Market Area Analysis of Ports in Japan

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Market Area Analysis of Ports in Japan: An Application of Fuzzy Clustering

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Abstract

This study reviews port cargo flow structure on hinterland/foreland (i.e. shippers' port use propensity) in Japan to examine port policy. Port service areas are analysed by conducting fuzzy clustering for 47 prefectures in Japan. Container cargo flow survey data from 1988 to 2008 at five-year intervals are used. Clusters of shippers' use of ports are discussed; that is, shippers' groups are determined using export/import handling cargo data on the basis of weight, cross section, and time series. The share changes of major Japanese ports for handling international container cargo indicated that only the Kobe port experienced significant volume reduction. However, port market areas have greatly changed in the last 20 years. Major ports lost shares of neighbouring market areas and gained small shares of remote areas (i.e. from regional ports). In contrast, regional ports groups expanded their market area beyond their regional areas. These structural changes to port market area differ between export and import cargo. For example, the Kyushu ports group lost significant market area in the Kyushu region on import cargo, but expanded them on export cargo in some prefectures in the Kyushu region.

Keywords: port market area, port use propensity, hinterland/foreland, fuzzy clustering, Japan

1. Introduction

Containerization started during the 1970s. The expansion in container handling volumes resulted from export-led economic development in Japan and the newly industrializing economies (NIEs) in the Asian region. For example, the port of Kobe, which had been the largest container handling in Asia until 1981, was the fourth largest port in Asia in 1990 after the ports of Singapore, Hong Kong, and Kaohsiung. After the Great Hanshin Earthquake in 1995, the port of Kobe began dropping gradually in ranking. In the most recent rankings conducted in 2010, the port's position was 49th in the world. The rankings of other Japanese ports have also fallen: After 2006, the rankings of all Japanese ports fell below the 20th position. In contrast, the ports of Hong Kong, Singapore, and Busan, which ranked among the top 10 ports in 1975, have maintained their positions. In the 2010 rankings, these ports were still in the top 10. In 2010, six Chinese ports, including the port of Hong Kong, ranked among the top 10 ports in the world (see annual *Containerisation International Yearbook*).

Adding to the shift of the relative positions of container handling volumes from Japan to China, the transhipment cargo volumes at major Asian ports (excluding the Japanese ports) began to expand. For example, around 1990, the transhipment rates (i.e. the proportion of transhipment cargos to the total port throughput) of the ports of Yokohama and Kobe were approximately 15% and 25%, respectively. In 2006, the transhipment rate at the port of Tokyo was only 8.8%, whereas the average transhipment rate of Japanese ports was less than 4%. In contrast, although the transhipment rate at the port of Busan in South Korea was approximately 15% in 1990, it increased to 43.3% in 2006. The transhipment rate at the port of Singapore, which traditionally boasted high transhipment cargo volumes, was 81.5%. Moreover, the rate at the port of Tanjung Pelepas, an emerging container port in Malaysia, was remarkably high (95.8% in 2006). Alternatively, the foreign transhipment rates, that is, the proportion of container cargo from/to a third country to the total international container cargo at the port, in Japan are increasing. For example, the share to/from Asian countries from/to Japanese ports was 15.2% in 2008 (3.3% in 1993). Similarly, the 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 are able to take the feeder container services of Asian hub container ports, such as the port of Busan, to Japanese container users because shipping companies skip Japanese ports on main routes (see the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT)).

In these surroundings, the target of the high-standard central port policy, which indicates the change in policy for port investments from quantitative expansion to qualitative expansion, is the formation of a logistics hub function and the use of deregulation for attracting industries in Japan. Specifically, the MLIT in Japan designated three port groups—the Keihin port (the ports of Tokyo and Yokohama), the ports of Nagoya and Yokkaichi, and the ports of Osaka and Kobe—as 'super-centre ports' in July 2004. The ports of Hakata and Kitakyushu were demolished from the designation after the last round. Nevertheless, export container cargos were shipped from Japanese regional ports via the ports of Busan and Shanghai to Western countries because of rapidly escalating container cargo transport from the Asian region with a focus on China. However, domestic hub container ports in Japan continue to play an important role in maintaining industrial competitiveness, and, hence, serve as the main ports for European/North American routes. Therefore, in August 2010, the MLIT designated the Keihin port (the ports of Tokyo, Yokohama, and Kawasaki) and the Hanshin port as 'international container strategic ports', which received focused investments and support.

This study discusses the structural changes of inland container cargo flow on the hinterland/foreland (i.e. shippers' port use propensity) in Japan for port policy. The port service area is analysed by conducting a fuzzy clustering for 47 prefectures in Japan and container cargo flow survey data from 1988 to 2008 at five-year intervals is used. Clusters of shippers' use of ports (i.e. shippers' groups based on export/import handling cargo data on the basis of weight, cross section, and time series) are discussed.

The remainder of this paper is structured as follows: Section 2 provides a background on port hinterland analysis and Japanese port cargo handling in the past 20 years. Section 3 explains the methodology and the database used for the numerical analysis. Section 4 shows the calculated results by using a fuzzy clustering and maps the changes in the port market area over the past 20 years. Finally, Section 5 summarizes the research and indicates future challenges.

2. Research significance of port market analysis

2.1. Port hinterland/foreland

Inland cargo flow is becoming a critical dimension of the globalisation/maritime transportation/freight distribution paradigm. Port users select the port for shipping in/out based on parameters such as the costs for transporting cargo and inventory. Inland accessibility is a crucial factor of port competition. Therefore, port hinterland analysis serves as the most important and universal research topic in the field of transport geography (specifically, maritime cargo transport). 'Port hinterland/foreland' refers to the market area of the port handling the cargo (i.e. the place/area of origin or destination).

Notteboom and Rodrigue (2005) discussed new patterns on the spatial and functional evolution of ports and port systems by introducing a port regionalisation phase that adds to the existing literature (Bird, 1963; Hoyle, 1989). Doi (2003) mentioned that container ports, in collaboration with their own regional economies—including the location of inland facilities and transport networks on the hinterland/foreland—compete with each other; this is especially the case in Asia because of geographical factors and a higher concentration of people in large coastal areas. Moreover, Lee et al. (2008) showed that different geographical areas exhibit varied hinterland spatial patterns in Western Europe, North America, South Asia, and East Asia. Furthermore, Rodrigue and Notteboom (2010) analysed regionalism in freight transport systems by providing a comparative analysis of gateway logistics practices (i.e. inland distribution/warehouse networks) in North America and Europe. However, empirical research on maritime freight remains far less developed because of the lack of data on hinterland/foreland freight flows that enable the delineation of regions containing most port users (Darnton, 1963; McCalla et al., 2004; Guerrero, 2010).

