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THE ADOPTION AND DIFFUSION OF SERVICE PRODUCTS*

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The objective of this paper is to theoretically explore the innovation, adoption and diffusion of service product. A theoretical model of the diffusion of service product is developed that takes account of transportation, waiting and searching costs in the adoption of service product. The main results of the model are; (1) the diffusion of service product is slower than that of the manufacturing equivalent and (2) the delivery or retail distribution service speeds up the diffusion of the manufacture product. The implications of these results are also explored.

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I. INTRODUCTION

The growth of service sectors in the economy is one of the great trends in the second half of the twentieth century. However, for a surprisingly long time, economists largely ignored the growing significance of service sectors. Much of theory and many of statistics still remain based upon approaches developed to deal with the manufacturing sectors. Although researches on service sectors recently start to grow particularly in management science (Metcalfe and Miles (2000)), any attempt to develop a micro-founded economic theory on service has not been made yet. Reflecting on this, the objective of this paper is to theoretically explore the static and dynamic demand (i.e. the adoption and

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diffusion) of service innovation.

One of the idiosyncratic features of service product is that production and consumption simultaneously occurs. In other words, the utility for service product is generated in the course of contact between service provider and consumer (for example, think of the case of hairdressing or health care service). This implies that consumers must travel to service providers for the consumption of service product and wait at service providers' site in the case of excess demand. This feature makes a critical impact on the static and dynamic demand of service product. For example, traveling and waiting for the consumption of service product increases adoption costs and these costs may prohibit consumers adopting service products or slow down the diffusion speed. Then, the questions follow such as (1) how are the static and dynamic demands (i.e. adoption and diffusion) of service product different from those of the manufacture product? (2) what time path will the demand for service product follow? and (3) if the static demand of the manufacture product is *de facto* the demand for a composite product of manufacture product itself and retail distribution service, how does the retail distribution service influence the static and dynamic demands of the manufacture product? We try to answer these questions in this paper.

The insight about the consumption of service product shows that transportation (or contact), waiting and searching costs delay the adoption and diffusion of the service product. This is also true for the manufacture product if the adoption of retail service is a precondition for the adoption of the manufacture product. The implications about these results are; (1) the development of ICT technologies makes it possible to trade at virtual space and this decreases transportation, waiting and searching costs relating to the adoption of service product. As a result, the market and sales of service product grow with the development of ICT technologies, (2) the slower diffusion of service product makes it difficult to finance R&D investment in service innovation particularly in the imperfect financial market where the short term profit is preferred, (3) retail distribution service generates vertical externality to the demand for the manufacture product and (4) welfare improvement effect is greater in the diffusion of service product than in that of manufacture product. These implications invite government intervention in service industries.

The remainder of this paper is structured as follows. In the next section, we discuss the idiosyncratic features of production and consumption of service product and the need for change in the classification criteria of the service sectors. In section Ⅲ we build a model on the adoption and diffusion of service product, and in section Ⅳ analyze the relation between service diffusion and product/process diffusion. In section Ⅴ we discuss the empirical and policy implications of the theoretical findings of this paper. Conclusions are stated in section Ⅵ.

Ⅱ. A NEW APPROACH ABOUT SERVICE PRODUCTS

2.1. The Definition of Service and Its Measurement Problem

It is not easy to define or to describe intangible service products or service activities. Reflecting this difficulty, there are in fact many different definitions of service, and this causes demarcation problems in manufacturing and service within manufacturing and between service sectors. Probably, the broadest definition of service may be that services are defined as 'activities' directed at making changes or transformation of some entities (Metcalfe and Miles, (2000)). The transformation can be of form, place or time of availability, and the entities can be material objects, goods, people, natural environment or symbolic representations such as data and text. This definition indicates that most activities relating to manufacturing production as well as service production should be included in the category of service. For example, according to the above definition, the labor used in the manufacture of physical goods is actually service and subsidiary activities of production such as purchasing, financing and marketing are also services. A research suggests that within manufacturing 75% to 85 % of all activities involves service activities (Rod Coombs and Ian Miles (2000)).

Although most economic activities are composed of service activities, they have not been properly represented in statistics. In most industrial production statistics, the service activities within manufacturing are not counted as service. Furthermore, in that statistics services are classified by the way developed for the manufacturing sectors. For example, services are classified as three categories: services subsidiary to manufacturing (retailing, wholesaling, transportation and etc), services relating to public utility (communication, electric and gas, water and railway) and other services. This classification distorts not only the measurement of service activities but also the intrinsic function of service. The misrepresentation of service may be partly due to the ignorance and partly to the difficulty in separately measuring services in the production that services and manufacturing activities are assimilated into. Thus, it is urgently required to find a new classification method that is able to expose the intrinsic function of service and to correctly measure service activities. For this purpose, we first examine the idiosyncratic features of service.

2.2 General Features of Service: Production vs Consumption

The production and consumption of service are, to some extent, different from those of manufacture product. We will first examine the properties of service production that distinguish from those of the manufacture product.

Like the production of manufacture product, service is also produced from various combinations of production inputs such as capital and labor. However, production inputs used in service production are slightly different from those of manufacture product. First, major capital input required in service production is, in most cases, physical facilities such as building rather than machinery such as equipments and plants. This implies that the ratio of asset specificity to total capital is lower in service production than in manufacturing production. Thus it is less risky to set up service business. Second, labor input required in service production is industry-specific. That is, in non-delivery service sectors[1] (e.g., medical service, hair-dressing, management consulting, education, legal service, etc), high professional staffs (such as doctor, lawyer, expert in each field) are used. However, in delivery service sectors (e.g., retail and wholesale trade, postal service, transportation service, etc), relatively unskilled labor is used. Third, service production is similar to 'craft production'. That is, there is considerable discretion for individual laborer and limited management control of the pace and quality of work. As such, service production is non-continuous production and technically speaking, service production technology is convex. Thus, there is limited economies of scale in service production. This implies that the size of a service firm is generally small.

The above properties of service production are clearly distinguishable features from the manufacture product but the existing analytical framework developed for the manufacture product can be still used to the analysis of service. We continue to explore the properties of service consumption.

