Changes in Japan's Inter-regional Business Linkage Structure

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Abstract:

In 1990's, Japan's domestic transportation service and telecommunication service had been improved owing to the investments of transportation facilities, and the information-technology revolution. Such improvement in communication technology would greatly influence on business linkage structure. This study estimates Japan's business network structure based on inter-regional information traffic data, in order to clarify longitudinal changes in branch office function headquarter and branch office arrangement. The results shows that branch-offices becomes to concentrate on transportation-hub cities. Further, the interactions between headquarter to branch office becomes much knowledge-intensive than before.

Key Words: Nation-wide firm, Branch Office, Communication Media Split

1. Introduction

In 1990's, Japan's domestic transportation and telecommunication service had been improved, and concurrently the knowledge-intensive business, which requires the intensive communication, becomes the most important activity in the economy. Improvement in communication technology would influence in two different ways, on inter-regional business linkages made up for business information interaction (Gatrell, 1999). One is to increase the interaction along the conventional linkages based on geographic adjacency. The other is to directly connect the distant regions. That direct connection can result both pulling out of branch offices in intermediate regions, so called as 'straw effect', and pushing the new office into local regions. In addition, there is a possibility of drastic restructuring in business linkage structure, on which geographic transportation accessibility is not important, so called as 'foot-loose economy' (Lyons 2003). Above influences should be carefully considered in long-term regional planning, as well as inter-regional transportation planning, because such change may cause a drastic change in not only inter-regional communication demand, but spatial distribution of economic activities (or arrangement of cities, in other words). Changes in latent inter-regional business linkage structure have so far been discussed intuitively, lacking theoretical or empirical bases. The empirical analysis based on statistical modeling is necessarily to clarify the change in business linkage structure influenced by an improvement of inter-regional communication technology.

Empirical study on business linkage structure was firstly started by geographers, because business linkages on an inter-regional office network represent the relations between cities (Goddard, 1971). When the vertically and strongly integrated business network made up of a large headquarter and small branches is widely adopted, a system of cities shows a strong hierarchy including a few number of mega cities. Such a system of cities is called Christaller type. Conversely, when the horizontally and weakly integrated business network, made up of not so large headquarter and several number of branches is dominant, such system of cities shows a weak hierarchy including some medium cities. It is called Pred type (Pred, 1976).

Conventionally, Japanese firms have been shaped vertically integrated linkage which headquarters mostly concentrate on Tokyo. However in eraly '90s, many researchers prospected that the Japanese system of cities would shift into Pred-type (with a weak hierarchy). The virtically integrated, conventional business linkage would not take an advantage, because increasing knowledge-intensive business activities (e.g. R&D) require wider and dynamic interactions, Abe surveyed administrative relationships among offices located different cities in '90, in Japan (Abe, 1996). His study found that the hierarchical business structure with highly concentrated in Tokyo, was still dominant. A similar survey for branch office location on inter-regional level conducted by Hino in

'94, also showed that the system of cities is mostly concentrated in Tokyo (Hino, 1999).

Okabe compared Japanese car industry firms to Americans in terms of business linkage structure (Okabe, 2001). Her study showed that American firms rapidly shift into horizontal business linkage, but Japanese firms remain with vertical business linkage. Then, Okabe pointed out that Japanese firms are used to a closed sharing of business information, so that fixed and stable communication on vertically integrated linkage remains. Akiyama discussed that the organization of firms should become more flexible and adoptive for the change in business environment, e.g., price of goods or customer's demand (Akiyama, 2001). Both vertical linkage and horizontal linkage have different disadvantages for adoptive changes, such as creativity for new business, or controllability for promoting. Hanibuchi investigated longitudinal change in business linkage structure by using the national yearbooks of enterprises in 1980, 1990, and 2000, sampling over 1,000 representative firms for each year (Hanibuchi, 2002). Hanibuchi's study reported that the total number of branch offices in local city is unchanged, due to the balancing newly located offices with abolished offices, therefore the restructuring in business network is still on going.

Theoretical analysis on spatial distribution of economic activities are begun with 'a system of cities', which purposes to clarify the formation of a city-system considering positive and negative externalities caused by a agglomeration of economic activities (Ueda, 1995). However, only a few studies considering business linkage have been done. Mun studied an influence of communication cost (face to face and telecommunication) on office location on two-city system and one firm, applying general equilibrium approach for goods, labor, and land use market of each city (Mun, 1993). Simular analysis on three-city system and two firms is done by Gersbach and Schmutzlar, whose study considers a inter-firm spillover of production technology (Gersbach and Schmutzlar, 2000). Other approach for business linkage structure is based on simulation using actual communication and office location cost. Itoh compared the total cost summing up the communication and office location cost between the case of office in major cities, and the case of office in non-major cities (Itoh, 1999). A total cost of the later case is lower than the former case. Suda simulated multiple branch office locations covering whole regions in Japan, and clarified the influence of communication cost on office location (Suda, 1998).

As repeatedly discussed in above studies, inter-regional communication cost is an important determinant for business linkage structure. IT (Information Technology) revolution in early '90s which brought a 'death of distance' society would certainly make a change in business communication (Cairncross, 1997). In case that IT substitutes most of business face to face communication, economic activities would not be bound to spatial agglomeration. In order to clarify the substitutive or complementary relationship between face to face communication and telecommunication, questionnaire surveys for individual office worker have been done. The surveys in Japan showed that emerging IT media sub-
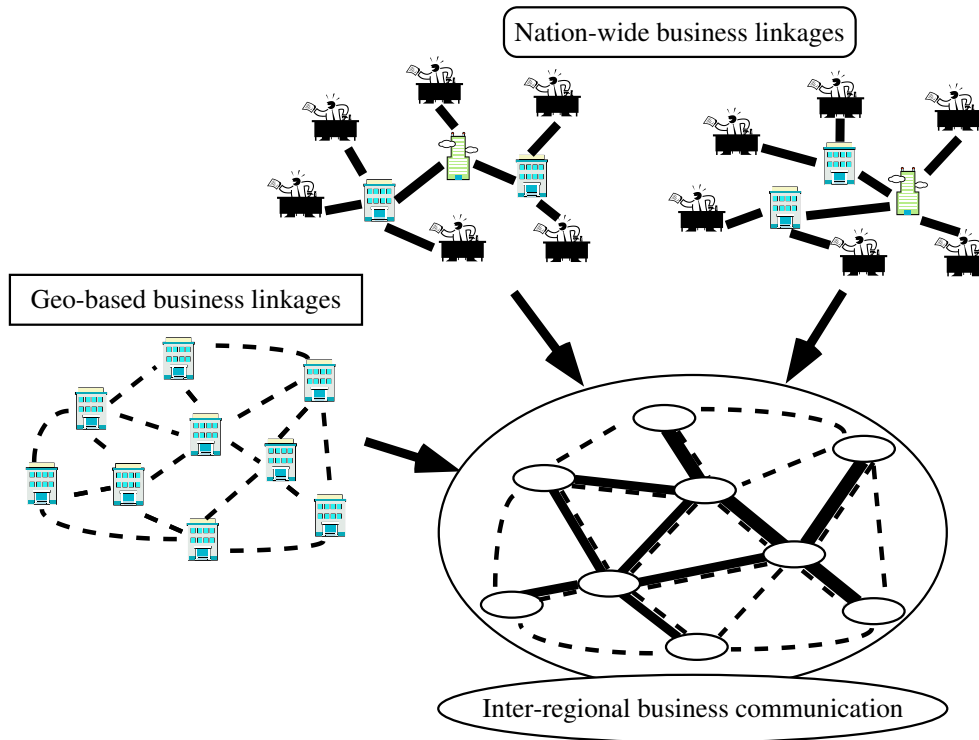
Fig.1 Overlaying different types of business linkage

