STATISTICAL TEST FOR INTER-CITY INFORMATION INTERACTION

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Abstract: In Japan, the rapid growth of IT started in the early '90s. That drastic change might have an influence on information interaction through the traffic of both inter-city passenger trips and telecommunications. Until now many researchers have claimed that the relationship between transportation and telecommunications is either substitution or complementation, but still controversies continue because of a lack of evidence for both aspects. In this paper, the authors have tried to analyze the structural change in inter-city information interaction, and to clarify the relation between passenger traffic and telecommunications in a way that is would be useful for planners of the national transportation system. This study purposes to clarify such changes based on a statistical test for model parameters, using aggregate interaction data. The statistical test shows that structural change in information interaction has certainly progressed through the '90s. It has been particularly remarkable in telecommunications. For transportation, change appeared in the late in '90s.
Key Words: information technology, inter-city traffic, statistical Test

1 INTRODUCTION

A revolutionary development of information technology started in the early '90s in Japan. Intensive investment in telecommunications infrastructure, as well as rapid growth of new communication tools, such as mobile phones, and e-mail and Internet equipped in personal computers, gave broad opportunities to access information at any time and anywhere. Many social scientists claim that a drastic improvement in communication tools might influence information interaction (Salomn, 1986; Garrison, et. al., 1988). Because not only telecommunications but also face-to-face communication in passenger trips can transmit information to distant areas, IT's impact on telecommunications as well as on transportation becomes an important issue.

The relationship between transportation and telecommunications is typically discussed from two opposite aspects: substitution and complimentarity (Schular, 1992). Moktarian (2001) notes that complimentarity between transportation and telecommunications is historically observed in individual information media choice behavior, and there is not much evidence that this will change in the future.

Substitution and complimentarity are frequently discussed by national and local infrastructure policymakers, but there is a slight difference in the initial interest or motivation for the analysis, which is affected by the characteristics of the field and problems a policymaker confronts. Substitution is discussed when a negative externality, such as congestion or environmental load mainly caused by the transport sector, is at issue. In order to alleviate the problem, tele-working and IT-supported logistics are often mentioned as policy instruments (Barepur, et. al., 1998; Gebresenbet, et. al., 2001). On the other hand, complimentarity is expected when there is positive externality such as stimulating economic activities (Horan, et. al., 1998). The above cases show that substitution tends to be discussed for local issues that involve temporal policy, but complimentarity tends to be discussed for global issues that involve long-term policy. We have to be careful that such differences stem from the spatial size of a target area, or from target duration, otherwise we misread the results.

In order to settle the argument between substitution and complimentarity, various empirical approaches have been tried. One standard approach is to analyze disaggregated data collected in communication diaries in which respondents are asked to record their frequency of information media use, including face-to-face and telecommunications media. Such an approach has the advantage of providing a detail of information-media choice behavior. Moktarian et. al. (1999) adopted this approach, additionally considering the temporal change of frequencies of information media use. They summarized the impact of the new communication tools into four types, and compared them in frequency with other conventional tools. Cross-mode substitution entails utilizing a new tool instead of a conventional one, and cross-mode complimentarity is when a new one is used together with the conventional one so that the usage frequencies of both tools increase. Generation is when the new tool is used independently from the conventional tool so that only the frequency of its use increases. Generation with cross-mode complimentarity is when all the usage frequencies of new and conventional communication tools increase. Two questionnaires were conducted over a six-month interval, including details of interactions (e. g, media, time, contents, urgency, characteristics of the respondent), and the changes in frequencies of media use are modeled based on comparisons in the data, with variance-covariance structural analysis. The result shows that complimentarity is found in many relations rather than just substitution.

Moktarian's study gives useful insights into individual information media choice behavior. Among the four types of relationships, the former two -cross-mode substitution and cross-mode complimentarity - correspond to conventional concepts. The later two types - generation and generation with cross-mode complimentarity- are often mentioned as "induced" interactions. By introducing a longitudinal comparison, her study clearly counts on the change in total amount of interaction. However, there are some difficult issues involved with the disaggregated approach. One important task is whether the trend observed in the disaggregated approach can also be observed in aggregated interactions; but such studies are scarcely found. Imagawa (2002) analyzed it using aggregated passenger traffic and telecommunications data pooled from '88 to '94. In his study, complimentarity between transportation and telecommunications is often observed in inter-city interaction by an estimation of gravity model. In order to utilize such insights in infrastructure planning, engineers still need to research whether the observed complimentarity is temporal or stable, and when the change appears in aggregated demand.