In general, utility of manufacture product is obtained by "using" the goods. However, this is not the case for service product. Utility for service product is generated in the course of "contact" between service provider and consumer. Of course, 'material' or 'need' that consumer wants is delivered in the course of contact. This property of service consumption is derived from the feature of the service product that outputs of service production are, in most cases, immaterial, intangible and one-off products, so that they are hard or impossible to store or transport. This implies that consumers must travel to service provider for the consumption of service product. In other words, consumers have to incur transportation costs for the consumption of service product.

This intrinsic feature of service consumption leads to the following distinguishable properties; first, transportation costs required for service consumption limits the range of the market. Thus, for most services products, the relevant market is local or regional. Second, production and consumption of service occurs simultaneously. Third, in designing, producing and delivering service, consumer's participation is required. That is, interchange of information about consumer's requirement on service product specifications is an essential ingredient in service provision. These properties of service consumption are basically different from those of manufacture product consumption and thus uncover the difference between service and manufacture product. From these idiosyncratic

[1] See the next section for the classification of non-delivery and delivery service

features of service consumption, we try to reclassify service sectors.

2.3. A New Classification of Service Industries

Industries have been conventionally classified in terms of manufacturing activities, such that agriculture, forestry, fishing and mining are grouped as the primary industry, construction and manufacturing as the secondary industry and services as the tertiary industry. However, as stated above, this classification leads to misrepresent service sectors or to underestimate service activities. In fact, attempts for the alternative classification have been made to overcome these problems (Freeman (1978), Pavitt (1984), Soete and Miozzo (1989)). In line with this attempt, we try to classify service sectors in a way of reflecting the intrinsic feature of service. That is, given the fact that production and consumption are separable for manufacture product but not for service product, the feasibility of delivery can be a criterion to demarcate service and manufacture product. Services are basically non-deliverable but manufacture products are deliverable. The interesting fact here is that the delivery of deliverable manufacture product has been conventionally an important function of service and thus has become the center of service sectors. The reason why delivery becomes a service product is related to the economies of scale in transportation. That is, it is much cheaper for one producer to take all the transportations of consumers than each consumer individually transports. Following this criterion, we classify service sectors into conventional delivery sectors and non-delivery sectors. The services in the same sectors are regrouped according to whether the object of service is physical (or material), human or information and network. Table 1 shows the summary of this classification.

Although other classifications may be possible[2], this new classification has the following merits; (1) contact or transportation costs can be exposed as a critical factor in estimating service consumption and (2) the impact of ICT innovation, which is understood to have been making considerable change on conventional contact ways between service provider and consumers, can be correctly assessed. So, this new classification will be used in following discussion on the adoption and diffusion of service innovation.

Ⅲ. INNOVATION, ADOPTION AND DIFFUSION OF SERVICE PRODUCTS

3.1 Service innovation

Innovation is conventionally classified into two categories, i.e. product and process innovations, and they are defined respectively as goods or production

[2] Another dichotomy criterion for classification may be possible: e.g. customization vs standardization, externality vs non externality or end user service vs transmission service

methods that are new to the markets. This categorization, like the classification of industries, mainly reflects technological aspects of manufacturing and thus overlooks the existence of other types of innovations. For example, as Schumpeter (1912) put in his classical book, 'The Theory of Economic Development', delivery and market innovations can be suggested as equally important innovations.

[Table 1] An alternative classification of service sector

	Physical service	Human service	Information/network Service
Non Delivery Services	Hotel Traditional restaurant Laundry Publishing Fast food restaurant	Health care Hairdressing Education Security service	Management consulting Legal consulting Technology (R&D) consulting Business services Public administration Finance Insurance Banking Estate agency
Delivery Services	Postal service Freight service Retail service Wholesale service Waste disposal Electric and Gas service	Public transport (bus, train, taxi, etc.)	Telephone service Internet service Broadcasting service Communication service

Product and process innovations are a well-suited concept for explaining innovations in manufacturing sectors but have some problems in applying to service goods. The reason lies in the fact that in service sectors process, product and delivery innovations are tied to one another, so that it is quite difficult to distinguish one innovation from the other. We may explain this feature of service innovation by an example of service innovation in 'emergence response service' introduced by Athey and Stern (2002).

Suppose that health care service introduces an enhanced emergency response system (so called E911 system) that links caller identification to a location database. The previous system is that an individual experiencing an emergency calls a local call-taker or a local service agency, who gathers information about the caller's location and severity of the incident and then passes this information to central emergency health service agency for dispatch of emergency personnel. The new system is to directly connect a caller to the central emergency health service agency by using of information technology to link digital identification from incoming telephone calls to a database containing location information. Furthermore, in this new system a call-taker in the central emergency service center may use emergency-specific protocols to provide emergency personnel in ambulance with emergency medical instruction. As a result, callers would receive emergency medical service in the ambulance on the way to the hospital.

This new system includes a chain of three different innovations; process, product and delivery innovation. That is, for the new system to be operated, first of all, the big organizational change has to be made. For example, the local telephone operator or local service agency in the intermediate level has to be removed and specialized training for emergency medical dispatching has to be given to call-takers in central service agency. This organizational change produces the change in the way of providing emergency service. Likewise, in service sector the process innovation is much associated with change in business organization and work practices rather than with change in plant and equipment. With the change in the way of providing the service, the emergency service provides callers with faster service and medical treatment. This service can be regarded as rather a new service and it is thus equivalent to product innovation in the manufacturing sector. Furthermore, in this new emergency service, the way of delivering the service has been changed from simply carrying service to package service including both carrying and medical treatment. So, this new way of delivery can be described as a delivery innovation. The chain of innovations illustrated in this example is a general feature of service innovation.

To summarize, the new emergency response service is definitely a process innovation. But at the same time it can be both product and delivery innovation. So it is not quite appropriate to apply the conventional concept of product and process innovation to this service innovation.

There is another reason that conventional concept of product innovation is not suited to apply to service innovation. In non-delivery service sectors, services are generated anew for each consumer and in some service sectors like legal and business consulting the provision of the same service is not possible and never completely repeatable. Thus, if the concept of "the newness to the market" as a criterion for innovation is applied to service, service is new in every trial and therefore always is innovation in every provision. However, even though service is generated anew to each consumer, there are a few service goods that are 'completely' new to the market. The largest groups of service innovations are either innovations on service delivery or a combination of existing services (B. Preissl, 2000). In this context, innovation in service sectors is close to the concept of product differentiation rather than to that of product innovation. This is the reason why the conventional concept of product innovation is not suited to apply service innovation.