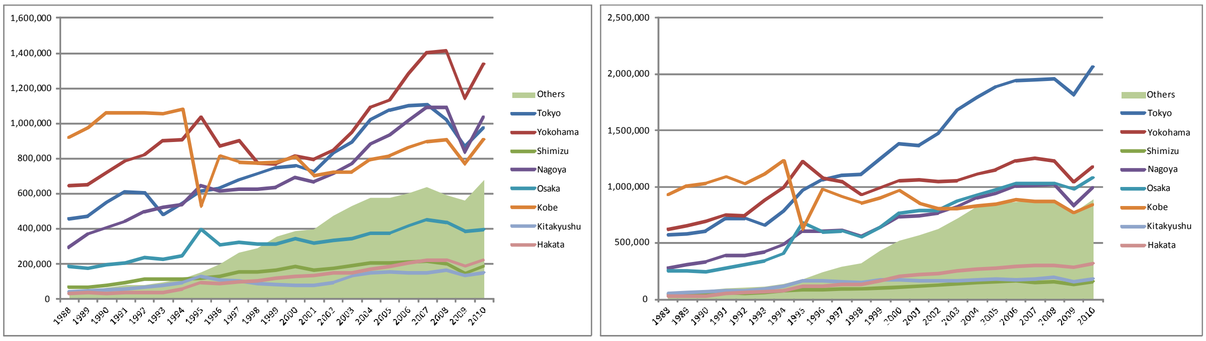
Port and shipping line selection behaviours of exporters and importers have been evaluated separately in various studies. Itoh (2007) compared the port cargo flow structures between Japan and China by applying the estimated discrete choice functions used in early studies

(Itoh et al., 2002; Tiwari et al., 2003). Tongzon (2009) evaluated the main factors influencing a forwarder's port choice in Southeast Asia. Furthermore, Ducruet (2006) conducted an empirical analysis on commodity composition, characteristics of port handling cargo, and economic characteristics of the surrounding area (i.e. the port hinterland/foreland). Specifically, Ducruet (2006) discussed the relationship between port-related variables and socioeconomic variables. Ducruet et al. (2012a, 2012b) identified the mutual influences between the specialization of traffic passing through seaports and the socioeconomic characteristics of their surroundings, and proposed a typology of port regions to map the distribution of port regions and to zoom in on specific local conditions.

Based on the survey of the hinterland/foreland of container cargo flow in Japan, the current paper discusses the market area of Japanese ports. Moreover, the structural changes of port service area (i.e. hinterland/foreland) are shown because of time-series data on a matching basis. For example, Osman and Inamura (1997) discussed the origin and destination of container cargo by counting data from the same survey. However, early studies only focused on simple aggregation for the database. In addition, simple counting does not enable a discussion on the characteristics of port hinterland/foreland with numerous port systems for analysis (Figures 4, 5, 6, and 7).

2.2. Japanese port influence

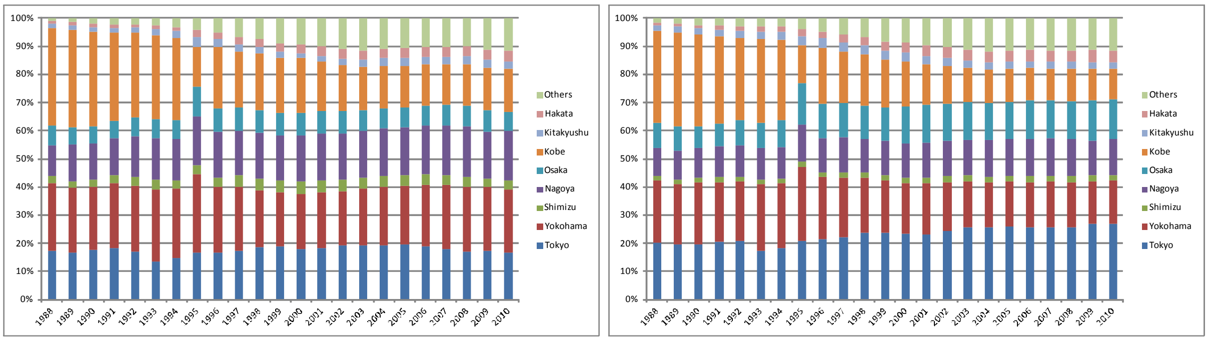
Figure 1 shows the container handling volume trends in terms of TEU (i.e. 20-footer equivalent units) sorted by export and import for the eight major container ports and an aggregation of all other ports in Japan. Although Kobe handled most containers during the first half of 1990s for both export and import, the Great Hanshin earthquake in January 1995 cut the handling volume to less than half of the pre-earthquake levels. The handling volume has partially recovered, but has not reached the pre-earthquake levels yet. Moreover, the port of Kobe lost its transhipment functions (transhipment share declined from 31.6% in 1994 to 4% in 2007) because budgets were insufficient for both reconstruction and modernisation after the earthquake. The foregone demand of Kobe shifted to Osaka, which is geographically close to Kobe, and to smaller extents to Yokohama and Nagoya, especially for imports. Although both export and import handling volumes at Tokyo port have been increasing gradually since 1993, Yokohama did not experience consistent import demand growth and was caught up to by Tokyo in 1996. Since the late 1960s, the port of Tokyo has continuously upgraded its facilities and has maintained efficient port operations (Itoh, 2002); in addition, the Tokyo Port Terminal Corporation modernized a number of deepwater berths between 1996 and 2004 (MLIT). The handling volumes at Shimizu, Kitakyushu, and Hakata are smaller than those at the major five ports, but are growing because of the increasing Asian route demand. The aggregate of the regional ports has been gradually increasing port handling volumes both in exports and imports.



(a) Export **(b) Import**

Figure 1 – The changes of Japanese container port handlings (Source: port statistics yearbook)

Figure 2 illustrates the changes of port handling shares on each major Japanese port based on Figure 1. Although Kobe port has lost much of its port handling shares in 1995, these figures do not show the drastic changes on the other five major Japanese ports. In contrast, the share of the other ports (shown on the top of each figure) has increased in the past 20 years, and was over 10% in 2010. The shares of Kitakyushu and Hakata, which are in the Kyushu region, are also increasing. The share of import cargo in Keihin port, which consists of the ports of Tokyo and Yokohama, has not changed; however, the share of the port of Yokohama has decreased and the share of the port of Tokyo has increased after 1996.



(a) Export **(b) Import**

Figure 2 – The share changes on Japanese container port handlings (Source: port statistics yearbook)

This research focuses on the port market area only for container cargo movements, and it does not cover bulky cargo that comprises most maritime port cargo. However, for example, the study of *the bulk cargo flow survey* (MLIT, 2009) notes that 96% of the place of origin/destination of bulky cargo is from/to a municipality with the port locates in Japan. That is, the impact of bulky cargo on broad area cargo movements is limited. Moreover, Debrie and Guerrero (2008) noted that wide differences exist among commodities passing through ports in terms of travelled distance, and showed that manufactured goods, such as container cargo, travel longer distances than liquid and dry bulks do in French ports.

2.3. Analytical method and research motivation

The purpose of this research is to analyse port market area as the aggregated results of shipper's port choice behaviours. Dynamic fuzzy clustering analysis is applied on three-way data: time, individual (i.e. shippers at the prefecture), and index (the port handling share of each port at each prefecture). Clustering analysis is used to classify each prefecture (individual) based on the usage per cent of each port for export and import on each prefecture (index): how much per cent of some port does a shipper use for shipping out/in from/to their place. We define the typical port use propensity of each ports group by using the cluster centroid (i.e. the gravity) of each cluster on the classified ports group, where each cluster is classified with the minimum distance between the gravity of the cluster and each individual included in the cluster. Therefore, prefectures (shippers) with similar port use propensity are classified within the same ports group. By discussing the port use propensity (i.e. the port handling share of abbreviated/classified shippers), from the gravity of each cluster, we interpret the characteristics of each ports group. In contrast, we identify the port market area from the prefectures' combination included in that cluster.

