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THE CONTRIBUTION OF TELECOMMUNICATIONS SECTOR TO ECONOMIC GROWTH

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This study contributes to clarifying the relationship between economic growth and telecommunications facility provision. For this task, a two sector model is constructed. By using this model, the author examines the contribution of telecommunications to economic growth in static and dynamic framework.

I. PAST STUDIES

Since Jipp(1963) brought to public attention the strong correlation between telephone density and what he called national wealth, the so-called Jipp formula has been used to examine the relationship between telecommunications provision and economic development. It can be expressed as:

$$K = aQ^{b}$$

with K being the number of main lines, and Q the GDP.

The simplicity of this approach and its modest requirements for data made it attractive as a tool in the initial stages of analyzing the effect of telecommunications in economic development(Bebee and Gilling 1976; Hardy1980a,b). However, such an approach is not without crucial limitations. Several such aspects have already been pointed out:

1) The relationships between telecommunications and economic activity are far too complex to be usefully represented by a single equation analysis with only one or a few independent variables.

2) The data used for both the cross-sectional and time series correlation exercises are generally not comparable. The highly developed countries tend to be closer to an equilibrium state in terms of telecommunications demand and supply, while the developing countries are in a state far from equilibrium, which means excess demand.

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3) The correlation between telephone density and GDP data does not necessarily imply that increased telephone supply causes growth of the economy.

One way to obtain a more detailed picture about the demand and supply of telecommunications would be to break down the economy into sectors, and to analyze the level of input of telecommunications in specific sectors, such as agriculture, industry, public services, et cetera. But limitations to such I-O analysis have also been noted(Jonscher 1981; Saunders et al 1982; Jussawalla 1986). Among them:

1) The input coefficient of telecommunications or the volume of purchases of telecommunications services is limited by a supply shortage in most developing countries.

2) This approach suffers from the drawback that it is based on an implicit assumption that each sector requires a fixed level of telecommunications input per unit of output.

3) The conventional industrial classification schemes focus on the material goods flow, and are unable to examine the relationship between the telecommunications and other sectors.

Jonscher(1981) proposed econometric modeling approach "based on the estimation of a production function defining the level of output of a given sector of the economy in terms of a number of inputs: $Y = f(X_1, X_2, X_3, \ldots\ldots, X_n)$, where X_i are the levels of various types of input, one of which is telecommunications." Jonscher, in this argument, considers telecommunications as an input that an economy requires as well as labor and capital, and assumes a substitutability among the inputs.

If this hypothesis that information can replace capital and labor is tenable, then neoclassical economics should abandon the two-factor approach embodied in traditional Cobb-Douglas type production functions(Jussawalla and Cheah 1984).

Jonscher(1982) also tried to build a model which is based on a production function in which information, or more precisely the delivery of information services, is included in order to derive the information services and information labor requirements.

Jonscher's model is quite interesting in that it is based on a behavioral assumption of a two sector economy, with a specific production function in which information, or more precisely the delivery of information services, is viewed as a factor of production.

Terleckyj(1984) employed the standard variables of price and income in his analysis of demand for telecommunications. His demand function was specified so that quantity of communications output is a constant elasticity function of the relative price of communication and of the GDP, which represents the real income of the economy:

$$Q_c = A(P_c/P)^a\ (GNP)^b\ [C(-2)]^r$$

where Q_c is telecommunications demand, A a constant, Pc the telecommunications price, and P the price of the net output of total business economy. The number of computers, C(-2), was also introduced into the demand equation with a two-year lag, because the structural changes reflected in an increasing use of computers may also have generated additional demand for communications.

For the production function of the communications industry, Terleckyj found the following as the best fit equation:

$$Q = AL^aK^{bR}R^r,$$

where L is labor, A a constant, K capital and R the stock of R&D capital in communications industry.[1]

Terleckyj's effort is quite advanced, in the sense that he employed the relevant price variables and tried to model both the demand and supply side of telecommunications. However, he basically relied on statistical methods to search for significant explanatory variables in order to find the best fitting demand and supply curves for the telecommunications industry. His analysis is dichotomous in that there is no interface between the demand and supply sides and, consequently, the price variable is not in equilibrium. His model also did not take into account the interdependence between the communications industry and the rest of the economy.

Gille(1986) tried to establish a theoretical background to analyze the demand and supply of telecommunications. He thinks that the communications services is a subset of the exchange services for material and information such as transpotation, telecommunications etc. Using the Cobb-Douglas production function, Gille proposed a demand function for exchange services of his two sector model comprising of production and exchange sector[2] as follows:

$$Q_e = g_eQ^{we} \text{ and, } Q = qK_e^{re}N^aK^b$$

In this functions, Q and Q_c are the total outputs of production and exchange sector; K and K_e are the capital inputs of production and exchange sectors; N is labor input.

The general philosophy of the demand function is that, a given level of development, Q, requires a certain level of output Q_e of exchange networks.

For the supply of exchange services, Gille claimed that, from the normative

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[1]Note that his production function may not be neutral in technological change. In previous research Nadiri and Shankerman (1980) argued that the technological change in communications had not been neutral.

[2]Gille's model originally was comprising three sectors, production, exchange, and information, However, two sectors, production and exchange, are enough te explain the supply and demand of telecommunications in Gille's terms.

aspect of the nature of telecommunications, there accrues a trade-off between the positive impact of efficient modes of communication on growth and their capital cost, so an equilibrium model is arrived at on the basis of the choice of a capital stock, K_e, on exchange networks. Thus, he claims if an economic system operates at its optimal state, then it must follow the optimization

$$\max (pQ-PeQe)$$

One important contribution of Gille's model is that he tried to analyze the interaction between the growth of the economy and telecommunications industry by defining the two sector economy which consists of production and exchange sectors.[3] But, his formulation for the demand side is almost an exact replica of Jipp's formula. Hence, the effect of the changes in the exchange services market and the subsequent price changes on the demand for communications is totally neglected.

