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Complement and Network Externalities in the Mobile Devices Industry

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Complement and Network Externalities in the Mobile Devices Industry

Lim Yeon Gyuⁱ, Kim Sang Taekⁱⁱ

ABSTRACT

If examined the past history, communication market began on a regular basis together with a starting operator's control on the early market and such an operator has been holding an early higher market share till now even after a second player appeared. As the representative industry having a network effect, communication market shows a phenomenon that advantage of the starting operator is maintained and intensified with a lock-in effect. This study aims at identifying that lock-in effect of a first player may be resulted from the existence of additional products in the mobile device market through a hotelling model. Based on a higher market power of the first player, compatible additional products appear and it takes a role in reducing transportation cost of the primary product manufactured by the first player through improving primary product's functional and aesthetic aspects. However, second player comes to have a lower market power since the first player already occupied most of the market and it prevents additional products from appearing through aggravating expected profits of additional products. Accordingly, there is a difference in the transportation cost between the first and second players, making the first player have advantage and maintain the early higher market share continually. Based on the modeling on such a phenomenon, this paper examines what change price and market share of each product have in a given asymmetric situation in terms of the transportation cost. Through the hotelling linear city model, response functions of each company are derived, and the price and market share of each product are calculated. The price and market share of the primary product having the additional product were higher than those of the primary product having not.

Key Words: Hotelling Model, Transportation Cost, Complement Goods, Mobile Devices

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I . Introduction

On 24th, March, 2011, 16 months after smart phone was introduced to the country in 2009, the number of domestic smart phone subscribers exceeded 10 million. On Sep., 2014, the number of subscribers passed 40 million¹, so smart phone became necessities in our life.² Along with the growth of smart device markets and activation of peripheral device and accessory markets, 2012 IT Accessory & Smart Device Show was firstly held at SETEC from 26th to 28th, July, 2012. This exposition was held firstly in 2012 (67 domestic & foreign companies, 127 booths, 3,130m²), and expanded to a larger scale in 2014 (108 domestic & foreign companies, 201 booths, 5,164m²). It has such backgrounds as annual increase of IT accessory and peripheral device markets and business scales to 2 times and also increase of IT accessory specialty and chain stores.³ As such, IT accessory and peripheral device markets have been growing up with IT device popularization

IT accessory & peripheral device and IT device construct a network as a complementary relation and network economy has a characteristic of forming a monopolistic market naturally from the lock-in effect as a world of Winner Takes All. So, second player comes to have difficulty in entry and settlement so forming a competitive environment. Accordingly, regulatory authorities may prevent a tipping effect by integrating every product into the same network through technological standardization. It contains peripheral devices using 3.5 π earphone⁴ or Bluetooth. On the contrary, it is difficult for design-related peripheral devices to have compatibility owing to their physical characteristics including their size, thickness and a location of terminals. Such accessories contain a protective film and a cover. They aim at preventing a damage of IT device as a kind of durable goods and enhancing the utility of consumers in the aesthetic aspect, becoming necessities for using an IT device. Therefore, existence of design-related accessories and their varieties may be a factor to differentiate a size of each IT device network, and a size of the existing network may have an effect on that of a network hereafter.

We may call IT device a primary product and its accessory an additional product. A primary product has its own inherent value and also external value connected to other services.⁵ On the other hand, an additional product has an extra character so may have the value only together with a compatible primary product, having no its own inherent value. An additional product strengthens durability of a primary product so contributes to its extended life. Also, it is almost essential to change a device fitting for individual taste in the design aspect. Given that utility of consumer increases when

1 The number of subscribers passed 20 million on Oct. 2011 and 30 million on Aug., 2012.

2 Kukmin Ilbo, 12.10.22, [Age of 3 million Smart Phone] 6 of 10 people attracted by the 'world in my hand', Ministry of Science, ICT and Future planning, Wireless communications subscriber statistics.

3 See <http://www.kitas.kr>

4 Most common earphone standard now adopted globally. Before 2009 popularization of smart phone, there was a trouble in compatibility because of different earphone terminals in cell phones. Though generalized now, it was uncommon to apply 3.5 pi earphone terminal to a cell phone so its application of Samsung Electronics Haptic Amoled launched on Sep. 2009 became the advantage (Economy Today, 2009.09.02.[The Other Side of New Product] Samsung Electronics Haptic Amoled).

5 Here, inherent value means the one possessed when a product is used independently. On the other hand, external value means the one possessed when a product is used in connection with other product or service through network. That is, in case of electronic devices, inherent value is the one user can enjoy when there is an electronic device independently. External value is the one obtained using other service through an electronic device. Hence, as there are more related networks, potential external value user can obtain is greater.

they can use a primary product cleanly without failure or harmonize it with their taste, peripheral devices related to design and performance may take a role in reducing transportation cost for purchasing a product in the hotelling model in that they allow consumers to customize an IT device as they like. Accordingly, the advent of an additional product influences a demand behavior of primary product consumers. Consumers regard it convenient to use a primary product as there are more quantities and kinds of an additional product compatible with the primary product because of lowered transportation cost. It may be a factor in continual advantage of a primary product having additional products. Besides, through the rational prediction, enterprises can reflect it in the cost and maximize profits based on reaction of consumers.

In the beginning of smart devices, it failed in predicting a size of an accessory market. So, existence of an accessory was not considered in the early primary product production. However, as time passes and kinds of accessories increase, its existence may be a factor for evaluating and selecting a primary product. Based on such perception, analysis is done centered on the model. In the Chapter II, this study examines significance of this paper and the existing research on the network and hotelling model, also derives findings and conducts an analysis on the hotelling model in the Chapter III. In the Chapter IV, it summarizes contents with follow-up discussion.

II. Significance of Existing and Current Research

Katz and Shapiro(1985) conducted the research and segmented the network externalities. According to their research, network externalities may be divided into 3 as follows. Firstly, there is a direct effect. As the effect given by the network size, it means that the number of communicative cases increases exponentially and the value also increases rapidly according to a size of members on the network including a phone, fax and Internet. Secondly, there is an indirect effect. As the effect given by a size of another network connected to the network, it is also called the Hardware-Software paradigm. Hardware spread widely has the increased number of the compatible software. It contains a video game, video player, recorder, camera and a computer. Finally, there is a positive feedback effect and it applies to durable goods. In case of durable goods, maintenance service is a key point if there is a failure after using for a long time. Therefore, depending on the degree of the construction of such a maintenance service network, the existing network may be expanded or contracted. It contains automobiles and electronic devices as the representative durable goods. They asserted that network externalities exist as 3 types, and in case such externalities exist, consumers pursue purchasing products by a dominant operator having a great network, early movers pursue having independence and followers pursue having compatibility. Electronic device accessory analyzed in this study has both indirect and positive feedback effects. Since, IT peripheral device and accessory may have an indirect effect in terms of complement goods and be similar to maintenance service in that they offer long-term using of electronic devices as durable goods.

In particular, case studies on the indirect network related to complement goods have been done in many industries. As several representative case studies, the first is the case study on the computer & operating system of the representative Hardware/Software paradigm by Lindquist and Johnson(1993). Also, there are Ducey and Fratrik(1989)'s case study on the indirect network in color

TV industry and KUROKI Akihiro and KATO Akira (1994)'s Hardware/Software paradigm study in the game industry. These three studies commonly show a positive relation between spread of devices(computer, color TV, game machine) and that of contents(operating system, color TV program, game software) in an actual case. In this model, Hardware/Software paradigm applies to different hardware. It examines what effect one hardware has on the price and sales of another hardware.