In general, hard clustering models (i.e. non-hierarchy clustering, like k-means models; Anderberg, 1973; Hartigan, 1975) can be used to classify each prefecture in groups (i.e. clusters) with similar port use propensity according to their port handling share at each port. By contrast, from the viewpoint of a single port cluster, each prefecture may or may not be included within this cluster (i.e. alternative choice). However, even though individual shippers can use some ports as their items, lot size, and the place of origin/destination. In addition, various shippers in one region (i.e. prefecture) can use some ports in combination. Because hard clustering models cannot analyse a shipper's real-life behaviour regarding multi-port clusters, a fuzzy clustering model is preferred to be able to classify a single prefecture (i.e. region) to partially define port markets (i.e. clusters) by port use propensity (Itoh et al., 2003).

By applying fuzzy clustering on three-way data in this paper, we analysed how much each prefecture was attributed to each ports group and observed the time-series changes of the extent of attribution for each port cluster. The extent of attribution for each cluster at each prefecture is defined by the degree of membership (i.e. the 'membership function'). Moreover, the sum of the degree of membership in each cluster must be 1.0. Similarly, for hard clustering, the classification mechanism used in fuzzy clustering is that which minimizes the distance between the centroid of the cluster and the individual (i.e. prefecture); the distance is weighted by the degree of membership on the membership function (Dunn, 1973; Bezdek, 1981; Bezdek et al., 1999). Moreover, similar to hard clustering, we can characterize the port market area of each ports group constructed using several ports based on the centroid of each cluster as virtual port use propensity indexes. Simultaneously, we can analyse to what extent each prefecture should be attributed to a single port group, and to what extent the membership of each prefecture to a single port group shifts (i.e. how much the port market area changes).

3. Fuzzy clustering and database

3.1. Fuzzy clustering and fuzzy analysis (FANNY) algorithm

3.1.1 Hard clustering (k-means model)

To explain clustering analysis, we used the k-means model, which is a widespread non-hierarchal clustering model. The clustering evaluation criterion on the k-means model is the sum of the squares of the average deviation (AD). That is, the total variation of the data is the sum of the deviation within the cluster and the deviation between clusters.

The set of *n* observations $x_1, \cdots, x_n$ is expressed as follows:

$$S = \{x_1, \cdots, x_n\}, \quad x_i = (x_{i1}, \cdots, x_{ip}) \qquad (1)$$

The purpose of the k-means model is to classify the set of *n* observations, S to *k* clusters, and $C_1, \cdots, C_n$.

We can denote (1) as follows.

$$\mathrm{X} = \begin{pmatrix} x_1 \\ \vdots \\ x_n \end{pmatrix} = (x_{ia}), \quad i = 1, \cdots, n, \quad a = 1, \cdots, p \qquad (2)$$

where X is a matrix with *n* lines and *p* columns. The purpose of the k-means model is to minimize the following on the evaluation criterion:

$$J = \sum_{k=1}^{K} \sum_{X_i \in G_k} d(x_i, v_k)^2 \qquad (3)$$

where v_k expresses the cluster centroid of C_k:

$$v_k = (v_{k1}, \cdots, v_{kp}), \quad k = 1, \cdots, K$$

In matrix notation,

$$V = \begin{pmatrix} v_1 \\ \vdots \\ v_K \end{pmatrix} = (v_{ka}), \quad k = 1, \cdots, K, \quad a = 1, \cdots, p$$

where $d(x_i, v_k)^2$ is a square value of Euclidean distance between the centroid of the *k*-th cluster and observation *i*.

3.1.2 Fuzzy clustering (FANNY algorithm)

In a fuzzy clustering, each observation is 'spread out' over various clusters. Because *n* is the number of data observations and *K* is the number of clusters, the purpose of this fuzzy clustering model is to minimize the following objective function:

$$J(U, V) = \sum_{i=1}^{n}\sum_{k=1}^{K}(u_{ik})^m d(x_i, v_k)^2 \quad (1 < m < \infty) \tag{4}$$

where

v_k: the centroid of the *k*-th cluster,

x_i: specification vector of database,

$d(x_i, v_k)$: dissimilarity between x_i and v_k,

$U = (u_{ik})$: u_{ik} is membership function of x_i to *k*-th cluster,

and $\left(u_{ik} \in [0,1],\ \sum_{k=1}^{K} u_{ik} = 1,\ \sum_{i=1}^{n} u_{ik} > 0 \right)$.

Every membership function (u_{ik}) must be between 0 and 1, every cluster must not be empty, and the sum of the membership function of each observation is equal to 1.0. $d(x_i, v_k)^2$ is a square value of the Euclidean distance between the centroid of the *k*-th cluster and observation *i*. Moreover, *m* is a parameter for the degree of membership, where $1 < m < \infty$. The parameter defines the extent of fuzziness. If $m = 1$, the model is a hard clustering model.

The following equations are derived from Equation (4):

$$\begin{aligned} J(U,V) &= \sum_{i=1}^{n}\sum_{k=1}^{K}(u_{ik})^m d(x_i, v_k)^2 \\ &= \sum_{i=1}^{n}\sum_{k=1}^{K}(u_{ik})^m (x_i - v_k, x_i - v_k) \\ &= \sum_{i=1}^{n}\sum_{k=1}^{K}(u_{ik})^m (x_i - h_k + h_k - v_k, x_i - h_k + h_k - v_k) \\ &= \sum_{i=1}^{n}\sum_{k=1}^{K}(u_{ik})^m \left[(x_i - h_k, x_i - h_k) + 2(x_i - h_k\, h_k - v_k) + (h_k - v_k, h_k - v_k)\right] \end{aligned} \tag{5}$$

Here, $(\bullet,\bullet)$ shows the inner product.

$$h_k = \sum_{i=1}^{n}(u_{ik})^m x_i \bigg/ \sum_{i=1}^{n}(u_{ik})^m \tag{6}$$

Assuming Equation (6) holds, the minimization of Equation (4) is equivalent to the following equation.

$$J(U,V)=\sum_{k=1}^{K}\left(\sum_{i=1}^{n}\sum_{j=1}^{n}\left((u_{ik})^{m}(u_{jk})^{m}d_{ij}\right)\Big/\left(2\sum_{l=1}^{n}(u_{ik})^{m}\right)\right) \tag{7}$$

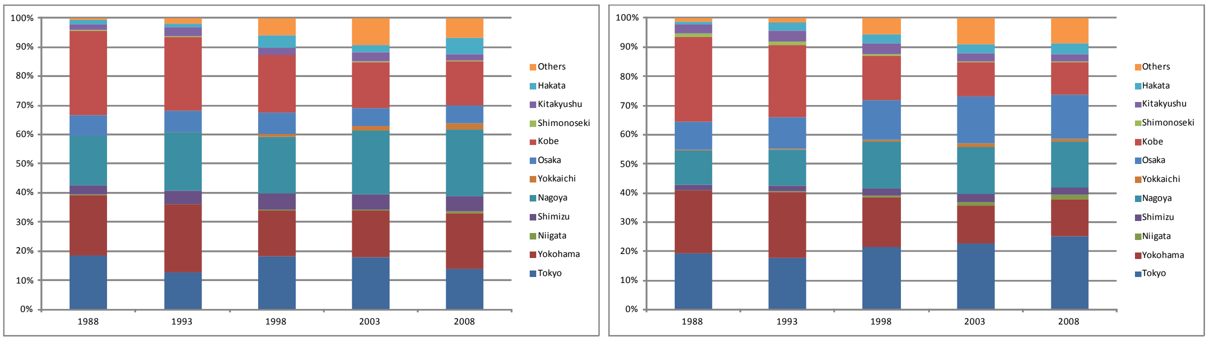
and $d_{ij}=\sqrt{\sum_{a=1}^{p}(x_{ia}-x_{ja})^{2}}$.

