case has two port groups (Cluster 1 (C1) and Cluster 2 (C2)), and each group has 5 ports. In Case 1, the total handling volumes of each group are the same (300), and the cargo distributions within the group are different. In Case 2, the total handling volumes of C1 are half that of its counterpart in Case 1. Finally, in Case 3, the cargo distributions within a group are the same, while the total handling volumes of each group are different; the total handling volume of C1 is half that of C2.

Table 1: Data for the numerical example of decomposition analysis

Case 1				Case 2				Case 3			
Cluster 1 (C1)		Cluster 2 (C2)		Cluster 1 (C1)		Cluster 2 (C2)		Cluster 1 (C1)		Cluster 2 (C2)	
Port	Ton	Port	Ton	Port	Ton	Port	Ton	Port	Ton	Port	Ton
A	60	F	20	A	30	F	20	A	10	F	20
B	60	G	40	B	30	G	40	B	20	G	40
C	60	H	60	C	30	H	60	C	30	H	60
D	60	I	80	D	30	I	80	D	40	I	80
E	60	J	100	E	30	J	100	E	50	J	100
Total	300	Total	300	Total	150	Total	300	Total	150	Total	300

(Source: Devised by the author.)

The estimated results of each component of the decomposition analysis of the Gini index are shown in **Table 2**. Although the handling level of C1s in each case is the sole difference between Case 1 and Case 2, it is worth noting that the value of each component is quite different. For example, the values of G_b between C1 vs. C2 of Case 1 and Case 2 are 0.000 and 0.167 respectively, because the value of REA in Case 1 is 0.000. On the other hand, the values of G_t between C1 vs. C2 in Case 1 are not zero (0.100). If we focus solely on the *inequality between port ranges*, or G_b , we can evaluate the equality between C1 and C2 in Case 1. Moreover, because Case 2 and Case 3 differ in terms of the cargo flow distribution for C1, the value of each component, including that of REA, is also different. However, the values of G_b between C1 vs. C2 are the same for Case 2 and Case 3. Due to these differences, the trend in changes between G_b and G_t allow a detailed analysis

data pertaining to family income distribution in the US in 1990.

¹⁰ See, Dagum (1980) and Dagum (1960) in details.

of port cargo flow.¹¹ This simple example shows that the value of REA will change based on not only total handling volumes, but also on the cargo flow distribution for each port group. Therefore, the discussion of *overlapping effect*, or G_t , is also quite important in the decomposition analysis.

Table 2: Results of the numerical example of decomposition analysis

	Case 1	Case 2	Case 3
$\vec{G} (= G_w + G_{gb})$	0.167	0.278	0.331
G_w	0.067	0.089	0.133
(G_w in C1)	(0.000)	(0.000)	(0.044)
(G_w in C2)	(0.067)	(0.089)	(0.089)
G_{gb} between C1 vs. C2	0.100	0.189	0.198
(G_b between C1 vs. C2)	(0.000)	(0.167)	(0.167)
(G_t between C1 vs. C2)	(0.100)	(0.022)	(0.031)
REA	0.000	0.882	0.843

(Source: Devised by the author.)

3. RESEARCH MOTIVATION FOR ASIAN PORT CARGO FLOW STRUCTURE

3.1 Port cargo flow structure and container handling concentration in Asia

Containerization started sometime in the 1970s. The expansion in container handling volumes was a result of the export-led economic development in Japan and the newly industrializing economies (NIEs) in the Asian region. Volumes also grew owing to the economic development in the Association of Southeast Asian Nations (ASEAN) countries and China against a background of foreign direct investment (FDI) by Japanese enterprises. This prompted them to develop their own ports, and thus become hub ports in Asia. In the West (Europe and North America), ports compete with each other to assume the gateway function for origin/destination of container cargo in each region. However, geographically, Asia is composed of islands and peninsulas, and a number of big cities are located peripherally along the coasts, which results in big cities serving as port hinterlands for major ports.¹² Therefore, we can safely say that a regional economy-regional port pair will compete with another economy-port pair, which in turn may be considered as a different type of inter-port competition.

Consider the strong competition between the transshipment cargos of the ports of Singapore and Hong Kong, which account for more than half their total container cargo. In contrast, Chinese ports have developed rapidly due to the rise in the number of production centers on account of port investments (after all, China is called the “factory of the world”). For example, the container handling cargo of the port of Shenzhen in China has expanded rapidly in the last fifteen years due to the expansion of Hong Kong’s enterprises in the South China region. Moreover, the port of Shanghai, which became the world’s biggest container port in 2010, collects cargo from Shanghai, the provinces of Jiangsu and Zhejiang, and the middle-upper stream area on the Chang River, where economic

¹¹ Therefore, Notteboom (2006b) cannot discuss the structural changes in port cargo flow distribution. As the values of G_b between C1 vs. C2 are the same (0.167) in Case 2 and Case 3, Notteboom’s (2006b) interpretation would indicate that there is NO change between C1 vs. C2 in these two cases. Moreover, because G_b between C1 vs. C2 in Case 1 is zero, Notteboom (2006b) would interpret C1 and C2 as being in perfect equality. However, the values of G_{gb} are different for all three cases.

¹² See Doi (ed.) (2003) for details.

development has boomed in recent years.

As compared with the container movements in North America and Europe, the Asian port systems have experienced drastic changes over the last 30 years. **Table 3** shows the trend of annual increasing rate of container throughput by country and region. The increasing rate of container throughput in Japan had reached its zenith during the period between 1975 and 1980, and began decreasing after this period. Similarly, the increasing rates in Asian NIEs and ASEAN countries have slowed down after the 1990s. In contrast, the increasing rate of container throughput in China (not including Hong Kong) was over 30% after the 1990s. However, in the second half of the 2000s, because of the economic slowdown in Western countries, the annual rate of container throughput recorded a net decrease. Moreover, many countries and regions, including China, experienced negative growth (almost 10.0% worldwide) owing to the fall of the Lehman Brothers in 2008.

However, among the Asian NIEs and ASEAN countries, South Korea and Malaysia have maintained comparatively high increasing rates in container throughput. For example, investments in the Busan New Container Terminal enhanced container hub function in Northeast Asia by diverting container cargo from the port of Kobe in the first half of the 1990s. Also, the new container terminal of Tanjung Pelepas (Malaysia) positioned itself as a choice alternative to the port of Singapore.

Table 3: The increasing rates on container handling volumes by country and region
(unit: %)

Country and Region/Year	1975-80	1980-85	1985-90	1990-95	1995-2000	2000-05	2005-06	2006-07	2007-08	2008-09
World	16.4	8.5	8.9	9.9	11.0	11.1	11.8	10.5	5.2	-10.0
Japan	12.8	10.1	7.6	5.9	4.4	5.4	8.3	3.0	-0.4	-14.0
USA	10.2	6.1	5.7	4.6	7.4	7.1	6.2	1.8	-5.6	-12.8
UK	10.2	5.0	7.0	3.2	6.4	5.1	2.2	4.0	-18.1	-16.7
Netherland	12.5	6.1	6.3	5.3	5.6	8.1	6.1	12.4	0.6	-11.4
Asia NIEs	22.8	12.1	16.9	15.2	8.3	6.1	4.4	7.9	2.5	-12.7
Taiwan	28.4	13.3	12.1	7.6	6.0	4.0	2.4	4.7	-5.5	-12.5
South Korea	28.9	13.1	13.5	13.9	14.9	10.8	2.7	12.2	2.0	-9.5
Hong Kong	12.8	9.3	17.4	19.7	7.6	4.5	4.1	2.0	2.1	-14.1
Singapore	32.9	13.1	25.2	17.8	7.6	6.3	6.9	12.7	7.1	-13.5
ASEAN	38.3	13.3	21.0	13.2	12.9	12.5	2.0	17.4	8.8	-6.4
Indonesia		21.3	32.2	17.3	13.1	7.7	-21.6	46.3	17.3	-13.6
Malaysia	21.1	17.8	17.9	18.5	17.5	21.3	10.0	10.5	8.1	-1.2
Philippines	35.7	7.9	17.1	6.1	9.9	3.7	1.2	18.0	-0.6	-4.6
Thailand	69.4	16.1	21.9	12.7	10.1	10.0	9.0	11.2	8.5	-12.3
China		12.5	18.2	22.3	18.9	17.0	20.6	18.0	9.1	-8.9
(No, Hong Kong)		52.6	21.9	31.2	37.3	24.1	26.1	22.4	10.7	-7.8
South Asia										
India		22.0	11.8	14.6	12.5	15.2	23.3	20.1	4.0	2.8
Pakistan		32.3	9.8	7.1	7.1	16.8	5.4	8.9	0.1	6.2
Sri Lanka		38.8	22.0	12.0	11.0	7.2	25.4	9.8	9.0	-1.1
West Asia										
Israel	15.4	2.3	8.5	14.0	9.0	4.6	3.6	10.4	6.8	-2.7
Saudi Arabia		2.9	-3.6	6.7	6.6	20.0	3.5	8.9	10.5	-4.8
UAE		15.9	17.0	17.6	7.6	14.3	11.3	0.4	34.0	-2.2

(Source: *Containerisation International Yearbook* (every year).)