stitute only for conventional telecommunication media, rather they are complementary
to face to face communication (Takita, 1995). Mokhtarian conducted communication diary
survey, twice with six months interval (Mokhtarian, 1999). The longitudinal change
in communication media use also suggests complementary relationships between face
to face and telecommunication. Imagawa analyzed the aggregated inter-regional business
communication traffic by estimating gravity type model, then also found that telecommunication
is complementary to face to face communication (Imagawa, 2001). According to
office communication studies, telecommunication with lower interaction cost is used in
order to have efficient face to face communication with higher interaction cost. Therefore,
accessibility on transportation network is still significant on business communication, but
the influence of lower interaction cost provided by telecommunication on business linkages
would not be ignored.

This study purposes to clarify the change in business linkage structure, which would
significantly influence on the inter-regional business interaction. We considered that observed
communication traffic is made by local firms, and by nation-wide firms. **Fig.1**
shows the concept of traffic overlaying. There are two types of business linkages, one is
conventional geo-based linkages of local firms, the other is linkages of nation-wide firms,
covering whole regions.

The proposed model system consists of three sub-models; hierarchical branch-office location model, gravity model, and communication media split model. The hierarchical branch-office location model describes the business linkage structure covering nation-wide regions. This model considers a headquarter, branch offices, and customers. The optimal business linkage structure are obtained by a minimization of the total cost including branch office location and communication cost. Given a headquarter region and the index of branch-office function, the hierarchical branch-office location model outputs possible business linkage patterns of nation-wide firms. A gravity model describes conventional geo-based linkages. Communication media split model is required to estimate an unit communication cost, as inputs to the hierarchical branch-office location model. In this study, media split between transportation and telecommunication is modeled, because knowledge-intensive business requires intensive communication by using these media.

Both the gravity model for conventional geo-based linkages and the weights of business linkage patterns of nation-wide firms obtained by hierarchical branch office location model, are simultaneously estimated with communication media split model. Note that the estimated nation-wide firm's business linkage structure do not correspond to the specific industries or particular firms, but captures the representative linkages embedded in an aggregated communication traffic. This model can capture a cross-sectional business linkage structure. Therefore, we repeatedly applied the system for 1990 and 1995, and compared the estimated structures in order to clarify longitudinal change. Hence, 'straw effect' will be clarified by the change in business linkage structure.

The following sections are organized as follows. **Sec.2** formulates three of sub-models; gravity model, hierarchical branch-office location model, and communication media split model. Then, the estimation procedure of integrated model system including three sub-models is proposed. **Sec.3** shows the estimated business linkage structure from the integrated model. Finally, **Sec.4** summarizes the discussion, and shows further research issues.

2. Model Formulation

This section formulates the three of sub-models; hierarchical branch-office location model, gravity model, and communication media split model, corresponding to nation-wide firm's linkage, geo-based firm's linkage, and communication media split, respectively. After these formulations, the estimation procedure of integrated model system is shown.

2.1 Hierarchical Branch-office Location Model

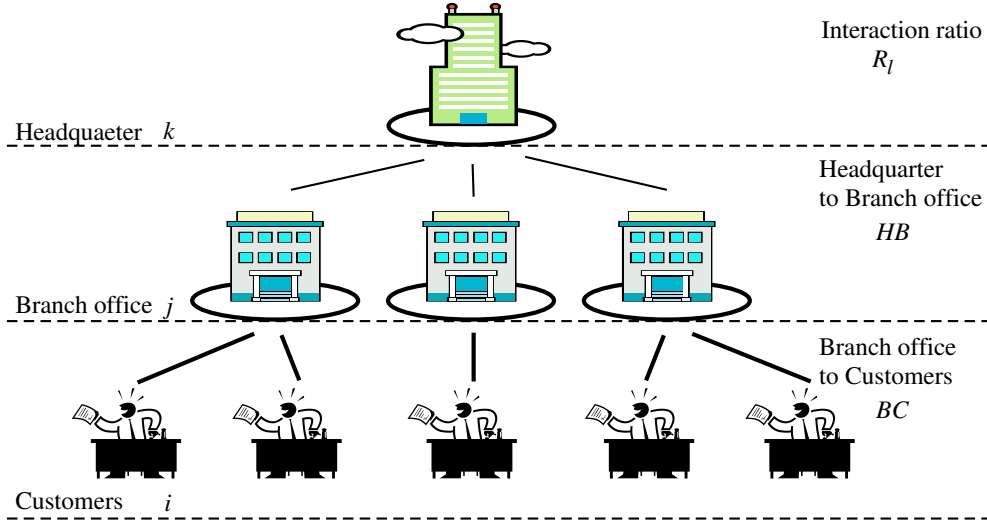Nation-wide firm in this study is supposed to fulfill following assumptions (Tsukai, 2001).

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Fig.2 Hierarchical business linkage structure

1) The nation-wide firm covers the 46 prefectures (except Okinawa prefecture).

2) The firm has a hierarchical structure with a headquarter, several branches, and customers in 46 prefectures. A headquarter has linkages with each branch offices, and each branch has linkages with each customer within the covering prefectures. (Headquarter can not directly cover the customers).

3) Interaction between headquarter and each branch is proportional to the total interaction between branch and the customers.

4) Headquarter and branch office need a fixed cost to locate.

Fig.2 shows the hierarchical business linkage structure corresponding to the assumption 2). According to the assumption 3), the ratio of the interaction between headquarter and each branch, HB_{jk}, to the interaction between branch and customer, BC_{ij}, is called *interaction ratio*, R_l. Branch office accepts the requests from customers. Within the accepted requests, some are fulfilled in the branch, others are transmitted to the headquarter. Therefore, HB_{jk} is less than $\sum_i BC_{ij}$ then R_l ranges from 0 to 1. A branch office with high functions which transmits only a few within the accepted requests, its R_l is close to 0, and a branch office with low functions which transmits almost all the accepted requests, its R_l is close to 1.

A problem to locate several facilities in a discrete candidate points by minimizing sum of interaction cost and location cost (fixed cost for a facility) is formulated as incapacitated facility location model, which has been studied in Operations Research. Hierarchical branch office location model has the upper interaction between headquarter and branch

with R_l proportional to lower interaction modeled in conventional incapacitated facility location problem.