The fuzzy analysis (fanny) algorithm estimates the membership function (u_{ik}) required to minimize Equation (7) (Kaufman and Rousseeuw, 1990). Compared to other fuzzy clustering models, the fanny method has the following advantages: (i) it accepts a dissimilarity matrix, (ii) it is more robust for the spherical cluster assumption, and (iii) it provides a novel graphical display—the silhouette plot (see Statistical Data Analysis Software *R* web site manual).

3.2. Database for fuzzy clustering

The database for this research details container handling volumes by domestic export ports and domestic import ports in each prefecture from the annual MLIT container cargo flow survey conducted between 1988 and 2008 at five-year intervals. The survey period covered in this study is just one month, October 1st to 31st, in each year. Moreover, the database includes container cargo declared at national customs, and acquired container handling tonnage volumes for export and import separately in each municipality by using a questionnaire survey. The database constructed for this numerical analysis converted the original handling volumes to the port handling shares at the export and import ports in 47 prefectures because of the reduction of scale impacts. In this numerical analysis, by using a three-way database (Sato et al., 1997), that is, (1) individual (prefecture), (2) index (port handling shares at each prefecture to/from each port by export and import), and (3) time (from 1988 to 2008 at five-year intervals), we can discuss the changes of port market area (i.e. port service area) in Japan. The database includes port handling shares for the 11 major container ports and the aggregate share of all other regional ports in Japan. The 11 major container ports in Japan covered in this analysis are the Ports of Tokyo, Yokohama, Niigata, Shimizu, Nagoya, Yokkaichi, Osaka, Kobe, Shimonoseki, Kitakyushu, and Hakata.

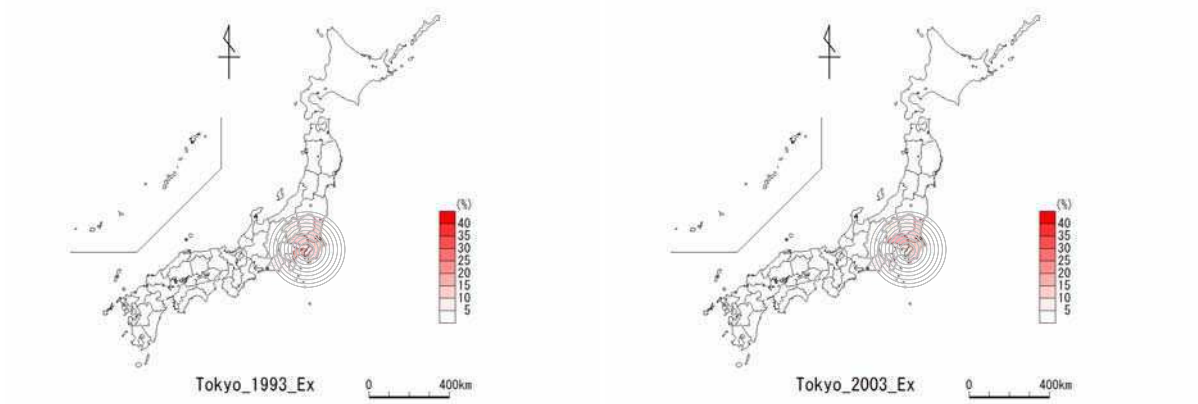
Before showing the calculated results, the remainder of this section shows the port handling shares of major container ports in Japan based on the database for numerical analysis to confirm data stability and consistency (Figures 3(a) and 3(b)). Although this study period includes just one month each year, the database is comparatively stable compared to that based on data in Figures 2(a) and 2(b), which were retrieved from the statistics yearbook. For example, the survey database indicated such trends as import cargo share increase at Tokyo, cargo share reduction of both exports and imports at Kobe, and cargo share increase at local ports (i.e. the aggregate of the other ports).



(a) Export **(b) Import**

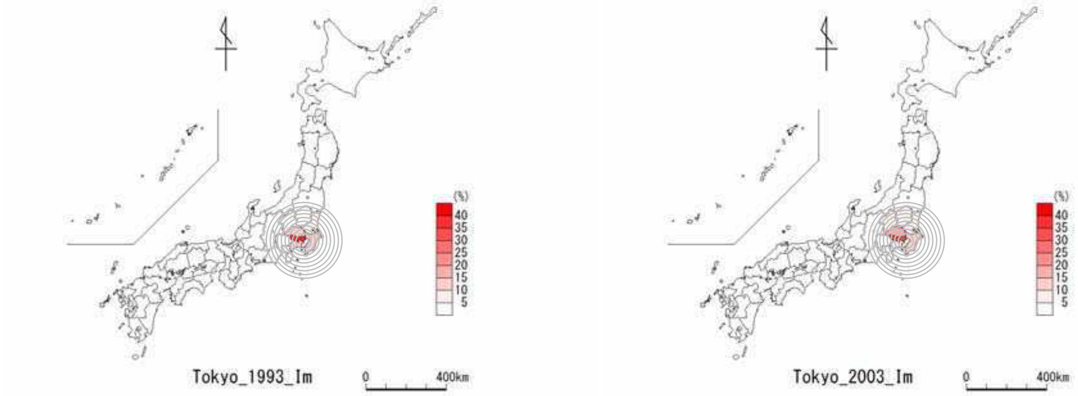
Figure 3 – The share changes on Japanese container port handlings (Source: container cargo flow survey)

To discuss the hinterland/foreland changes from the viewpoint of ports, Figures 4, 5, 6, and 7 show the hinterland/foreland of the ports of Tokyo and Kobe on export and import cargos using a simple aggregation for the database used for numerical analysis as a reference. These figures show the hinterland/foreland shares of container cargo at each prefecture for the two ports. The (a) and (b) sections of each figure show the shares after applying a weighted moving average method between 1988 and 1998 and between 1998 and 2008, respectively. Although the port of Tokyo expanded its import cargo handling shares in the past 20 years (e.g. Tokyo increased its share of cargo from the North Kanto area (i.e. the Gunma and Tochigi prefectures); see Figure 2(b)), the relevant figure does not show clear foreland changes. By contrast, the port of Kobe has depended recently on increased local cargos (e.g. from the Hyogo prefecture) for import and export because of the reduction in their port handling share in the past 20 years. However, simple counting does not enable a significant analysis of the characteristics of port hinterland/foreland with numerous ports systems from the viewpoint of *ports*, or port service provides. By applying fuzzy clustering, this empirical analysis discusses the port market area changes from a viewpoint of *shippers*, or port users.