There is also a dubious case that service innovations cannot be interpreted as either product or process innovation. That is the case of delivery innovation. The delivery innovation can be regarded as a process innovation if delivery is perceived as a part of production process. It can also be regarded as a product innovation if delivery is perceived as a part of the product. However, it is fair to regard delivery as an independent category of innovation. Since many service goods are defined by particular delivery or distribution (see Table 1) it is therefore reasonable to regard the delivery innovation as a service innovation.

Based upon the above reasons, we may define service innovation by the 'package innovation', in the sense that process, product and delivery innovation are directly linked to each other. So it is more reasonable to conceptualize this package innovation as service innovation rather than to separate this package innovation into process, product and delivery innovation. In this paper we thus name this package innovation 'service innovation'.

3.2. Adoption and Diffusion of Service Innovation

Since we have clarified the concept of service innovation, we now examine how this service innovation is adopted and diffused. The adoption model of service innovation is built upon a conventional decision theoretic model.

(1) An Uncertainty model

Before starting the model, we clarify the relation between service innovation and service diffusion. Innovation is a supply-side of the new technology, in that it makes impact on the cost and performance of the new technology. However, when diffusion (a demand-side of the new technology) was analyzed, innovation or the supply side of the new technology was generally taken as determined exogenously to diffusion process itself (see the representative diffusion models such as Mansfield (1968), Davies (1979), Reinganum (1981,1983), Fudenberg & Tirole (1985), Stoneman & Kwon (1994, 1996)). This may be justified by the fact that innovation is protected by the patent law and thus that the monopolized supply market is not changed for long time, although there is possibility for change in the supply market such as the appearance, improvement and technological obsolescence of new technology. The analysis of service diffusion may continue to proceed in this way as far as service innovation can be effectively protected. However, there is a restricting case that the supply market of the new service can be changed to the diffusion process. Let us explain this case by the example in (3-1). Suppose that 'hospital A' patented the enhanced emergency response system (EERS). If 'hospital B' wants to copy EERS, it has to adopt the same process innovation as 'hospital A'. So, if 'hospital A' patented a new service product, EERS, then it can automatically protect the service process innovation. Suppose now that 'hospital B' with telephone operators invests in IT and a database on location information, and proceeds the process innovation such as training for the dispatch for emergency personnel to operators. Then, 'hospital B' can supply a new service product similar but not the same to EERS. In this case, since hospital B's process innovation is not the same as 'hospital A', hospital A's EERS may not be protected, depending upon the scope of the patent and the range of the market. This example illustrates that the supply market of service innovation is more susceptible of entry than that of the product or process innovation, depending upon the extent that service process innovation is able to produce different kinds of new service products. Thus, the supply market of service innovation is more likely to change to the diffusion process. However in our model, we assume for the simplicity of the analysis that the monopolized supply market of service innovation is taken as determined exogenously (an endogenous model of the interaction of supply and demand will be dealt with in a separate paper).

We also make two additional assumptions that underlie in the model. First, we assume that service indicated in the model means service traded on off-line market. Service traded in on-line market will be separately discussed in section V. Second, we assume that there is considerable uncertainty about a new service product, particularly its quality to consumers. This uncertainty is different from that about manufacturing products, in that this uncertainty comes from the intrinsic features of service product. As explained in (2-2), service product is immaterial, intangible and one-off, so that service suppliers are difficult to demonstrate or advertise their service products in advance of purchase and consumers cannot also inspect service products in advance of purchase. Furthermore, a word of mouth effect from existing adopters is more limited than the case in the manufacturing products, because their experience is difficult to be objective. Thus, the depth of initial information concerning the service product is limited. So it is not absurd to assume that the quality of service product is more uncertain than that of manufacturing product. This assumption may be particularly true of non-delivery service where few service firms produce the same service product.

Suppose that a money metric indirect utility function of consumer i $(i=1,\cdots,n)$ from consuming a new service product j, x_j at time t is specified as

$$U_{ij}(X_j(t))=U_{ij}(x_j(p(t),\ I_i(t))),\ \ x_j\geq 0 \tag{1}$$

where $U_{ij}(t)$ represents consumer i's money metric indirect utility function over service product j in time t, which measures the expenditure incurred for reaching the utility of consumer i for service product j in time t (see A. Mas-Colell, etl (1995) pp81 for the discussion of the money metric indirect utility function). $p(t)$ is a price vector[3] and $I_i(t)$ is the income of consumer

[3] The substitution among all products are allowed.

i at time t.

Given uncertainty about the quality of service product j, (1) may be written as (2)

$$EU_{ij} = \sum_{K=0}^{L} U_{ijk}(X_{jk}(t)) \cdot \Phi_k(x_{jk}) \tag{2}$$

where $\Phi_k(x_{jk})$ is the probability that service product x_j *ex post* turns out to be the quality of x_{jk}.

Then, the adoption cost of the service product j by consumer i at time t, $Pc_{ij}(t)$ is written as (3)

$$Pc_{ij}(t) = P_j(C_j(t)) + h(t) \cdot d_{ij} + w_i(t) \cdot T_{ij}(t) + Cs_j(t)$$

$$\partial P_i / \partial C_j(t) > 0, \quad \partial C/\partial t > 0, \quad \partial P/\partial C \cdot \partial C/\partial t < 0,$$
$$\partial Cs_j(t)/\partial t < 0, \quad \partial^2 Cs_j(t)/\partial t^2 < 0 \tag{3}$$

where $P_j(t)$ is the retail price of the new service product j at time t, $C_j(t)$ the production cost of service product j at time t, h(t) the unit transportation cost incurred by consumer i traveling to service production site, d_{ij} the distance from consumer i to the site of service provider j, $w_i(t)$ the unit waiting cost of consumer i at time t, $T_{ij}(t)$ waiting time of consumer i for the contact with service provider j at the production site at time t and $Cs_j(t)$ searching cost incurred in collecting information on the new service product j at time t.