Table 4 indicates the changes in the rankings of container throughputs in the world from 1975 to 2010, 35 years, and mainly Asian top 10 container ports (*see, the end of this paper*). The port of Kobe, which had been the largest container handling in Asia until 1981, became the fourth largest port in Asia after the ports of Singapore, Hong Kong, and Kaohsiung in 1990. In particular, after the Great Hanshin Earthquake in 1995, the ranking of the port of Kobe began dropping gradually. In the most recent 2010, the position of the port of Kobe was 49th in the world. Moreover, the rankings on the other Japanese ports have also fallen. Finally, after 2006, the rankings of all the Japanese ports fell below the 20th position.

On the contrary, the ports of Hong Kong, Singapore, and Busan, which ranked among the top 10 ports in 1975, have maintained their positions. Even now, these ports are

reaching the top 10 in 2010. In 2010, six Chinese ports, including the port of Hong Kong, such as the ports of Shanghai and Shenzhen, ranked among the top 10 ports in the world.¹³ This table indicates that Japanese ports were replaced by Chinese ports in terms of container traffic rankings during the last 35 years. Moreover, like the Japanese ports, the ports of Kaohsiung and Keelung in Taiwan also dropped out of the top 10 slots. The latest statistics show that the port of Shanghai is poised to occupy the top-most position in 2010 by overtaking the ports of Singapore and Hong Kong, which have been occupying the top ranks since the mid-1980s. The Asian region experienced fluctuations in container throughput rankings.

Adding to the shift of the relative positions for container handling volumes from Japan to China, the transshipment cargo volumes at other major Asian ports excluding the Japanese ports began to expand. For example, around 1990, the transshipment rates, i.e., the proportion of transshipment cargo to the total throughput at port, of the ports of Yokohama and Kobe were approximately 15% and 25%, respectively. In 2006, the transshipment rate at the port of Tokyo was 8.8%, while the average transshipment rate of Japanese ports was less than 4%. On the other hand, although the transshipment rate at the port of Busan in South Korea was approximately 15% in 1990, it increased to 43.3% in 2006. The transshipment rate at the port of Singapore, which traditionally boasts of high transshipment cargo volumes, was 81.5%. Moreover, the rate at the port of Tanjung Pelepas, one of the emerging container ports, was remarkably high (95.8% in 2006).¹⁴ Alternatively, the foreign transshipment rates, i.e., the proportion of container cargo from/to a third country to the total international container cargo at port, are increasing in Japan. For example, this share to/from Asian countries from/to Japanese ports was 15.2% in 2008 (3.3% in 1993). Similarly, this share to/from Europe and North America was 24.7% (1.4% in 1993) and 13.9% (0.4% in 1993), respectively, in 2008. This data indicates that Japanese ports will be able to take the feeder container services of Asian hub container ports, like the port of Busan, to Japanese container users since shipping companies skip Japanese ports on main routes.

For example, transport to foreign consuming markets from Japan via a third country takes a longer time compared to direct shipping from Japan to the country of import. Finally, domestic supply chains become fragile and global competitiveness also falls. On the other hand, foreign port authorities, like that of Busan's Newport International Terminal in South Korea, follow a logistics strategy aimed at transforming it into a hub port for Northeast Asia. The port serves not only as a transshipment center, but also as a production center due to the creation of a free trading zone (FTZ) around the container terminal, decrease in land use charges, and improvements in tax benefits.

One of the reasons for the increase of foreign transshipment cargo on main routes to/from Western countries from/to Japan is port passing. For example, **Figure 2** shows the number of ship calls along main routes to/from North America and Europe on major Japanese and Asian container ports between 1995 and 2009. The number of ship calls to/from Asian main container ports is higher than that for Japanese ports. Notably, ship calls on the ports of Shanghai and Busan have been increasing, especially on the North

¹³ The Chinese Academy of Science and the City University of Hong Kong announced in June 21, 2012, that the port of Tianjin will become the 10th port replacing the port of Rotterdam in the world. Finally, the top 10 ports will become all Asian container ports in 2012, or seven Chinese ports and the ports of Singapore and Busan in South Korea, and Dubai in UAE.

¹⁴ In addition, in 2006, the transshipment rates of the ports of Hong Kong and Kaohsiung in Taiwan were 30.0% and 52.5%, respectively. On the other hand, the transshipment rates of the ports of Shanghai and Shenzhen in China were 3.6% and 10.1%, respectively during the same period. Port functions pertaining to regional economy (port hinterlands) differ for each region.

American route. However, ship calls on Japanese ports have been decreasing.

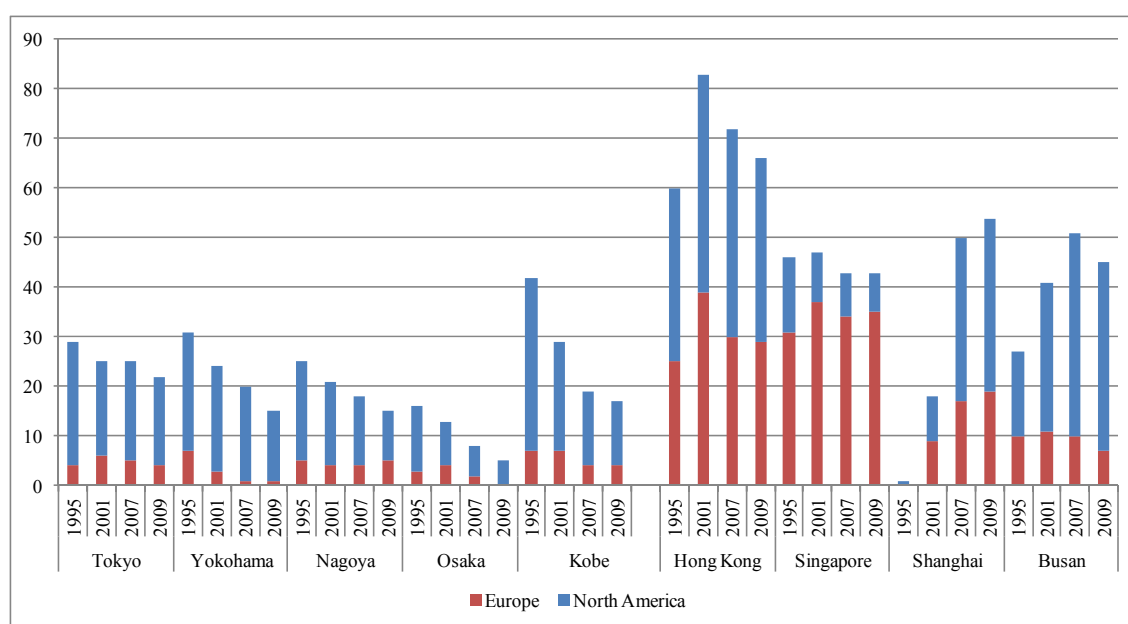


Figure 2: Changes in the number of ship calls on major Asian container ports

(Source: MLIT.)

Moreover, the role of container terminal operators is also important. For example, Maersk Sealand, whose parent company is the Denmark Shipping Company, developed their terminal strategy considering transshipment cargo and their shipping routes. Similar strategies were planned by Hong Kong-affiliated Hutchison Port Handling (HPH), whose mother body is the port terminal operating company; the Port of Singapore Authority (PSA), which had been the statutory board under the Ministry of Transport of the Singapore Government; and DP world, formerly known as Dubai Port International (DPI). In fact, the world's top four terminal operators are said to be nurturing oligopolies. This is especially true in Asia, where these four terminal operators have recognized the potential for high future economic growth for the ports of Laem Chabang in Thailand and Ho Chi Minh in Vietnam, and have consolidated their hold over them. Therefore, the presence of mega terminal operators is also essential for port throughput expansion.