II. TWO SECTOR MODEL FOR TELECOMMUNICATIONS

This study is going to start with an examination of a firm's activities for the purpose of deriving a demand and supply schedule for communications.

Arrow(1980) considered the organization(firm) as an effort to economize in the acquisition of information. He pointed out that the individual has a limited capacity for the acquisition of information:

> Among the ways of overcoming this bottleneck, the greatest innovation has been the social concept of an organization... Speciálization in information gathering is one instance, in my view the most important instance, of the economic benefits of organization... But it is the essence of the economics of information that conveying information is costly.

This view can be usefully represented as follows. Let there be a firm i, which is to maximize its profit, πi:

$$\text{Max } (\pi_i = pQ_i\ (N_i,\ K_i,\ Q_{ci}) - P_cQ_{ci})$$

where P and P_c are the prices of its output and the price of its use of communications services, Q_i and Q_{ci} are the amount of total output and the total use of com-

[3]Actually, Gille proposed a 3 sector economy, consisting of the production, exchange, and information sectors. But in developing theory he virtually considered a 2 sector economy, involving the production and exchange sectors (Gille 1986).

munications, and N_i and K_i are the labor and capital input for production.[4] As shown, the amount of total output is a function of labor, capital, and the level of communications usage.

If we aggregate the above maximizations for each firms, we get:

$$\text{Max } (pQ\ (N, K, Q_c) - P_cQ_c)$$

as an equivalent behavioral assumption for the whole economy.[5]

Now let's turn the focus to the supply side of communications. First, let's think about the behavioral assumption of a firm j that provides communications services (Q_{cj}). It wants to maximize its profit and follows the behavioral pattern:

$$\text{Max } (P_cQ_{cj}\ (N_{cj}, K_{cj}) - sN_{cj} \text{-} uK_{cj})$$

where s and u are the unit costs of labor and capital[6] required in the production of its communications service, respectively.

The reader should note that it is assumed that the communications services market is competitive. "Although modes individually may be considered slightly or even usually noncompetitive owing to the fact that they are operated by state monopolies, governments are rarely in a position to implement sufficient intermodal coordination to eliminate areas of substitution between modes completely(Gille 1986)."

Aggregating the optimizations of supply side, we have:

$$\text{Max } (P_cQ_c\ (N_c, K_c) \text{-} s_cN_c \text{-} u_cK_c)$$

for the whole industry which provides the communications services and infrastructures.

For the sake of convenience, the study hereafter defines two sectors of the economy, production and communications. The production sector consists of economic activities producing goods and services other than communications. A firm in the production sector has a demand for communications services and the associated infrastructure. The communications sector is defined as the industries producing and providing communications services. A firm in the communications

[4] The complete model should be:

Max ($\pi_i = pQ_i\ (N_i, K_i, Q_{ci}) - P_cQ_{ci} - P_nN_i - P_kK_i$). However, we assume that the cost function is additive in factors so that the reduced optimization produces the same equilibrium conditions for Qc as the complete model does.

[5] Here, we are only considering the direct benefit of telecommunications in terms of business profits. Leff (1984a, 1984b) had different perspective and discussed conceptual socio-economic benefits from telecommunications investment project for better social benefit-cost analysis.

[6] There can be more inputs other than labor and capital. But we can ignore these inputs, as long as labor and capital are major inputs and the cost function is additive in inputs.

sector supplies them[7]. Although there is a variety of communications modes, communications is here defined(or limited) as two-way exchange system of information, primarily by means of telecommunications[8], transportation[9], post, etc.

III. DEMAND AND SUPPLY OF COMMUNICATIONS SERVICE

This section aims to derive demand and supply functions by assuming a specific production function. It will use a classic Cobb-Douglas function for the production function of Q, which, in turn, implies that growth is based on a process of substitution between capital and labor, and it can be expressed as:

$$Q = qN^aK^b$$

where N and K are labor and capital allocated to the production sector.

To incorporate communications into the production function, we will consider communications as a factor of production just like, perhaps, petroleum or electricity. More specifically, communications services will be inputted as a public intermediate good. This is particularly appropriate in developing countries situations where usually commercial and industrial uses of telecommunications by far outweigh in significance the residential uses(Saunders, Warford, and Wellenius 1983). Thus, we now include another factor called communications services, and the optimization for demand side of communications becomes:

$$(1)\ \text{Max}\ (pqQ_c^{r_c}N^aK^b - P_cQ_c)$$

The first order conditions from this optimization give us an equilibrium relationship which indicates where communications activity realizes its maximum contribution to the production sector of the economy:

$$(2)\ \frac{r_c}{Q_c}PQ - P_c = 0 \ \text{or}\ Q_c = \frac{r_c}{P_c/P}Q$$

[7]One might think about the secondary communications sector within firms. But, here, the communications sector is defined (or limited) as information transmission services, which production firms have to buy. There could also be a firm that produces goods and, at the same time, communications service. But, in this study, these firms are ignored for the sake of simplicity.

[8]This paper limits itself to discussing only a subset of telecommunications, that is two-way common carrier communication by technical means. This includes telephones, telegraph, telex, facsimile, teleconferencing, computer data network, etc.

[9]There is some difficulty in adopting transportation as a mode of communications since it is not a means of transmitting information. But transportation is generally considered as an alternative of means of communication. Where there is no adequate telecommunications facility, transportation contributes to communications over space.

This production function is assumed to behave well enough to have interior solutions,(i.e. r_c, a and b<1).

Alternatively, by again assuming a Cobb-Douglas[10] production function, this time for the communications sector, the optimizing behavior of communications sector can be expressed as:

$$(3)\ \text{Max}\ (p_c q_c N_c^{ac} K_c^{bc} - s_c N_c - u_c K_c),$$

where s_c and u_c are the unit costs of labor and capital inputs in the communications sector.