As compared with the adoption cost of manufacturing product/process innovation (see Stoneman and Kwon (1994, 1996) for adoption cost of the manufacturing products), the adoption cost of service product in equation (3) shows four different features. First feature is not different from the manufacturing product and is represented in the first item in the R.H.S. of (3); $P_j(C_j(t))$. It is quite obvious in (3) that the price of the service product j is a function of its production cost. As time goes by, the production cost decreases by 'learning by doing', and thus so does the price: $\partial P_j/\partial t < 0$. Second feature is represented in the second item of the R.H.S of (3), $h(t) \cdot d_{ij}$. Service products are intangible and thus unlike the manufacturing products, are unable to be carried to the site of consumers. In other words, as for service products, consumption must take place at the site of production. This implies that consumers have either to incur transportation costs or to pay delivery cost (if production of service can be moved to the site of consumers) for consumption of service product. Thus, this transportation cost should be considered as a significant component of adoption cost. Third feature is represented by

$w_i(t) \cdot T_{ij}(t)$ in (3), i.e. the waiting cost for adoption. As explained in (2-2), production and consumption of service occurs simultaneously. This implies that unlike manufacturing products, the service provider cannot control excess demand by the stored products and thus consumers must wait at the production site in the case of excess demand. As time is scarce resource, waiting works as a cost for consumers. Waiting is dependent upon the size of service production and the cycle of diffusion. The larger is the size of service firm, the less the chance of waiting is. The chance of waiting is more likely to increase in the middle stage of diffusion than in the early and later stages of the diffusion that the speed of the diffusion is slow. Fourth feature is represented by $Cs_j(t)$ in (3). As explained above, there is considerable uncertainty about quality of service product. So the adoption of service product accompanies the risk. Furthermore, the irreversibility of service adoption (which comes from the feature of one-off consumption) adds extra risk to the existing one. This implies that as compared with the case of the manufacturing product, the risk in relation to the consumption of service is relatively big. It is therefore reasonable to assume that consumers more actively engage in collecting information before the adoption in order to reduce uncertainty relating to consumption of service product, although the degree of search for information varies with service products. For example, consumers may not make active search for delivery services where much of quality is known to consumers from repeated purchase. However, this is not the case for non-delivery services where consumption is one-off. As far as searching cost is concerned, it is reasonable to assume that this cost decreases with increasing rate over time: $\partial Cs_j(t)/\partial t<0$, $\partial^2 Cs_j(t)/\partial t^2<0$. The rationale for this assumption is that information spills over among consumers as time goes by. It is further assumed that consumers do not incur additional search for repeated purchases: i.e. $Cs_j(t)$ is a constant at time t.

We now consider the adoption decision by consumer i. Consumer i must decide whether or not to buy and if he buys, when to buy. The adoption decision and adoption timing is determined by two conditions: the profitability condition and the arbitrage condition (see Ireland and Stoneman (1986) for the discussion of these two conditions). The profitability condition implies that the adoption value of the new service product must be at least greater than the value of non-adoption. The arbitrage condition implies that the adoption value should not increase over time.

Defining $Z_{ij}(t)$ as the adoption value of service product j for consumer i in time t, the profitability condition is

$$Z_{ij}(t)=\sum_{k=1}^{L} U_{ij}(t)\Phi_k-P_j(t)-h(t)\cdot d_{ij} \\ -w_i(t)\cdot T_{ij}(t)-Cs_j(t)\geq \overline{U}_{ij}(0) \tag{4}$$

where $\overline{U}_{ij}(0)$ is the value of utility when consumer i does not adopt service product j.

Inequality (4) implies that consumer i adopts a new service j if and only if the adoption value of the new service j is at least greater than the utility value of non-adoption.

We here try to expose the feature of service adoption by introducing the concept of the manufacturing equivalent of service product. Suppose that there exists a manufacturing product, Y_j which has the same utility value as service product j; $U_{ij}(Y_j)=U_{ij}(X_j)$. And further assume that $P_{Xj}(t)=P_{Yj}(t)$. Then, we define Y_j as the manufacturing equivalent of service product j. Now, by comparing the adoption value $(Z_{ij}(t))$ between service product and the manufacturing equivalent, proposition 1 can be stated as follows:

Proposition 1: The adoption value of the manufacturing equivalent of service product j is at least greater than that of service product j.

Proof: It is clear from the above assumptions that (1) $Cs(Y_j)\leq Cs(X_j)$, (2) $h(t)\cdot d_{ij}(X_j)> h(t)\cdot d_{ij}(Y_j)=0$ (see section 4 for the reason of $h(t)\cdot d_{ij}(Y_j)=0$) and (3) $w_i(t)\cdot T_{ij}(X_j(t))\geq w_i(t)\cdot T_{ij}(Y_j(t)$. The difference of adoption value between Y_j and X_j can be calculated as follows;

$$
\begin{aligned}
Z_{ij}(Y_i)-Z_{ij}(X_i)= &\sum_{k=1}^{L}(U_{ij}(Y_j)\Phi_j(Y_j)-(U_{ij}(X_j)\Phi_j(X_j))\\
&-h(Y_j)\cdot d_{ij}+h(X_j)\cdot d_{ij}-w_i(t)\cdot T_j(T_j)\\
&+w_i(t)\cdot T_j(X_j)-Cs(Y_j)++Cs(X_j)
\end{aligned}
$$

It is clear from (1) and (2) that $Z_{ij}(Y_i)-Z_{ij}(X_i)\geq 0$. Q.E.D.

Proposition 1 implies that transportation cost, waiting cost and searching cost make more critical impact on service adoption than manufacturing product adoption. Proposition 1 has an implication that the adoption timing may be different between service product and the manufacturing equivalent. So, we now examine the adoption timing of service product vis-a-vis the manufacturing equivalent.

The optimal adoption timing of the new service product j by consumer i is obtained by differentiating $Z_{ij}(t)$ with respect to time, t:

$$
\begin{aligned}
\frac{\partial Z_{ij}(t)}{\partial t} = &\sum_{k=1}^{L} U_{ijkt}\cdot \Phi_k - P_{jt}(t)-h_t(t)\cdot d_{ij}\\
&-w_i(t)\cdot T_{ij}(t)-Cs_{ti}(t)\leq 0
\end{aligned}
\tag{5}
$$

where subscript t denotes the derivative with respect to time.