3.2 Implications of early studies and research motivation

As discussed in Section 2, many empirical research papers have applied the Gini index towards transport geography, especially port systems. Before proceeding to the empirical analysis of container handling inequality in Asia, we shall review the analytical implications of the inequality indexes, like the Gini index and Herfindahl-Hirschman Index (HHI) etc., applied in previous studies, and describe the contributions of these empirical analyses. The following four papers have focused empirically on Asian container port systems (see **Table 5**): De and Park (2004), Notteboom (2006b), Le and Ieda (2010), and Itoh (2011).

De and Park (2004) estimated various inequality coefficients including the Gini index, for the US, Europe, and other regions, with a focus on Asia. By taking multiple country/regional classifications, the large regional classification result showed the trend of expanding inequality; however, the classification for smaller regions showed the trend of shrinking inequality for East/Southeast Asia. The paper concluded that container cargo

movements within Asia were well balanced because of port investments made in each Asian country/region. Further, it noted that the center of gravity of container cargo movements was shifting from Japan, Taiwan, and Hong Kong, to China and Singapore.

Table 5: Analytical framework of previous studies on Asian container port systems

	De and Park (2004)	Notteboom (2006b)	Le and Ieda (2010)	Itoh (2011)
Area	East/Southeast/South Asia, including the US, Europe, and other regions	East Asia, 27 container ports	Japan (34 container ports in 2005), China (26*, similarly), South Korea (8, similarly)	Asia, 40 container ports
Data	1985-2000, every 5 years, national/regional level	1978-2004, every year, port level	1980-2005, every 5 years, port level	1980-2005, every 5 years, port level
Methodology	Gini index, HHI, Kendall's coefficient of variance, Spearman's rank correlation, coefficient of variance	Gini index, decomposition analysis (focusing on G_b)	Geo-economic Concentration Index (developed based on HHI), with consideration of geographical distance	Gini index, decomposition analysis (focusing on G_{gb})

(Source: Devised by the author.)

* Note: Excluding the port of Hong Kong and Taiwanese ports.

Notteboom (2006b) classified major East Asian container ports into seven port ranges: Japan, South Korea, Taiwan, Bohai Bay, Yangtze Delta, Trans-Taiwan, and Pearl River Delta in China.¹⁵ This paper confirmed that the trend of shrinking inequality in all East Asian ports and within each port range. However, the inequalities for some pairs between port ranges showed a diverging/expanding trend. Especially, the inequality (G_b) between Japan and the Pearl River Delta was noticeably high, with this inequality index expanding to the level of a quarter of the sum of the total inequality between port ranges. However, Notteboom (2006b) discussed inequality changes based on the results of G_b alone, or in other words, *the between-range effect* in the *total inequality between port ranges* (G_{gb}).

Le and Ieda (2010) examined concentration dynamics in Japan, China, and South Korea by using the Geo-Economic Concentration Index (GECI), which is a comparable concentration index in different countries. Their results showed that container port systems in different countries may not follow the same concentration pattern for the period under consideration. For example, Japan maintained the same level of concentration with minor fluctuations. However, the Chinese port system evolved from being deconcentrated before 1990 to one that was very much concentrated after 1990. Moreover, barring the period between 1995 and 2000, South Korea showed a concentration tendency. Thus, country government policies and port governance structure of each country strongly influence concentration dynamics of container port systems.

Like Notteboom (2006b), Itoh (2011) also employed decomposition analysis. However, the study area was wider as it considered not just East Asia, but also Southeast, South, and West Asia. Itoh (2011) classified major Asian container ports into five port ranges: Japan, East Asia (including South Korea, China and Taiwan), Southeast Asia, South Asia, and West Asia. As in previous research, this paper also confirmed that traffic inequalities in the ranges of Japanese and East Asian container ports are clearly decreasing, even though there was little change in the traffic concentration level, or the simple Gini coefficient, of the total port system during the data period. Moreover, the share of the *between-range effect*, which reflects the structural difference between port ranges for the total port system, increased from 47% to 67%. In contrast, the share of the *overlapping*

¹⁵ Notteboom (2006a) discussed inequality/concentration in container port systems in Europe and North America by conducting a decomposition analysis of the Gini index.

effect, which reflects the structural similarities between port ranges for the total port system, decreased from 35% to 18%. Although container hub function enhancements have been made in major ports in China, Korea, and Southeast Asia, an increasing trend of the *between-range effect* is noticeable; in other words, the degree of relative homogeneity between the ranges of Asian ports is decreasing. Thus, this study concluded that the trends in the container handling concentration in Asian port systems are based on the economic growth of each region.

The research framework for this study was prepared after considering the implications from previous research. This paper expands the analytical framework by considering the number of ports and annual handling volumes after 1980. Thus, the number of container ports included in this analysis is 229.¹⁶ Moreover, this estimation also considers the effect of world container handling shrinking after Lehman's fall and the effects on port cargo flow structure in Asia by expanding the data period up to 2009. Since 2000, the market share of Chinese container handling volumes has expanded prominently. Indeed, the Chinese, including Hong Kong, enjoyed almost a quarter of the world market (27.7%) in 2009. Considering this rapid expansion in China's market share, this paper evaluates not only the inequality changes in container throughputs, but also the changes in the port cargo flow structure or geographical distribution in Asia, and the provides suggestions for future port policy.

The advantage of this empirical analysis is that we can discuss the structural changes in port cargo flow distribution in Asia by comparing the differences in index changes between G_b and G_t . While some papers have evaluated container handling concentrations in Asia, they have been unable to expand on the structural changes in port cargo flow distribution due to the lack of methodology. For example, even though Notteboom (2006b) employed the same methodology used in the current paper, structural changes in port cargo flow distribution remained unaddressed as his paper focused on one component only, namely, G_b of G_{gb} .¹⁷

4. ASIAN CONTAINER PORT SYSTEMS

4.1 Estimation method

This section presents the analytical framework employed in this empirical study. We evaluate the inequality in Asian container port systems based on regional and port-related developments in this area. Owing to data constraints, this paper covered 229 container ports between 1980 and 2009. These ports were then classified into fifteen port ranges according to their geographic locations, using the research frameworks of Notteboom (2006b) and Itoh (2011) as guides. **Table 6** indicates the classification of Asian container ports for this empirical study. Notably, we classified Chinese ports into four port ranges based on the results of Notteboom (2006b). Moreover, we classified Japanese ports into

¹⁶ For example, the minimum coverage rate of this data set was 96.1% in 1989, while the average coverage rate between 1980 and 2009 was 99.7% for total Asian container throughputs (based on *Containerisation International Yearbook*, every year). Le and Ieda (2010) also discussed the importance of data coverage rate on index analysis.

¹⁷ As discussed in the numerical example of decomposition analysis in Section 2.3, Notteboom's (2006b) discussion is insufficient as G_b is only one of the two components, G_t and G_b , of the *total inequality index*, G_{gb} . The Appendix to this paper discusses the shortcoming of Notteboom (2006b) by conducting a comparison between the evaluated results of the empirical analyses.

four port ranges¹⁸ (Eastern Japan, Chubu, Hokuriku and Kansai, and Western Japan), so as to verify which Japanese port ranges had experienced changes in port cargo flow structure compared to their Southeast Asian counterparts (following research implications from Itoh (2011)). We classified ports in Southeast Asia into three port ranges; the *stair area* on the Malay Peninsula in Malaysia and Singapore, whose maritime cargo is mainly transshipment cargo; the *peninsula area* on the Indochina Peninsula in Thailand and Vietnam; and the *island chain area* for Indonesia and the Philippines. By applying these elaborate/large port range classifications, we found detailed changes in port cargo flow structure in Asia, and also provided further insight into the findings from Itoh (2011).