This study statistically tests the structural change in inter-city information interaction in Japan during the '90s. The purpose is to clarify how the patterns of aggregated traffic in passenger and telecommunications traffic have longitudinally changed, and whether the trends are significant. Empirical data for our statistical test includes aggregated inter-city trips and telephone traffic from '89 to '98. Through a statistical test for model parameters, short and long term changes are identified.

This paper is organized as follows. The following section shows the model system at first, then suggests a statistical test procedure for the structural change. The section after that presents a detail of empirical data: model estimation. The results of the statistical test with its implications are also discussed. Conclusions and further remaining issues are summarized in the final section.

2 MODELS

A test procedure based on empirical interaction data is as follows. The transportation-modal split model is first estimated in order to get a Level-of-Service (LOS) index function which includes time and cost. The LOS index for each OD pair is calculated as an input, then the information media split model is estimated for each year. For a simplified notation, subscript (indicating 'year') is abbreviated for all the following equations.

2.1 Transportation-Modal Split Model

Transportation modes for inter-city trips, car, rail, and air are considered in this study. Demand of each mode is a function of transportation time and cost. If the provided service level of a certain mode is very low, no trips are observed in an actual interaction. This is often observed for distance air and car ODs. Therefore, modes with no observed trips in aggregated data would be excluded from the mode choice alternative in that OD pair. The compound LOS index in transportation is expected to reflect the number of substantial alternatives. An aggregated logit-type model is assumed for the modal choice ratio. Considering the difference in the number of alternatives, parameters in transportation mode choice are estimated by maximizing likelihood function (1):

$$L = \sum_{ij} \sum_{k} p_{ij}^{k} \log P_{ij}^{k}. \tag{1}$$

$$p_{ij}^{k} = \frac{T_{ij}^{k}}{\sum_k T_{ij}^{k}}. \tag{2}$$

$$P_{ij}^{k} = \frac{\delta_{ij}^{k} \exp(V_{ij}^{k})}{\sum_k \delta_{ij}^{k} \exp(V_{ij}^{k})}. \tag{3}$$

$$V_{ij}^{k} = \beta_c C_{ij}^{k} + \beta_t H_{ij}^{k} + \mathrm{const}^{k}. \tag{4}$$

where, i and and j are subscripts for OD pairs, p_{ij}^{k}, H_{ij}^{k}, P_{ij}^{k}, V_{ij}^{k} are observed modal splits, observed traffic, modal splits by model, and utility of mode k in ij, respectively. V_{ij}^{k} is a linear function of cost C_{ij}^{k} and time T_{ij}^{k}. β_c and β_t are parameters. δ_{ij}^{k} is the dummy variable which is one if $T_{ij}^{k} > 0$, otherwise zero if $T_{ij}^{k} < 0$. The LOS index for each OD pair (LOS_{ij}) is calculated by $LOS_{ij} = \sum_k \delta_{ij}^{k} \exp(V_{ij}^{k})$, and the conversion coefficient for travel time into cost (TV) is calculated by β_c/β_t. LOS_{ij} monotonically increases in an additional alternative, therefore the provision of substantial mode improves LOS_{ij}.

2.2 Information Media Split Model

The information media split model proposed by the authors formulates the aggregated interaction, including media split between transportation and telecommunications (Tsukai and Okumura, 2001). The model system consists of the following equations. I_{ij} is a latent amount of interactions between cities, which is interacted on both the transportation and telecommunications networks.

$$I_{ij} = AP_i^{\alpha} P_j^{\beta} LOS_{ij}^{\phi} c\ \mathrm{cost}_{ij}^{\Psi} AR_{ij}^{\varphi}. \tag{5}$$

$$AR_{ij} = \frac{1}{2}\left(\sum_i^{i\neq j}\frac{Pi}{rtime_{ij}} + \sum_i^{i\neq j}\frac{Pi}{rtime_{ij}}\right).$$

where, P_i and P_j are populations in cities i and j, $c\mathrm{cost}_{ij}$ are the telecommunications cost per minute in ij. AR_{ij} is an accessibility index to the surrounding cities measured by rail time ($rtime_{ij}$) in ij (Fotheringham, 1983). $A, \alpha, \gamma, \phi, \psi$, and φ are parameters to be estimated.