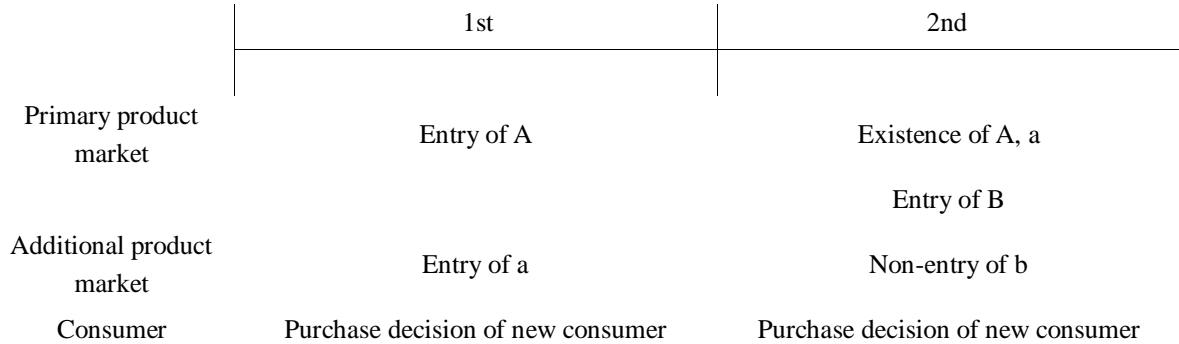
In terms of models, there is research on hotelling model. The first Hotelling(1929) linear city model, considering a symmetrical state of two enterprises, is easy to analyze but has a weak point of difference from the reality. Accordingly, hotelling linear city has developed into Salop(1979)'s circular city and Chen and Riordan(2007)'s spoke city, mitigating the existing assumption. Particularly, it is possible to reflect the reality through mitigating the hypothesis that two enterprises are symmetrical. In other words, asymmetry may be introduced firstly in terms of the marginal cost and secondly in terms of the transportation cost.

Kim Seong-Hyeon(2007) analyzed on what balance may happen in case two enterprises have different marginal costs and concluded that enterprise with a lower marginal cost has a higher market share since it can fix a price lower than other enterprise. On the other hand, 4 researchers including Son Sang-Young(2007) presented a model having a transportation cost only on one side. They presented as the model situations that a user pays the price of music only in case of downloading by a normal distributional path without transportation cost while he does not have to pay the price and transportation cost differs from his computer skills in case of downloading by an illegal path. Though conclusions may differ from a size of the transportation cost, it showed a possibility for preventing illegal downloading by increasing the transportation cost as a policy variable. As an expansion, Kim Song-Nyeon(2009) presented a model that two enterprises have different transportation costs. The main conclusion is that a supplier wants to supply a product having a lower transportation cost to a distributor.

This model also addresses a situation that both enterprises are asymmetric, especially that transportation costs are different. Compared with models above, there is a difference in that consumers have to bear the extra burden to reduce the transportation cost. So, it deals with different aspects of consumers who bear certain additional burden and select reduced transportation cost and those who accept the original transportation cost without any additional burden. As shown from words meaning characteristics of modern consumers including DIY or prosumer, consumers want production of various products or manufacture what they want in order to make the most use of their individuality. Especially, there is a phenomenon of customizing electronic devices they use including reform or intensification of durability. It was identified that primary product of a first operator having more users, through difference in the transportation costs among primary products by activities of additional product manufacturers, can acquire the advantage in the market. It may be an example showing the lock-in effect to maintain and strengthen first operator's higher market share.

III. Model & Analysis

1. Model Description



<Figure 1> Timing Schema

This is a 2-period model, and in the 1st period, a first player A appears, produces A and gives a showroom service. Accordingly, market share of A is 100%. Based on such wide primary product users, an additional product producer a appears and manufactures an additional product, 'a', compatible with A . Primary product market follows the hotelling linear city model. Consumers are distributed singly on a straight line of $[0, 1]$ and an enterprise maximizes its profits through a demand function derived from consumers' utility function and a cost function according to its technological conditions. In such a process, both the price of a primary product and market share are determined. Market share is estimated only on sales in each period with a criterion of the number of sales. On the other hand, share calculated in both the 1st and 2nd periods is called Usage Share, also based on the number of sales.⁶ In the 2nd period, a new primary product producer B appears. Both A and B determine product prices maximizing their profits, p_A^* and p_B^* . Likewise, the existing additional product producer a determines p_a^* . In the same manner as the 1st period, it determines the price maximizing its profits through a cost function by predicting a demand function rationally. A consumer N_2 appeared in the 2nd period selects a product package providing him with the highest utility. A , B and a know about transportation cost by situation, product quality as a technological condition of each enterprise, fixed cost and marginal cost, and they are matters of common knowledge.

The reason why only A exists in the 1st period is that A can provide an opportunity for the advent of an additional product by occupying a showroom as the first enterprise. Through the existence of the primary product having a higher market share, there is an incentive for the additional product producer to make an additional product of the primary product having a higher market share,

⁶ Market share may be calculated differently according to earning or selling of each company in the entire market during certain period. (http://en.wikipedia.org/wiki/Market_share) A representative IT market researcher, IDC(International Data Corporation, <http://www.idckorea.com/>) announces market share of IT products by year & quarter based on the number of sales. On the other hand, usage share means the usage weight of each product in the whole users, mainly used for operating system or web browser markets(http://en.wikipedia.org/wiki/Usage_share_of_operating_systems) Mobile communication device market closely related to operating system has something to do with usage share. Connection with related markets increases when there are a wide range of users.

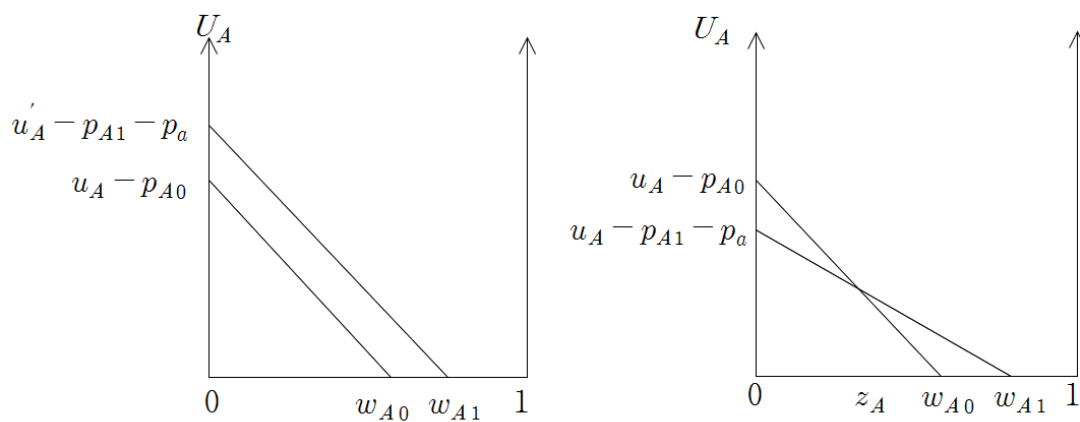
a product with a higher possibility for collecting the sunk cost from the production cost. It serves to increase the market share of the relevant primary product in the 2nd period.

1) 1st Period

(1) Producers of Primary and Additional Products

The enterprise *A* appeared in the 1st period monopolizes since it has no competitor. And then, according to the quality of the product, it gives some market or showroom service. This model concentrates on the showroom service and hypothesizes that *A* has the quality enough for every consumer to purchase despite the monopolistic price. On the premise of the showroom service condition, it may be interpreted that *A* is essential goods in that every consumer in the market purchase *A*.

On the other hand, additional product manufacturer *a* predicts rationally how many primary products are sold in the market, derives a demand function by calculating purchasers having the incentive to the additional product among those of the primary product, and acquires the price maximizing profits using its cost function. In the meantime, it may appear when sales can collect the variable and sunk costs. Therefore, for convenience sake, this paper postulates a level of the sink cost as the level *a* can appear, and sets specific values hereafter.



< Figure 2 > Comparison of cases of increased inherent value & decreased transportation cost

Consumers can use the primary product while increasing their utility by purchasing the additional product. Accordingly, appearance of the additional product may act as a factor to reduce the transportation cost consumers pay while using the primary product. Since the additional product 'a' has to be used together with the primary product *A* so it can't be used independently, its inherent value u_a is 0, instead the pure utility obtained from using the product *A*, U_A increases by reducing the transportation cost t . It may be interpreted as the increase of the external value. And then, increase range of U_A differs from a location of consumers since the height changing on each x coordinate varies as the gradient of a graph varies in the geometrical aspect. It may be interpreted that additional

product cannot ensure utility identical to every user in terms of design and function. Since, consumers' utility varies with design including color, form, material and secondary functions. In the aspect of durability, it may also be interpreted as reflecting consumers' differentiated attitudes to repair cost of the primary product which may be saved from avoiding a failure as they use the additional product.

On the other hand, it may be said that protective film of simple design can ensure the utility identical to every user but it is relatively simplistic so excluded here. Future study can be conducted on a case of increased u_A , u_B rather than the transportation cost. In the meantime, it is possible to consider a case imposing a higher transportation cost on consumers at a psychologically closer location but it is also excluded.