The first order conditions from this optimization problem provide the factor demand schedules for Nc and Kc as follows:

$$(4)\ N_c = \frac{a_c c}{s_c} P_c Q_c \text{ and } K_c = \frac{b_c}{u_c} P_c Q_c$$

IV. DISAGGREGATION

The disaggregation of communication modes can be accomplished by a multiplicative decomposition of communications inputs in the aggregate production function:

$$(5)\ pQ = pq \prod_m Q_m^{r_m} N^a K^b$$

The multiplicative decomposition allows substitutability among modes. For the communications sector, the disaggregation results in the additive communication cost:

$$(6)\ \sum_m P_m Q_m$$

Using the decomposed production function and communication cost, we get the following maximization regarding the production sector:

$$(7)\ \text{Max}\ (pQ - P_c Q_c),$$

which is: $(8)\ \text{Max}\ (pq \prod_m Q_m^{r_m} N^a K^b = \Sigma P_m Q_m)$.

From the first order conditions, come the following equilibrium conditions:

[10]The adoption of Cobb-Douglas production for communications industry is mainly because of the mathematical simplicity. Nadiri and Shankerman (1980) argued that the technological process in the communications industry was not neutral.

$$(9)\quad r_m = \frac{P_mQ_m}{pQ}, \text{ or } \sum_m r_m = \sum_m \frac{P_mQ_m}{pQ} = \frac{P_cQ_c}{pQ}$$

for all m's.

On the other hand, the disaggregation of the production sector can be represented by the following additive form of production function:

$$(10)\quad pQ = \Sigma P_iQ_i = \Sigma q_iQ_c^{r_{ci}} N_i^{a_i} K_i^{b_i}$$

where i indicates a sector of an economy, such as tertiary, agriculture, etc. Note that Q_c is a global input, which means Q_c's contribution to production is not limited to any certain sector i. This would be clear if we think of communications services as a public intermediate good. The term r_{mi} in the equation can be interpreted as the economic performance of a given communication mode, m, for a production sector i.

The maximizing behavioral assumption for the demand side of communications, therefore, becomes:

$$(11)\quad \text{Max } (pQ-P_cQ_c),$$

$$(12)\quad \rightarrow \text{Max } (\sum_i p_iq_i\, Q_i-P_cQ_c),$$

$$(13)\quad \rightarrow \text{Max } (\sum_i p_iq_i\, Q_c^{r_{ci}} N_i^{a_i} K_i^{b_i} - \sum_m P_mQ_m)$$

The first order conditions are, then:

$$(14)\quad \sum_i r_{c_i}P_iQ_i = P_cQ_c$$

$$(15)\quad \text{or } \sum_i r_{c_i}d_i = \frac{P_cQ_c}{pQ} = r_c$$

$$, \text{ where } d_i = \frac{P_iQ_i}{pQ}$$

Thus the elasticity, r_c, at the aggregate level is expressed as a weighted sum of the elasticities of the disaggregated level with the i^{th} sector's proportion in total production, d_i, giving its weight. Comparing the results, (9) and (15), with the equilibrium condition of aggregated optimization in (8), we get the following equivalence relationships among the levels of disaggregation:

$$(16)\quad r_c \equiv \sum_m r_m$$

$$\equiv \sum_i r_{ci}d_i$$

For supply side, assume that each mode m has a production function observed by a Cobb-Douglas production function:

(17) $Q_m = q_m N_m^{a_m} K_m^{b_m}$

for all m.

Then, the optimization in the communications sector becomes:

(18) $\text{Max } (P_c Q_c - \sum_m s_m N_m - \sum_m u_m K_m)$, or

or (19) $\text{Max } (\sum_m p_m q_m N_m^{a_m} K_m^{b_m} - \sum_m s_m N_m - \sum_m u_m K_m)$,

From the first order conditions of this maximization, we get:

(20) $N_m = \frac{a_m}{s_m} P_m Q_m$ and $K_m = \frac{b_m}{u_m} P_m Q_m$,

By substituting the first order conditions in equation (14) into the above equations, we have the labor and capital requirement in the supply side of the communications sector as follows:

(21) $N_m = \frac{a_m}{s_m} \sum_i r_{mi} p_i Q_i$ and $K_m = \frac{b_m}{u_m} \sum_i r_{mi} p_i Q_i$

Hence, the factor requirements for the production of communications service and infrastructure, thus, are dependent on the structural changes of an economy. The capital-labor ratio also varies according to the changes in economic structure and becomes:

(22) $kc = \frac{K_c}{N_c} = \frac{\sum_m K_m}{\sum_m N_m} = \frac{s \sum_m b_m P_m Q_m}{u \sum_m a_m P_m Q_m} = \frac{s \sum_m b_m \sum_i r_{mi} P_i Q_i}{u \sum_m a_m \sum_i r_{mi} P_i Q_i}$

V. EXTENSION OF THE MODEL INTO DYNAMIC FRAMEWORK

1. Economic Contributions of Communications Sector

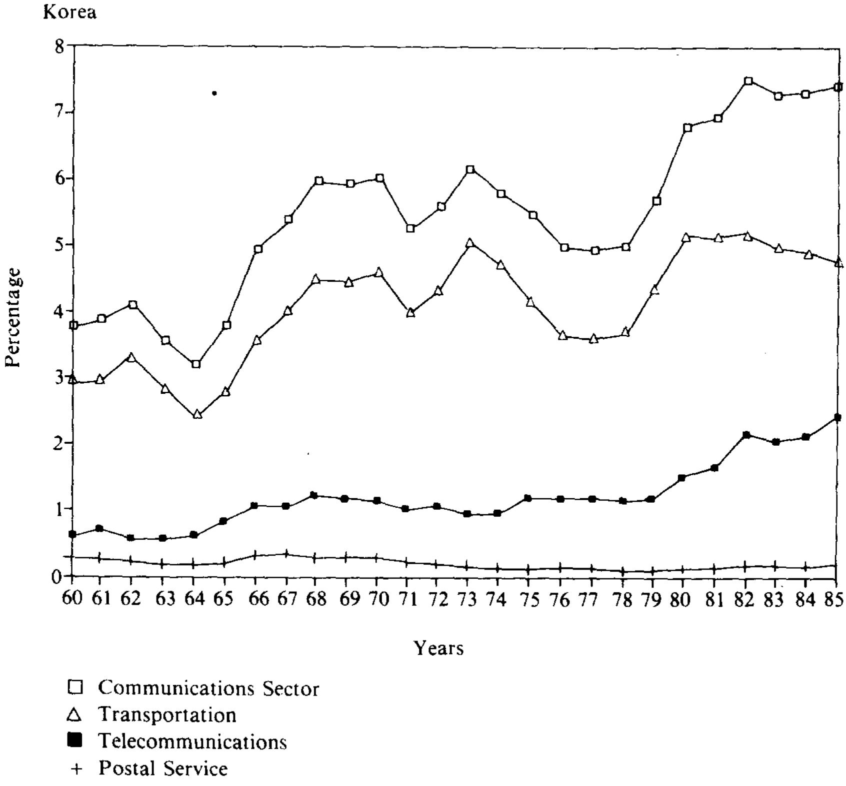
The economic contribution of a communications sector, r_c in equation(16), is changing over some period. By using the first order condition of Eq.(16) we can trace its trend. In Fig. (1), we can see that the contribution[11] of the communica-