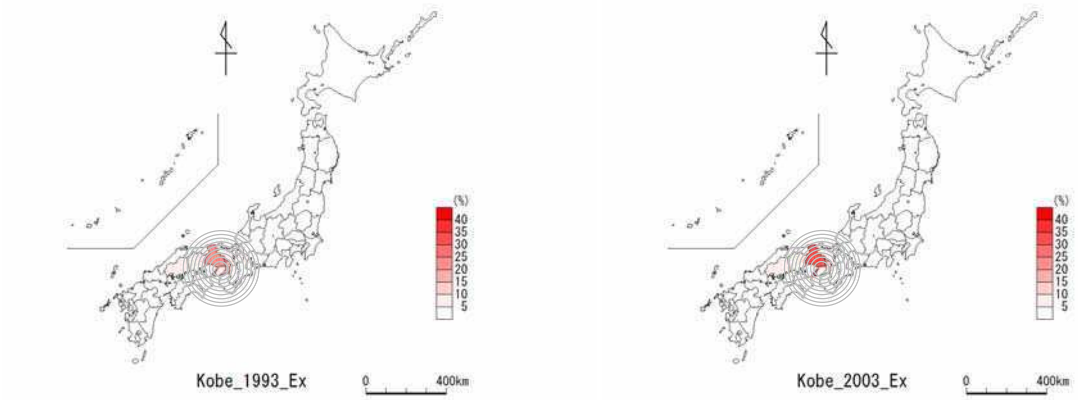
(a) the first decade (1988-1998) **(b) the second decade (1998-2008)**

Figure 4 – Tokyo port's hinterland on export cargo (Source: container cargo flow survey)



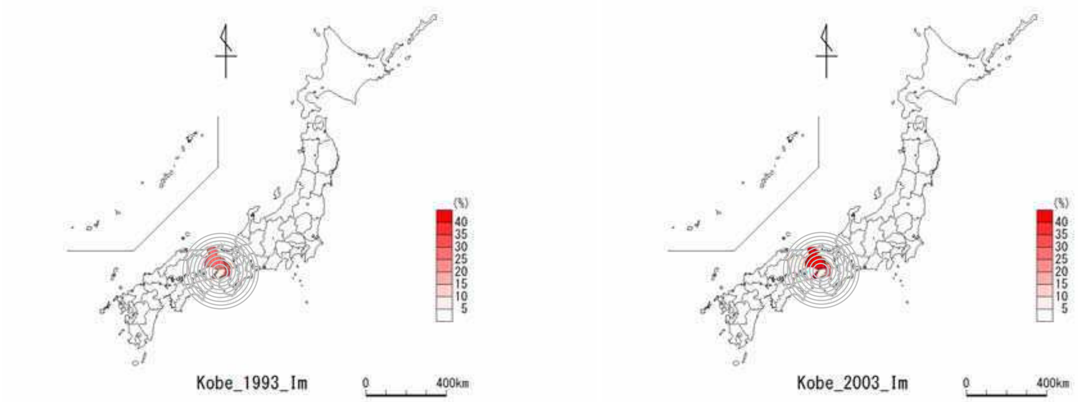
(a) the first decade (1988-1998) **(b) the second decade (1998-2008)**

Figure 5 – Tokyo port foreland on import cargo (Source: container cargo flow survey)



(a) the first decade (1988–1998) **(b) the second decade (1998–2008)**

Figure 6 – Kobe port hinterland on export cargo (Source: container cargo flow survey)



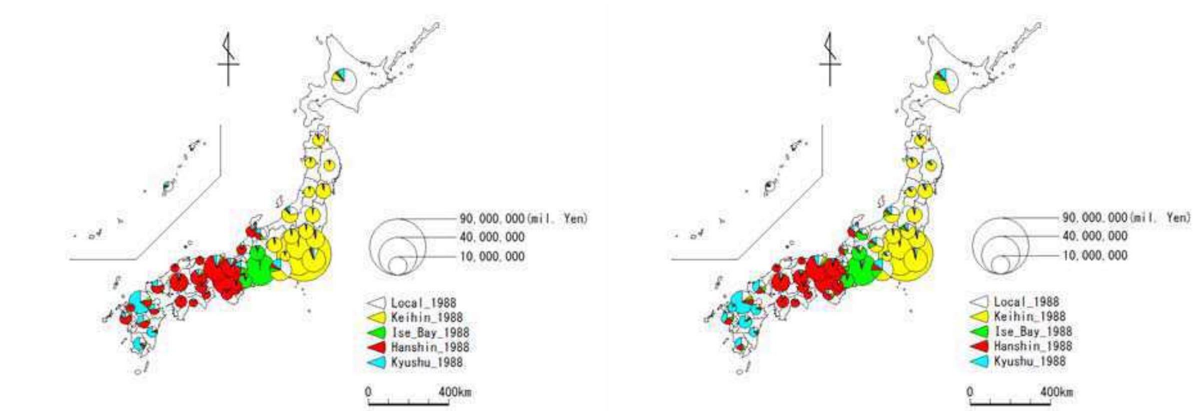
(a) the first decade (1988–1998) **(b) the second decade (1998–2008)**

Figure 7 – Kobe port foreland on import cargo (Source: container cargo flow survey)

4. Structural changes of port market area

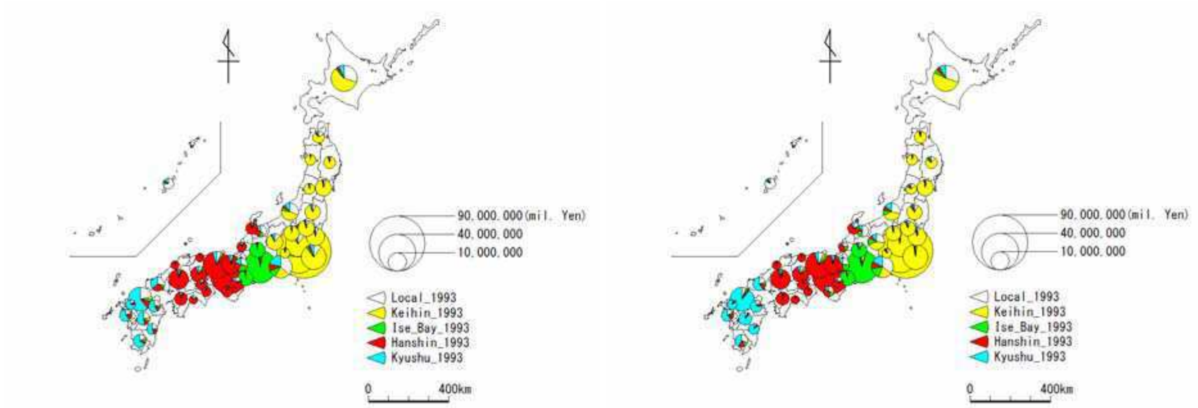
4.1. Calculated results using fuzzy clustering

This research performed fuzzy clustering with a fanny algorithm for the database discussed in the previous section. We achieved reasonable and meaningful results of clusters by adjusting the parameter *m*, which represents the degree of membership, from 1.0 to 2.0, and the number of clusters *k*. Figures 8, 9, 10, 11, and 12 show the calculated results, or the membership function of each prefecture, based on five clusters and $m = 1.5$, which is the middle fuzziness. Other options, such as including seven clusters with $m = 1.5$, produce results with two Keihin ports clusters that are not suitable for discussion because of high complexity and fuzziness.