$$X_{ij}^0 = \frac{gtc_{ij}}{avcc_{ij}} = \frac{\sum P_{ij}^k (C_{ij}^k + TV \times H_{ij}^k)}{c\ \mathrm{cost}_{ij} \times \overline{CT}_{ij}}. \tag{6}$$

X_{ij}^0 is an interaction cost ratio in ij. The numerator is a generalized per-trip trans portation cost (gtc_{ij}) considering modal split, and the denominator is a per-call telecommunications cost ($avcc_{ij}$) incorporating average communication time ($\overline{CT}_{ij}$).

Telecommunications and face-to-face (transportation) differ in their equivocality; face-to-face can provide a lot of cues through voice tone and gesture, but telecommunications can not (Daft, 1996). Telecommunications can be used for only simple interaction, but face-to-face communication through transportation can be used for more complicated interaction.

Therefore, using telecommunications several times is sometimes necessary in order to substitute for one face-to-face communication. Here we define the transmission difficulty of an interaction by the number of telecommunication usages which completely substitutes the interaction, denoting it as (x_{ij}). Comparing x_{ij} to X_{ij}^0 (interaction cost ratio), media which give smaller communication costs might be used. In the case of $x_{ij} < X_{ij}^0$, telecommunications give a smaller cost for the interaction, and vice versa.

I_{ij} includes various kinds of interactions with differing difficulties. In other words, the transmission difficulty distributes in I_{ij}. Weibll distribution with concave shape (a shape parameter = 2) is assumed for x_{ij} as (7). ρ_{ij} is a scale parameter which influences media split by adjusting the median of the distribution, and is a function of distance and populations (d_{ij}, P_{ij}, P_{ij}), as (8).

$$f_{ij}(x) = \frac{2}{\rho_{ij}^2}\exp\left(-\left(\frac{x}{\rho_{ij}^2}\right)^2\right). \tag{7}$$

$$\rho_{ij} = \exp(\mu_1 d_{ij} + \mu_2 P_i + \mu_3 P_i. \tag{8}$$

From (5) to (8), observed transportation and telecommunication traffics follow in (9) and (10), respectively.

$$TR_{ij} = I_{ij}\int_{X_{ij}^0}^{\infty} f_{ij}(x)\mathrm{d}x + \varepsilon_{ijt}. \tag{9}$$

$$TC_{ij} = I_{ij}\int_0^{X_{ij}^0} f_{ij}(x)\mathrm{d}x + \varepsilon_{jc}. \tag{10}$$

where, TR_{ij} is transportation traffic (sum of traffic by car, rail, and air), TC_{ij} is telecommunications traffic, and ε_{ijt} and ε_{ijc} are error terms. Parameters are estimated by FGLS (Feasible Generalized Least Square) for these equations.

2.3 Substitution and Complimentarity in Model System

In the model system, substitution and complimentarity are formulated by the combination of common terms appearing in equations (9) and (10). For a simple notation, following definitions are used; $g(X_{ij}^0) = \int_{X_{ij}^0}^{\infty} f_{ij}(x)\mathrm{d}x$, $G(X_{ij}^0) = \int_{X_{ij}^0}^{\infty} x f_{ij}(x)\mathrm{d}x$. Concerning to cost elasticity, substitution is considered through $g(X_{ij}^0)$ and $G(X_{ij}^0)$, and complimentarity is considered through I_{ij}. If all the parameters have "expected" signs, following relations are fulfilled;

$\partial g(X_{ij}^0)/\partial gtc_{ij} < 0, \partial g(X_{ij}^0)/\partial avcc_{ij} > 0$,

$\partial G(X_{ij}^0)/\partial gtc_{ij} < 0, \partial G(X_{ij}^0)/\partial avcc_{ij} > 0$,

$\partial I_{ij}/\partial gtc_{ij} < 0, \partial I_{ij}/\partial gtc_{ij} < 0$. Direct elasticities for TR_{ij} and TC_{ij} are calculated by following equations.