Table 6: Port range classification for Asian container port systems

Port Ranges (Group)		Port Name	Port Ranges (Group)		Port Name
Japan	G1	Eastern Japan	Southeast Asia	G11	Island chain area
		Hokkaido + Tohoku			Tanjung Priok / Jakarta
		Tokyo			Tanjung Perak
		Yokohama			Other Indonesia
	G2	Chubu		Manila	
		Shimizu		Other Philippines	
		Nagoya		Port Kelang	
	G3	Hokuriku and Kansai		Tanjung Pelepas	
		Osaka		Penang	
	G4	Western Japan		Kobe	Other Malaysia
Hokuriku + Other Kansai			Singapore		
Kitakyushu		Other Singapore			
Hakata		Laem Chabang			
South Korea	G5	South Korea	South Asia	G13	Peninsula area
		Gwangyang			Bangkok
		Incheon			Other Thailand
		Ulsan			Ho Chi Minh
	China	G6		Bohai Bay	Other Vietnam
				Dalian	Other Southeast Asia
				Tianjin	Chennai / Madras
		G7		Yangtze Delta	Kolkata / Calcutta / Haldia
				Other Yangtze Delta	Mumbai / Bombay
				Fuzhou	Other India
G8		Trans-Taiwan	Xiamen	Karachi	
			Other Trans-Taiwan	Other Pakistan	
		Shenzhen	Colombo		
	Guangzhou	Other South Asia			
G9	Pearl River Delta	Zhongsan	Mina Sulman		
		Jiuzhou	Limassol		
	Hong Kong	Other Cyprus			
	Other Pearl River Delta	Haifa			
	Keelung	Ashdod			
Taiwan	G10	Taiwan	Other Israel		
		Taichung	Aqaba		
		Kaohsiung	Beirut		
		Other Taiwan	Salalah		
West Asia	G15	West Asia	Port Sultan Qaboos / Mina Qaboos		
			Jeddah		
			Dammam		
			Other Saudi Arabia		
			Mersin		
			Izmir		
			Haydarpasa / Istanbul		
			Other Turkey		
			Dubai / Jebel Ali		
			Khor Fakkan / Sharjah Combined		
			Mina Zayed / Abu Dhabi		
			Other UAE		
			Aden		
			Other Yemen		
			Other West Asia		

(Source: Devised by the author.)

The container traffic data (in total TEUs) for each of the 229 Asian container ports for the period between 1980 and 2009 are obtained from the *Containerisation International Yearbook*. Owing to the data constraints, this study employs the total container throughput at each port as a variable for inequality estimation.

This database mentions “other(s)” as a port name for each port range or each country/region, because many container ports were non-existent in 1980, and the *Containerisation International Yearbook* (every year) employed in this research does not

¹⁸ For the classification of Japanese ports, this paper consulted the implication of Itoh *et al.* (2003) in Doi *et al.* (2003), and Itoh (2010). The latter discussed the inequality/concentration of Japanese container ports handling volumes by conducting a decomposition analysis of the Gini index.

cover handling cargo data for all 229 container ports from year to year. Furthermore, the number of ports in the port range affects the results of the decomposition analysis. As a result, estimates have been provided where required during the period under consideration. In this way, it is possible to discuss detailed changes in the port cargo flow structure. It is possible, for example, to analyze not only the inequalities for all fifteen Asian ports ranges and for each port range (G_w), but also inequalities between port ranges (G_{gb}) by evaluating the various components of the Gini indexes based on the decomposition analysis by Dugum (1997).

The classification of port ranges proposed here will enable the study of inter-regional changes in port cargo flow structure in the region during the last 30 years. As discussed in the previous section, until the first half of the 1990s, for example, the port of Kobe had managed to develop its transshipment cargo handling from/to East Asian countries because of inadequate port development. However, after the second half of the 1990s, the Japanese container port traffic ranking started decreasing owing to the new container terminal developments in China and South Korea and the Great Hanshin Earthquake in January, 1995. On the other hand, the traffic ranking of Chinese container ports has risen due to rapid economic growth. However, the pace of economic growth differs across China's domestic regions. Moreover, although the port of Singapore has traditionally served as a transshipment hub, other Southeast Asian countries like Vietnam and Thailand started expanding port handling activities due to their new supply center status for China. Therefore, Asian ports have different histories with respect to the growth of their influence. This empirical analysis estimates various Gini coefficients by separating these ports geographically, and discusses the growth of port influence.

4.2 Estimation results

This section presents the various types of Gini coefficients that were calculated and discusses the changes in port cargo flow structures of Asian ports over the last 30 years. The section ends with a summary of the main findings of the empirical analysis.

(1) Inequality changes in Asian ports and within port ranges

Figure 3 summarizes the components of the Gini coefficient for Asian container port systems over time. The total Gini indexes (G) of all Asian port systems show a shrinking trend for inequality; from 0.821 in 1980 to 0.669 in 2009. Considering the proportion of each component to G (although the extent of changes is very small), the share of component G_w fell from 7.7% in 1980 to 7.0% in 2009, while that of component G_t similarly decreased from 29.3% to 27.7% during the same period. On the other hand, the share of component G_b rose from 63.0% to 65.3% during this time.

That is, the share of inequality within port ranges, i.e., *within-range effect Gini coefficients* (G_w) and the inequality between a pair of two port ranges, i.e., *the overlapping effect between port ranges* (G_t), which reflects structural similarities between port ranges, decreased. Moreover, the share of inequality of *the between-range effect Gini coefficients* (G_b), which reflects the structural difference between port ranges, shows a relative increase. Against a background of port investment progress and economic growth in Asia, we can confirm the balanced port function's progress and the growth of port influence for comparatively small regions/ports. We will then discuss the changes in the port cargo flow structure by focusing on the changes of each component (or proportion) of each pair (or a

set of two port ranges) for the Gini index over time.

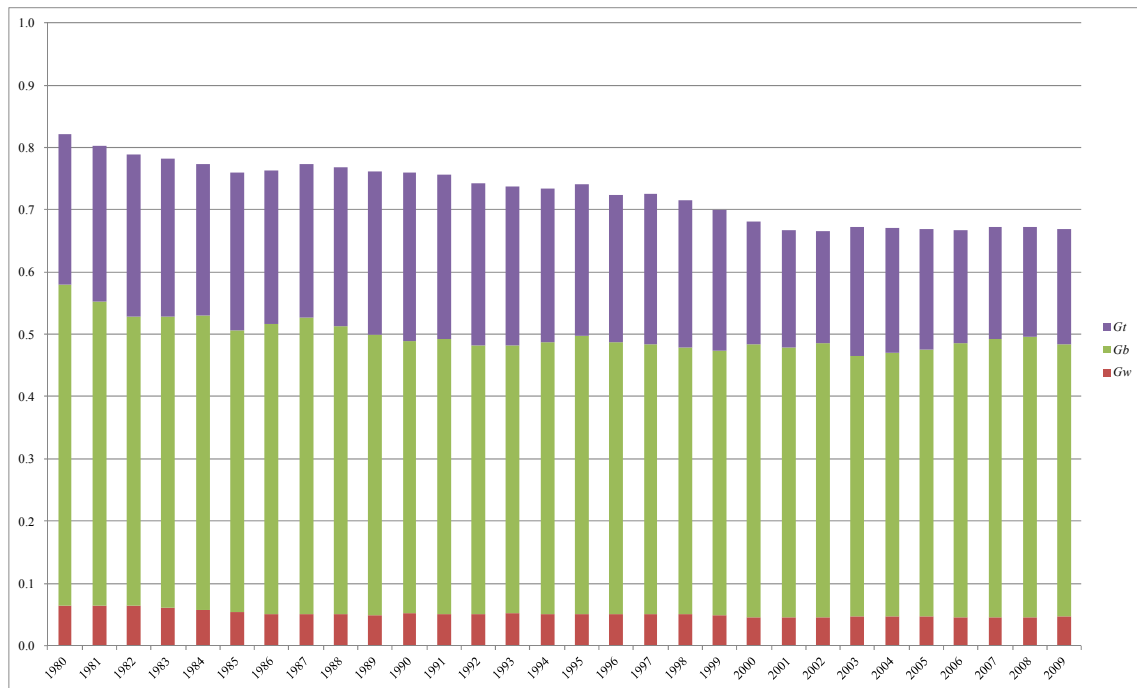


Figure 3: Decomposing the Gini indexes for Asian ports

(Source: Devised by the author.)

G_w shows a shrinking trend (see **Figure 4**); this is particularly discernible for West Asia (G15). The inequalities in Pearl River Delta (G9) with the port of Hong Kong, and the *stair area* of Southeast Asia (G12) with the port of Singapore (both ports are highly ranked in terms of container handling), have decreased since 1995 and 1998, respectively. Moreover, the inequalities in Western Japan (G1), Hokuriku and Kansai in Japan (G3), and Taiwan (G10) also decreased. Furthermore, the inequalities in South Korea (G5) and the *island chain area* of Southeast Asia (G11) have also reduced slightly. These changes in inequality are not unexpected, given the increase in handling volumes owing to regional port investments in Japan, and policy-concentrated investments due to limited container ports in South Korea and Taiwan.