Here, a city headquarter locates is indicated by k, dummy variables to indicate each branch office location in city j are y_j, and dummy variables to indicate the supervising linkage between branch office city j and customer city i are x_{ij}(i, j, k indicates 46 cities). Given k and R_l, hierarchical branch office location model is formulated as follows;

$$\min_{y_j, x_{ij}} Z^{kl} \quad = \quad \min_{y_j, x_{ij}} \sum_{i \in I} \sum_{j \in J} C_{ij}^{BC} W_i x_{ij}^{kl} + R_l \sum_{j \in J} C_{jk}^{HB} \sum_{i \in I} W_i x_{ij}^{kl} + \sum_{j \in J} F_j y_j^{kl} + D_k \quad (1)$$

where, Z^{kl} is total cost, W_i is number of customers in i. C_{ij}^{BC} is a unit interaction cost between branch at j and customers in i, C_{ij}^{HB} is a unit interaction cost between headquarter at k and branch at j, F_j is a fixed cost for branch office of j, and D_k is a fixed cost for headquarter of k. Constraints are follows;

$$\sum_{i \in I} x_{ij}^{kl} = 1 \qquad \forall i \in I \qquad (2)$$

$$x_{ij}^{kl} \leq y_i^{kl} \qquad \forall i \in I, \forall j \in J \qquad (3)$$

$$x_{ij}^{kl} \in \{0, 1\} \qquad \forall i \in I, \forall j \in J \qquad (4)$$

$$y_j^{kl} \in \{0, 1\} \qquad \forall j \in J \qquad (5)$$

Eq.(2)corresponds to the assumption 1) to cover all the prefectures are covered. Eq.(3) is a consistency condition that linkage x_{ij} can not be made without a branch office in j, eq.(4)and eq.(5)are integer conditions.

This is a integer programming problem in x_{ij}, y_j. Simplex method can apply for a linear programming problem without Eq.(4) and Eq.(5), but it is not efficient because infeasible, non-integer solutions may be obtained. Instead, dual ascent / dual adjacent procedure which ascents duality variables in order to maximize a duality problem for eq.(1),proposed by Erlenkotter, can efficiently find the optimal, or at least feasible solutions (Erlenkotter, 1978).

In this model, 9 points of R_l are discretely set ($R_l = 0.1, \cdots, 0.9$). Through minimization of total cost, Z^{kl} of eq.(1), given headquarter k and interaction ratio R_l, linkages between branch office and customer, x_{ij}^{kl}, and branch office locations, y_j^{kl}, are obtained. We call x_{ij}^{kl} and y_j^{kl} as business linkage pattern.

The interactions by nation-wide firms, N_{ij}, is made up of the business linkages both headquarter to branch office, and branch office to customers. The former is $HB_{ij}^{kl} = R_l \sum_g W_g x_{gj}^{kl}$, and the later is $BC_{ij}^{kl} = W_i x_{ij}^{kl}$. The natuion-wide business linkage consists of several kinds of patterns of different headquarter, k, and different interaction ratio, R_l. Therefore, N_{ij} is formulated as follow;

$$N_{ij} \quad = \quad \sum_k \sum_l \beta^{kl} (HB_{ij}^{kl} + BC_{ij}^{kl}) \qquad (6)$$

where, β^{kl} are weight parameters for each business linkage patterns with headquarter, k and interaction ratio, R_l. Note $\beta^{kl} > 0$.

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2.2 Gravity model for geo-based firm

Interaction by geo-based firms, I_{ij}, is formulated by gravity type model, as follow;

$$I_{ij} = A(P_i P_j)^{\alpha}(ttime_{ij})^{\psi}(tcost_{ij})^{\upsilon}(ccost_{ij})^{\phi} \tag{7}$$

where, P_i and P_j are number of employees in city i and j, $ttime_{ij}$, $tcost_{ij}$, and $ccost_{ij}$ are passenger transportation time, passenger transportation cost, and telecommunication cost, respectively. α, ψ, υ, ϕ, and A are parameters.

2.3 Communication media split model

Total interaction between city i and j, TI_{ij}, is sum of interaction by nation-wide firm, N_{ij}, and interaction by geo-based firm, I_{ij} (Okumura and Tsukai, 1999).

$$TI_{ij} = I_{ij} + N_{ij} \tag{8}$$

Based on a difference in characteristics, called 'media-richness', of face to face communication and telecommunication shown in previous studies, we can consider the mechanism of communication media split between transportation and telecommunication (Daft and Lengel, 1986). Face to face communication is often used for negotiation or knowledge-intensive transmission, so that it can transmit more complicate contents than telecommunication. In other words, the contents transmitted by one time of face to face communication are identical to that by several times of telecommunication.

When an employee transmits a contents to others, firm makes a choice whether one time of face to face communication, or z times of telecommunications which can transmit the contents equivalent to one time of face to face. Here, z is an index of transmission difficulty. Consider the cost ratio between transportation and telecommunication in ij, as z_{ij}^0. When $z < z_{ij}^0$, total transmission cost is lower in use of z times of telecommunication, but when $z > z_{ij}^0$, total transmission cost is lower in use of one time of face to face communication. Since total interaction in ij, TI_{ij}, includes various contents characterized by a index z, we assume Weibull distribution with scale of 2, as a distribution of z included in TI_{ij}. Eq.(9)to(11) can be derived as a communication media split model;

$$TR_{ij} = TI_{ij} \int_{z_{ij}^0}^{\infty} f_{ij}(z)dz + \varepsilon_{ijt} \tag{9}$$

$$TC_{ij} = TI_{ij} \int_{0}^{z_{ij}^0} z f_{ij}(z)dz + \varepsilon_{ijc} \tag{10}$$

$$f_{ij}(z) = \frac{2z}{\rho_{ij}^2} \exp\left(-\left(\frac{z}{\rho_{ij}}\right)^2\right) \tag{11}$$

where, TR_{ij} and TC_{ij} are observed transportation, and telecommunication traffic, respectively. $f_{ij}(z)$ is a distribution function of transmission difficulty, ε_{ijc} and ε_{ijt} are error terms
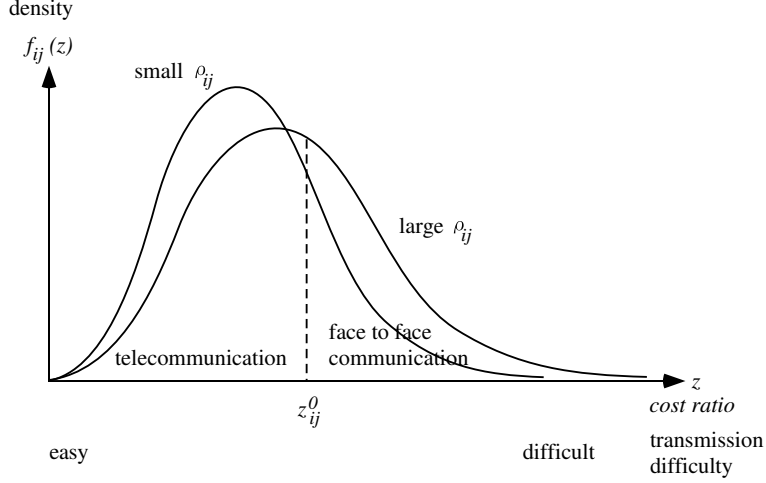
Fig.3 ρ_{ij}, **and a distribution function of transmission difficulty,** $f_{ij}(z)$

in eq.(9), and in (10), respectively. Cost ratio, z_{ij}^0, is defined as the ratio between generalized transportation cost and telecommunication cost, as $z_{ij}^0 = gcost_{ij}/ccost_{ij}$. Note in communication media split model, one time of face to face communication is substituted by several times telecommunication, so that TI_{ij} (interaction in ij) is not eqal to the sum of observed transportation traffic, TR_{ij}, and observed telecommunication trafic, TC_{ij}.