$$\frac{\partial TR_{ij}}{\partial gtc_{ij}} = \frac{\partial I_{ij}}{\partial gtc_{ij}} g(X_{ij}^0) + I_{ij}\frac{\partial g(X_{ij}^0)}{\partial gtc_{ij}} < 0. \tag{11}$$

$$\frac{\partial Tc_{ij}}{\partial avcc_{ij}} = \frac{\partial I_{ij}}{\partial avcc_{ij}} G(X_{ij}^0) + I_{ij}\frac{\partial G(X_{ij}^0)}{\partial avcc_{ij}} < 0. \tag{12}$$

Equations (11) and (12) ensure negative sign of direct elasticities, due to all the terms with negative sign.

$$\frac{\partial TR_{ij}}{\partial avcc_{ij}} = \frac{\partial I_{ij}}{\partial avcc_{ij}} g(X_{ij}^0) + I_{ij}\frac{\partial g(X_{ij}^0)}{\partial avcc_{ij}}. \tag{13}$$

$$\frac{\partial TC_{ij}}{\partial gtc_{ij}} = \frac{\partial I_{ij}}{\partial gtc_{ij}} G(X_{ij}^0) + I_{ij}\frac{\partial G(X_{ij}^0)}{\partial gtc_{ij}}. \tag{14}$$

Equations (13) and (14) show that signs of cross elasticities can not be predetermined, which depends on each term. Therefore, an asymmetric relation between indirect elasticities are possible.

2.4 Test for Structural Change

A statistical test for structural change was originally developed in time-series analysis, e. g, Chow-test (Chow, 1960). In a time-series analysis, a statistical test for structural change is not sensitive to the short-term change. Different from an ordinal time-series analysis, the data set used in this study has enough observations to estimate cross-sectional models. The data can provide a great deal of information about parameters at specific cross-sections, therefore tests using cross-sectional information give detailed knowledge in terms of the turning point of information interactions. Our test procedure is based on the extent of prediction failure proposed as a type-II Chow test, as follows.

The change in observed transportation and telecommunications traffic between $t-1$ and t may occur due to the change in structural parameters Γ_t, or explanatory variables Z_t. If Γ_t does not change between $t-1$ and t, change in observed traffic is due to changes in explanatory variables. Therefore, the variance S_{t-1}^2 in prediction errors calculated by Γ_{t-1} and Z_t is statistically identical to the variance in reproduction errors S_t^2, calculated by Γ_t and Z_t. In addition, if change in observed traffic is due to a change in Γ_t, S_{t-1}^2 is significantly different from S_t^2. S_{t-1}^2 and S_t^2 follow x^2 distribution with $N-k$ degrees of freedom (N : number of observations, k : number of parameters). Note that the estimated errors asymptotically follow the normal distribution, and test statistics $F=S_{t-1}^2/S_t^2$ follows the F distribution with $N-k$ and $N-k$ degrees of freedom (null hypothesis : H_0^{t-1}).

Further, in order to identify the change in the much longer term, we set a bench mark year as '90, then $S_{90}^2=S_t^2$ implying $\Gamma_{90}=\Gamma_t$ is tested (null hypothesis : H_2^{90}, S_{90}^2 is calculated by Γ_{90}, and Z_t, with $t \geqslant 92$). H_0^{t-1} and H_0^{90} are separately tested for transportation and telecommunications interactions.

3 RESULTS AND DISCUSSIONS

3.1 Data

The empirical data used in this study are aggregated to prefecture-units. We exclude Okinawa Prefecture due to its geographical uniqueness, so 1, 035 pairs among 46 prefectures are available to analyze. All traffic data are converted into symmetric matrix, because a traffic direction does not always correspond to a substantial transmission direction. All data sets were prepared for each year between '89 and '98, inclusive. TR_{ij} is the net passenger traffic by car, rail and air provided by the Institution for Transportation Policy Studies in Japan. c $cost_{ij}$ and telecommunication time are net telephone traffic including NTT and NCCs (New Common Carriers). Transportation time and cost are from the Navi-Net system provided by the Ministry of Land, Infrastructure and Transportation, and telecommunications costs between the prefectural capitals are from the annals of Telecommunication Carriers Association. P_i (P_j) is from the National Demographic Census which carries out a survey every five years. Missing data in the population is linearly interpolated. P_i indicates the population of larger cities, and P_j is of smaller ones.