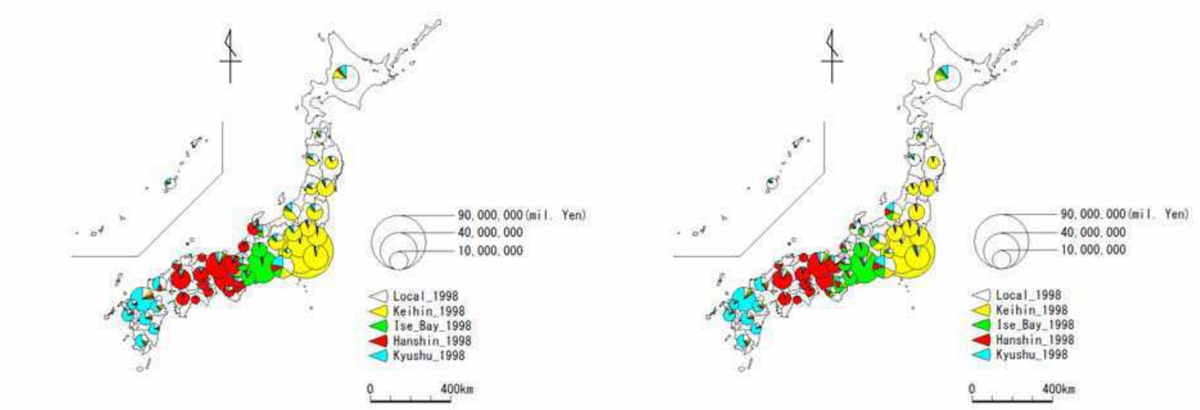
(a) Export **(b) Import**

Figure 8 – Port market area (membership function) in 1988 (Source: Devised by the author.)



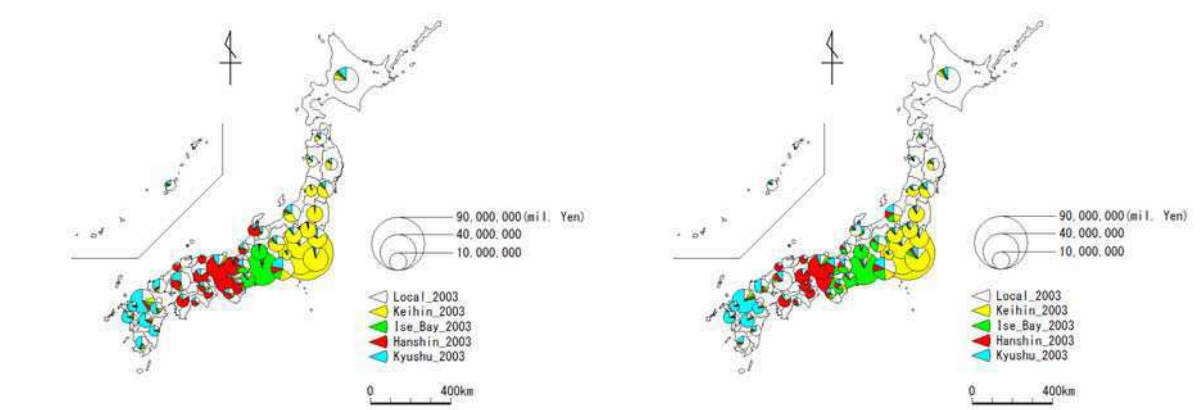
(a) Export **(b) Import**

Figure 9 – Port market area (membership function) in 1993 (Source: Devised by the author.)



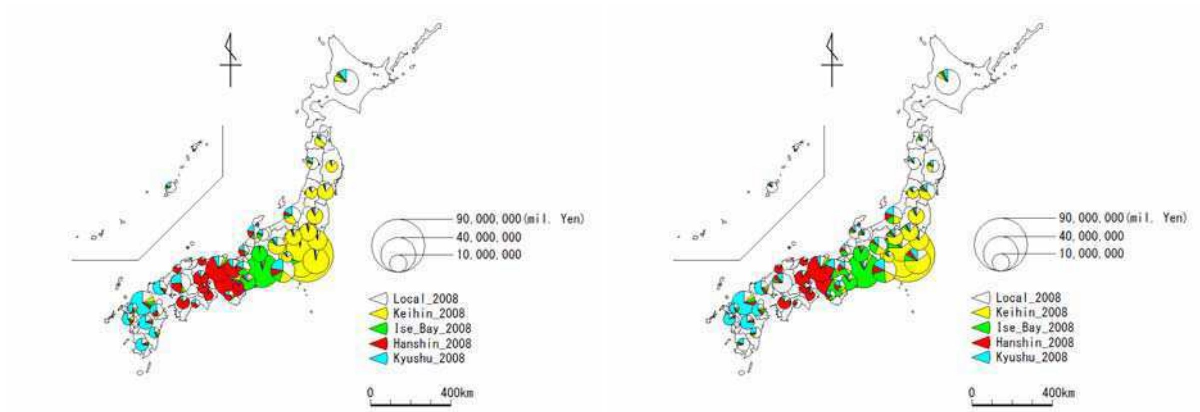
(a) Export **(b) Import**

Figure 10 – Port market area (membership function) in 1998 (Source: Devised by the author.)



(a) Export **(b) Import**

Figure 11 – Port market area (membership function) in 2003 (Source: Devised by the author.)



(a) Export **(b) Import**

Figure 12 – Port market area (membership function) in 2008 (Source: Devised by the author.)

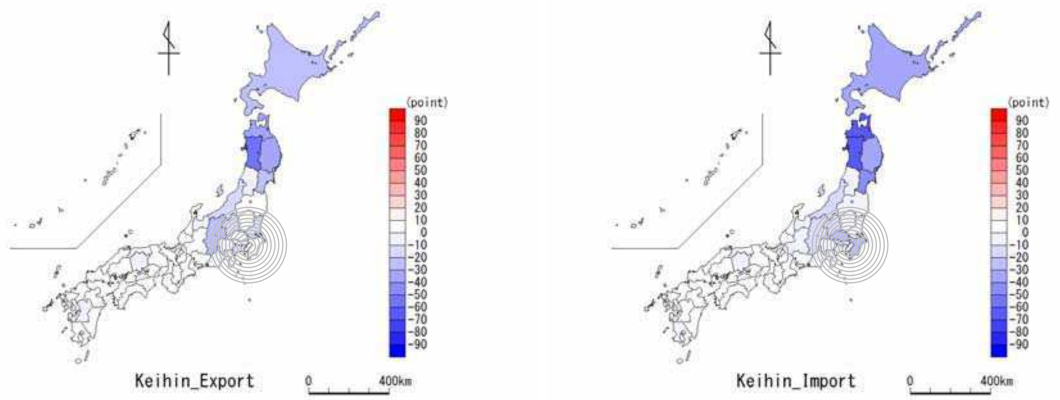
The results indicate that five clusters are constructed: (1) the Keihin ports group (*yellow* in figures): the ports of Tokyo and Yokohama; (2) the Ise Bay ports group (*green* in figures): the ports of Nagoya and Yokkaichi; (3) the Hanshin ports group (*red* in figures): the ports of

Osaka and Kobe; (4) the Kyushu ports group (*blue* in figures): the ports of Kitakyushu and Hakata; and (5) the local (regional) ports group (*white* in figures), which includes the cluster centroids. These first four clusters are constructed using the 'central international ports' which were designated as high standard ports in 1995, having North American and European routes. Each circle graph on the prefecture in the figures shows the degree of membership (u_{ik}) and the size of each circle shows the economic level of prefecture, or the gross regional products (GRP) at constant prices in 2000 (**Note**: these are not port traffic sizes on the database, because the survey only spans 1 month). The most noticeable point of this numerical analysis is that the database provides three-way data. Therefore, we can compare the changes of the degree of membership for each cluster over time, or how these differences show the changes in port market area.