As for pricing, independent variables contain the transportation cost t , fixed cost f restrained by technological conditions and the marginal cost m when manufacturing the additional product.

(2) Consumer

Consumers appear by N -person in the early period. So, in this 2-period model, the final number of consumers is $2N$. Consumers select a product i maximizing their utility $U_i = u_i - p_i - tx$ according to their preferred location, x . Here, u_i is the inherent value of the product and relates to enterprise's production conditions. After selecting the product maximizing the utility, purchasing or non-purchasing of the additional product can be determined by comparing the utility of purchasing with that of non-purchasing of the additional product. If purchasing, transportation cost t lowers before purchasing. Here, purchasing or non-purchasing of the additional product can be determined by considering decrement of the transportation cost t spent at one's location and extra cost from purchasing the additional product. Since the additional product tends to be a kind of supplies, in the actual reality, many purchases may be done within one period. However, here for convenience sake, it postulates only one additional product is purchased. In such a situation, purchased products are arranged in a parenthesis to show customers' purchased products in each period. The possible cases are (A), (A, a) in the 1st period and (A), (A, a), (B) in the 2nd period, and a case (a), (B, a) is postulated as the impossible. Such a selection may not happen because one cannot enjoy the utility if he has only additional product and there is no compatibility among additional products.

Consumers purchase one primary product in the period when they appear. When there happens no vertical differentiation of products, users continually use the existing product without purchasing the product giving greater utility than the existing one when it appears in the next period. Since, the primary product can be used for 2 or more than periods as durable goods and consumers cannot use the remainder excepting the utility enjoyed for the 1st period from the purchase price if they use it only for the 1st period. Suppose that the utility from the product itself u_A is used up from the 1st through the 2nd period and u_A may be divided as $u_A = v_A^I + v_A^{II}$ by period. Here, if the range of the utility v_A^I enjoyed for the 1st period satisfies $v_A^I < p_{A1}^I + p_a + t_1$, $v_A^I + v_A^{II} > p_{A1}^I + p_a + t_1$, it is not rational to use A only for the 1st period. If the product appeared newly in the 2nd period develops qualitatively more than the product purchased in the 1st period and its utility

increases so satisfies $v_A^I + v_B^{II} \geq (p_{A1}^I + p_a + t_1) + (p_B + t_0)$, users of the 1st period will use the product appeared newly in the 2nd period. However, this paper postulates the quality of the product appeared in the 2nd period does not differ from that of the product appeared in the 1st period. In other words, for the 2nd period, horizontal differentiation occurs but vertical differentiation does not. This study set 2-period since it is the minimal cardinal showing the difference of the market power between both products in the relevant period. It may be meaningless to examine more than 2-period since difference of the market power between both products increase greatly in the relevant period.

2) 2nd Period

(1) Producers of Primary and Additional Products

When the existing players, the primary product producer A , and the additional product producer a still exist, a new primary product producer B and a new consumer N appear. Producers A , B manufacture primary products A , B respectively. The producer a manufactures an additional product 'a', assuming that 'a' is compatible with A but not with B . As for primary products A and B , each goods has its demand function according to a characteristic of consumers, and price maximizing profits is determined by these demand and production functions. A and B are symmetrical to each other and A has the same production condition as that of the 1st period. However, A has the additional product 'a' but B does not. Products A and B differentiated horizontally have the same inherent values. Since A and B ensure the same inherent values to consumers, it may be said that their own utility u_A , u_B are the same. In other words, u_A , u_B are terms related to product's core function and restrained by technological conditions. However, B has a characteristic of horizontal differentiation from A in terms of extra functions or design, and it may be expressed as differentiated locations of consumers and the transportation cost t in the linear city.

They determine the price based on independent variables and the demand function. Independent variables for pricing contain inherent values of products restrained by the transportation cost t and technological conditions, u_A , u_B , fixed cost FC , marginal cost of the primary product c , and marginal cost of the additional product m . Furthermore, here the fixed cost is at the level enough for B to appear in the 2nd period. The additional product producer is restrained by the fixed cost fc and the marginal cost m when manufacturing the product. In particular, it is assumed that the sunk cost of B , FC exists within a range that B can appear in the 2nd period and it is determined specifically through calculation hereafter, Also, an additional product b compatible with B can appear but it is postulated that sunk cost of b , fc is a too large number for b to appear in the 2nd period. Compared with a situation of the 1st period above, it is possible to determine a range of the sunk cost allowing 'a' to appear in the 1st period but preventing b from appearing in the 2nd period.

(2) Consumer

As mentioned before, primary product may be used for 2 or more than periods as durable goods. Accordingly, when there is no vertical differentiation of products, consumers of the 1st period

make no new purchase in the 2nd period market, and new consumers purchase a product. And then, new consumers, like the 1st period consumers, select a product i maximizing their utility $U_i = u_i - p_i - tx$ according to a location x they are. Since B exists in the 2nd period, there are possible cases of (A), (A, a), (B). Consumers select a product maximizing their utility considering the transportation cost t , according to their location, price and inherent value of products. B having no additional product competes with A considering difference in transportation costs. Producers and consumers behave rationally, and such information is a matter of common knowledge.

In the meantime, the number of cases possible in the 2nd period may be classified into 5 as follows.

- i . A case having no additional product 'a' with the same transportation costs for both companies
- ii . A case having no additional product 'a' with less transportation cost of A than that of B
- iii . A case having additional product 'a' with the price equal to 0
- iv . A case having additional product 'a' with the price more than 0
- v . A case having additional products 'a', 'b'

This paper concentrates on the case iv, having additional product 'a' with the price more than 0. Without the additional product, in the 2nd period A and B are symmetrical so market share is 50%, respectively. However, this study aims at identifying that market share of A having the additional product is more than 50% in the 2nd period because of difference in transportation costs by the existence of the additional product.

Each sign means the following. Besides, Timing described above may be summarized as follows.

<Table 1> Sign Description

Sign	Meaning	Sign	Meaning
A	First primary product manufacturer	p	Product price
B	Second primary product manufacturer	q	Quantity
A	First primary product	s	Additional product purchase rate ($= \frac{u-a}{z}$)
B	Second primary product	t	Transportation cost
a	Additional product compatible with first additional product manufacturer	δ	Transportation cost discount factor
a	Additional product compatible with first additional product	$\Delta = 1 - \delta$	Transportation cost discount rate
c	Primary product marginal cost	u	Inherent value, quality of product
m	Additional product marginal cost	U	User's pure utility from product purchase
FC	Primary product fixed cost	w	Primary product market share

Sign	Meaning	Sign	Meaning
fc	Additional product fixed cost	x	Consumer location
N	No. of consumers per period	z	Additional product non-purchaser rate
Sup	I, II	Related term in each period	
Sub	A, B, a 0 1	Term related to a pertinent product Term of a case having no additional product Term of a case having additional product	

<Table 2> Timing Schema

	First A bloc	Second B bloc	Consumer
1st	Pricing of A : p_A^*	-	N-person appears : N_1 person
	Pricing of a : p_a^*	-	
	Selection of new consumer N_1 : purchase decision on A, a : (A), (A, a)		
2nd	Pricing of A : p_A^*	Appearance of B & pricing : p_B^* B incompatible with a.	N-person appear : N_2 person Total consumer number : $(N_1 + N_2)$ person
	Pricing of a : p_a^*	-	
	Selection of the existing consumer N_1 : using products purchased in the 1st period Selection of new consumer N_2 : purchase decision on A, a, B : (A), (A, a), (B)		

2. Analysis

1) 1st Period

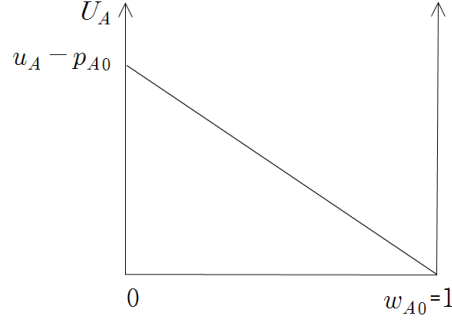
Utility function of consumers is estimated in the market where A and 'a' exist. Here, primary product market follows the hotelling linear city model. Cases before and after entry of the additional product 'a' may be considered depending on existence or non-existence of a showroom service. It contains a case of a partial market service before and after entry of the additional product 'a', a case of a partial market service before entry of the additional product 'a' but a showroom service after entry, a case of a showroom service before entry of the additional product 'a' but a partial market service after entry and a showroom service before and after entry of the additional product 'a'. For convenience sake, this paper focuses on a case of a showroom service before and after entry of the additional product 'a'.