Figure. 1 shows gross national longitudinal trends of telecommunications traffic and inter-city passenger trips. The number for telecommunications is larger than for other transportation traffic. It shows a non-monotonous trend which came to a peak in '96 but later decreased. Car traffic also shows a non-monotonous trend, with its peak in '95, then decreasing later. Rail traffic is roughly constant in a gross amount, but traffic between each pair of cities is rather unstable according to the change in the amount of air traffic. Air traffic shows the smallest total, but is increasing continuously.

3.2 Results of the Model Estimation

Table 1 shows the estimated parameters of the transportation-modal split model for each year. Likelihood ratios in all years exceed 0.20, thus the fitness of the model is good with the significant parameters. The transportation cost parameter shows an instable trend, especially between '89 and '95. The transportation time parameter shows a stable trend with increasing its t-value. For transport time and cost trends, specific trend changes are suspected of corresponding to the collapse of the "Bubble Economy" in the early '90s, the Hanshin-Awaji earthquake in '94, and the IT revolution. The time value increases from about 2, 000 yen/hour (about 17 dollars/hour) in '89 to about 7,200 yen/hour (about 60 dollars/hour) ten years later. This increase trend in time value indicates a modal shift form a time-consuming mode to a cost-required mode. Considering the growth of air transport, that change reflects a modal shift among distant cities. Although the trend may be a bit emphasized because time and cost data do not reflect the real price affected by many kinds of discount tickets in air and rail transport, this increase in travel time values is not dubious.

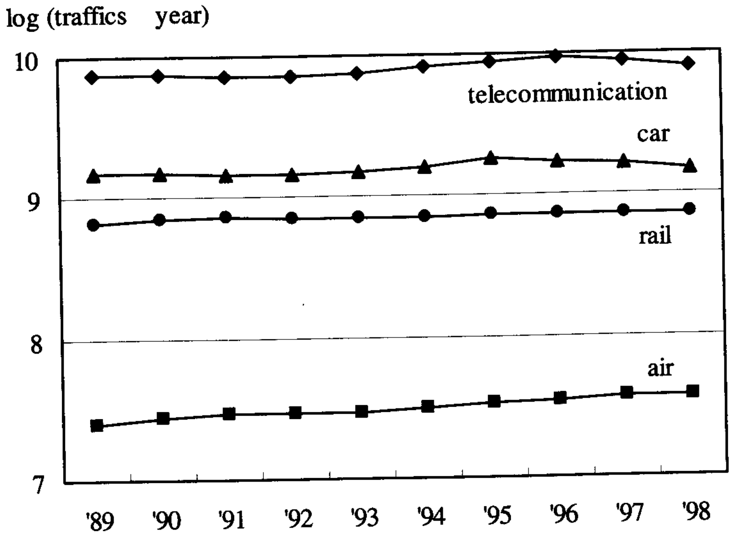

Figure 1. Gross National Longitudinal Trend of Traffics

Table 1. Transportation-Modal Split Estimation

	'89		'90		'91		'92		'93	
$cost_{ij}$	-0.149	**	-0.109	**	-0.141	**	-0.116	**	-0.104	**
	-(6.35)		-(4.28)		-(4.12)		-(5.00)		-(4.27)	
$time_{ij}$	-0.301	**	-0.344	**	-0.381	**	-0.381	**	-0.322	**
	-(5.46)		-(6.47)		-(6.59)		-(7.21)		-(7.08)	
$const_a$	-2.191	**	-2.546	**	-2.411	**	-2.364	**	-2.113	**
	-(5.96)		-(7.14)		-(6.35)		-(6.60)		-(6.32)	
$const_c$	0.809	**	0.876	**	0.898	**	0.903	**	0.782	**
	(4.22)		(4.58)		(4.53)		(4.92)		(4.39)	
$\bar{\rho}^2$	0.281		0.274		0.292		0.271		0.239	
No. ofObs.	1035		1035		1035		1035		1035	
TV	2.014		3.163		2.694		3.294		3.109	
	'94		'95		'96		'97		'98	
$cost_{ij}$	-0.069	**	-0.105	**	-0.084	**	-0.088	**	-0.068	**
	-(3.05)		-(5.24)		-(3.71)		-(3.23)		-(2.45)	
$time_{ij}$	-0.366	**	-0.406	**	-0.437	**	-0.471	**	-0.497	**
	-(7.10)		-(7.61)		-(8.63)		-(8.61)		-(8.77)	
$const_a$	-2.272	**	-2.053	**	-2.083	**	-2.005	**	-2.094	**
	-(6.61)		-(6.35)		-(6.42)		-(5.99)		-(6.25)	
$const_c$	0.748	**	0.843	**	0.881	**	0.990	**	1.045	**
	(4.32)		(4.66)		(5.11)		(5.47)		(5.48)	
$\bar{\rho}^2$	0.223		0.243		0.225		0.223		0.213	
No. ofObs.	1035		1035		1035		1035		1035	
TV	5.323		3.884		5.189		5.383		7.280	