That is, the optimal adoption timing is a point in time when 'waiting' is no longer generating more adoption value. This requires that as specified in (5), the value of utility of consuming the new service product j should not be increasing over time. When we ignore the possibility of corner solutions (i.e. the case where the adoption at the first introduction date of a new service product is optimal) the optimal adoption date is the timing when $\partial Z_i(t)/\partial t$ is equal to zero:

$$\frac{\partial Z_{ij}(t)}{\partial t} = \sum_{k=1}^{L} U_{ijkt} \cdot \Phi_k - P_{jt}(t) - h_t(t) \cdot d_{ij} - w_i(t) \cdot T_{ij}(t) - Cs_{it}(t) = 0 \quad (6)$$

Equation (6) implies that the optimal adoption timing is determined at the time when the increase in the value of expected utility from waiting for a time interval is equal to any expected reduction in the retail price, the transportation cost, waiting cost and search cost. Analysis of equation (6) leads to Proposition 2.[4]

Proposition 2: The adoption timing of consumer i for the manufacturing equivalent of service product j, Y_j is earlier than that of service product, X_j.

Proof: Define t^* and t' as the optimal adoption timing of X_j and Y_j that satisfies equation (6). It can be stated from Proposition (1) that for all t, $Z_{ij}(Y_j(t)) > Z_{ij}(X_j(t))$. Therefore, $t' < t^*$. Q.E.D.

Proposition 2 implies that the diffusion of the manufacturing equivalent of service product j is faster than that of service product j. The economic rationale of this implication can be explained by the features of service consumption, i.e. consumers wait longer to obtain information about the uncertain product quality more cheaply or/and reluctant to adopt until nuisance costs such as traveling and waiting become trivial. This interesting feature relating to the diffusion of service product provides a couple of discussion points about policy prescription, which will be dealt with in section 5.

(2) Diffusion of service innovation

We confirm in the above section that the diffusion of service products is generally slower than that of manufacturing products. We reach a point to ask a

[4] An implicit assumption that underlies in Proposition 2 is that the price of the manufacturing equivalent of the service product decreases over time. This assumption is justified by 'learning by doing' in production process over time, and thus generally used in the literature on "the diffusion of the manufacturing innovation" (Davis (1979), Reinganum (1981), etc.).

conventional question about the diffusion, i.e. what time path (i.e. the shape of the diffusion curve) will service products follow? We attempt to find the answer to this question in this section.

Following the suggestion that income distribution may be better described by lognormal distribution than any other distributions (*J.* Aitchison and *J.* Brown (1954)), we assume that income of consumers, which is specified in (1), is log normally distributed and has a probability density and cumulative function, $f(I)$ and $F(I)$, respectively. Suppose that the consumer exhausts his income for $X_j(j=1\cdots n)$. Then, money metric indirect utility function (which is a expenditure function) can be replaced by equivalent income. So, (4) may be rewritten as (7)

$$\sum_{k=1}^{L} I_{ij}(t)\cdot \Phi_k - P_j(t) - h(t)\cdot d_{ij} - w_i(t)\cdot T_{ij}(t) - Cs_j(t) \geq \overline{U_{ij}}(0) \qquad (7)$$

Inequality (7) simply restates the adoption condition of a new service product j in terms of income.

Define $\bar{I}(t)$ as the income level that makes (7) to be equality: $\bar{I}(t)=\overline{U}(t)=P_j(t)+h(t)\cdot d_{ij}+w_i\cdot T_{ij}(t)+Cs_j(t)+\overline{U}_{ij}(0)$. Then, $\bar{I}(t)$ is the income level of the marginal consumer whose adoption value of the service product j is just equal to the opportunity cost of adoption, i.e. the critical income level.

Making use of $\bar{I}(t)$, the proportion of consumers (i.e. population) having consumed the new service product j in time t, $S(t)$ may be written as (8)

$$\begin{aligned} S(t) &\equiv Pr(I(t)\geq \bar{I}(t)) \\ &= \int_{\bar{I}(t)}^{\infty} f(I)dI \\ &= 1-F(\bar{I}) \end{aligned} \qquad (8)$$

Equation (8) states that consumers whose income is at least greater than the critical income level have consumed the new service product j in time t. We now trace out how this proportion changes over time. Suppose that income level (I) and critical income level $(\bar{I})$ changes proportionately over time. Then, the change in diffusion of the new service product j over time is totally dependent upon change in the retail price, $P_j(t)$, transportation cost, $h(t)\cdot d_{ij}$, waiting cost, $w_i\cdot T_{ij}(t)$, and search cost, $Cs_j(t)$. As specified in (3), the retail price, $P_j(t)$, and search cost, $Cs_j(t)$, decrease over time. As for the transportation cost, $h(t)\cdot d_{ij}$, there is no specific theory about how it changes over time but the general technological progress guarantees that the transportation cost does not at least increase over time. As for waiting cost, $w_i \cdot T_{ij}(t)$, we are agnostic about how it changes over time. It may increase or decrease during diffusion. However, it is quite certain that the service provider will reasonably respond to excess demand over time and thus the increase in waiting cost will not be in excess of the sum of decrease in transportation and search costs over time.

So, the change in the critical income level over time can be written as (9)

$$\partial\bar{I}/\partial t = \underset{-}{\partial P_j(t)/\partial t} + \underset{-/0}{\partial h(t)\cdot d_{ij}/\partial t} + \underset{?}{\partial w_i \cdot T_j(t)/\partial t} + \underset{-}{\partial Cs_j(t)/\partial t} < 0 \tag{9}$$

Furthermore, (8) can be written as (10)

$$\partial S(t)/\partial\bar{I} = -f(\bar{I}) < 0 \tag{10}$$

From (9) and (10), the time path of diffusion curve about the new service product may be specified as (11)

$$\partial S(t)/\partial t = \partial S(t)/\partial\bar{I} \cdot \partial\bar{I}/\partial t > 0 \tag{11}$$

Equations (8) and (11) state that the proportion of consumers consuming a new service product j follows the reverse time path of a cumulative lognormal distribution, i.e. "$1-F(\bar{I})$". This time path shows a positively skewed S shaped curve. It needs here to emphasize that in our model the decrease in price, search cost and possibly transportation cost are deriving forces for the diffusion of the new service product (see equation (9)).