On the other hand, the trend of expanding inequality in Bohai Bay (G6) and the Yangtze Delta (G7) within the group of Chinese port ranges, differs from the above results. Though G_w basically showed the decreasing trend, the inequalities in G6 and G7 (which include the rapidly-developing ports of Qingdao and Shanghai in terms of container terminal investments since the second half of 1990s) will be affected by the relative scale changes of handling volumes.¹⁹ While comparing details, the “simple” Gini indexes (G_{ij}) of these two port ranges showed the trend of shrinking inequality (see **Table A5** in appendix). Moreover, though the inequality level was low compared to the above-mentioned port ranges, the inequality within port ranges in South Asia (G14) expanded all the same.

Figure 5 summarizes G_{gb} in countries/regions (NOT pairs of port ranges). The total inequality between Japan vs. Southeast Asia, followed by China vs. Taiwan, and Japan vs. Taiwan (and Japan vs. South Korea, and South Korea vs. Taiwan) decreased during the study period. However, the trend of expanding inequality for China vs. Southeast Asia was

¹⁹ In order to grasp the situation in mathematical terms, see the results of G_w for each cluster in Case 3 of the numerical example discussed in Section 2.3.

different from the above results, and in comparison, this inequality level was also high. Moreover, the proportion of this inequality to G changed from 6.3% in 1980 to 13.2% in 2009. Similarly, its proportion to G_{gb} also changed from 6.8% to 14.2% during this period. Furthermore, total inequality between port ranges for Japan vs. China decreased till 1998, after which it increased. Though the inequality in all Asian container port systems shrank, some pair of port ranges (groups) indicated quite a different situation.

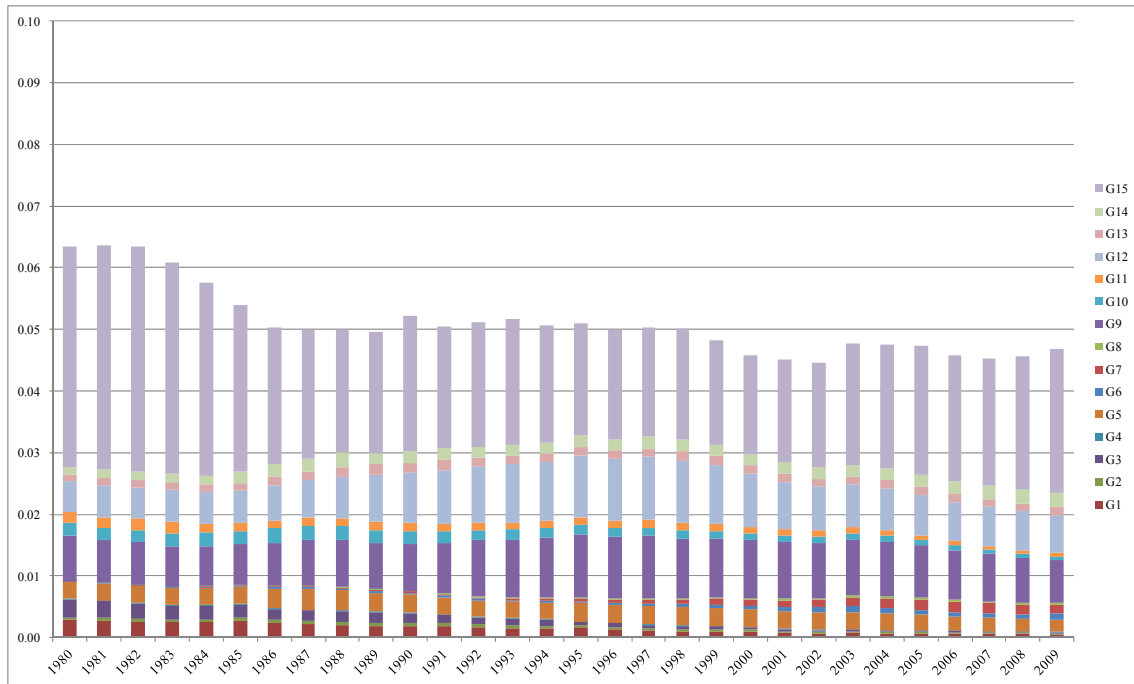


Figure 4: Inequality within Asian port ranges (G_w)

(Source: Devised by the author.)

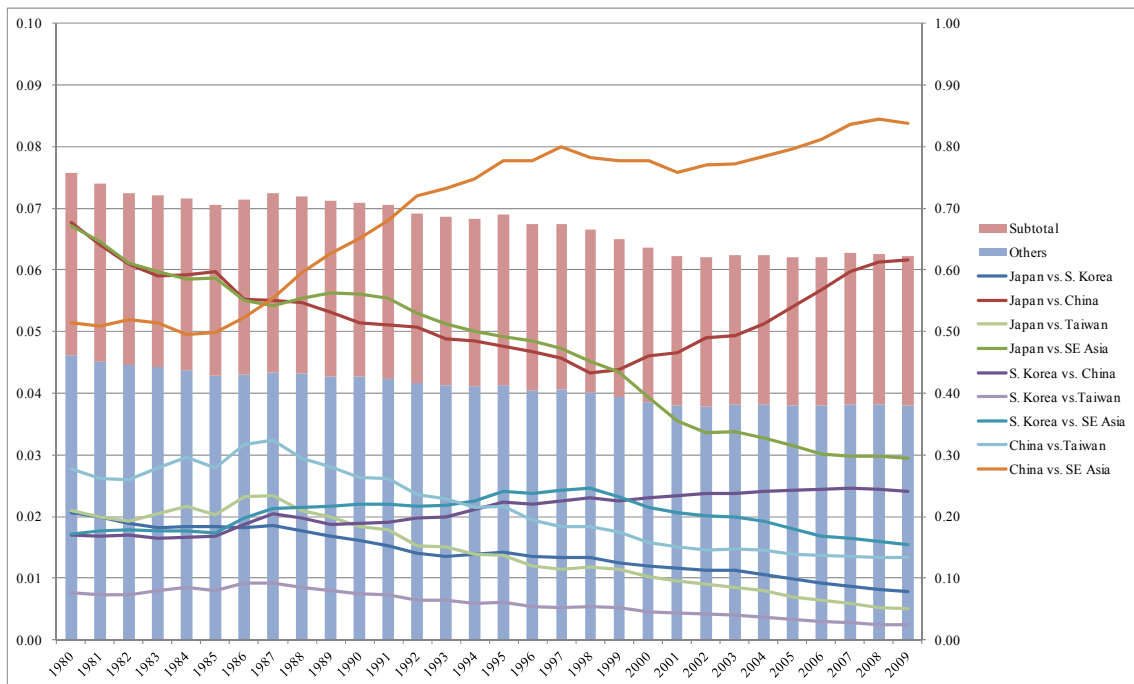


Figure 5: Total inequality between Asian port ranges (G_{gb})

(Source: Devised by the author.)

In the following sections, we shall discuss distinctive inequality changes in detail. However, due to space constraints, we summarize the main implications for the following four pairs of port ranges, separately divided into G_b and G_t , without detailed numerical results. In addition, this paper's appendix gives the relative ratios (RRs), which show the changes between two time points, 1987 and 2002, by applying the moving average (MA) method for each component of the Gini index and relative economic affluence (REA). This appendix will help the reader appreciate the detailed discussion that follows. However, the reader must note that the RRs show the relative changes, and NOT the level of inequality and/or similarity.

(2) Changes in inequality between port ranges

(i) Japan vs. Southeast Asia: the trend of shrinking inequality

Overall, these indexes indicate the trend of shrinking inequality; the total inequalities (G_{gb}) for pairs of port ranges between Eastern Japan (G1), Hokuriku and Kansai (G3) vs. the *peninsula area* on Southeast Asia (G13), followed by the *island chain area* on Southeast Asia (G11), decreased. G_t has been the main component of total inequality between Japanese port ranges vs. G13 and G11 since the second half of 1990s. That is, we can understand that this trend of shrinking inequality between Japanese port ranges vs. the region (port ranges) will continue, as the latter receive FDI and develop port infrastructure, thereby increasing their port influence on smaller container ports in Southeast Asia, especially the *peninsula* (G13) and the *island chain* areas (G11). As G_t is the main component, the port cargo flow structures of these areas will become synchronized with those of the Japanese port group.