[11] The contribution of communications sector (or communication mode m) on the production sector was estimated by the equation (8) (or 9). For the value of the total output of production sector was approximated by the GDP less the transportation and communications sector.

tions sector to the Korean economy[12] is increasing as time passes, and that of Japan is slightly decreasing[13].

The equation (16) indicates that economic structural change contributes to this movement of the economic contributions of communications sector and that the total contribution of a communications sector is composed of a variety of communication modes, including telecommunications. Hence, in order to examine the pattern of economic contribution of telecommunications, we need to examine both the changing process of the composition of communication modes within the com-

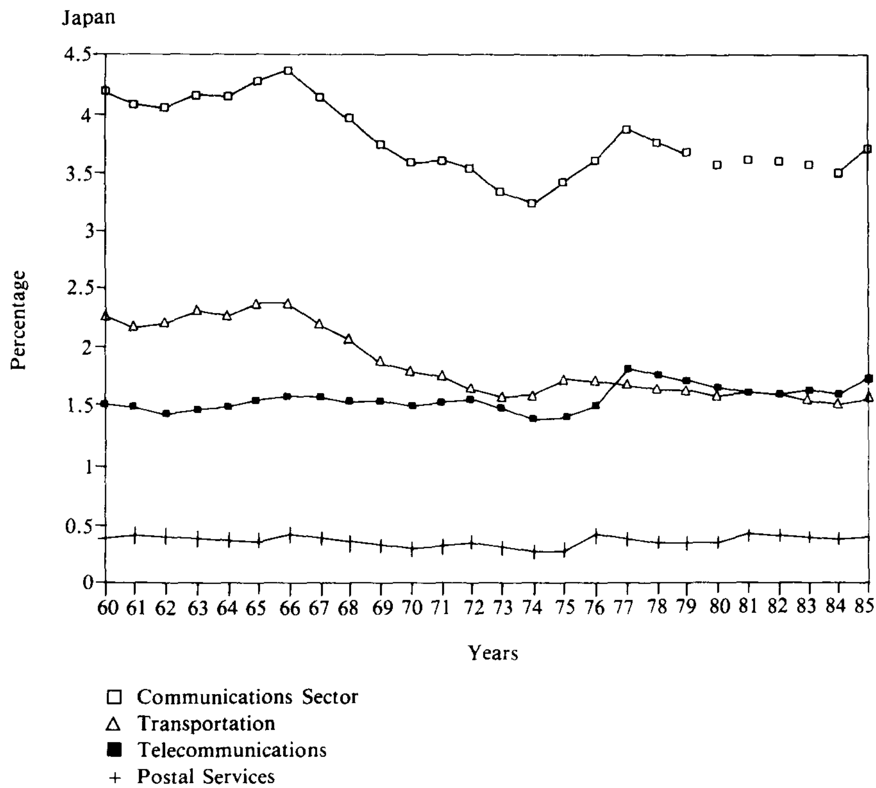
[Figure 1] Economic Contributions of Communications by Modes: Korea and Japan



Note: See Appendix A and B for data and sources.

[12]It would be more precise to call an economy a production sector. Here, it is assumed that an economy approximates a production sector which is a subset of a economy.

[13]The decrease in the economic contribution of communications sector of Japan is contributed by the decrease in the relative income of transportation industry to the GDP. And the decrease in the relative income of the transportation industry is contributed by replacement of private transportation for public transportation. Hence the interpretation of the movement of the economic contribution of communications sector in Japan should be carefully conducted.



Note: See Appendix A and B for data and sources.

munications sector, as well as the movement of the total economic contribution of communications sector in conjunction with the economic structural change.

2. Analysis of the Communications Composition

If we divide the both sides of Equation (16) by r_c, we get the following:

(23) $1 = \sum_m r_m/r_c$,

where r_m/r_c is share of communication mode of m in total contribution of communications sector to an economy[14]. Hence the vector $(r_1/r_c, r_2/r_c, \ldots, r_m/r_c)$ represents the composition of the total economic contribution of a communications sector by communication mode. Since there are substitutions among modes, the composition does not remain unchanged as time passes by. This changing pro-

[14]Hereafter, "economy" and "total economy" will be used as equivalent terms of the production sector of an economy.

cess of the composition can be analyzed by introducing the methodology of a Markov process.(Hillier and Lieberman 1980).