(1) A case A exists only

In order to satisfy showroom service requisites, an inequality on the inherent value of a product shall be established as follows. It means that showroom service can be achieved when product quality is higher enough than certain level.

$$c + 2t_{A0} \leq u_A$$

Such a situation may be roughly expressed on a graph.



<Figure 3> Showroom service before entry of additional product

The total utility each consumer x acquires from purchase of the primary product A may be expressed as $U_A = u_A - p_A - t_{A0}x$. Since, showroom service is possible while satisfying the hypothesis above, marginal consumer's location is 1, and such a consumer's pure utility is 0. Hence, it may be expressed as follows so demand function may be derived from it.

$$\begin{aligned} u_A - (p_{A0} + t_{A0}x) &= 0 \\ x &= \frac{u_A - p_{A0}}{t_{A0}} = 1 \end{aligned}$$

Likewise, profit function may be generated using a cost function and price is as follows.

$$\begin{aligned} \pi_A &= (p_{A0} - c_A) \left(\frac{u_A - p_{A0}}{t_{A0}} \right) - FC_A \\ \pi'_A &= \frac{u_A + c - 2p_{A0}}{t_{A0}} = 0 \text{ (F. O. C.)} \\ p_{A0}^{I*} &= \frac{u_A + c}{2} = t_{A0} + c \\ x_{A0}^* &= \frac{u_A - p_{A0}^{I*}}{t_{A0}} = \frac{u_A - c}{2t_{A0}} = 1 = w_{A0}^* \end{aligned}$$

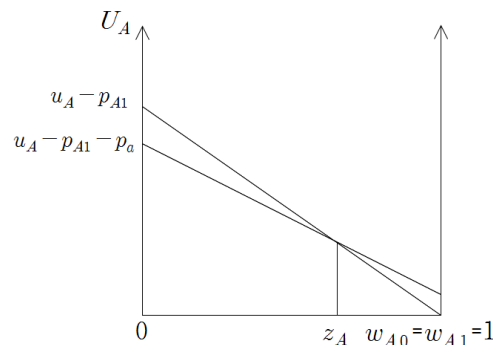
Price is the sum of transportation and marginal costs, and here demand is equal to 1 so covers a showroom.

(2) A case both A and a exist

Quality is identical to that of a case above and transportation cost decreases by entry of the additional product 'a'. Transportation cost in case of not using the additional product is expressed as t_{A0} and the transportation cost in case of using it is expressed as t_{A1} with $t_{A0} > t_{A1}$. When t_{A1} is δ times than t_{A0} , $t = t_{A0}$ and, $\delta t = \delta t_{A0} = t_{A1}$, here, range of δ is $0 < \delta < 1$. Introduction of the

additional product causes difference in the transportation costs to $(1 - \delta)t = \Delta t$. Let's examine a case of a showroom service before and after entry of the additional product 'a'.

In order to satisfy the showroom service requisites before entry of 'a', product, utility shall be large enough and satisfy $+2t_{A0} \leq u_A$. Besides, for satisfying the showroom service requisites after entry of 'a', it is required that $w_{A1}^{I*} = 1$. And as mentioned above, since this requisite was already satisfied before entry of 'a', price of A will be the maximum price satisfying the showroom service, and it may be roughly expressed by a graph as follows.



<Figure 4> Showroom service after entry of a

Consider the utility function $U_A = u_A - p_A - t_{A0}x$ when using A only and the utility function $U_A = u_A - p_A - p_a - t_{A1}x$ when using both A and a. Using of 'a' causes decrease of the transportation cost from t_{A0} to t_{A1} and additional pay of the price of 'a', p_a . Firstly, demand functions of A and 'a' are derived. A formula as follows may be established to calculate consumers who purchase only A, that is, z_A . For consumers located at z_A , utility when purchasing only A or both A and 'a' does not differ.

$$\begin{aligned} u_A - p_A - t_{A0}x &= u_A - p_A - p_a - t_{A1}x \\ p_a &= (t_{A0} - t_{A1})x \\ x &= \frac{p_a}{(t_{A0} - t_{A1})} = z_A \end{aligned}$$

z_A is the size of consumers not purchasing 'a' from those who purchase A. It is in proportion to the price of the additional product and in inverse proportion to difference of the transportation costs. The difference of the transportation costs refers to the decrement of the transportation cost by additional product purchase so may be said as savings of cost. In other words, for consumers, since incentive to purchase the additional product increases as additional utility increases by using the additional product, a size of consumers not purchasing it tends to decrease.

When 'a' exists, s_a , a size of consumers purchasing both A and 'a' may be calculated by subtracting a size of consumers not purchasing 'a', z_A from the entire size of those purchasing A, w_{A1} . w_{A1} corresponds to marginal consumers who purchase A, resulting in x that satisfies $U_A = u_A - p_A - p_a - t_{A1}x = 0$.

$$w_{A1} = \frac{u_A - p_A - p_a}{t_{A1}}$$

It may be used as the demand function of A. It is in inverse proportion to the price of its own and complement goods, 'a', also to the additional transportation cost for purchase of the product. Besides, it is in proportion to the quality of the product. On the other hand, according to the prior assumption on the satisfied showroom service, demand corresponds to 1, here relationship between prices of A and 'a' may be calculated.

$$w_{A1} = \frac{u_A - p_A - p_a}{t_{A1}} = 1$$

$$p_A = u_A - p_a - t_{A1}$$

Here, demand function of 'a' may be calculated by subtracting z_A , size of consumers who purchase A only.

$$s_a = w_{A1} - z_A = 1 - z_A = \frac{t_{A0} - t_{A1} - p_a}{t_{A0} - t_{A1}}$$

It is in inverse proportion to both price of 'a' and that of the complement goods A. Also, it is in proportion to the existing transportation cost and in inverse proportion to a new transportation cost. That is, it is in proportion to savings of the transportation cost. Since, as pure utility from the additional product 'a' increases, demand also increases.

Based on the postulated cost function above, it is possible to derive the profit function together with reaction functions of A and 'a'. In case of A, demand is 1 and satisfies the showroom service requisites, meaning that showroom service is possible in any price. Accordingly, instead of the reaction function by the profit function, a relational expression between prices of A and 'a' is used for calculating the price allowing the showroom service. Therefore, reaction function of A for 'a' is as follows.

$$p_A = u_A - p_a - t_{A1}$$

In the meantime, the price maximizing profits p_a^{I*} may be calculated by the demand function of 'a' above and given cost requisites.

$$\pi_a = (p_a - m) \left(\frac{t_{A0} - t_{A1} - p_a}{t_{A0} - t_{A1}} \right) - fc$$

$$\pi'_a = \frac{t_{A0} - t_{A1} - 2p_a + m}{t_{A0} - t_{A1}} = 0 (F.O.C.)$$

$$p_a^{I*} = \frac{t_{A0} - t_{A1} + m}{2}$$

p_{A0}^{I*} may be calculated by substituting for the reaction function of A.

$$p_{A1}^{I*} = u_A - \frac{t_{A0} + t_{A1} + m}{2}$$

The price of A is in proportion to the utility of the product itself and in inverse proportion to the transportation cost and marginal cost of the complement goods a. It shows that the price of a is in proportion both to its marginal cost and savings of the transportation cost regarded as the utility of 'a'.

On the other hand, demands w_{A1}^{I*} and s_a^{I*} may be calculated by substituting each price value for the utility and demand functions as follows.

$$w_{A1}^{I*} = 1$$

$$s_a^{I*} = \frac{t_{A0} - t_{A1} - m}{2(t_{A0} - t_{A1})}$$

As for sales of A, showroom service continues by the price satisfying showroom service requisites and maximizing profits. Sales of 'a' is in proportion to the contributory portion of 'a', $(t_{A0} - t_{A1})$ and in inverse proportion to its marginal cost.