Fig.2 shows a mechanizm of communication media split based on transmission difficulty function, $f_{ij}(z)$, and cost ratio, z_{ij}^0. When a parameter ρ_{ij}, (> 0), included in eq.(11) is large, the median of transmission difficulty shifts to right-hand side (higher in difficulty), then an area for face to face communication becomes large. The parameter ρ_{ij} is proportional to an average transmission difficulty parameter $E[z]$, as $E[z] \simeq 0.886 \, \rho_{ij}$. Now we call ρ_{ij} as transmission difficulty in ij, for convenience.

Transmission difficulty parameter, ρ_{ij}, would differ for each OD. Especially, on the linkage of nation-wide firm between headquarter and branch office, the requests collected from customers are turned into more knowledge-intensive contents with higher transmission difficulty by through the branch office.Therefore, transmission difficulty of HB_{ij} would be higher than that of BC_{ij}. Based on above consideration, ρ_{ij} is formulated as follows;

$$\rho_{ij} = \omega d_{ij}^{\gamma} + \theta_1 r_{ij}^{HB} + \theta_2 r_{ij}^{BC} \tag{12}$$

where, $r_{ij}^{HB} = \sum_k \sum_l \beta^{kl} HB_{ij}^{kl}/TI_{ij}$ and $r_{ij}^{BC} = \sum_k \sum_l \beta^{kl} BC_{ij}^{kl}/TI_{ij}$ are the shares of interaction of HB_{ij}, or BC_{ij}, in TI_{ij}, respectively. d_{ij} is distance. ω, γ, θ_1, θ_2 are parameters. The estimated parameters would be $\theta_1 > \theta_2$, resulting in $C_{ij}^{HB} > C_{ij}^{BC}$. That is, average interaction cost of headquarter to branch office is higher than that of branch office to customers.

2.4 Estimation procedure for business linkage

Average interaction cost, C_{ij}^{HB}, and C_{ij}^{BC} are the function not only of transportation service level, and telecommunication service level, but of the share of nation-wide firm's interaction in TI_{ij}, on business linkages x_{ij}. On the other hand, business linkage, x_{ij}, are obtained through the minimization of Z^{kl} including C_{ij}^{BC} and C_{ij}^{HB}. At the equilibrium, average interaction cost input into the hierarchical branch office location model should be identical to the output from the communication media split model with r_{ij}^{HB} and r_{ij}^{BC} based on x_{ij} input. In order to estimate the parameters at the equilibrium, integrated model requires iterative calculation procedure.

2.4.1 Initial setting

As an initial setting, we consider only geo-based firm's interaction; i.e. $TI_{ij} = I_{ij}, \beta^{kl} = 0$, $\rho_{ij} = \omega d_{ij}^{\gamma}(\theta_1 = \theta_2 = 0)$. With these setting, communication media split model and gravity model; i.e., eq.(9), (10), (11) and eq.(7)) are simultaneously estimated in order to obtain initial values of parameters as $\omega, \gamma, \alpha, \psi, \upsilon, \phi, A$. Based on these initial values, initial estimates of $\widehat{TI}_{ij}, \widehat{TR}_{ij}, \widehat{TC}_{ij}$ are obtained. Further, initial average interaction cost, $\overline{C_{ij}}$, is calculated by eq.(13);

$$\overline{C_{ij}} \quad = \quad \frac{ccost_{ij}\widehat{TC}_{ij} + gcost_{ij}\widehat{TR}_{ij}}{\widehat{I}_{ij}} \tag{13}$$

where, $gcost_{ij}$ is generalized transportation cost reflecting time and cost$(step-1)$

$\overline{C_{ij}}$ is input into hierarchical branch office location model as both C_{ij}^{HB}, and $C_{ij}^{BC}(C_{ij}^{HB} = C_{ij}^{BC} = \overline{C_{ij}})$. Miyagi, Tokyo, Aichi, Osaka, Hiroshima, and Fukuoka are set as headquarter cities k. For 6 headquarter cities above, 9 points of R_l are considered. Then for 54 business linkage patterns, x_{ij}^{kl} are estimated by minimization of each Z^{kl}. x_{ij}^{kl} are converted into the headquarter to branch office interaction, HB_{ij}^{kl}, and branch office to customer interaction, $BC_{ij}^{kl}(step-2)$. Total interaction TI_{ij} made up of nation-wide firm's interaction of eq.(6), and geo-based firm's interaction of eq.(7) are simultaneously estimated with communication media split model of eq.(9) to (11), then parameters $\beta^{kl}, \omega, \gamma, \alpha, \psi, \upsilon, \phi$, and A are obtained. Based on the estimated parameters, r_{ij}^{HB} and r_{ij}^{BC} which are the shares of interaction of HB_{ij}, or BC_{ij}, in TI_{ij}, respectively, are calculated$(step-3)$.

Until $step-3$, average interaction cost, C_{ij}^{HB} and C_{ij}^{BC} that nation-wide firm faces, can not be calculated because the parameters θ_1 and θ_2 are not yet estimated. Using r_{ij}^{HB} and r_{ij}^{BC}, parameters θ_1 and θ_2 in eq.(12) are simultaneously estimated with other parameters, $\beta^{kl}, \omega, \gamma, \alpha, \psi, \upsilon, \phi$, and A in eq.(6) to (11).

In next step, initial setting for C_{ij}^{HB} and C_{ij}^{BC} are calculated using θ_1 and θ_2.

$$C_{ij}^{HB} = \frac{ccost_{ij}\widehat{TC}_{ij}^{HB} + gcost_{ij}^*\widehat{TR}_{ij}^{HB}}{\widehat{TI}_{ij}^{HB}} \tag{14}$$

$$C_{ij}^{BC} = \frac{ccost_{ij}\widehat{TC}_{ij}^{BC} + gcost_{ij}^*\widehat{TR}_{ij}^{BC}}{\widehat{TI}_{ij}^{BC}} \tag{15}$$

where, $\widehat{TC}_{ij}^{HB}$, $\widehat{TR}_{ij}^{HB}$, $\widehat{TI}_{ij}^{HB}$ are the estimates of transportation, telecommunication, and total interaction, respectively, for headquarter to branch office interaction, i.e., $r_{ij}^{HB} = 1$ and $r_{ij}^{BC} = 0$. $\widehat{TC}_{ij}^{BC}$, $\widehat{TR}_{ij}^{BC}$, $\widehat{TI}_{ij}^{BC}$ are the estimates for branch office to customers interaction, i.e., $r_{ij}^{HB} = 0$ and $r_{ij}^{BC} = 1$. Further, r_{ij}^{HB} and r_{ij}^{BC}, shares of nation-wide firm's interaction in TI_{ij}, are renewed ($step - 4$).