Generally, these circle graphs become more complex as time passes, and the *white* segment (i.e. the local ports cluster) increases in remote regions after 2003, especially in the Tohoku region. For example, the Hanshin ports group maintained some market area in the Kyushu region for both export and import in 1988, which it lost after 1993. In contrast, the Kyushu ports group gained market area in the Chugoku region after 2003.

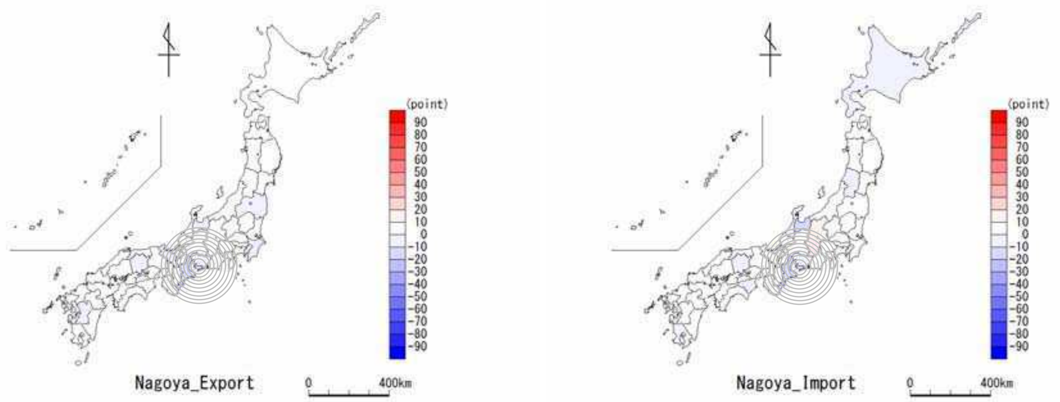
4.2. Port market area in Japan

To see visual changes in port market area for the five port clusters, we calculated the differences of *the degree of membership* for each cluster at each prefecture between 1993 and 2003 by applying a weighted moving average method (Figures 13, 14, 15, 16, and 17). A deeper red colour on the map for the prefecture indicates how much the ports cluster expanded its market area on the prefecture. By contrast, a deeper blue colour on the map for the prefecture shows how much the ports cluster lost market area in the prefecture (**Note**: a white colour for the prefecture indicates that the port market area expanded by 0-10 points). In total, the major Japanese ports groups lost imports and exports in Eastern and Western Japan to regional ports. For example, the Keihin port and the Hanshin port lost much of the Eastern Japan region (especially the Tohoku region and the Hokkaido prefecture) and the Western Japan region, respectively, because of regional port development and foreign transhipment expansion. The Hanshin ports cluster claimed a portion of the port market area in the Kyushu region in 1988, especially for export cargo, but gradually lost that share (Figure 15) because the budget was insufficient for both reconstruction and modernisation after the 1995 earthquake at the port of Kobe. By contrast, these port groups comparatively gained market area in regions that require more travel distance. The Ise Bay ports group expanded their port market area in the Kansai region and the Nagano prefecture for importing cargo, but lost its share of both exports and imports in the Mie prefecture, which is near the port of Nagoya. The port of Nagoya, which is the major port in the Ise Bay ports group, has road links with major highways leading to/from the Kanto (i.e. Tokyo) and Kansai (i.e. Osaka and Hyogo) areas, as well as new road improvements that connect the inland hinterland/foreland (i.e. the Nagano prefecture). The Kyushu ports group gained market area in the Kumamoto and Nagasaki prefectures for export cargo, but lost most of its market share in the Kyushu region for import cargo. The new container-dedicated terminal developments at the port of Hakata, which is part of the Kyushu ports group, support the handling of export cargo (e.g. plastics, rubber tires, tubes, auto parts) for Asian emerging markets. Finally, the local ports group gained significant market area in remote regions in Japan, as well as in the Eastern Japan, Shikoku, Chugoku, and South Kyushu regions. After the second half of the 1990s, Japanese regional port handling increased because of new port investments. For example, the ports of Hiroshima (in the Hiroshima prefecture) and Sendai (in the Miyagi prefecture) increased their port handling because of port investments by the national works budget after being designated as ‘special major ports’ in 1992 and 2001, respectively. The port of Sendai connected domestic feeder containers on Pacific routes with North America and provided new rail cargo services to complement the Tokyo Bay ports (i.e. the Keihin ports), since 1998 (MLIT, Figure 13). Moreover, the prefectures of Aomori, Iwate, Kochi, and Miyazaki created tight-positive connections with local ports by carrying basic commodities in 2008 (Ducruet et al., 2012a), indicating how the local ports’ market area increased on import cargo (Figure 17).



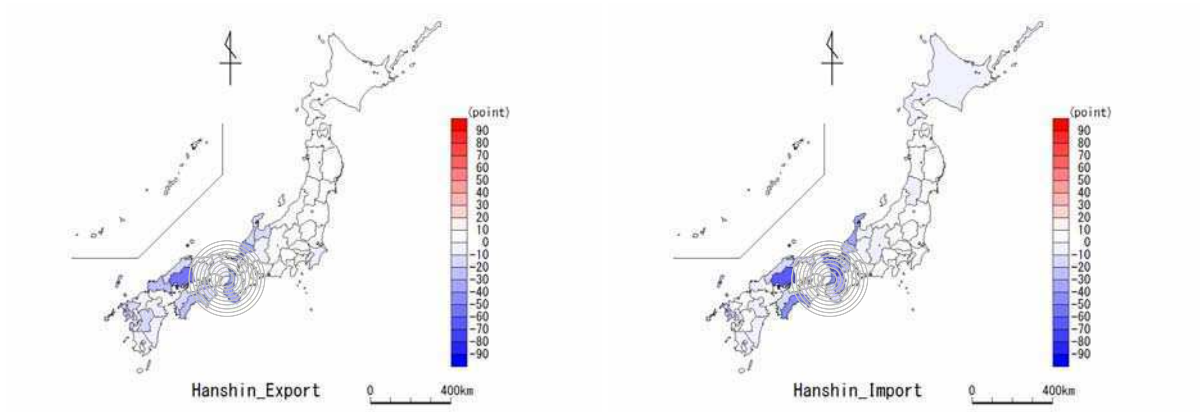
(a) Export **(b) Import**

Figure 13 – Keihin ports group’s market area changes (Source: Devised by the author.)



(a) Export **(b) Import**

Figure 14 – Ise Bay ports group’s market area changes (Source: Devised by the author.)



(a) Export **(b) Import**

Figure 15 – Hanshin ports group's market area changes (Source: Devised by the author.)