On the other hand, total inequalities between Japanese port ranges vs. the *stair area* on Southeast Asia (G12) do not indicate distinct shrinking trends; rather, the inequality between G1 vs. G12 increased till 1995. In contrast to the inequality indexes of G11 and G13 (where G_t has been the main component of inequality between Japanese port ranges (for example, G1 and G3 vs. G12)), G_b became the main component of inequality since the early 1990s. The port of Singapore and Malaysian ports in the *stair area* had grabbed a part of the transshipment function on the port of Kobe at the same time as the Japanese bubble economy burst. In this result, the main component shifted from G_t to G_b because of the weakening of Japanese ports and changes in the comparative cargo handling scale.²⁰

(ii) China/Taiwan vs. Southeast Asia: High levels of inequality accompanied by trend of expanding inequality

Though total inequalities between port ranges in the Chinese vs. the Southeast port range groups showed a smoothly expanding trend, the inequality indexes are quite different for each pair of port ranges. For example, inequality levels between the Pearl River Delta (G9) vs. the Southeast Asian port ranges group are high. Moreover, the expanding inequality between the Yangtze Delta (G7) vs. the Southeast Asian port ranges group, and the shrinking inequality between Taiwan (G10) vs. the Southeast Asian port ranges group

²⁰ In **Figure A4**, the RRs of REA between G1 vs. G12, and G3 vs. G12 were 3.157 and 2.361, respectively. This shows that there is little similarity in port cargo flow distribution between G1 vs. G12, and G3 vs. G12.

display a trend different from that seen for other pairs of port ranges. Although the expanding inequality between Bohai Bay (G6) vs. the *peninsula area* on Southeast Asia (G13) has not shown a large change, the estimation results show evidence of growing trade in China's Northwest region and the progress of port investments supporting that trade.

Let us turn to the proportion of G_b and G_t within the total inequality between port ranges. G_t accounted for most of the total inequality between G9 vs. the *stair area* (G12), which contains major hub container ports, and the level of inequality is also high. For example, the share of this inequality coefficient in the total inequality between the Chinese vs. the Southeast port range groups was 22.7% in 1995. This suggests inter-port competition between these port ranges,²¹ which include the ports of Hong Kong and Singapore, with a focus on transshipment cargo. Moreover, G_b was the main component in the total inequality between G7 vs. the Southeast Asian port ranges group. G7 includes the port of Shanghai, whose port influence grew rapidly, and the inequality between this port ranges vs. G13 accounts for the majority of the inequality (with G_b being the main component) between G7 vs. the Southeast Asian port range groups. Therefore, the reason of this inequality change will be the difference in economic growth in the supply center for each port hinterland. In other words, economic growth in the Shanghai area (G7) is higher than that for G13.²²

On the other hand, though the total inequalities between the Southeast Asian port ranges group vs. (partially G8 and) G10 show shrinking inequality, this trend differs from that seen for G6 or G7; the main component in this case is G_b , because cargo handling volumes at Southeast Asian ports caught up with those of southern ports in China and Taiwan. This can be attributed to the shift in the center of gravity of container cargo from the Taiwan peripheral area (G8 and G10) to northern ports in China (G6 and G7).

(iii) Japan vs. China/Taiwan: From shrinking inequality to expanding inequality

Notteboom (2006b) pointed out the trend of expanding inequality (G_b) between Japanese ports vs. the Pearl River Delta (G9). Though inequality levels between G9 vs. Eastern Japan (G1), or Hokuriku and Kansai (G3), are comparatively high, total inequalities (G_{gb}) are decreasing. Notably, the main components of the total inequality between these two port ranges characteristically change from G_t to G_b . For example, as we discussed in (ii), over time, G_t continues to be the main component of the total inequality between G9 vs. G12. This result shows that the port cargo flow structures between G9 vs. G1 and G3, which include the Keihin and Hanshin ports, are becoming dissimilar with each other.²³ Moreover, the total inequalities between Trans-Taiwan (G8) vs. the Japanese port ranges group, especially G1 and G3, show the trend of shrinking inequality, while the main component of total inequality between port ranges (G_b) are the same. This result shows the comparative low standing of cargo handling in these areas, or the downturn of container handling ranking in Japan.

On the other hand, total inequalities between the Chinese port ranges group vs. Chubu (G2) and Western Japan (G4) show a slight trend of expanding inequality, with G_b

²¹ Note that this trend differs from the inequality seen between the Japanese port ranges vs. G12 in (iii).

²² In **Figure A4**, the RRs of REA between G7 vs. G13 was 4.069. This was the highest RR between the Southeast Asian and Chinese port range groups. This result indicates changes in port cargo flow structure owing to rapid economic growth in G7.

²³ In **Figure A2**, the RRs of G_b between G1 vs. G9, and G3 vs. G9 are 4.983 and 2.422, respectively. Moreover, on the **Figure A4**, the RRs of REA between G1 vs. G9 and G3 vs. G9 are similarly 5.472 and 3.074, respectively.

as the main component of the total inequalities between port ranges. Moreover, though the inequality levels are comparatively low, total inequalities between Bohai Bay (G6) and the Yangtze Delta (G7) vs. G2 and D4 display a trend of expanding inequality. In this case too, G_b is the main component of the total inequalities between port ranges.²⁴ This trend has been noticeable since early 2000. Although regional Japanese ports experienced an increase in port handling owing to investments, this result shows the difference between the pace of handling increases between Japan and China (G6 and G7).

Returning to the inequality between G9 vs. the Japanese port ranges group (for which Notteboom (2006b) pointed out the trend of expanding inequality), only G_b within the total inequalities between G9 vs. the Japanese regional port ranges (G2 and G4) displays the trend of expanding inequality. However, G_t , which is based on structural similarities between port ranges, has been apparently decreasing since 1990. In other words, this result shows the trend of shrinking inequality (G_t), proving that the ports in the Pearl River Delta (G9) had caught up with the superiority of Japanese major ports. This also resonates with the trend of expanding inequality (G_b) for all groups of Japanese port ranges.

(iv) Inter-regional differences between China/Taiwan: Shrinking inequality between these two countries

In this section, we shall see that the pace of the growth in port influence between northern and southern Chinese domestic ports (G6 and G7, and G8 and G9, respectively) differs. This result implicitly suggests structural changes in port cargo flow distribution for transshipment cargo on southern ports due to port investments in northern ports (the latter utilized the transshipment function of southern ports until their own port functions expanded). Therefore, we focus on the total inequalities between the Chinese vs. the Taiwanese port range groups (G10), which has shown the trend of shrinking inequality since 1987. This section will also explore structural changes between/within Chinese and Taiwanese ports (including the port of Kaohsiung, whose transshipment rates are traditionally high). We also discuss China's inter-regional inequalities between port ranges.

There are NO apparent inequality changes, but only a slightly decreasing trend, between the Chinese and Taiwanese port ranges. However, the total inequalities between Taiwan (G10) vs. the Pearl River Delta (G9), and Trans-Taiwan (G8), and Yangtze Delta (G7), show trends of shrinking inequality, with G_b being the main component. On the other hand, the total inequalities between G9 vs. Bohai Bay (G6), and G7 in China, show the trend of expanding inequality, where the main component of these inequalities shifted from G_b to G_t .²⁵

Similarly, in the case of Japanese port ranges, this result indicates decreasing inequality due to the growth of port influence of southern Chinese ports (G9), which have captured transshipment cargo from Taiwanese ports. We can also confirm the shift in the center of gravity of cargo movements from southern Chinese ports to their northern counterparts; the *overlapping effects* (G_t) between the southern and northern ports show the trend of expanding inequality, thus suggesting inter-port competition within Chinese ports.

²⁴ In **Figure A1**, the *RRs* of G_{gb} between G2 vs. G7, G4 vs. G6, and G4 vs. G7, for example, are 2.692, 3.322, and 5.297, respectively.

²⁵ In **Figure A3**, the *RRs* of G_t between G6 vs. G9 and G7 vs. G9 are 2.389 and 4.256, respectively.