Let $S^n = (s_1^n, s_2^n, \ldots, s_m^n)$ be a vector representing a composition of the total economic contribution of a communications sector at a time period n, and p a transition matrix, whose element p_{ij} represents the probability that a unit of economic contribution made by a communication mode i at a time period n will be done by a communication mode j at a time period n + 1. Hence, the probability p_{ij}[15] explains the substitution effect between communication modes i and j over time, say intertemporal substitution between modes.[16]

Mathematically, we have the following equations:

$$(24)\ S^n = S^{n-1}p$$

$$\text{or } (s_1^n, s_2^n, \ldots, s_m^n) = (s_1^{n-1}, s_2^{n-1}, \ldots, s_m^{n-1}) \begin{bmatrix} P_{11} & P_{12} & \cdots & P_{1n} \\ P_{21} & P_{22} & & P_{2n} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ P_{m1} & P_{m2} & \cdots & P_{mm} \end{bmatrix}$$

The above equations show how the composition represented by the vector S changes as time proceeds. The changing process is governed by the transition matrix P.

The elements of the matrix P can be estimated by using a statistical method. The matrix expression of equation(24) comprises the following m equations:

$$(25)\ s_j^n = \sum_i S_i^{n-1} P_{ij}, \text{ for } j = 1, \ldots, m.$$

Introducing a stochastic term $\varepsilon_{j's}$ for errors, we have the following set of equations from E_q.(25):

$$(26)\ s_j^n = \sum_i s_i^{n-1} P_{ij} + \varepsilon_j, \text{ for } j = 1, \ldots, m$$

In the author's analysis, the set of equations becomes:

$$(27)\ S_p^n = s_p^{n-1} p_{pp} + s_c^{n-1} p_{cp} + s_t^{n-1} p_{tp} + \varepsilon_p$$

$$S_c^n = S_p^{rh} P_{pc} + S^n{}_c^{-1} P_{zc} + \varepsilon_c$$

$$s_t^n = s_p^{n-1} p_{pt} + s_c^{n-1} p_{ct} + s_t^{n-1} p_{tt} + \varepsilon_t,$$

[15]The term "substitution" should be interpreted to include a substitution of a potential unit demand of communication mode i by communication mode; at the next time period as well as a substitution of a unit of communication which is carried out by a communication mode i at current time period, in the case that the total volume of communications demand is increasing (or decreasing).

[16]The substitution between communication modes can be analyzed by obtaining the elasticity of substitution. However a quantification of the elasticity of substitution is extremely difficult because of the complexity of price data of each communication mode. And elasticity of represents degree of substitutability does not involve time. It is a static analysis. On the other hand, the transition probability represents a intertemporal substitution effect which is dynamic.

where s_p represents r_p/r_c, and the subscripts, p,c, and t stand for postal service, telecommunications, and transportation.(Remember that c in r_c stands for communications sector)

The ε_i's in the system of equations are assumed to be contemporaneously correlated, since a positive error in one mode means a negative error in at least one of the other two modes. We can observe the time series of s_j's, and hence p_{ij} can be estimated by using Zellner's(Theill 1971) method for a system of equations(or Seemingly Unrelated Regression(SUR)). Since, for a given i, the P_{ij}'s are conditional probabilities, the constratints:

$$\sum_j p_{ij} = 1, \text{ for } i = p,c,t$$

are imposed.

The following matrices shows the transition probabilities estimated by SUR on time series data(1960-1985) for Korea and Japan(See Appendix A and B for data and Sources):

Korea:

$P_k =$		P	c	t	
	p	0.64180*	0.0	0.35820*	[17]
	c	0.03110*	0.96890*	0.0	
	t	0.00274	0.02936*	0.96790*	

Japan:

$P_j =$		P	c	t
	p	0.67611*	0.32389*	0.0
	c	0.07625*	0.91596*	0.00779
	t	0.0	0.01498	0.98502*

For Korea, a strong substitution of postal service by transportation is found. Substitutions from telecommunications to postal service and from transportation to telecommunications are also found to be significant, but those are at marginal levels. On the other hand, the substitutions between the postal service and transportation are not significant in Japan. Instead, there exists a strong substitution from the postal services to telecommunications, and a weak but significant one in the opposite direction. The transportation mode seems to be almost independent, and no significant substitutions between transportation and other communication modes were found.

[17] "*" denotes that the estimate is significantly different from zero at the 5% level of significance. The elements p_{pc} and p_{ct} of the transient matrix p_k, and p_{pt} and p_{tp} of p_j are constrained to zero, since in the first run those had negative signs and had no evidences that those were significantly different from zero.

Since the postal service is generally considered as a distant communication mode, connecting distant places, one can easily understand the result, if one compares the different levels of long distance calls during the period in both countries. In Korea, DDD service was provided only on a point-to-point basis in limited urban areas with step-by-step switches, throughout the analysis period. The installation of a nationwide Direct Distance Dialing(DDD) with digital switching was completed only at the end of 1984. Operator assisted long distance calls were the only nationwide calling system during the period. Moreover, as shown in the above table, the call completion rate for DDD calls was very low. Operator assisted calls took more than 30 minutes. In some areas the call waiting period was longer than the time that transportation would take to get there.(Lee 1985) Because of this poor quality of services, the telecommunications of Korea seems less competitive in substituting postal services than the transportation system.

The situation of Japan is different. Japan already had a nationwide DDD network from the beginning of the analysis period. As shown in the above table, the percentage of DDD in nationwide long distance telephone network already reached 80.4 percent in 1966. Moreover, the call completion rate(74.5%) of this DDD service in 1966 was even higher than that(57%) of Korea in 1983. Hence, it seems that a good nationwide telecommunications network of Japan has actively been substituting for the postal service.

3. Steady State Communications Composition

In a Markov Process, a steady state probability is defined as the probability of finding the process in a certain state, say j, after a large number of transitions, and tends to the value z_j. In our problem the steady state probabilities are the elements of a steady state composition vector and interpreted as the steady state share of a communication mode in the total economic contribution of a communications sector.