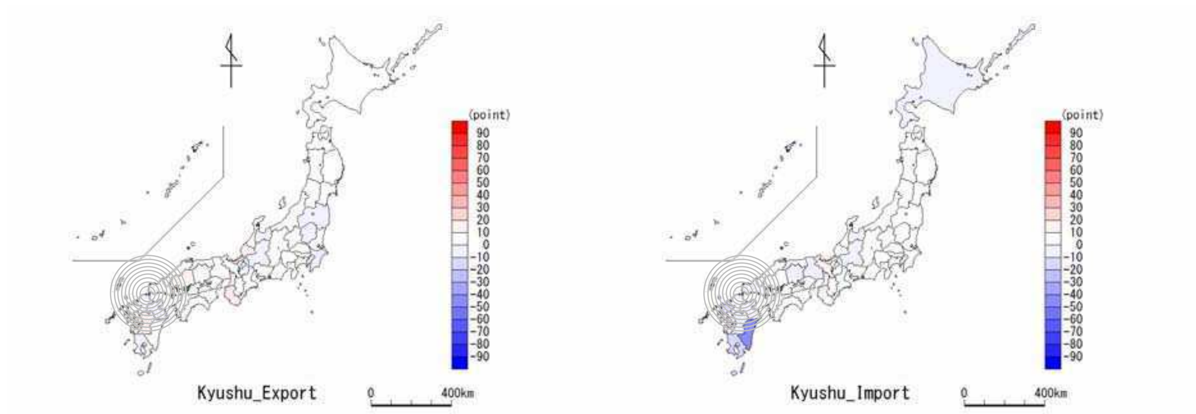
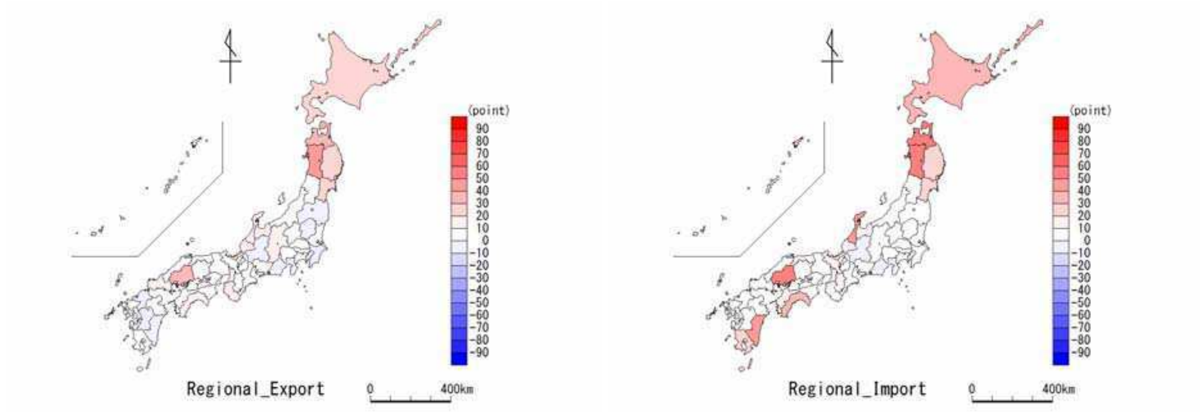


Figure 16 – Kyushu ports group's market area changes (Source: Devised by the author.)



(a) Export **(b) Import**

Figure 17 – Local ports group's market area changes (Source: Devised by the author.)

Although the handling shares of major Japanese ports for international container cargo (excluding the port of Kobe) did not experience a major drop in shares, their market areas had greatly changed in the past 20 years. In particular, major ports lost their market areas to their neighbouring areas, only having gained slight market area in remote areas (**Note**: these are the prefectures coloured white in the figures). This was caused by the increase of foreign transhipment cargo on the main routes to/from Western countries from/to Japanese regional ports. For example, the number of ship calls along the main routes to/from North America and Europe on major Japanese ports has been decreasing (Section 1). Therefore, contrary to our expectations, the market area of each major Japanese port(s) user group has been expanding thinly and widely: the port handling shares at regional ports, including the ports of Hakata and Kitakyushu, have increased. Some early empirical studies (Le and Ieda, 2010; Itoh, 2010, 2012) noted that the concentration levels of container handling at Japanese ports has been stable, slightly decreasing, or balanced with regional ports.

The Japanese government started a new port policy in 2011, and have invested in high-standard container terminals in two major ports groups, the Keihin and Hanshin ports, to support Japanese manufacturing companies and logistics service providers. However, these ports have gradually lost their domestic market areas in the past 20 years. By contrast, the geographical extent of the hinterland/foreland for these ports has expanded. For example, the Keihin ports group (i.e. the ports of Tokyo and Yokohama) and the Hanshin ports group (i.e. the ports of Osaka and Kobe) have started integrated operations as a business alliance based on the Act on Port Regulations and the Customs Act of the second half of the 2000s. The effects on port selection behaviour of shippers are expected to be seen in the near future. New port logistics companies started feeder services to the Hanshin port from Western regional ports in Japan in 2011, and the city of Kobe started the promotion program for domestic feeder services by taking foreign transhipment cargo via East Asian countries ports in 2012 (Kobe city, press release).

Finally, the ports of Tokyo and Yokohama will merge to become the 'Keihin port' and the ports of Osaka and Kobe will merge to become the 'Hanshin port' in 2014 and 2015, respectively. These 'business mergers' must support both operational efficiency at ports and domestic manufacturing companies' competitiveness against other Asian emerging economic regions through inland transportation network improvements and new container terminal improvements in place since 2005 (Shinohara, 2009). Specifically, the Hanshin port is enriching their port service level through the development of an inland container depot for their cargo. For example, they started a new contract for an inland container depot in Shiga prefecture that is near the Osaka port with Shandong International Transportation Corporation (SITC) and Orient Overseas Container Line (OOCL) in February 2013 (Osaka Port Corporation, press release). This is because the Hanshin ports group lost their port users (i.e. market area) in the Shiga prefecture. The port users changed their preferences to the Ise Bay ports group, according to the results of this study. Inland warehouse location is also an important factor for port selection in Japan, especially in major ports groups (Itoh, 2005). Many port and logistics activities also shifted inland around dry ports during the so-called regionalisation phase to expand hinterland control and relieve the seaport city from congestion and lack of space (Notteboom and Rodrigue, 2005).

5. Conclusion

The purpose of this analysis is to review the structural changes of port market areas in Japan by applying fuzzy clustering to time-series data. The applications of fuzzy clustering enable users to turn each port service area into a typology with visual mapping. The study period is 20 years, between 1988 and 2008, and the data is presented at five-year intervals. The results of the numerical analysis showed that there were various port user groups based on their port use propensities.

Although the handling shares for international container cargo of major Japanese ports (except the port of Kobe) did not have experience significant drops in shares, their market areas have greatly changed in the past 20 years. In particular, major ports have lost their market areas to their neighbouring areas, and have only gained slight market area in remote areas (i.e. regions). In contrast, the regional ports groups expanded their market areas in rural areas. Moreover, these structural changes of port market area vary between export and import cargo. For example, the Kyushu ports group lost much of their market area in the Kyushu region on import cargo, even though they had expanded them in some prefectures in the Kyushu region on export cargo because of the expanding Asian markets.

This study classified shippers (prefecture-wise) into port user groups in terms of their port use propensity based on the port handling volumes. However, this paper does not discuss the factors influencing the structural changes by using empirical testing. For further research, factor analysis explaining these changes is needed.

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