( ) : t-statistics, ** : significant with 1%, * : significant with 5%

Table 2 shows the estimation results of the information media split model for each year. Determinant coefficients show good fit with 0.75 for transportation and 0.90 for telecommunications, and all parameters are significant. Parameters of both LOS_{ij} and telecommunications costs have appropriate and unsurprising signs. Both of them, along with rail-transportation accessibility are becoming more significant for I_{ij}. The negative sign in AR_{ij} indicates the competitive effect in rail-transport accessibility. It means higher accessibility to surroundings by rail tends to have a smaller interaction. Populations (large and small) show a constant trend. Distance and population parameters in media split are also changing, but the estimates are not so different between '89 and '90. All the above results suggest a structural change in inter-city communications. The statistical test will give us the evidence.

Table 2. Information Media Split Model Estimation

		'89		'90		'91		'92		'93	
I_{ij}	LOS_{ij}	0.411	**	0.495	**	0.465	**	0.537	**	0.589	**
		(30.44)		(37.35)		(45.84)		(49.56)		(45.91)	
	$ccost_{ij}$	-0.019	**	-0.025	**	-0.030	**	-0.042	**	-0.035	**
		-(14.60)		-(16.22)		-(16.53)		-(16.03)		-(15.76)	
	AR_{ij}	-1.194	**	-1.290	**	-1.321	**	-1.378	**	-1.308	**
		-(14.71)		-(15.76)		-(16.80)		-(17.37)		-(16.61)	
	P_i	1.593	**	1.582	**	1.577	**	1.579	**	1.562	**
		(48.74)		(48.27)		(49.95)		(49.60)		(49.82)	
	P_j	1.160	**	1.053	**	1.012	**	1.021	**	1.111	**
		(26.11)		(23.66)		(23.58)		(23.59)		(26.14)	
	$A.Rsq.$	-19.896	**	-16.950	**	-15.743	**	-14.968	**	-17.507	**
		-(28.54)		-(23.89)		-(22.70)		-(20.90)		-(25.28)	
ρ_{ij}	d_{ij}	-0.130	**	-0.119	**	-0.095	**	-0.089	**	-0.096	**
		-(13.22)		-(12.25)		-(10.04)		-(8.75)		-(8.80)	
	P_i	0.037	**	0.031	**	0.029	**	0.045	**	0.039	**
		(3.56)		(3.07)		(2.93)		(4.28)		(3.35)	
	P_j	0.067	**	0.072	**	0.065	**	0.048	**	0.061	**
		(5.73)		(6.31)		(5.76)		(4.08)		(4.68)	
$TR_{ij}:A.Rsq$		0.762		0.776		0.789		0.772		0.737	
$TC_{ij}:A.Rsq$		0.899		0.896		0.902		0.902		0.906	

		'94		'95		'96		'97		'98	
I_{ij}	LOS_{ij}	0.663	**	0.551	**	0.631	**	0.596	**	0.634	**
		(45.38)		(45.89)		(51.55)		(51.88)		(52.61)	
	$ccost_{ij}$	-0.037	**	-0.035	**	-0.046	**	-0.078	**	-0.119	**
		-(16.39)		-(15.99)		-(13.56)		-(14.12)		-(13.32)	
	AR_{ij}	-1.353	**	-1.344	**	-1.487	**	-1.438	**	-1.436	**
		-(16.92)		-(17.21)		-(18.27)		-(17.88)		-(17.58)	
	P_i	1.573	**	1.556	**	1.552	**	1.534	**	1.537	**
		(49.87)		(50.31)		(48.47)		(48.81)		(48.66)	
	P_j	1.106	**	1.093	**	1.092	**	1.086	**	1.093	**
		(25.85)		(26.04)		(24.97)		(25.16)		(25.05)	
	A.Rsq.	-17.115	**	-16.639	**	-15.094	**	-14.526	**	-14.078	**
		-(24.28)		-(23.95)		-(20.30)		-(19.35)		-(17.74)	
ρ_{ij}	d_{ij}	-0.102	**	-0.112	**	-0.100	**	-0.115	**	-0.129	**
		-(10.19)		-(11.04)		-(9.73)		-(10.96)		-(11.15)	
	P_i	0.055	**	0.062	**	0.069	**	0.064	**	0.059	**
		(5.03)		(5.71)		(6.28)		(5.89)		(5.09)	
	P_j	0.047	**	0.043	**	0.035	**	0.052	**	0.066	**
		(3.82)		(3.51)		(2.88)		(4.23)		(5.05)	
$TR_{ij}:A.Rsq$		0.762		0.761		0.766		0.766		0.745	
$TC_{ij}:A.Rsq$		0.906		0.908		0.899		0.901		0.898	