Since the composition does not change at the steady state, we can calculate the steady state probabilities using the following set of equations, which are steady state equations:

$$z_p = z_p p_{pp} + z_c p_{cp} + z_t p_{tp},$$
$$z_c = z_p p_{pc} + z_c p_{cc} + z_t p_{tc},$$
$$z_t = z_p p_{pt} + z_c p_{ct} + z_t p_{tt},$$
and $1 = z_p + z_c + z_t$,

where z_p, z_c, and z_t stand for the steady state shares of postal service, telecommunications and transportation

The steady state-probabilities calculated from the equations above are as follows:

Korea: $z_p = 0.0440656$ $z_c = 0.4642216$ $z_t = 0.4917228$
Japan: $z_p = 0.1341080$ $z_c = 0.5696558$ $z_t = 0.2962362$

The steady state probabilities, or compositions, indicate that the share of the economic contribution of postal service will stay at 0.04407 in Korea and 0.1341 in Japan in steady state. Likewise, the share of economic contributions of the telecommunications and transportation will approach the corresponding probabilities of the steady state, which are shown in the table.[18]

According to the steady state composition, Korea's transportation will still assume the largest portion of the total economic contributions of the communications sector in the steady state. But for Japan the results show that telecommunications will be the largest in terms of economic contribution among the three communication modes.

However, the steady state composition is based on the assumption that the current pattern of the Markov process is sustained for good. If there happens to be a change in the substitution pattern among the communication modes, in other words a change in technology, the steady state composition should change accordingly.

The lower level of the Korean steady state probability compared to Japan's implies a poorer quality of existing Korean telecommunications during the analysis period, 1960-1985. This is partly because the acquisition of telecommunications systems in Korea was heavily reliant on expensive foreign sources throughout the period. However, since a public corporation, the Korea Telecommunication Authority (KTA), was established to assume control of the government operated telecommunications services, R&D investment for technological self-reliance has been sharply increased (Seo 1986; Seo, Son, and Lee 1987). These R&D efforts of Korea will strengthen the competitiveness of its telecommunications. And it is expected that the Korea's telecommunications will claim a larger share in economic contributions than shown in the steady state analysis which only involves the technological situation during the period 1960-1985.

4. Effects of Economic Structural Change on the Economic Contribution of a Communfcations Sector

In this section, we are going to examine the economic structural effects on the economic contributions of the communications sector or a communication mode. This analysis will be applied to Korea and Japan, which have the different economic situations of a developing and an advanced economy.

A. Korea

In Eq (16) the parameters r_{c_i}'s are interpreted as the contribution of a com-

[18]It should be noted that this interpretation is appropriate only on the assumption that current substitution pattern is sustaining for good. In other words the result is appreciated only when the communication technology is not changing.

munications sector to a subsector i of the production sector. Thus, the economic contribution of the communications sector at the macro-level is represented as a weighted sum of the contributions of the communications sector to each subsector of the economy, with the proportion of the subsector in total value of output being a weight. The equation explains how the economic contributions of the communications sector changes as the structure of the economy varies.

The r_{ci}'s can not however be easily estimated from the raw data. Hence, we rely on the statistical methodology of regression analysis. For this purpose, a constant, a, and stochastic term, , are added into the equation as follow:[19]

$$(28)\quad r_c = a + r_{c1}d_1 + r_{c2}d_2 + r_{c3}d_3 + r_{c4}d_4 + \varepsilon.$$

As shown in the above equation, the economy is disaggregated into four sectors; Primary or agriculture, secondary or manufacturing sector, tertiary or service sector, and quarternary or information sector.[20]

We cannot use the OLS method directly since the d_i's sum to 1. The linearity or perfect multicollinearity (Theil 1971) among d_i's violates the assumption of ordinary regression analysis. Hence, we need some manipulation to avoid this violation. We know that $d_1 = 1\text{-}d_2\text{-}d_3\text{-}d_4$, since $\Sigma d_i = 1$. Replacing d_1 of equation (4.4) with the above equation, we get:

$$(29)\quad r_c = c\text{-}r_{c1} + (r_{c2}\text{-}r_{c1})\, d_2 + (r_{c3}\text{-}r_{c1})\, d_3 + (r_{c4}\text{-}r_{c1})\, d_4 + \varepsilon$$

This equation has no linearity, and so we can use ordinary least squares (OLS) method. But in the regression results, the estimate of r_{c1} is captured in the constant, and the estimates of parameters of d_2, d_3, and d_4 only show the differences from the parameter of d_1, which is $r_{ci}\text{-}r_{c1}$ correspondingly. Moreover it is clear that there is no unique set of estimates of coefficients minimizing the sum of squares of errors, since for any constant k added to the value of each estimates of the r_{ci}'s and subtracted from the constant, the values of errors are not changed and hence the sum of squares of errors are left unaffected.[21]

The following is the result of this OLS regression analysis on Korea (1960-1985):

$$\begin{aligned} r_c = &-3.3132 + 0.07181d_2 + 0.19114d_3 + 0.15516d_4 \\ &(-2.0346)\quad (3.4436)\qquad (2.9433)\qquad (2.9543) \end{aligned}$$

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[19]The constant, a, can be interpreted as a part of the constant of Cobb-Douglas production function which represents a level of technology.

[20]The finance, insurance, estate, services etc. are contained in information sector. This sector specification complies with the Engelbrecht's specification (1986).

[21]Suits (1984) discussed a problem of interpretation for such a case, and transformed the equation into a form which is easier to interpret.

(note: The numbers in parentheses are t-statistics.) The dependent variable is the total value of output of communications sector, which includes the total income of postal service, telecommunications, and transportation.

In the estimated equation above, the coefficients of d_2 represents the difference of r_2 and r_1. And as explained earlier, there is no unique set of estimates for the model. The original equation (4.4) can be fitted only subject to the imposition of some constraint of the values of the r_1 (it can be r_2, r_3, or r_4), Hence the coefficient of d_1, a contribution of communications to the agricultural sector, is arbitrarily set to zero.[22] We assume therefore that there is no significant relationship between the income of the telecommunications industry and the output value of agricultural sector. The regression results will be explained on the basis of this assumption.

The estimated coefficients are all significant at the 5% level of significance. In terms of the magnitude of its coefficient, the largest is the third sector, the second largest the fourth sector, and the smallest the second sector.