(3) Implications for changes in Asian port cargo flow structure

Based on this empirical analysis, we can draw the following implications. Japanese ports are characterized by changes to port cargo flow structure on account of downturn in port function compared to other major Asian ports, and the growth of port influence of regional ports in Western Japan. Though the impact of the Great Hanshin Earthquake of January 1995 on cargo handling at the port of Kobe was quite huge, its overall effect on inequality changes in Asian container port systems was very small. Moreover, the inequalities between the South Korean port range (which also exhibit shrinking inequality as do Japanese ports), and other Asian port range groups do NOT indicate apparent changes. This is because although increases in transshipment rates for South Korean ports are noticeable, the inequalities between the South Korean vs. Chinese port range groups are stable.

On the other hand, Chinese ports are characterized by the expanding inequality between northern Chinese ports (i.e., those in the Bohai Bay and the Yangtze Delta areas) vs. other groups of port ranges. Other characteristics between Chinese port ranges (including Taiwan) are the shrinking inequality between Taiwan vs. other Chinese ports, and the expanding inequality between northern and southern Chinese ports. In these cases, G_t accounts for the main component of these inequalities. This result implicitly points to changes in port function, namely, the substitution of transshipment cargo transport to northern ports on account of port investment and inter-port competition in China. In addition, the center of gravity of cargo movements has shifted in Southeast Asia from the *stair area* to the *peninsula area*, which has also exhibited the trend of expanding inequality with the Chinese port range group since 2000.

This empirical analysis implies changes in the centralized port cargo flow structure, where major Asian container ports (for example, the ports of Yokohama and Kobe in Japan, Kaohsiung in Taiwan, Hong Kong in China, and Singapore) compete with each other for transshipment cargo owing to the under-development of ports in China and South Korea. Therefore, port cargo flow structure has been seeing changes over the last 30 years based on economic growth in Chinese coastal regions (especially Northeast China), and the peninsula and island chain areas in Southeast Asia. The simple Gini index of each port range shows the trend of shrinking inequality (see **Table A5** in appendix). Notably, port cargo movements in Asia are affected by the peripheral regional economy, because consuming markets and supply centers located along the coastal regions and major ports correspond directly to their port hinterlands. Though the transshipment rates of major ports in South Korea, the Pearl River Delta, and the stair area in Southeast Asia are quite high, the center of gravity of container movements is nevertheless shifting. Inter-port competition between northern and southern ports of China is another contributing factor. Therefore, Asia is clearly in need of balanced and planned port investments responsive to economic conditions of port hinterlands, network of shipping routes, and expansion of mega terminal operators.

5. CONCLUSION AND CHALLENGES FOR THE FUTURE

In this paper, we provided a detailed study of the concentration/inequality levels of Asian container port systems by conducting a decomposition analysis of the Gini index and drew several implications concerning port infrastructure development. Specifically, this paper discussed inequality changes within and between port groups by classifying fifteen port

groups geographically and by using Asian container port handling volumes for the last 30 years (1980 to 2009). A special contribution of this paper was to discuss the structural changes in Asian port cargo flow distribution by focusing on the differences between various inequalities between port ranges.

The results confirmed the trend of shrinking inequality all in all. Progress in port development in Asia allowed us to confirm similar trends for each port range from a time series estimation. Moreover, our result also revealed the trend of expanding inequality for pairs of port ranges. The *overlapping effects*, G_t , between Chinese ports vs. Southeast Asian ports were especially noticeable. Based on the trends of various inequalities, the following changes were observed: **(a)** the trend of shrinking inequality within and between port ranges due to regional port developments in Japan, **(b)** the trend of slightly shrinking inequality within and between port ranges in South Korea and Taiwan on account of policy-concentrated investments tackling limited container ports, and **(c)** the changes in the center of gravity of container movements and inter-port competition within the Chinese and Southeast Asian port range groups. This estimated result also shows the changes in the center of gravity of container movements from the Pearl River Delta (including the ports of Hong Kong and Shenzhen, which support the rapid economic development in China) to the Yangtze Delta (including the port of Shanghai, which became the world's biggest container port in 2010), and also from the *stair area* (including the port of Singapore, which developed as a transshipment hub, and the port of Tanjung Pelepas, an emerging port) to the *peninsula area* (Vietnam and Thailand) in Southeast Asia, where many plants have relocated due to labor cost advantages for China.

In each case, the inequalities for each port range, as seen through the "simple" Gini index, showed the trend of shrinking inequality. This was attributed to the increase in container handling volumes for all ports in *each* region, rather than increase in container handling volumes solely for specific/major ports in a particular region. The comparative difference in the pace of economic growth in Asia is thought to produce such changes in inequalities. As port cargo movements in Asia are affected by the peripheral regional economy, the relationship between large cities, which have consuming markets and supply centers, and ports is comparatively tight. Therefore, Asia is in need of policy changes triggering port infrastructure investment and development of access roads, to balance the economic condition on port hinterlands (see Ducruet (2006)).

While this study was limited to a simple analysis for traffic inequality index, we recognize that factor analysis is also required to estimate inequality indexes as dependent variables. We hope to pursue this line of study in the future.

APPENDIX: Comparison analysis between two time points (1987 and 2002)

In this empirical analysis, each estimated result of the decomposition analysis for each year has 15 values for G_w , and 105 values for G_{gb} , G_t , G_b , and REA. Therefore, due to space constraints, it is very hard to show numerical results for structural changes in container handling concentration and port cargo flow distribution between each pair of port ranges. This appendix gives some aggregated values of the estimated components of the Gini index and REA to allow easy understanding of these structural changes.

In particular, we calculate RR between two time points for each index based on the stable estimated results by using the MA method. For example, the RR of G_{gb} is calculated as follows.

$$RR = \frac{\frac{1}{n} \sum_{l=1}^n \overline{G}_{gb}^{2002,l}}{\frac{1}{n} \sum_{l=1}^n \overline{G}_{gb}^{1987,l}} \quad (A1)$$

with

$$\overline{G}_{gb}^{i,l} = \frac{\sum_{i=t-(l/2)}^{t+(l/2)} G_{gb}^i}{l}, \quad (A2)$$

where l is an odd number from 1 to L ; L is half the estimated period of 30 years between 1980 and 2009, or 15; i is the time ($i = 1987$ and 2002); and $n = (L + 2)/2 = (15 + 2)/2 = 8$. Moreover, $l/2$ is cut off on the MA. Average values in 1987 and 2002 in Eq. A1 are employed as these two values mathematically include much information as the MA for the condition that the maximum two time spans, or 15, for 1987 and 2002 are not covered.

Tables A1, A2, and A3 show the RR s of G_{gb} , G_b , and G_t , respectively for each pair of port ranges. $RR = 1$ implies that the inequality change between two port ranges was not observed between 1987 and 2002. The expanding inequality between two pairs of port ranges is said to be high when $RR > 1$. Otherwise, $RR < 1$ depicts shrinking inequality between pairs of port ranges. The yellow and green colors in **Tables A1, A2, and A3** depict the top 10 and bottom 10 of the 105 RR s, respectively. As reference, the pink colors in **Table A1** show the RR s of G_w .

Table A1: Relative Ratio (RR) of G_w and G_{gb} between 1987 and 2002

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
G1	0.352														
G2	0.354	0.611													
G3	0.250	0.232	0.178												
G4	0.335	0.585	0.229	0.367											
G5	0.598	0.829	0.472	0.863	0.906										
G6	0.411	1.250	0.301	3.322	1.188	3.316									
G7	0.912	2.692	0.723	5.297	1.702	5.239	5.794								
G8	0.348	0.706	0.232	1.229	1.023	3.996	6.244	7.383							
G9	0.886	1.265	0.792	1.439	1.205	1.451	1.595	1.566	1.229						
G10	0.451	0.420	0.409	0.423	0.495	0.372	0.507	0.401	0.653	0.488					
G11	0.341	0.767	0.243	0.871	0.857	1.015	2.421	0.785	1.188	0.382	0.700				
G12	0.797	1.169	0.697	1.291	1.120	1.299	1.634	1.298	1.217	0.628	1.123	1.184			
G13	0.348	0.663	0.234	0.801	0.919	1.725	3.550	1.363	1.403	0.398	0.717	1.201	0.905		
G14	0.348	0.683	0.238	0.821	0.893	2.023	4.062	1.050	1.364	0.412	0.881	1.257	0.818	0.995	
G15	0.373	0.659	0.251	0.720	0.893	2.143	3.935	1.111	1.398	0.430	0.881	1.262	0.834	0.865	0.778

(Source: Devised by the author.)