2.4.2 Iteration Procedure

Input C_{ij}^{HB} and C_{ij}^{BC} into hierarchical branch office location model, x_{ij}^{kl} are obtained. Based on x_{ij}^{kl}, corresponding HB_{ij}^{kl} and BC_{ij}^{kl} are calculated, in order to renew r_{ij}^{HB} and r_{ij}^{BC}, respectively($step - 5$). Given the renewed r_{ij}^{HB} and r_{ij}^{BC}, parameter β^{kl}, ω, γ, θ_1, θ_2, α, ψ, υ, ϕ, and A are renewed by re-estimation of eq.(6)to(11). Then, r_{ij}^{HB}, r_{ij}^{BC}, C_{ij}^{HB}, and C_{ij}^{BC} are renewed again, respectively($step - 6$).

$Step-5$ and $step - 6$ are iterated until average interaction cost C_{ij}^{HB} and C_{ij}^{BC} are converged, or until branch office location y_j^{kl} and business linkage x_{ij}^{kl} are converged. The converged parameters, y_j^{kl}, and x_{ij}^{kl} are considered as outputs of integrated model. Simultaneous estimation in $step-1, 3, 4, 6$ is done by applying NLFGLS, Non-Linear Feasible Generalized Least Square method. **Fig.4** shows the iteration procedure of the integrated model.

3. Estmation and Discussion

3.1 Data

We applied the integrated model to '90 and '95 situations. Transportation traffic, TR_{ij}, is business passenger trip data between 46 prefectures except Okinawa prefecture, based on the National Net Passenger Trip Survey. Telecommunication traffic, TC_{ij}, is business telephone traffic data between 46 prefectures, based on NTT business line data, and NCC line data. In case of a passenger trip made by calling from headquarter, or a telephone call back, a direction of trip or of telephone is not identical to the direction of transmission, so that symmetrized traffic data is used in following analysis.

Transportation cost is based on TRANET system provided by Ministry of Land and Transportation, on the shortest travel time path. Generalized transportation cost, $gcost_{ij}$,
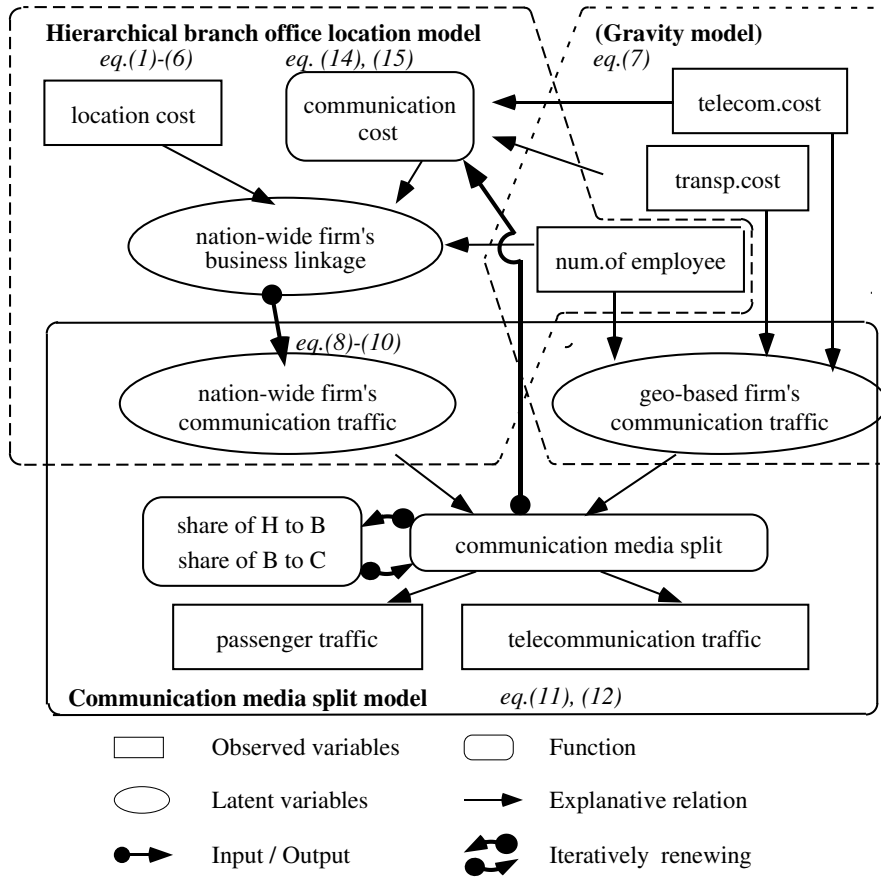
Fig.4   Iteration procedure of integrated model

is calculated as follows; time and cost is added with value of time as 25 dollar / hour, and rail and air is aggregated by using transportation modal split from the Net Passenger Trip Survey. Telecommunication cost is a cost of average calling cost, by calculating telephone call cost times average call time. Branch office location cost and headquarter location cost, F_j and D_k, are based on the actual office rents database.

3.2   Results of estimation

On a calculation for integrated model, some of branch office location are instable that two sets of y_j^{kl}, and x_{ij}^{kl} are alternately estimated, which makes parameters in transmission difficulty, ω, γ, θ_1, θ_2, instable. In order to get stable estimates, we added a constraints on the transmission difficulty parameters, i.e.; $\theta_2 = 0$ for '90, and $\theta_1 = 0$ for '95. under these constraints, parameters are converged. Among 54 possible patterns of N_{ij} (6 headquarters, and 9 points of R_l), the combination of N_{ij} which gives significant β^{kl} for observed traffic, is found. **Table.1** shows the estimation results of integrated model, which are converged after 5 iterations for '90, after 9 iterations for '95.

The order of t-values among distance-decay parameters in geo-based firm's interaction,

I_{ij}, is transportation cost, telecommunication cost, and transportation time in both '90 and '95. Constant of distance, ω, and power of distance, γ, in transmission difficulty are estimated positive and significant in both '90 and '95. A parameter of share of headquarter to branch office interaction, θ_1, is estimated positive, but insignificant(in '90). Therefore, a higher share of headquarter to branch office, r_{ij}^{HB}, results in higher transmission difficulty. A parameter of share of branch office to customer interaction, θ_2, is estimated negative and significant(in '95). Therefore, a higher share of branch office to customer, r_{ij}^{BC}, results in lower transmission difficulty. Both θ_1 and θ_2 fulfills the condition of $C_{ij}^{HB} > C_{ij}^{BC}$.