For convenience sake, an expression may be simplified by an assumption. The transportation cost when not using the additional product is represented as t_{A0} and the transportation cost when using as t_{A1} with $t_{A0} > t_{A1}$. When t_{A1} is δ times of t_{A0} , $t = t_{A0}$ and $\delta t = \delta t_{A0} = t_{A1}$ with the range of δ at $0 < \delta < 1$. Also, substitution of $c + 2t_{A0} = u_A$ is possible using showroom service requisites. Accordingly, above expressions may be represented as follows.

$$p_{A1}^{I*} = c + \frac{3t_{A0} - t_{A1} - m}{2} = c + \frac{(3 - \delta)t - m}{2}$$

$$p_a^{I*} = \frac{t_{A0} - t_{A1} + m}{2} = \frac{(1 - \delta)t + m}{2}$$

$$w_{A1}^{I*} = 1$$

$$s_a^{I*} = \frac{t_{A0} - t_{A1} - m}{2(t_{A0} - t_{A1})} = \frac{(1 - \delta)t - m}{2(1 - \delta)t}$$

On the other hand, profits of A and 'a' are as follows.

$$\pi_{A1}^{I*} = \left(c + \frac{(3 - \delta)t - m}{2} - c \right) (1) - FC = \frac{(3 - \delta)t - m}{2} - FC$$

$$\pi_a^{I*} = \left(\frac{(1 - \delta)t + m}{2} - m \right) \left(\frac{(1 - \delta)t - m}{2(1 - \delta)t} \cdot 1 \right) - fc = \frac{[(1 - \delta)t - m]^2}{4(1 - \delta)t} - fc$$

<Table 3> Comparison on price, sales & profits, consumer's & producer's surplus of each product in the 1st period

1 st period		Entry of A only	Size Comparison	Entry of both A & a
A	Price	$t + c$	<	$c + \frac{(3-\delta)t-m}{2}$
	Sales	$\frac{u_A-c}{2t} = 1$	=	1
	Profits	$t - FC$	<	$\frac{(3-\delta)t-m}{2} - FC$
a	Price	-		$\frac{(1-\delta)t+m}{2}$
	Sales	-		$\frac{(1-\delta)t-m}{2(1-\delta)t}$
	Profits	-		$\frac{[(1-\delta)t-m]^2}{4(1-\delta)t} - fc$ ⁷
Consumer's Surplus		$\frac{t}{2}$	>	$\frac{t^2(3\delta^3-5\delta^2+\delta+1)-2\delta tm+(1+\delta)m^2}{8(1-\delta)^2t}$
Producer's Surplus		t	<	$\frac{t^2(1-\delta)(7-3\delta)-4tm(1-\delta)+m^2}{4(1-\delta)t}$

In formulas on the price, sales and profits of A when there is 'a', $\delta = 1$ and the value for $m = 0$ is equal to each value when there is no 'a'. For convenience sake, if assumed that m , marginal cost of 'a,' is a very small number, it leads to findings as follows. Transportation cost decreases compared with that of entry of the additional product as δ is smaller so $1 - \delta$ becomes larger. It means increase of consumers' convenience so enterprises come to have room for increasing the price while reflecting such convenience in the price.

<Theorem 1>

- ① p_{A1} in inverse proportion to δ ② $q_A=1$ ③ π_{A1} in inverse proportion to δ
 ④ p_a in inverse proportion to δ ⑤ q_a in inverse proportion to δ ⑥ π_a in inverse proportion to δ
 ⑦ cs_{A1} in proportion to δ ⑧ ps_{A1} in inverse proportion to δ

<Proof>

- ① Following is the differential of $c + \frac{(3-\delta)t-m}{2}$, a formula on the primary product price for δ .
 $-\frac{t}{2} < 0$ ■
 ③ Following is the differential of $\frac{(3-\delta)t-m}{2} - FC$, a formula on the primary product profits for δ .

⁷ Since 'a' may enter when profits are greater than 0, a range of sunk cost allowing entry of 'a' is as follows.

$$\frac{[(1-\delta)t-m]^2}{4(1-\delta)t} \geq fc$$

$$-\frac{t}{2} < 0 \blacksquare$$

- ④ Following is the differential of $\frac{(1-\delta)t+m}{2}$, a formula on the additional product price for δ .

$$-\frac{t}{2} < 0 \blacksquare$$

- ⑤ Following is the differential of $\frac{(1-\delta)t-m}{2(1-\delta)t}$, sales of additional product for δ .

$$-\frac{m}{2(1-\delta)^2 t} < 0 \blacksquare$$

- ⑥ Following is the differential of $\frac{[(1-\delta)t-m]^2}{4(1-\delta)t} - fc$, profits of the additional product producer for δ .

$$-\frac{(1-\delta)^2 t^2 - m^2}{4(1-\delta)^2 t} < 0 \blacksquare$$

- ⑦ Following is the differential of $\frac{t^2(3\delta^3 - 5\delta^2 + \delta + 1) - 2\delta tm + (1+\delta)m^2}{8(1-\delta)^2 t}$, consumer's surplus for δ .

$$\frac{-3t^2\delta^3 + 9t^2\delta^2 - (9t^2 - 2tm + m^2)\delta + 3t^2 - 2tm + 3m^2}{8(1-\delta)^3 t} > 0 \blacksquare$$

- ⑧ Following is the differential of $\frac{t^2(1-\delta)(7-3\delta) - 4tm(1-\delta) + m^2}{4(1-\delta)t}$, producer's surplus for δ .

$$-\frac{3t^2\delta^2 - 6t^2\delta + 3t^2 - m^2}{4(1-\delta)^2 t} < 0 \blacksquare$$

Price of each product is in inverse proportion to δ . In other words, when a reduction ratio of the transportation $(1 - \delta)$ increases, prices of primary and additional products increase. Reduction ratio of the transportation cost relates to benefit of consumers by introduction of the additional product since it gives a primary product producer an opportunity for raising profits through price increase of primary and additional products as such benefit increases. So, producer's surplus increases but customer's surplus decreases by price increase of the primary product and extra consumption of the additional product.

In the meantime, when profits of 'a' ≥ 0 in the 1st period, entry of **a** into the market is possible. A level of the fixed cost satisfying above is as follows.

$$fc < \frac{[(1-\delta)t - m]^2}{4(1-\delta)t}$$

So far, this study has examined a situation there are one primary product and one additional product. To reflect the reality, it is possible to consider a situation that a new company enters the primary product market and competes with the existing company. Firstly, **a** can achieve sales to cover sunk and variable costs by selling 'a' to consumers of **A** company having a great market share in the 1st period. Accordingly, even after entry of a new product **B** in the 2nd period, 'a' is still manufactured and sold to some consumers of **A** among new consumers. However, as a second player having a few users, if **B** can achieve sales under sunk and variable costs owing to low sales of compatible additional products, an additional product **b** compatible with **B** may not enter the market. Through modelling on such a situation, competition between **A** and **B** may be considered.

2) 2nd Period

There are two primary product producers, A, B, and they are in a symmetrical situation in terms of production conditions. However, existence and non-existence of the additional product cause difference in the transportation cost. Their products show horizontal differentiation by design or some functions despite identical basic performance so compete based on the hotelling linear city model. Consider a case showroom service has been done already in the 1st period with the same product performance as that of the 1st period. Consequently, showroom service is possible in the 2nd period at a range of u satisfying the showroom service in the 1st period. A condition for the showroom service is $u \geq 2t + c$ in the 1st period and a condition for the showroom service is $u \geq \frac{3}{2}t + c$ in the 2nd period when there are both symmetrical operators since a showroom service condition of the 1st period already satisfies that of the 2nd period.

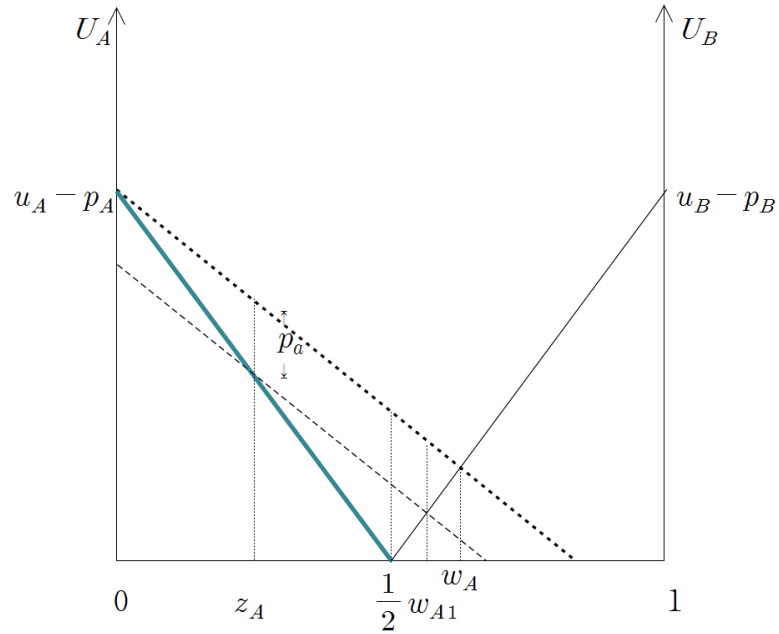
On the other hand, additional product producer produces a product 'a' only compatible with A. It is assumed that 'a' has no its own utility and pure utility of the primary product increases with decrease of the transportation cost by using 'a' together with the primary product.