We summarize the above result in Proposition (3) :

Proposition 3: The time path of service product j follows a conventional sigmoid curve.

Proposition 3 states that the diffusion curve of service product is not different from that of manufacturing products. However, it can be stated from Proposition 2 that the curvature of sigmoid diffusion curve of service products is less steep than that of manufacturing products.

Ⅳ. SERVICE INNOVATION DIFFUSION vs PRODUCT/PROCESS INNOVATION DIFFUSION

It is argued in section 3 that the adoption and diffusion of service product is influenced by the factors such as transportation, waiting and searching costs. It may be countered by the argument that the adoption of manufacture products also incurs transportation, waiting and searching costs. For example, consumers/

firms who purchase a product/process innovation must travel to stores/middle men and thus incur transportation costs. They may also engage in searching activity in order to reduce the risk relating to the quality of the product. So, it may be argued that adoption and diffusion of service product is not basically different from that of manufacture product. However, if we observe the adoption of the manufacture products with a little more attention, we will easily find that the counter argument against the findings in section 3 is groundless. What is generally missed in the literature on 'adoption and diffusion of product/process innovation' is that in reality consumers do not adopt 'manufacture product/process innovation' but adopt 'the composite product of manufacture product/process innovation and retailing distribution service'. Strictly speaking, they cannot purchase the manufacture product/process innovation unless they first purchase retailing distribution service. In this sense, the manufacture product/process innovation and retailing distribution service are perfect complements. This implies that what appears to incur transportation cost for the adoption of manufacture product/process innovation is in fact not for the manufacture product/process innovation but for the purchase of retailing distribution service. Therefore, there is nothing wrong in most of the literatures on 'the diffusion of product/process innovation' (Davis (1979), Stoneman (1983), Reinganum (1981)) to specify only the price of production/process innovation as the adoption cost of product/process innovation. However, it is necessary to consider how the existing analysis of the adoption and diffusion of product and process innovation should be changed if adoption is *de facto* not the adoption of the product/process innovation but the adoption of a composite product of product/process innovation and retailing service. We will do this analysis in the framework of our previous study, i.e. the adoption and diffusion of multiple technologies (Stoneman and Kwon (1994)).

We posit a setting that consumers are aware of both existence of retail outlet and quality of its retail service, x_{js} but not of the quality of product innovation, x_{jm}. This assumption may be contrary to the model in (3-2) where quality of service product is uncertain. However, the retail service is a delivery service with the features of repeated purchase and simplicity in service provision and thus it is not absurd to assume that the quality of this service is generally known to consumers. Furthermore, it is plausible to assume that the adoption of retail distribution service is a precondition for adopting product innovation (not vice versa) but the adoption takes place in the form of the joint (simultaneous) adoption. Using the same notations used above, the money metric indirect utility function of consumer i from consuming a composite product, $(x_{jm}+x_{js})$ is specified as (12)

$$U_{ijsm}(t)=U_{ijs}(x_{js}(t))+\sum U_{ijm}(x_{ijm}(t))\cdot\Phi_k+V_{ijsm}(t)\geq 0 \tag{12}$$

where U_{ijs} and U_{ijm} are the money metric indirect utility from consuming retail distribution service and product innovation respectively, $\Phi_k(x_{jkm})$ is the probability that product innovation x_{jm} *ex post* turns out to be the quality of x_{jkm}, and V_{ijsm} is the money metric indirect utility of the benefit generated from complementary between x_{jm} and x_{js}. If the retailer's main function is only to distribute product innovations to consumers, V_{ijsm} is 'zero'. However, if retailer's function is not only to distribute the products but also to add the quality of the products through sales effort such as local advertising, special exhibition, demonstration and after-service (see Mathewson and Winter (1984) for this kind of retailer's function), V_{ijsm} has a positive value. As long as the retailer's additional function is to provide information on the quality of product innovation, it will reduce consumer's searching cost.

The adoption cost of the composite product j at time t, $Pc_{jsm}(t)$ may be written as (13)

$$
\begin{aligned}
Pc_{js}(t) &= P_{js}(t) + h(t)\cdot d_{ij} + w_i \cdot T_{ij}(t) \\
Pc_{jm}(t) &= P_{jm}(t) + Cs_{jm}(t) \\
Pc_{jsm}(t) &= Pc_{js}(t) + Pc_{jm}(t) \\
&= P_{js} + P_{jm} + h(t)\cdot d_{ij} + w_i \cdot T_{ij}(t) + Cs_{jn}(t)
\end{aligned}
\tag{13}
$$

where $P_{js}(t)$ and $P_{jm}(t)$ are the prices of retail distribution service j and product innovation j at time t, $h(t)$ is the unit transportation cost incurred by consumer i traveling to service production site, d_{ij} is the distance to service production site j from consumer i, $w_i(t)$ is the unit waiting cost of consumer i at time t, $T_{ij}(t)$ is waiting time of consumer i for the contact with service provider j at the production site j at time t, and $Cs_{jm}(t)$ is searching cost incurred in collecting information on the product innovation j at time t.

Then, the adoption value, adoption condition and adoption timing of the composite product $(x_{jm}+x_{js})$ of consumer i in time t may be specified as (14), (14-1) and (14-2) respectively

$$
\begin{aligned}
Z_{ijsm}(t) = U_{ijs}(t) + \sum U_{ijm}(t)\cdot \Phi_k + V_{ijsm}(t) - \{&P_{js}(t) + P_{jm}(t) \\
&+ h(t)\cdot d_{ij} + w_i(t)\cdot T_{ij}(t) + Cs_{jm}(t)\}
\end{aligned}
\tag{14}
$$

$$Z_{ijsm}(t) \geq \overline{U}_{ijsm}(0) \tag{14-1}$$

$$\partial Z_{ijsm}(t)/\partial t = U_{ijst}(t) + \sum U_{ijst}(t)\cdot \Phi_k + V_{ijsmt}(t) - P_{jst} - P_{jmt} - h(t)_t \cdot d_{ij} - w_i(t)\cdot T_{ij}(t) + Cs_{jmt}(t) \leq 0 \tag{14-2}$$

where $\overline{U}_{ijsm}(0)$ is the value of utility when consumer i does not adopt composite product j. If $\overline{U}_{ij}(\cdot)$ is a money metric indirect utility, $\overline{U}_{ij}(0)$ represents the opportunity cost of the adoption of the composite product j.