As to N_{ij} in '90, 5 patterns of business linkages are estimated in the converged result. In order to quantify the share of nation-wide firm in total interaction, PN as the share of nation-wide firm (all patterns) in total interaction, and PN^{kl} as the share of each pattern with kl in total interaction, are defined;

$$
\begin{aligned}
PN &= \sum_{ij}\left(r_{ij}^{HB} + r_{ij}^{BC}\right) = \frac{\sum_{ij}\sum_{kl}\beta^{kl}(HB_{ij}^{kl} + BC_{ij}^{kl})}{\sum_{ij}TI_{ij}} \\
PN^{kl} &= \frac{\sum_{ij}\beta^{kl}(HB_{ij}^{kl} + BC_{ij}^{kl})}{\sum_{ij}TI_{ij}}
\end{aligned}
$$

In '90, a share of nation-wide firm, PN, is 9.92%. Shares of each pattern, PN^{kl} in '90 are descendingly ordered as follows ($R_l : PN^{kl}$); Tokyo decentralized (0.6 : 7.83%), Osaka(0.3 : 1.56%), Fukuoka(0.7 : 0.31%), Miyagi(0.4 : 0.12%), Hiroshima(0.5 : 0.09%). β^{kl} of Tokyo decentralized, Osaka, and Fukuoka are significant. **Fig. 5** shows the branch office location and territories in '90. Branch offices in Tokyo decentralized(0.6) pattern are located in Hokkaido, Tokyo, Aichi, Osaka, Hiroshima, and Fukuoka. Branch offices in Osaka pattern (0.3) are located in Hokkaido, Miyagi, Tokyo, Aichi, Hiroshima, and Kumamoto. In '90, sum of PN^{kl} of Tokyo decentralized (0.6) and Osaka(0.3) is 9.39%, that is over 90% in nation-wide firm's share, 9.92%. As to N_{ij} in '95, 7 patterns of stable business linkages are estimated; i.e., Tokyo centralized(0.7 : 2.96%), Tokyo decentralized(0.3 : 2.64%), Osaka(0.3 : 1.37%), Fukuoka(0.5 : 1.14%), Miyagi(0.4 : 0.40%), Hiroshima(0.5 : 0.32%), and Aichi(0.5 : 0.07%). β^{kl} are significant except Aichi. **Fig.6** shows the branch office location and territories in '95. Branch offices in Tokyo centralized (0.7) pattern are located in Hokkaido and Tokyo. Branch offices in Tokyo decentralized (0.3) pattern are located in Hokkaido, Miyagi, Tokyo, Aichi, Osaka, Hiroshima, and Kumamoto. Branch offices in Osaka (0.3) pattern are located in Hokkaido, Tokyo, Aichi, Osaka, and Kumamoto. Branch offices in Fukuoka (0.5) pattern are located in Hokkaido, Tokyo, Osaka, and Fukuoka. In '95, sum of 4 patterns of PN^{kl}, Tokyo centralized (0.7), Tokyo decentralized (0.3), Osaka (0.3), and Fukuoka (0.5) is 8.12%, that is barely over in nation-wide firm's share, 8.91%.

Table 1 Results of estimations of integrated model

	variables / headquarter	parameters	'90	'95
I_{ij}	constant	A	0.080	0.028
			(1.54)	(1.59)
	sum of employee	α	1.677 **	1.715 **
			(44.68)	(47.64)
	transportation time	ψ	-0.237 **	-0.254 **
			-(3.47)	-(3.62)
	transportation cost	ν	-1.187 **	-1.233 **
			-(21.24)	-(24.76)
	telecommunication cost	ϕ	-0.312 **	-0.257 **
			-(6.89)	-(6.80)
$N_{ij}^{\dagger}$	Miyagi headquarter	0.4/0.3‡	0.361	1.088 **
			(1.92)	(3.62)
	Tokyo decentralized	0.6/0.3	22.188 **	6.294 **
			(5.68)	(3.00)
	Tokyo centralized	-/0.7	-	7.512 **
			-	(3.32)
	Aichi headquarter	-/0.2	-	0.227
			-	(0.31)
	Osaka headquarter	0.3/0.3	5.207 **	3.929 *
			(3.49)	(2.40)
	Hiroshima headquarter	0.5/0.4	0.241	0.798 **
			(1.11)	(3.15)
	Fukuoka headquarter	0.7/0.5	0.742 **	2.585 **
			(3.03)	(5.04)
ρ_{ij}	constant of distance	ω	0.358 **	0.418 **
			(10.92)	(14.12)
	power of distance	γ	0.116 **	0.133 **
			(20.96)	(26.44)
	share of H to B	θ_1	0.055	-
			(1.66)	-
	share of B to C	θ_2	-	-0.424 **
			-	-(5.48)
	R^2 for telecom.		0.887	0.905
	R^2 for transportation		0.769	0.820
	share of nation-wide firm, PN		9.92%	8.91%

** : significant with 1%, * : significant with 5%
† weights parameters of each pattern, β^{kl} are shown
‡ R_l in '90 / R_l in '95

3.3 Comparison of results, and consideration

Comparing the estimation results in '90 and '95, absolute values of parameters for transportation time, and for transportation cost become large, but that for telecommunication cost become small on geo-based firm's interaction. Above changes suggest that the influence of level-of-service about transportation, on information interaction becomes strong.
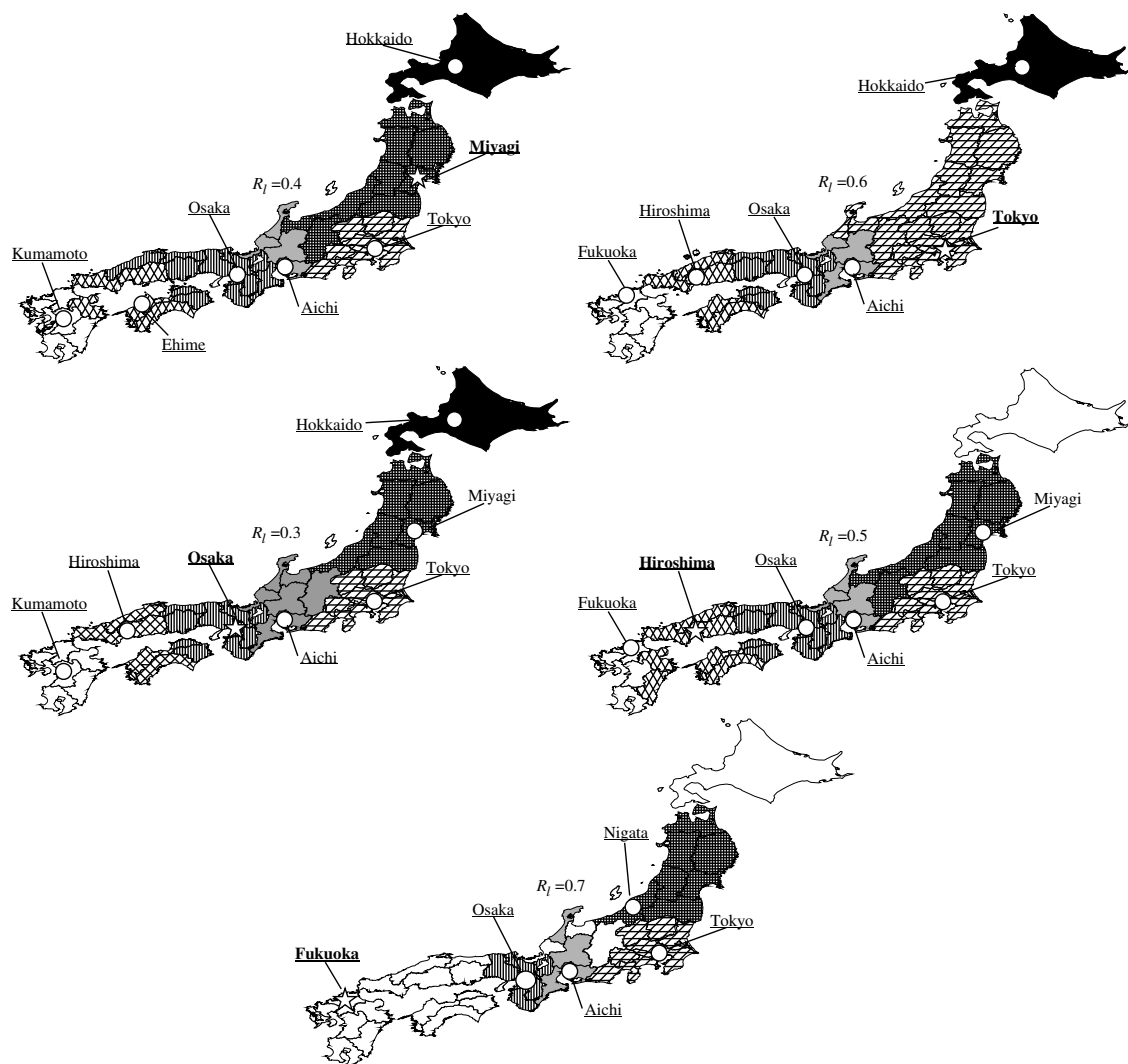
Fig.5 Branch office location and territories in '90
(: Headquarter : Branch office)