( ) : *t-statistics*, ** : *significant with* 1%

3.3 Statistical Test and Discussions

Table 3 shows the results of the statistical test for H_0^{90} and H_0^{t-1} in the information media split model. Structural changes from the previous year are identified (rejection in H_0^{t-1}) in '90 for transportation, and in '90, '92, and '95 for telecommunications. Compared to the interaction in 1990, significant changes are identified (rejection in H_0^{90}) in '94, '96, '97, and '98 for transportation, and in '92, '93, '94, '96, '97, and '98 for telecommunications.

Tracing identified structural changes, there are four turning points. The first change, appearing in '90, corresponds to economic growth, and it continues to '91. The second change, appearing in '92, corresponds to the collapse of the "Bubble Economy" and the beginning of recession. This change is identified only in telecommunications. This trend sustains up to '94 when long-term change in transportation appears. The third change appears in '95, caused by the Hanshin-Awaji earthquake. In spite of the terrible confusion in transportation, the disturbance is not identified in transportation in this short-term test. The fourth change starts in '96. Long-term change appears in both interactions as well as in '94, although neither sector shows short-term change. The test results in '95 and '96 suggest that the long-term restructuring trend is stable, but its direction is somewhat modified. The fourth change remains up to '98.

Table 3. F-Statistic Test for Structural Change

	transportation				telecommunication			
	H_0^{t-1}		H_0^{90}		H_0^{t-1}		H_0^{90}	
'90	1.105	*	-		1.219	* *	-	
'91	1.002		-		1.024		-	
'92	1.074		1.063		1.133	* *	1.116	* *
'93	1.003		1.061		1.033		1.157	* * *
'94	1.056		1.114	* *	1.061		1.359	* * *
'95	1.037		0.061		1.225	* * *	1.075	
'96	1.054		1.102	*	1.082		1.246	* * *
'97	1.001		1.097	*	1.036		1.258	* * *
'98	1.037		1.094	*	1.050		1.345	* * *

F(1026,1026;0.01) = 1.156, F(1026,1026;0.05) = 1.108, F(1026,1026;0.10) = 1.083
* * * : significant with 1%, * * : significant with 5%, * : significant with 10%

Overall results show that structural change in information interaction does not appear in short-term, but gradually progresses through the '90s. Changes are triggered by exogenous shock as the economy changes and a natural disaster occurs, then goes on supported by a stable trend. Discounting the disturbance caused by the '95 disaster, it was around '92 or '93 that telecommunications interaction started to change, and after '96 that the change occurred in the transportation interaction. The IT revolution and improvements in the transportation network have continuously pushed the change.

4 CONCLUSIONS

This study statistically tested structural change in inter-city information interactions. At the beginning of the change, exogenous disturbances like the shift in economic situation or unexpected disaster concurrently occur and strongly push the change. Once it starts, the change gradually progresses. The IT revolution, as well as continuous improvements in the transportation network, encourage the change in interaction rather than give a new trend. The change appears faster in telecommunications interactions, and later appears in transportation.

Remaining issues in this study are as follows. A test for structural change around 2000 would also be important, because further improvement in transportation and telecommunications may strongly influence the interactions. In order to improve the model, transportation cost data counting on discounted prices should be used. If enough longitudinal data is available in the future, incorporating an analysis which combines mobile-phone traffic with other traffic data would be important to clarify the characteristics of information interactions.

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