Since the economic rationale behind (14), (14-1) and (14-2)) is similar to (4) and (6) we skip the explanation about (14), (14-1) and (14-2) to analysis of the difference between the adoption of conventional product innovation and the adoption of the composite product.

Denote the adoption value of retail distribution service j and product innovation j as $Z_{ijs}(t) = U_{ijs}(t) - P_{js}(t) - h(t)\cdot d_{ij} - w_i \cdot T_{ij}(t)$ and $Z_{ijm}(t) = \sum U_{ijkm}(t)\cdot \Phi_k - P_{jm} - Cs_{jm}(t)$, respectively. Then, the adoption condition of the composite product vis-à-vis product innovation may be stated as follows:

for the case of $Z_{ijsm}(t) = 0$ (i.e. the case where retailer' s function is confined to distribute product innovation);

$$Z_{ijsm}(t) \geq \leq Z_{ijm(t)} \text{ if } Z_{ijs}(t) \geq \leq 0. \tag{15}$$

Equation (15) implies that the adoption condition of the composite product vis-à-vis product innovation is totally dependent upon the adoption value of retail distribution service. For example, if the adoption value of retail distribution service is greater than zero, the adoption probability of the composite product is greater than that of product innovation at time t, leading to a conclusion in relation to (6) and (14-2) that the adoption of the composite product is earlier than that of product innovation. This also implies that diffusion of the composite product is faster than that of product innovation. This conclusion is reversed if the adoption value of retail distribution service is less than zero. However, since it is assumed above that the adoption of retail distribution service is a precondition for the adoption of product innovation, the negative adoption value of retail distribution service leads to non-adoption. So it is pointless in this case to compare the adoption and adoption timing of the composite product with those of product innovation. The results of the existing literature on 'the adoption and diffusion of product innovation' can hold if and only if the adoption value of retail distribution service is equal to zero.

For the case of $V_{ijsm}(t) > 0$ (i.e. the case where retailer's function is both to distribute product innovation and to contribute the improvement of product innovation quality);

$$Z_{ijsm}(t) \geq \leq Z_{ijm}(t) \text{ if } Z_{ijs}(t) \geq \leq -V_{ijsm}(t) \tag{16}$$

Equation (16) shows that when there is a synergy benefit from complementarity between product innovation and retail service (i.e. $V_{ijsm}(t)>0$), the probability of adoption for the composite product vis-à-vis product innovation is greater than that in the case of $V_{ijsm}(t)=0$ at time t and the adoption time and diffusion of the composite product vis-a-vis product innovation is earlier and faster.

The above results confirm that although the analysis relating to the adoption of product innovation accommodates more of reality and thus is carried to the case of the composite product (i.e. product innovation + retail distribution service), the propositions 1 and 2 still hold.

V. DISCUSSION AND POLICY IMPLICATION

In this section we discuss further the empirical and policy implications behind theoretical findings derived from the model.

(I) Equation 3 states that the adoption of service innovation is affected by transportation, waiting and search costs. This fact supplies a micro-founded theoretical rationale to the empirical observation that information/network services in non-delivery service sectors (see table 1 for the classification of these services) grow with development of ICT technologies (i.e., internet). The impact of internet on the purchase of service innovation is made through two ways. First, the use of internet reduces the searching cost of information on service products. Second, the use of internet has changed the way of the consumers contacting service provider. That is, for some non-delivery service products consumers are able to contact service provider at virtual space. This reduces transportation and waiting costs in the consumption of service product. So, in non-delivery service sectors such as banking, insurance, education, health care, consulting and etc. the business through internet is now partially replacing the conventional off-line business. The reason is, as explained above, because internet decreases the adoption cost of service product. The degree of reduction in adoption cost is greater particularly in information/network services in non-delivery sectors where transportation, waiting and searching costs are reduced far more than any other service sectors where only searching costs are reduced. Thus, sales and diffusion of information/network services in non-delivery service sectors (e.g. business service) rapidly increase with diffusion of internet. This fact can be loosely confirmed in table 2.[5] In the period (1997-2001) when internet starts to diffuse rapidly, sales of business service in non-delivery sectors grow faster than those of all service sectors, manufacturing sectors and G.D.P (average growth rate of business service, all service, manufacturing sectors and G.D.P in this period are 16.3 %, 11.28 %, 7.64% and 4.32 % respectively).

[5] It is premature now to do a rigorous econometric analysis about the impact of internet on the growth of non-delivery service sectors mainly due to the lack of enough time series data.

[Table 2] The Growth of Business Service and Diffusion of Internet

	97	98	99	00	01	average
Business service *	14.42	0.02	32.8	26.42	9.51	16.63
Total service*	15.51	3.96	12.51	18.67	6.19	11.28
Total Manufacture*	6.6	-7.4	21	15.9	2.1	7.64
G.D.P.*	5.0	-6.7	10.9	9.3	3.1	4.32
Number of Internet User**	1634	3103	10860	19040	24380	11803
Growth rate of Internet User(%)	124.5	90	250	75.3	28	113.5

Source : The Bank of Korea, Ministry of Statistics, KRNIC
*Growth rate ** Unit : thousands

(II) Proposition 2 states that the diffusion of service product is slower than that of manufacture product. This implies that the period of recovering the investment is longer in service product than in manufacture product. This fact, combined with the fact that lenders in the imperfect financial market prefer short-term profit and public administrators prefer short-term achievement, makes financial markets and public administrators be reluctant to lend or invest in service innovation. Reflecting this reality, many case studies and surveys (e.g., Brigitte Preissl (2000)) show that for service firms (for particularly small firms) a lack of capital or difficulty of financing is mentioned as the most important reason for reluctance to innovate. So, policy prescriptions to deal with this problem are needed.[6]

(III) The feature of service innovation in (3-1) implies that the diffusion of service process innovation increases the number of the same service provider. So by the time when diffusion reaches the saturation point, the market structure of service product changes from concentrated market to competitive market and thus the profits of service firms are transferred to consumer surplus and new consumer surplus is created. This result is a bit different from the case of conventional process innovation. Unlike the fact that the diffusion of service process innovation changes the market structure, the diffusion of the conventional process innovation maintains the existing market structure and only reduces production cost. Of course, this process innovation can reduce the price of the final product and thus create new consumer surplus. However, welfare improvement effect is greater in service process innovation than in manufacture process innovation if the marginal cost before adoption is not exceptionally high (see the appendix for the proof of this argument).