In the 2nd period, additional product producer may have an incentive to make b, a product compatible with the primary product B in addition to 'a'. However, in case of making both a and b, transportation costs of each product being the same, it may not lead to an interesting result any more. Accordingly, sunk cost in the cost function may be postulated as follows for the additional producer to have an incentive to make 'a' rather than b.

As for 'a', sunk cost may be collected by purchase of some users of the product A having the showroom service in the 1st period. However, in case of manufacturing b, A and B share some markets equally, having fewer users than those of the 1st period. So, let's assume that sunk cost may not be collected only by purchase of B product users in the 2nd period. In other words, profit function of 'a' ≥ 0 in the 1st period while that of b entering in the 2nd period is smaller than 0. Consequently, in the 2nd period, 'a' may be manufactured continually and b may not. Through such a hypothesis, asymmetry of A and B may be generated by entry of the additional product.

Firstly, dividing consumers into groups purchasing A, A and a, and B, demand function of each product may be calculated. Also, through deriving reaction function by profit function of each company, price may be calculated and each result may be compared.

(1) Demand Functions of A, B and a



<Figure 5> A situation when price of 'a' is larger than 0

—————	$U_A = u_A - p_A - t_{A0}x$	When using A without additional product
—————	$U_B = u_B - p_B - t_{B0}(1 - x)$	When using B without additional product
.....	$U_A = u_A - p_A - t_{A1}x$	When using A, a in case price of additional product is 0
.....	$U_A = u_A - p_A - p_a - t_{A1}x$	When using A, a in case price of additional product is $p_a (> 0)$
z_A	Ratio of consumers purchasing A rather than a	
w_A	Ratio of consumers purchasing A when price of additional product is 0	
w_{A1}	Ratio of consumers purchasing A when price of additional product is $p_a (> 0)$	

In order to fix the price of complement goods, a linear city may be considered as follows. Like the hypothesis above, consumers are distributed evenly on the segment of 0 and 1 and preference for the product may be represented by the product of the transportation cost and consumer location. Therefore, market shares of A, B and 'a' may be derived.

In case the price of the additional product is fixed as >0 , it leads to the utility function of $U_A = u_A - p_A - p_a - t_{A1}x$. When allying such an expression simultaneously with the utility function from B $U_B = u_B - p_B - t_{B0}(1 - x)$, market share of A w_{A1}'' may be calculated when the price of complement goods is as > 0 .

$$u_A - p_A - p_a - t_{A1}x = u_B - p_B - t_{B0}(1 - x)$$

$$w_{A1} = x = \frac{p_B + t_{B0} - p_A - p_a}{t_{A1} + t_{B0}} = 1 - \frac{p_A + p_a + t_{A1} - p_B}{t_{A1} + t_{B0}}$$

$$w_{B0} = 1 - w_{A1} = \frac{p_A + p_a + t_{A1} - p_B}{t_{A1} + t_{B0}}$$

It shows that market share of the primary product is in inverse proportion to prices of its own and that of complement goods. The reason is that price of complement goods has a negative effect acting as additional expenses for using A. On the other hand, in case transportation cost decreases by complement goods, market share of the compatible primary product increases.

In the meantime, since every consumer buying A does not purchase 'a', it is required to separate those who purchase 'a' from those who not. Here, let's assume that ratio of persons purchasing only A is z_A'' . It may be calculated by allying simultaneously utility function when not using complement goods $U_A = u_A - p_A - t_{A0}x$ with utility function when using $U_A = u_A - p_A - p_a - t_{A1}x$.

$$\begin{aligned} u_A - p_A - t_{A0}x &= u_A - p_A - p_a - t_{A1}x \\ z_A'' = x &= \frac{p_a}{t_{A0} - t_{A1}} \end{aligned}$$

z_A'' , a ratio for purchasing A and not purchasing 'a' becomes $\frac{p_a}{t_{A0} - t_{A1}}$. As the price of complement goods increases, the number of persons not purchasing 'a' increases, and it is in inverse proportion to the transportation cost when not using complement goods and in proportion to the transportation cost when using. That is, as decrement of the transportation cost according to use of complement goods, $(1 - \delta)t$ increases, the number of persons who use complement goods and do not purchase decreases. The reason is that $(1 - \delta)t$ acts as additional utility according to use of complement goods so increased $(1 - \delta)t$ induces its use.

Here, a ratio for purchasing 'a', s_a'' may be calculated by subtracting z_A'' , a ratio for purchasing A and not purchasing 'a' from the total purchase ratio of A, w_{A1}'' .

$$\begin{aligned} s_a'' &= w_{A1}'' - z_A'' = \frac{p_B + t_{B0} - p_A - p_a}{t_{A1} + t_{B0}} - \frac{p_a}{t_{A0} - t_{A1}} \\ &= \frac{p_B - p_A + t_{B0}}{t_{A1} + t_{B0}} - \frac{t_{A0} + t_{B0}}{(t_{A1} + t_{B0})(t_{A0} - t_{A1})} p_a \end{aligned}$$

A ratio for purchasing 'a', s_a is in inverse proportion to the price of 'a', p_a . So, s_a may be said as the demand function of 'a'. Besides, it is in inverse proportion to the price of A used together and in proportion to the price of B, a competitor of A. Also, it is in proportion to the contributory portion of the additional product, $(1 - \delta)t$

(2) Pricing of A, B and a

Through profit function based on the share above and cost function hypothesized, price of each product maximizing profits may be set. Firstly, let's calculate profit functions of A, B and a, and reaction functions for each price.

Based on the hypothesis above, when marginal cost of the primary product is c and its sunk cost is FC , profit function of A may be represented as follows.

$$\begin{aligned}\pi_A &= (p_A - c) \left(\frac{p_B + t_{B0} - p_A - p_a}{t_{A1} + t_{B0}} \right) - FC \\ \pi'_A &= \frac{p_B + t_{B0} - 2p_A - p_a + c}{t_{A1} + t_{B0}} = 0 \text{ (F. O. C.)} \\ p_A &= \frac{p_B + t_{B0} - p_a + c}{2} : \text{ Reaction Function of A}\end{aligned}$$

The price of A is in proportion to the price of B and the transportation cost resulted from purchase of the product by the competitor B. The reason is that there is room for joint price increase if other party raises the price, Also, it is in proportion to the marginal cost of its own company in terms of production. On the other hand, it is in inverse proportion to the price of the additional product. Profit function of B may be represented as follows.

$$\begin{aligned}\pi_B &= (p_B - c) \left(\frac{p_A + p_a + t_{A1} - p_B}{t_{A1} + t_{B0}} \right) - FC \\ \pi'_B &= \frac{p_A + p_a + t_{A1} - 2p_B + c}{t_{A1} + t_{B0}} = 0 \text{ (F. O. C.)} \\ p_B &= \frac{p_A + p_a + t_{A1} + c}{2} : \text{ Reaction Function of B}\end{aligned}$$

The price of B is also in proportion to the price of A and the transportation cost resulted from purchase of the product by the competitor A, the price of the additional product 'a' compatible with A and marginal cost of its own company in terms of production.