It was unexpected that the coefficient of the information (or quarternary) sector is smaller than that of the service (or tertiary) sector. But these results by and large comply with the average input coefficient of communications for each sector. As Table 2 shows, the third sector has the largest input coefficient of communications, the fourth sector the second, and the second sector the third.

The smaller-than-expected communications input coefficient of the information sector seems to result from the fact that the input coefficient of communications into finance and insurance industries, which assume the largest portion in information sector, decrease from 0.02033 to 0.01894 during the period 1970-1983[23]. Whang (1986, p45) explains this phenomenon by saying that "it seems that for the finance and insurance industries, a computerization of the industries and an introduction of on-line transaction systems demand relatively more data communications services than telephone services which are basically a voice transmission service."

However, we must remember that our data only represents the primary communications sector. If we included the secondary communications which are self-supported by firms, the results would likely be different.

B. Japan

The same analytics were applied to Japan. And the result is the following:

$$r_{com} = \underset{(6.5021)}{14.001} - \underset{(-5.5055)}{0.15074d_2} - \underset{(-2.2414)}{0.11876d_3} - \underset{(-6.9228)}{0.07881d_4}$$

[22]It can also be assumed that the real coefficient of first sector can hardly be away from zero (Saunders, Warford, and Wellenius 1984).

[23]Source: Input-Output Table of Korea (Annual), the Bank of Korea.

The esmations are all significant at 5% level of significance. But the sign of the estimations are unexplainable. These results resulted from the fact that the income of the transportation industry of Japan, which accounts for the largest share in the communications sector, has been declining.

Furthermore, a large portion of the telecommunications services of Japan are not intermediate, but final consumption goods.[24] In fact, 28.4%[25] of the total output of telecommunications was consumed by final consumers in 1980. On the other hand, the corresponding figure for korea for the same year was 18%[26]. This number should be lower since lots of in-house factories and small businesses are using residential telephones for their business in order to avoid higher business telephone rates as seen in other developing countries.[27].

In these contexts, the communications sector data for Japan which is gathered from public statistics data base, is considered to be inappropriate for examining the relationship between the contribution of the communications sector and economic structural change using the equivalence relationship in equation (4.2). This argument can be generalized for advanced countries, since a considerable portion of communications output becomes a final consumption good as per capita income grows.[28]

Besides, it should be remembered that our basic hypothesis for modelling was to maximize the total output value of the production sector. Hence, if a considerable portion of telecommunications services is for final consumption, the model begins to loose its analytical basis.

VI. CONCLUSION

The economic contribution of a communications sector is at the aggregate level represented as the ratio of communications sector output value to the production sector output value. By disaggregating the model by sectors and by communication modes, we found that this economic contribution of communication is expressed as a sum of all economic contributions of individual communication modes or as a weighted sum of contributions to subsectors of production sector, with the share of a subsector in total output value of production sector being a weight.

[24]Of course, the insignificances of the estimations can be considered due to the ignorance of transportation which is substitutable with telecommunications and post services.

[25]Source: Input-Output Table of Japan, op cit.

[26]Source: Input-Output Table of Korea (Annual), the Bank of Korea.

[27]"In many of the developing countries that differentiate between business and residential subscribers, subscribers in the business category are charged a higher monthly rental fee. One result of this is that, when a building is used for both business and residential purposes (small shops, farms, and so forth), there is an incentive for subscribers and potential subscribers to have their telephones listed as residential even though they are used mostly for business." (Saunders, Walford and Wellenius 1984, p181).

[28]Final consumption use represents 72 percent of the communications output in Spain in 1966 and over half of that in the U.S. in 1967. (CCITT 1976, p.6, chapter 3).

Hence, the economic contribution varies according to the composition of communications sector output by communication modes and to the changes in economic structure. These two important results are shown theoretically by the two sector model.

To examine the dynamic nature of the economic contribution of the communications sector over time, ordinary least square regression, and Markov Chain analysis were employed and empirical analyses were conducted. For this purposes, Korea and Japan were chosen, since both countries have experienced a rapid economic structural change and a rapid change in their communications technology.

The Markov Chain analysis showed that there were significant intertemporal substitutabilities among communication modes in both the data sets for Korea and Japan. But there was a significant difference between the two countries in their substitution patterns. For Korea a high level of substitution of postal service by transportation was detected. On the other hand, the postal service was more substituted by telecommunications in Japan. This difference is explained by the difference in the quality of the telecommunications services of the two countries. In Korea, the quality of telecommunications services was, during the analysis period, so poor that transportation has been more competitive in substituting postal services than telecommunications.

The analysis of economic structural influences on the economic contribution to the total economy of the communications sector was carried out with statistical estimates at the 5 percent significance level for Korea. The results show that the economic structural changes of Korea well explains the trend of its communications services.

From these analyses we can conclude that to examine the economic contribution of telecommunications, or an individual communication mode, we have to analyze, first, the trend of the total economic contribution of the communications sector in conjunction with economic structural changes and, next, the changes in the communication composition by modes.

Several problems in the data were detected, mainly for Japan. For Japan, the income date of the telecommunications industry includes the large revenues from residential use. For the basic assumption of the model was a profit maximization of firms, and telecommunications services were considered as a public intermediate good. The transportation data of Japan also was a porblem. Compared with the poor development of private transportation in Korea, Japan's private transportation and company, owned transportation are widely developed. And these private transportation expenses are hardly captured in the public statistics in the data set.

APPENDIX

Communications Sector Outputs: Data
Korea (unit: mil. won)

Year	Postal Services	Telecommunications	Transportation[1]
60	593	1293	6286
61	628	1795	7781
62	648	1692	10151
63	797	2406	12334
64	1163	3811	15388
65	1499	5873	20117
66	2855	9450	32392
67	3578	11257	43653
68	3810	15980	60085
69	5087	20249	78424
70	6407	24852	100927
71	6931	32647	127674
72	7966	40869	170275
73	8377	47156	254829
74	9274	68976	337683
75	13593	113722	399920
76	21655	154436	483324
77	23443	198348	612854
78	25816	261174	844102
79	30727	349217	1277192
80	44829	532190	1812541
81	65038	713344	2219362
82	99569	1044012	2507146
83	108091	1162306	2799594
84	129192	1361141	3127759
85	155030	1682230	3323881

Notes: 1, Transportation only includes land passenger transportation modes, such as urban bus, inter urban bus, express bus, taxicab, passenger train, and subway.