(IV) Equation (16) implies that retail distribution service generates vertical externality to the adoption of manufacture innovation. If retail distribution service generates positive vertical externality to the adoption of manufacture innovation,

[6] For example, the establishment of a special bank that specializes in financing service sector may be suggested.

diffusion of manufacture innovation becomes faster. Relating to this fact, we may have a policy implication such as "how can we internalize the vertical externality of retail distribution service if faster diffusion of manufacture innovation is socially desirable?" As for the answers to this problem, usually two types of policies are suggested: providing positive subsidy and creating or changing ownership. Since it is known that the creating or changing ownership incurs prohibitive costs in the process of implementation, we confine our discussion to provision of subsidy particularly in the context of equation (14). Equation (14) indicates that subsidy should be given to encourage the retailer either to improve quality of retail distribution service or to reduce the price of retail distribution service. In other wards, subsidy should be given to innovation of retail distribution service since both quality improvement and cost reduction can be possible through innovation. However, current technology policy in most countries including Korea has tended to focus predominantly on manufacturing R&D activities and to overlook the peculiarity and importance of R&D in retail distribution service. For example, current law specifies that tax benefits are not allowed to give R&D activities in service distribution. So, the current technology policy should be reconsidered on the way of paying particular attention to innovation in retail and delivery services.

Ⅵ. CONCLUSION

We have theoretically explored the adoption and diffusion of service innovation. The theoretical framework upon which this paper is built is a conventional decision theoretic model. The theory in this paper indicates that (1) the diffusion of service product is slower than that of manufacture product, (2) the time path of service product follows a conventional sigmoid curve but the curvature of this curve is less steep than that of manufacture product, (3) the retail distribution service may speed up the diffusion of the manufacture product.

In deriving all the theoretical findings, transportation, waiting and search costs incurred in the process of consumption are critical determinants. It can be therefore predicted that development of internet that makes it possible to considerably reduce those costs can speed up the diffusion of service product. This prediction is in fact supported by empirical observation that non-delivery service sectors rapidly grow with diffusion of internet.

The theoretical findings in this paper also have a couple of implications for the new policy prescription: (1) the slower diffusion of service product implies the longer period of recovering the investment, and this causes financial markets and public administrators to be reluctant to lend or invest in service innovation. So, any policy to correct current fund allocations between manufacture and service innovations should be considered. (2) The delivery service including retail distribution service generates positive vertical externality to the adoption of the manufacture product. To internalize this vertical externality produces positive social benefits. Thus, some policy prescriptions to internalize vertical externality (e.g. promotion of delivery service innovation) should be considered.

There is still considerable research potential in the topic of service innovation and service diffusion. An obvious extension to current analysis would include the supply side in diffusion analysis and then move to some empirical work relating to theoretical findings discovered in this paper. This is definitely on our future research agenda.

APPENDIX

This appendix provides the proof of the argument in section 5 that the diffusion of service process innovation produces more welfare improvement than that of manufacture process innovation.

Notations: subscript s and m represents service product and manufacture product respectively.

$P_s(t)$ and $P_m(t)$: prices at time t,
$Q_s(P_s)$ and $Q_m(P_m)$: demand as function of price,
$C_s(q_s)$ and $C_m(q_m)$: total cost as function of its output,
$C_s'(q_s)$ and $C_m'(q_m)$: marginal cost
$\hat{C}'_m(q_m)$: marginal cost after adoption of process innovation $(0<\hat{C}'_m(q_m) < C'_m(q_m))$
t_s^*: the saturation point of time of service process innovation
t_m^*: the saturation point of time of manufacture process innovation
N:the number of firms that have adopted service process innovation by t_s^*.
M:the number of firms that have adopted manufacture process innovation by t_s^*.

Assumptions:

(1) Price of service product is equal to price of its manufacturing equivalent; $P_s(t)=P_m(t)$. This strong assumption is simply for the comparison of welfare between service process diffusion and manufacture process diffusion.
(2) Both service and manufacturer firms have the same strictly convex technology (and thus the same cost condition). So, the profit maximizing conditions are satisfied.
(3) The adoption of service process innovation produces a new service product.
(4) The adoption of manufacture process innovation reduces the existing average and marginal costs.

(I) The equilibrium price of $P_s(t)$ at t_s^*.

As diffusion proceeds, market becomes more and more competitive. If N is a large number, service firms are in competitive market by t_s^*. So, the equilibrium price at t_s^* is $t_s^*(t)=C_s'(q_s(t))$.

(II) The equilibrium price of $P_m(t)$ at t^*_m.

By t^*_m the marginal costs of existing firms are reduced to $\hat{C}'_m(q_m)$ [where $0<\hat{C}'_m(q_m)<C_m'(q_m)$]. If M is not a large number, firms still have market power. The range of profit maximizing output levels is
$0\leq q_m\leq q_{mr}$, where $q_{mr}=Q_m(0)/2$. Then, if $C_m'(q_m)\leq C'_m(q_{mr})$, the profit maximizing price at q_{mr}, $P_m(q_{mr})$ is at least greater than the original marginal cost, $C'_m(q_m)$. Thus, the range of profit maximizing price is $C_m'(q_m)\leq P_m(q_{mr})\leq P_m(q_m)\leq P_m(0)$. From $0<\hat{C}'_m(q_m)<C_m'(q_m)$ and $C_m'(q_m)\leq P_m(q_{mr})\leq P_m(q_m)\leq P_m(0)$, the range of equilibrium price, $P^*_m(t)$ at t^*_m is $P^*_m(t)\geq C'_m(q_m)$.

(III) It can be concluded from (I) and (II) that $P^*_m(t^*_m)\geq P^*_s(t^*_s)$.

$$\int_{P^*_s(t^*)}^{P_s(t)} Q_s(P_s)dP_s-\int_{P^*_m(t^*_m)}^{P_m(t)} Q_m(P_m)dP_m>0$$

Thus, the diffusion of service process innovation generates more welfare improvement than that of manufacture process innovation. Q.E.D.

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