For example, the inequality between the two pairs of port ranges containing G3 is decreasing, whereas that between the two pairs of port ranges containing G7 is increasing. Moreover, the inequality within Chinese port groups is shown to increase overall, while the exact opposite is the case within Japanese port groups. Notably, the RR between G7 vs. G8 is high (6.244).

By decomposing the RR of G_{gb} into those of G_b and G_t , we can appreciate the shortcoming of Notteboom (2006b), whose main finding was that the inequality between Japanese ports and the Pearl River Delta was increasing. Of course, the RR of G_b between G9 (the Pearl River Delta) and Japanese ports (especially G1) has increased quite a bit. However, the RR of G_t between G9 vs. G1 is less than 1.0. This means that *the overlapping effects between port ranges* decreased. Finally, the RR of G_{gb} , which is *the total inequality between port ranges*, also decreased a little ($0.886 < 1.0$, and therefore, there was NO increase). **Tables A2 and A3** show different trends for pairs of port ranges between 1987 and 2002, respectively. Overall, the RR s of G_t are higher than those of G_b . Though the actual values of G_b exceed those of G_t (see **Figure 3**), the trends in relative changes are also important, because the values of each component of the Gini index are dependent

upon the number of ports within each port range.

Table A2: Relative Ratio (RR) of G_b between 1987 and 2002

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
G1															
G2	0.277														
G3	0.260	0.125													
G4	0.314	0.443	0.180												
G5	0.413	1.752	0.349	1.127											
G6	0.186	1.201	0.177	7.514	0.309										
G7	0.707	3.770	0.597	31.136	1.035	13.738									
G8	0.209	0.188	0.115	0.515	0.723	3.667	6.830								
G9	4.983	2.403	2.422	1.863	2.867	1.239	0.722	1.484							
G10	0.528	0.435	0.765	0.435	0.261	0.255	0.192	0.377	0.335						
G11	0.038	2.729	0.084	1.044	1.278	0.480	2.226	0.525	2.349	0.344					
G12	2.599	1.953	1.632	1.518	2.114	0.892	0.493	1.183	3.478	0.110	1.821				
G13	0.189	0.210	0.084	3.903	0.885	4.026	16.446	0.360	1.742	0.383	0.655	1.384			
G14	0.232	0.184	0.111	1.231	1.103	2.389	8.135	0.203	1.932	0.406	0.972	1.551	0.472		
G15	0.287	0.349	0.152	0.602	1.183	3.292	10.344	0.203	1.952	0.427	1.118	1.583	1.695	0.937	

(Source: Devised by the author.)

Table A3: Relative Ratio (RR) of G_t between 1987 and 2002

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
G1															
G2	0.528														
G3	0.247	0.598													
G4	0.509	0.811	0.749												
G5	0.726	0.446	0.614	0.343											
G6	3.375	1.399	2.241	0.435	4.027										
G7	2.532	0.939	2.154	0.231	3.108	2.680									
G8	10.827	14.437	7.770	78.881	5.460	5.961	3.413								
G9	0.245	0.262	0.201	0.250	0.680	2.389	4.256	3.267							
G10	0.316	0.280	0.098	0.000	1.475	7.590	9.607	50.859	1.076						
G11	0.860	0.367	0.662	0.185	0.757	5.305	3.061	95.403	0.440	0.667					
G12	0.313	0.331	0.250	0.238	0.812	4.391	6.808	5.876	1.071	1.533	0.574				
G13	1.229	1.050	1.362	0.402	0.970	0.783	0.649	5.960	0.598	0.717	0.798	0.692			
G14	0.877	0.970	1.089	0.569	0.670	1.406	0.857	22.641	0.391	0.520	0.765	0.535	0.896		
G15	0.805	0.865	0.908	0.776	0.546	0.931	0.561	13.648	0.343	0.482	0.585	0.441	0.688	0.847	

(Source: Devised by the author.)

Moreover, in order to observe the structural changes in port cargo flow distribution between port ranges in Asia, we apply this *RR* calculation to REA, or D_{ij} , as discussed in Section 2. Here, REA = 1 implies that port structure discrimination between two port ranges is perfect. In other words, the smaller the REA, the more similar the port structure between the two port ranges. $RR = 1$ implies that structural changes between a pair of port ranges is not observable during the two time points (between 1987 and 2002). $RR > 1$ implies that the similarity between pairs of port ranges come down, whereas $RR < 1$ depicts the contrary. **Table A4** shows the *RRs* of REA for pairs of port ranges. Similarly, the yellow and green colors in **Table A4** depict the top 10 and bottom 10 of the 105 *RRs*.

Table A4: Relative Ratio (RR) of REA between 1987 and 2002

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
G1															
G2	0.790														
G3	1.063	0.539													
G4	0.932	0.731	0.771												
G5	0.712	2.120	0.767	1.299											
G6	0.460	0.887	0.579	2.214	0.294										
G7	0.718	1.305	0.762	5.889	0.556	2.428									
G8	0.564	0.283	0.472	0.406	0.695	0.918	1.071								
G9	5.472	1.867	3.074	1.281	2.321	0.832	0.475	0.940							
G10	1.162	1.032	1.879	1.028	0.513	0.657	0.393	0.917	0.539						
G11	0.115	3.387	0.371	1.182	1.594	0.471	0.832	0.636	1.958	0.898					
G12	3.157	1.684	2.361	1.173	1.940	0.665	0.331	0.907	2.654	0.210	1.669				
G13	0.520	0.345	0.338	4.800	0.955	2.018	4.069	0.289	1.229	0.948	0.881	1.155			
G14	0.639	0.275	0.435	1.591	1.189	1.114	1.890	0.225	1.385	0.970	1.044	1.228	0.594		
G15	0.750	0.531	0.577	0.884	1.337	1.540	2.491	0.191	1.398	0.985	1.248	1.280	1.984	1.052	

(Source: Devised by the author.)

As mentioned earlier, **Tables A2** and **A3** show different trends of inequality. **Table A4** also gives valuable information about the structural changes in port cargo flow distribution.

For example, the inequalities between G1 vs. G9 show a different trend, that G_b increased and G_r decreased. The RR of REA between G1 vs. G9 is quite high (5.472) and the second largest among all pairs of port ranges. This means that the difference in port cargo flow distribution between these areas became marked. In addition, the structural changes between G4 vs. G7, G4 vs. G13, and G7 vs. G13 are apparent. On the other hand, the port cargo flow distribution between G1 vs. G11, G8 vs. G15, and G10 vs. G12 became similar. Moreover, the port cargo flow distributions between Japanese port ranges do NOT show apparent changes as the RR value hovers around 1.0, a finding that concurs with Le and Ieda (2010).

Finally, **Table A5** shows the RRs of G_{jj} and G_{jh} for each pair of port ranges. Similarly, the yellow and green colors in **Table A5** depict the top 10 and bottom 10 of the 105 RRs . Moreover the pink colors show the RRs of G_{jj} . Overall, the “simple” Gini index of each port range shows the trend of shrinking inequality.

Table A5: Relative Ratio (RR) of G_{jj} and G_{jh} between 1987 and 2002

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13	G14	G15
G1	0.879														
G2	0.781	0.983													
G3	0.781	0.684	0.669												
G4	0.735	0.852	0.702	0.440											
G5	0.955	0.946	0.948	0.872	0.877										
G6	0.512	0.792	0.499	1.371	0.741	0.714									
G7	0.746	1.077	0.762	1.411	0.762	0.919	0.857								
G8	0.604	0.647	0.565	0.699	0.775	0.802	0.917	1.053							
G9	0.912	0.932	0.964	0.939	0.852	0.730	0.666	0.854	0.754						
G10	1.022	0.864	1.054	0.860	0.844	0.559	0.581	0.724	0.811	1.045					
G11	0.610	0.953	0.563	0.937	0.851	0.589	0.953	0.586	0.830	0.700	0.731				
G12	0.950	1.016	0.995	0.999	0.901	0.742	0.750	0.827	0.796	0.869	0.905	0.858			
G13	0.642	0.761	0.589	0.720	0.822	0.660	0.911	0.638	0.869	0.743	0.659	0.869	0.660		
G14	0.696	0.911	0.649	0.908	0.881	0.938	1.235	0.653	0.901	0.802	0.919	0.977	0.722	1.013	
G15	0.797	0.955	0.735	0.890	0.917	1.026	1.190	0.729	0.936	0.865	0.971	1.001	0.784	0.988	0.979

(Source: Devised by the author.)

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