Constant of distance, ω, and power of distance, γ, in transmission difficulty also become large, which shows that an average transmission difficulty is higher in '95 on geobased interaction. Share of nation-wide firm decreased about 1 point, from 9.92% to 8.91%. In '95, difference between headquarter to branch office interaction cost, C_{ij}^{HB}, and branch office to customer interaction cost, C_{ij}^{BC}, become large in '95 with significant estimate in θ_2. **Fig.7** shows historically observed prefectures groups and regional center cities. Comparing these groups with the estimated territories in **Fig.5** and **Fig.6**, Tohoku, Kanto, and Kansai are not divided into different territories for any headquarter k, or any R_l. However, Tokai, Koshinetsu, Hokuriku, Cyugoku and Shikoku area are sometimes divided into different territory, or supervised by a branch located in different area, depending on k and R_l. Since the later areas do not have a distinct city in each area, and since the adjoining of these area have more customers (Koshinetsu with Shizuoka adjoin-
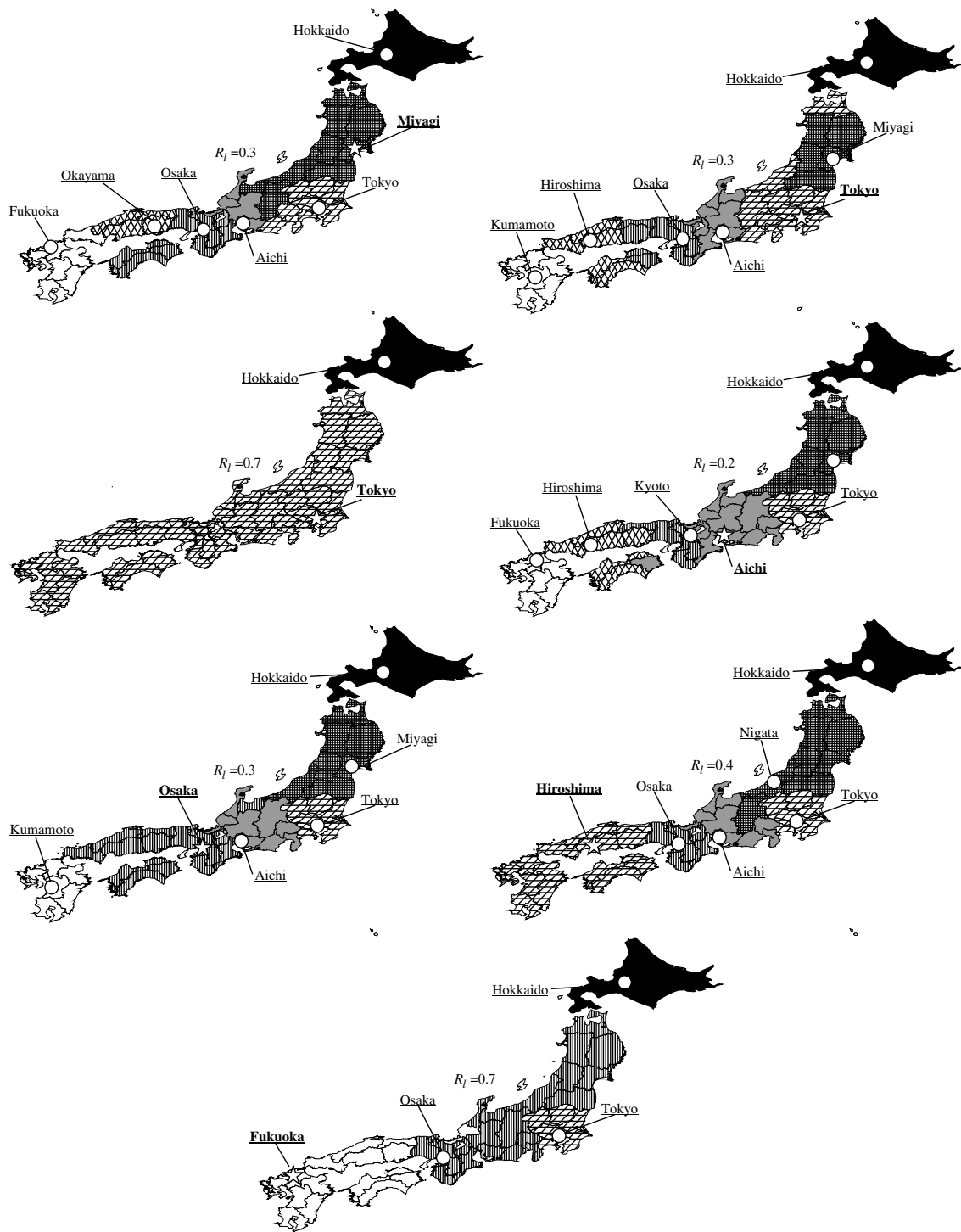
Fig. 6 Branch office location and territories in '95
(: Headquarter   : Branch office)

ing to Kanto and Cyubu, Hokuriku adjoining to Cyubu and Kansai, Cyugoku and Shikoku adjoining to Kansai and Kyusyu), these areas tend to be divided, and to be integrated to adjoining larger area.