Profit function is calculated to derive the reaction function of the additional product price, p_a . Here, based on the hypothesis above, cost function is represented as $TC_a = fc + mq$, fixed cost as fc and marginal cost as m .

$$\begin{aligned}\pi_a &= (p_a - m) \left(\frac{p_B - p_A + t_{B0}}{t_{A1} + t_{B0}} - \frac{t_{A0} + t_{B0}}{(t_{A1} + t_{B0})(t_{A0} - t_{A1})} p_a \right) - fc \\ \pi'_a &= \frac{p_B - p_A + t_{B0}}{t_{A1} + t_{B0}} - \frac{2(t_{A0} + t_{B0})}{(t_{A1} + t_{B0})(t_{A0} - t_{A1})} p_a + \frac{m(t_{A0} + t_{B0})}{(t_{A1} + t_{B0})(t_{A0} - t_{A1})} = 0 \text{ (F. O. C.)} \\ p_a &= \frac{1}{2} \left[\frac{(p_B - p_A + t_{B0})(t_{A0} - t_{A1})}{t_{A0} + t_{B0}} + m \right]\end{aligned}$$

The price of the additional product, p_a is in proportion to the price of its incompatible product B, in inverse proportion to that of its compatible product A, and in proportion to the marginal price. Since, as consumers purchase A much more when the price of B is higher, demand for the complementary additional product 'a' is also higher. Besides, it is in inverse proportion to t_{A1} , a new transportation cost of the compatible product A, since decrease of inconvenience by entry of the additional product may be reflected in the price. In other words, proportion to $(t_{A0} - t_{A1})$ means proportion to the contributory portion by entry of the additional product. Entry of the additional product gives consumers extra convenience, leading to increase of the price.

Price of each product may be calculated by allaying three reaction functions above

simultaneously. Firstly, reaction functions of A and B are allied simultaneously and represented as an expression for p_a .

$$p_A = \frac{t_{A1} + 2t_{B0} + 3c - p_a}{3}$$

$$p_B = \frac{2t_{A1} + t_{B0} + 3c + p_a}{3}$$

p_a may be calculated by substituting the expression above for the reaction function of 'a'.

$$p_a^{//*} = \frac{3(t_{A0} + t_{B0})m + (t_{A0} + 2t_{B0})(t_{A0} - t_{A1})}{2(2t_{A0} + t_{A1} + 3t_{B0})}$$

Again it is allied simultaneously, and solution may be calculated by substituting for reaction functions of p_A and p_B for p_a .

$$p_A^{//*} = \frac{(t_{A1}^2 + 4t_{B0}t_{A1} + 2t_{A0}t_{B0} + t_{A0}t_{A1} + 4t_{B0}^2) - (t_{A0} + t_{B0})m}{2(2t_{A0} + t_{A1} + 3t_{B0})} + c$$

$$p_B^{//*} = \frac{(t_{A1}^2 + 4t_{B0}t_{A1} + 2t_{A0}t_{B0} + 3t_{A0}t_{A1} + 2t_{B0}^2) + (t_{A0} + t_{B0})m}{2(2t_{A0} + t_{A1} + 3t_{B0})} + c$$

Based on result above, market share may be calculated using the demand function.

$$w_A^{//*} = \frac{(t_{A1}^2 + 4t_{B0}t_{A1} + 2t_{A0}t_{B0} + t_{A0}t_{A1} + 4t_{B0}^2) - (t_{A0} + t_{B0})m}{2(2t_{A0} + t_{A1} + 3t_{B0})(t_{A1} + t_{B0})}$$

$$w_B^{//*} = \frac{(t_{A1}^2 + 4t_{B0}t_{A1} + 2t_{A0}t_{B0} + 3t_{A0}t_{A1} + 2t_{B0}^2) + (t_{A0} + t_{B0})m}{2(2t_{A0} + t_{A1} + 3t_{B0})(t_{A1} + t_{B0})}$$

Now, market share of the additional product 'a' is calculated by substituting the value of the price for s_a above.

$$s_a^{//*} = \frac{(t_{B0}t_{A1} + 2t_{A0}t_{B0} + t_{A0}t_{A1} + 2t_{B0}^2) + [2 - \frac{3(t_{A0} + t_{B0})}{(t_{A0} - t_{A1})}](t_{A0} + t_{B0})m}{2(2t_{A0} + t_{A1} + 3t_{B0})(t_{A1} + t_{B0})}$$

The hypothesis says that transportation costs of A and B are the same when there is no additional product but for convenience sake suppose that the original transportation cost t_{i0} is t and t_{i1} is δ times of t_{i0} . That is, $t = t_{i0}$ and $\delta t = \delta t_{i0} = t_{i1}$ but $0 < \delta < 1$. It is regarded that transportation cost decrease as much as $(1 - \delta)t$ by entry of the additional product. If then, it may be interpreted that δ is the term related to a rate of change of the transportation cost by entry of the additional product. In other words, the more δ becomes larger, the less a reduction ratio of the transportation is. Here, each value is as follows.

<Table 4> Price, sales & profits of each product in the 2nd period

	Details	A	B
Primary Product	Price	$p_{A1}^{//*} = \frac{(\delta^2+5\delta+6)t-2m}{2(5+\delta)} + c$	$p_{B0}^{//*} = \frac{(\delta^2+7\delta+4)t+2m}{2(5+\delta)} + c$
	Sales	$w_{A1}^{//*} = \frac{(\delta^2+5\delta+6)t-2m}{2(5+\delta)(1+\delta)t}$	$w_{B0}^{//*} = \frac{(\delta^2+7\delta+4)t+2m}{2(5+\delta)(1+\delta)t}$
	Profits	$\pi_{A1}^{//*} = \frac{[(\delta^2+5\delta+6)t-2m]^2}{4t(5+\delta)^2(1+\delta)}$	$\pi_{B0}^{//*} = \frac{[(\delta^2+7\delta+4)t+2m]^2}{4t(5+\delta)^2(1+\delta)} - FC$ ⁸
Add Product	Price	$p_a^{//*} = \frac{(1-\delta)(\delta+2)t+6m}{2(5+\delta)}$	-
	Sales	$s_a^{//*} = \frac{(\delta+2)[(1-\delta)t-2m]}{(1-\delta)(1+\delta)(5+\delta)t}$	-
	Profits	$\pi_a^{//*} = \frac{[(\delta+2)[(1-\delta)t-2m]^2}{2(1-\delta)(1+\delta)(5+\delta)^2t}$	-

<Theorem 2>

- ① $p_{B0}^{//*} < p_{A1}^{//*}$: The price of the primary product having the additional product is higher than that of the primary product having not. In case, $\frac{(1-\delta)t}{2} > m$.
- ② $w_{B0}^{//*} < w_{A1}^{//*}$: The market share of the primary product having the additional product is higher than that of the primary product having not. In case, $\frac{(1-\delta)t}{2} > m$.
- ③ $\pi_{B0}^{//*} < \pi_{A1}^{//*}$: The profit of the primary product having the additional product is higher than that of the primary product having not. In case, $\frac{(1-\delta)t}{2} > m$.

<Proof>

$$\begin{aligned} \textcircled{1} \quad p_{A1}^{//*} - p_{B0}^{//*} &= \frac{(\delta^2+5\delta+6)t-2m}{2(5+\delta)} + c - \left[\frac{(\delta^2+7\delta+4)t+2m}{2(5+\delta)} + c \right] \\ &= \frac{(2-2\delta)t-4m}{2(5+\delta)} > 0 \quad (\because \frac{(1-\delta)t}{2} > m) \blacksquare \\ \textcircled{2} \quad w_{A1}^{//*} - w_{B0}^{//*} &= \frac{(\delta^2+5\delta+6)t-2m}{2(5+\delta)(1+\delta)t} - \frac{(\delta^2+7\delta+4)t+2m}{2(5+\delta)(1+\delta)t} \\ &= \frac{(2-2\delta)t-4m}{2(5+\delta)(1+\delta)t} > 0 \quad (\because \frac{(1-\delta)t}{2} > m) \blacksquare \\ \textcircled{3} \quad \pi_{A1}^{//*} - \pi_{B0}^{//*} &= \frac{[(\delta^2+5\delta+6)t-2m]^2}{4t(5+\delta)^2(1+\delta)} - \left[\frac{[(\delta^2+7\delta+4)t+2m]^2}{4t(5+\delta)^2(1+\delta)} - FC \right] \\ &= \frac{(1-\delta)t-2m}{(5+\delta)} + FC > 0 \quad (\because \frac{(1-\delta)t}{2} > m) \blacksquare \end{aligned}$$

Suppose a variable when there is no additional product 'a'. If then, $\delta=1$, $m=0$. Here, as for each price, $p_{A1} = t + c$, $p_{B0} = t + c$, so identical to the values in case of symmetry. On the other hand, suppose a case when there is no transportation cost of A at all via entry of 'a' so δ is 0. Here, $p_{A1} = \frac{3t-m}{5} + c$, $p_{B0} = \frac{2t+m}{5} + c$, and each value is less than $t + c$ when m is a small number, also

⁸ The profit formula shall be greater than 0 for entry of B in the 2nd period. Hence, in the 2nd period, a range of sunk cost allowing B to enter is as follows.

$$\frac{[(\delta^2+7\delta+4)t+2m]^2}{4t(5+\delta)^2(1+\delta)} \geq FC$$

the price of A is higher than that of B.