Source: a. Korea Statistical Yearbook, annual, EPB, ROK.
b. Statistical Yearbook of Communications, annual, Ministry of Communications, ROK.
c. Statistical Yearbook of Rail Road, Office of Rail Road, Korea.
d. Transportation Survey Report, EBP, ROK.

Japan (unit: 100 mil Yen)

Year	Postal Service	Telecommunication	Transportation[1]
60	658.10	2463.92	3682.29
61	823.30	2895.83	4224.38
62	813.70	3215.16	4969.28
63	1025.00	3752.48	5897.22
64	1139.00	4370.10	6661.18
65	1194.00	4998.37	7658.30
66	1556.00	5938.67	8935.49
67	1731.00	6998.47	9799.80
68	1859.00	8079.54	10881.34
69	2023.00	9592.45	11640.23
70	2197.00	11155.05	13389.70
71	2741.00	12649.06	14650.47
72	3321.00	14828.25	15796.36
73	3490.00	17343.70	18472.44
74	3793.00	19171.02	22127.84
75	4495.00	21555.39	26449.34
76	7065.00	25713.58	29670.74
77	7319.00	34784.10	32162.09
78	7503.00	37057.55	34610.00
79	7895.00	39255.09	37413.08
80	8540.00	41021.07	39053.55
81	10838.00	42624.94	42089.84
82	11129.00	44611.38	44174.21
83	11382.00	46914.56	45233.51
84	11574.00	48854.42	47101.09
85	12071.00	53074.66	49000.00

Notes: 1. Transportation only includes land passenger transportation modes, such as public bus, chartered bus, taxi, passenger train, and subway.

Source: a. Statistical Yearbook of Communications, annual, Ministry of Communications, Japan.

b. Yearbook of Telecommunications, annual, Ministry of Communication, Japan.

c. Statistical Yearbook of Land Transportation annual, Transportation Policy Bureau, Ministry of Transportation, Japan.

Appendix

Production sector outputs: Data
Korea (unit: %)

Year	1st Sector	2nd Sector	3rd Sector	4th Sector
60	44.23	16.35	10.80	28.62
61	47.17	16.56	10.48	25.79
62	44.16	17.14	12.20	26.50
63	48.75	17.60	12.40	21.25
64	51.81	18.72	12.20	17.27
65	44.79	21.77	15.00	18.44
66	42.17	22.71	15.88	19.24
67	38.56	23.41	17.06	20.97
68	35.43	25.72	16.86	21.99
69	35.39	26.57	17.43	20.62
70	34.32	27.01	17.90	20.76
71	29.76	27.73	19.49	23.13
72	29.09	28.45	20.21	22.25
73	27.47	31.65	20.60	20.28
74	27.13	32.45	20.64	19.79
75	27.52	32.84	19.55	20.09
76	25.93	34.22	18.29	21.57
77	25.03	35.40	17.01	22.46
78	23.13	38.22	16.06	22.70
79	21.51	40.00	16.02	22.58
80	17.33	41.06	16.47	25.24
81	18.97	39.80	16.58	24.75
82	17.63	39.76	16.76	25.74
83	16.43	40.20	16.65	26.83
84	16.05	40.83	17.14	25.98
85	16.34	39.76	17.32	26.69

Note: 1. Each sector is comprised of as follows:
1st sector; Agriculture forest and fishing, and mining and quarring,
2nd sector; Manufacturing, and construction,
3rd sector: Wholesale and retail trade, restaurants, hotels, and electricity gas and water,
4th sector: Finance and insurance, real estate, business services, government services, private non-profit services, and community social and personal services.
2. The percentage is the ratio of sector output value to GDP less transport and communications.

Source: 1. Economic Statistics Yearbook 1976, The Bank of Korea.
2. National Accounts 1987, the Bank of Korea.

Japan (unit: bil yen)

60	2324.7	6052.4	3023.5	3578.8
61	2567.6	7606.6	3539.8	4309.0
62	2839.3	8476.9	4397.6	5093.0
63	2901.5	9996.7	4753.3	6057.5
64	3150.0	11482.6	5290.8	7197.9
65	3423.1	12133.3	5815.5	8495.3
66	3856.9	14275.5	6578.5	10030.5
67	4606.1	17513.8	7544.5	11579.5
68	4841.7	20777.5	9257.4	13682.7
69	5053.3	25271.9	11244.2	16247.4
70	5121.2	30593.6	13566.5	19896.6
71	4907.9	34957.0	13025.0	25016.6
72	5712.9	39680.7	14879.8	30041.0
73	7497.4	49421.7	18046.2	36160.7
74	8452.5	56855.7	22587.0	44057.6
75	8917.3	59123.3	24935.8	51676.2
76	9712.9	66275.6	28724.2	57814.5
77	10360.1	71405.8	31828.0	65659.1
78	10544.6	79096.1	34443.5	73617.4
79	10863.3	85806.9	37250.9	81743.2
80	10210.2	92738.3	43372.7	87942.7
81	10277.6	98601.7	45802.6	94296.8
82	10350.4	102157.0	48313.4	101841.9
83	10484.9	103512.9	50649.2	109044.9
84	10849.5	110919.7	52213.1	115861.1
85	10833.2	111282.0	51946.7	116364.1

Note: 1. Each sector is comprised of as follows:
1st sector; Agriculture forestry and fishing, and mining,
2nd sector; Manufacturing, and Construction,
3rd sector; Wholesale and retail trade, and electricity gas and water,
4th sector; Finance and insurance, real estate, services, government services, and private non-profit services.
2. Transport and communications sectors are excluded.

Source: Annual Report on National Accounts, 1986, Economic Planning Agency, Government of Japan.

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