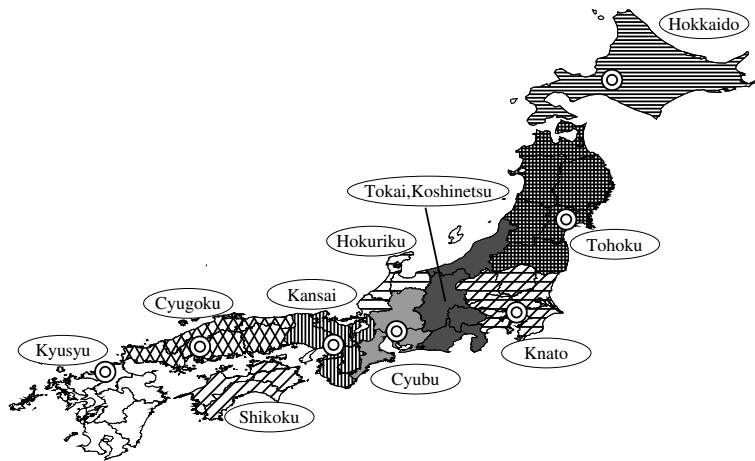Concerning to Tokyo headquarter pattern, only a decentralized pattern ($R_l = 0.6$)

Fig. 7 Municipal groups of prefectures (　　: Major city)

Table 2 Share of nation-wide firm in total interaction, PN_{ij}

i	j	'90	'95	Change*
Hokkaido	Miyagi	15.3%	29.2%	13.9
Hokkaido	Tokyo	75.4%	64.1%	-11.3
Hokkaido	Aichi	0.0%	3.8%	3.8
Hokkaido	Osaka	49.0%	44.4%	-4.6
Hokkaido	Hiroshima	12.7%	46.2%	33.5
Hokkaido	Fukuoka	33.8%	71.3%	37.5
Miyagi	Tokyo	46.2%	28.5%	-17.7
Miyagi	Aichi	10.9%	22.7%	11.8
Miyagi	Osaka	32.4%	54.6%	22.2
Miyagi	Hiroshima	32.6%	46.6%	14.0
Miyagi	Fukuoka	38.9%	63.2%	24.3
Tokyo	Aichi	46.8%	41.3%	-5.5
Tokyo	Osaka	72.8%	60.4%	-12.4
Tokyo	Hiroshima	66.2%	56.5%	-9.7
Tokyo	Fukuoka	80.9%	70.9%	-10.0
Aichi	Osaka	10.0%	18.0%	8.0
Aichi	Hiroshima	5.9%	15.1%	9.2
Aichi	Fukuoka	23.6%	40.3%	16.7
Osaka	Hiroshima	14.7%	29.8%	15.1
Osaka	Fukuoka	34.0%	58.8%	24.8
Hiroshima	Fukuoka	17.7%	47.9%	30.2

∗　'95-'90

with 6 branches is estimated in '90, but in '95, decentralized pattern (R_l = 0.3) with 7 branches, and centralized pattern (R_l = 0.7) with 2 branches are estimated. In other words, the decentralized pattern remains (even a branch in Miyagi is added), and the centralized pattern which covers almost all prefectures by Tokyo branch newly appears in '95.

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PN^{kl} of Tokyo headquarter is decreased, even summing up for 2 patterns in '95. Both of Osaka headquarter pattern are with $R_l = 0.3$, but its PN^{kl} slightly decreases. Note that in '95, branch office in Hiroshima is abolished, and its territory is merged to Osaka branch. Others, PN^{kl} of Miyagi, Hiroshima, and Fukuoka headquarter become large, and their R_l are decreased (function of branch offices of these patterns is strengthened). Changes in branch office location occurred as follows; Ehime to Hiroshima and Kumamoto to Fukuoka on Miyagi headquarter, Hokkaido (added), Miyagi to Nigata, and Fukuoka to Hiroshima (integrated) on Hiroshima headquarter, Hokkaido (added), Nigata and Aichi to Osaka (integrated) on Fukuoka headquarter. A linkage pattern of Aichi headquarter with $R_l = 0.2$ newly appears in '95, but its PN^{kl} is low.

Here, shares of nation-wide firm in each city pair ij denote PN_{ij} ($PN_{ij} = \sum_{kl} \beta^{kl}(HB_{ij}^{kl} + BC_{ij}^{kl})/TI_{ij}$). **Table 2** shows PN_{ij} for some major pairs. Pairs with $PN_{ij} > 50\%$ are Hokkaido-Tokyo, Tokyo-Osaka, Tokyo-Fukuoka in '90, and in '95, Hokkaido-Tokyo is added. From '90 to '95, PN_{ij}s including Tokyo, or Hokkaido-Osaka decrease, but most of other PN_{ij} increased. That is, share of nation-wide firm decrease in the interaction to Tokyo, but it increase on other major pairs.

To sum up, following results are obtained from the results. Business linkage of Tokyo headquarter was a decentralized pattern in '90 which have branches for each conventional regions, but a centralized pattern which covers almost all areas from Tokyo branch appears in '95. Comparing PN^{kl} among headquarters, Tokyo headquarter patterns decrease, and Osaka headquarter pattern slightly decrease. However, Miyagi, Hiroshima, and Fukuoka-headquarter patterns increase. Hence, decrease in share of nation-wide firm in total interaction (PN; 9.92% → 8.91%) is due to the decrease of Tokyo-headquarter pattern. This consideration can be derived from the change in PN_{ij}, also. Concerning to R_l of business linkage patterns, all of R_l appeared in '90 decrease, except newly appeared pattern (Tokyo centralized, and Aichi), so that the function of branch office to quantitatively compress the accepted requests tends to be strengthened. Further, the difference between average interaction cost from headquarter to branch office, C_{ij}^{HB}, and average interaction cost from branch office to customer, C_{ij}^{BC}, become large. It suggests that the function of branch office to heighten transmission difficulty of accepted requests tends to be strengthened. Comparing **Fig.5** with **Fig.6**, number of branch offices decrease, concurrently the territories of each branch office become large. Therefore, integration of branch office are on going.

4. Summary and conclusion

This study proposed a procedure to estimate nation-wide firm's inter-regional business linkages from inter-regional communication traffic data through the integrated model made up of three sub-models. The integrated model applied to '90 and '95 in order to

clarify the influence of transportation network improvement, and of telecommunication improvement, on change of business linkage structure in Japan.

Results showed that share of nation-wide firm's interaction decreased. The pattern with Tokyo headquarter(the capital of Japan) decreased, but local headquarter patterns rather increased. Interactions between headquarter and branch-office became much knowledge-intensive than before, that implies the enhancement of branch-office function. Branch-offices became to concentrate on transportation-hub cities. These results suggest that inter-regional communication on conventional geo-based linkages was increased, and business networks of nation-wide firms concentrate branch offices into the selected cities, as called 'Straw effect'. However, the further change such as 'foot-loose economy' did not appear in early '90s.

The 'Strew effect' of nation-wide firm will occur when a city in local area is directly connected with a major city by further improvement of transportation service, or in case of decrease in communication cost, in near future. If IT substitutes for most of the face to face communication, branch office is not always attracted to major city with high location cost, rather branch office will concentrate on the city with inexpensive location cost where facilitated for knowledge-intensive communication. In order to clarify the extent of substitution of IT for face to face communication on business, a study on latest data should be carried on. In that case, the communication traffic on the exclusive line is also to be analyzed.

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