In general, in case the price of the additional product is greater than 0, the price of the primary product having the additional product is higher than that of the primary product having not. However, it shall satisfy $\frac{(1-\delta)t}{2} > m$. Before entry of the additional product, each primary product bisects a market. Here, the maximum of the contributory portion to a society realized by entry of the additional product is $\frac{(1-\delta)t}{2}$ where x is $\frac{1}{2}$. Accordingly, when a social contributory portion realized by the additional product, $\frac{(1-\delta)t}{2}$ is greater than m , production cost of the additional product, production of the additional product may be desirable socially.

<Theorem 3>

- ① $\frac{dp_a}{d\delta} < 0$: $p_a^{//*}$ is in inverse proportion to δ . It means the lower transportation cost of the additional product is, the higher the price increases.
- ② $\frac{ds_a}{d\delta} < 0$: $s_a^{//*}$ is in inverse proportion to δ . It means the lower transportation cost of the additional product is, the higher the sales increases. In case, $\frac{(1-\delta)t}{2} > m$

<Proof>

$$\begin{aligned} \text{① } p_a^{//*} &= \frac{(1-\delta)(\delta+2)t+6m}{2(5+\delta)} \\ \frac{dp_a}{d\delta} &= -\frac{(2\delta+1)t}{2(5+\delta)} - \frac{6m+(1-\delta)(\delta+2)t}{[2(5+\delta)]^2} < 0 \quad \blacksquare \\ \text{② } s_a^{//*} &= \frac{(\delta+2)[(1-\delta)t-2m]}{(1-\delta)(1+\delta)(5+\delta)t} \\ \frac{ds_a}{d\delta} &= -\frac{(1+2\delta)t+2m}{(1-\delta)(1+\delta)(5+\delta)t} - \frac{t(1-10\delta-3\delta^2)(2+\delta)[(1-\delta)t-2m]}{[(1-\delta)(1+\delta)(5+\delta)t]^2} < 0 \quad \blacksquare \end{aligned}$$

p_a , the price of the additional product 'a', is in proportion to the marginal cost and the early transportation cost t but in inverse proportion to δ . As mentioned before δ is in inverse proportion to decrement of the transportation cost. Since, when δ approaches 1, it means entry of the additional product gives less utility actually, failing in inducing the demand and having an effect on lower price eventually. It shows that sales of the additional product are in proportion to consumers' increased utility according to lowered transportation cost by entry of the additional product. So to speak, the lower transportation cost of the additional product is, the more sales it reaches.

Based on the model above, this study analyzed a case when existence or nonexistence of the additional product causes asymmetry in the transportation of the primary product. Findings show that primary product having the additional product has a higher price and market share compared with the primary product having not. Furthermore, the more transportation cost decreases, the more price of the additional product goes up with increased sales. In the following section, a condition such a situation may happen is derived. Consider a level of the sunk cost allowing 'a' to enter in the 1st period and be manufactured continually while preventing b from entering in the 2nd period.

(3) **Deriving a condition against entry of b in a case there are A, B, a and b**

In order to continue a situation where A and B are asymmetrical by the additional product 'a', additional product compatible with the primary product B, in other words, b shall not be entered and if b is manufactured and sold, a condition satisfying it is that its profits $\pi_b = (p_b - m)q_b - fc$ is smaller than 0.

Suppose that A and B have symmetrical transportation costs again and then production conditions of 'a' and b are also symmetrical if b appears. Here, primary products A and B bisect a market. So, it results in cutting of the 1st period's primary product market in half. Accordingly, demand of 'a' decreases to half of the 1st period's demand and it results in symmetry in B and b.

If so, demand of 'a' becomes $s_a = \frac{1}{2} - \frac{p_a}{t_0 - t_1}$ and the price calculated by the reaction function through the profit function becomes $\frac{(1-\delta)t+2m}{4}$. On the other hand, here sales are $\frac{(1-\delta)t-2m}{4(1-\delta)t}$.

It also applies to b since both 'a' and b are symmetrical. Using the expression above, a range of the fixed cost fc preventing b from entering in the 2nd period may be calculated.

$$\begin{aligned}\pi_b &= \left(\frac{(1-\delta)t+2m}{4} - m \right) \left(\frac{(1-\delta)t-2m}{4(1-\delta)t} \right) - fc \\ &= \left(\frac{(1-\delta)t-2m}{4} \right)^2 \left(\frac{1}{(1-\delta)t} \right) - fc\end{aligned}$$

In the 2nd period, for b to be manufactured, a range of the fixed cost fc is as follows.

$$\left(\frac{(1-\delta)t-2m}{4} \right)^2 \left(\frac{1}{(1-\delta)t} \right) \geq fc$$

In the meantime, in the 1st period, a range of the fixed cost fc for 'a' to appear is as follows. So, a range of the sunk cost allowing 'a' to enter in the 1st period but preventing b from entering in the 2nd period may be calculated using the theorem.

$$\left(\frac{(1-\delta)t-2m}{2} \right)^2 \left(\frac{1}{(1-\delta)t} \right) \geq fc$$

<Theorem 4>

In case a range of the sunk cost in the additional product production is the same as following below, 'a' appears in the 1st period and b does not in the 2nd period so it causes asymmetry.

$$\left(\frac{(1-\delta)t-2m}{4} \right)^2 \left(\frac{1}{(1-\delta)t} \right) < fc \leq \left(\frac{(1-\delta)t-2m}{2} \right)^2 \left(\frac{1}{(1-\delta)t} \right)$$

If fc exists within the inequality above, 'a' may enter again in the 2nd period since every sunk cost was collected in the 1st period. However, despite the same condition as 'a', b may not enter since

the sunk cost could not be collected because of decreased demand to half compared with the 1st period. Setting of such a condition allows a situation that transportation cost is asymmetrical in the model above.

IV. Conclusion

Rapid advance of mobile communication device industry has taken a role in our nation's growing into an IT power. Along with acceleration of technological development, competitiveness of mobile communication devices is converging at certain speed and linkage between mobile communication device industry and other industries becomes more important to achieve its continual development. So, this paper identified that lock-in effect may happen by existence of the additional product in the communication market through the hotelling model. The first player holds an early market and then he maintains a higher share of the early period continually despite entry of the second player. This paper shows that such a phenomenon may occur existence or nonexistence of the first and second players' additional product. Based on a higher market power of the first player, a compatible additional product appears and it takes a role in lowering the transportation cost of the primary product manufactured by the first player through functional and aesthetic improvements of the primary product. However, the second player comes to have a lower market power since he already lost the market significantly by the first player, and the resulting aggravated prospective profits of the additional product operator prevents entry of the additional product. Accordingly, there is difference in the transportation costs between the first and second players and it gives the first player the advantage so makes him maintain a higher market share of the early period. As a result of analysis, when there are two horizontally differentiated primary products, it shows that product having the additional product may fix a higher price and occupy a wider market than product having not. The main research findings are as follows.

In case there are two primary products under symmetrical conditions, when additional product only compatible with the first player's product exists and the one compatible with the second players' fails in entry, both primary products have difference in the transportation costs. Also, the first player has a higher price of the additional product and a greater market share. On the other hand, the price and sales of the additional product are in inverse proportion to a size of the transportation cost changed by entry of the additional product. In other words, it is in proportion to decrement $(1 - \delta)$ of the transportation cost and may be interpreted that decrement of the transportation cost is the contributory portion of the additional product. (However, in case $\frac{(1-\delta)t}{2} > m$)

Hereafter, model may be expanded through mitigating the hypothesis to reflect the reality. This paper dealt with a case of horizontal product differentiation so postulated that inherent values of products are identical. However, since there are 'low-end' and 'premium' devices in reality, production aspects of additional products compatible with them may be an important research topic. Therefore, future study may consider a case that u_A and u_B are not identical by vertical differentiation.

Besides, along with empirical research to verify theories, follow-up study may be done about a method for overcoming the disadvantage by network through efforts by the second enterprise within a market in order to form more competitive IT device market. It considers about whether second player

can enter the IT market more easily using the network of the existing first player or it is better to construct his own network.

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