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Growing use of three-part tariffs by MNOs: Understanding incentives of MNOs

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Growing use of Three-part Tariffs by MNOs: Understanding Incentives of MNOs

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Abstract

This paper sets up a microeconomics model to analyze the market outcomes of two-part tariffs and three-part tariffs. Specifically, this paper compare the market outcomes of a single two-part tariffs to a single three-part tariffs under the assumptions that the market structure is monopolistic, there is no demand uncertainty, and demand curve is a linear straight line. The results show that a single two-part tariffs and a single three-part tariffs bring forth the same market outcomes except lump-sum fees. The lump-sum fees of the three-part tariffs are the lump-sum fees of the two-part tariffs plus the revenue loss caused by an allowance (free volume provided to customers). Therefore, according to this result, the monopolist has no reason to prefer three-part tariffs to two-part tariffs. However, if customers do not use up all allowance or there is demand uncertainty, three-part tariffs can generate more profits to the monopolist than two-part tariffs. Moreover, three-part tariffs can be used by the monopolist to raise lump-sum fees without losing customers and profits.

Keywords: Three-part tariff; Two-part tariff; Smart phone; Allowance; Lump-sum fees

Acknowledgement

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1. Introduction

Mobile network operators (MNOs) have been using nonlinear pricing schemes such as two-part tariffs and three-part tariffs. Nowadays, MNOs are, especially after smartphones were introduced in the mobile communications market, widely using three-part tariffs. They offer multiple three-part tariffs and induce customers to reveal their preferences voluntarily by selecting one of them. Two-part and three-part tariffs are typical strategies to segment customers depending on their willingness to pay. One interesting thing is that MNO are adopting three-part tariffs instead of two-part tariffs especially after mobile communications services evolve from voice oriented to data oriented services.

Three-part tariffs (3PTs), as shown in Table 1, are composed of three parts: monthly lump-sum fees, unit prices and allowances, whereas two-part tariffs (2PTs) have only monthly lump-sum fees and unit prices. Thus, allowances are a major feature that distinguishes three-part tariffs from two-part tariffs. In other words, the firms under three-part tariffs have an additional choice variable than the firms under two-part tariffs. So intuitively speaking, MNOs are likely to be better off (at least weakly) under three-part tariffs because two-part tariffs are three-part tariff with zero allowance and they are just special cases of three-part tariffs.[1]

[1] Sometimes 3PTs are considered as 2PTs because of the similarities between the two (Pindyck & Rubinfeld, 2013).

Table 1: Three-part tariffs used by Korean MNOs

MNOs	3PT Names	Lump-sum fees	Allowances	Unit prices
KT	LTE gold 150	15,000won	150MB	20.48won/1MB
	LTE olleh 45	45,000won	1.5GB	20.48won/1MB
	LTE olleh 55	55,000won	2.5GB	20.48won/1MB
SKT	LTE golden 150	15,000won	150MB	20.48won/1MB
	LTE 420	42,000won	1.6GB	20.48won/1MB
	LTE 520	52,000won	2.6GB	20.48won/1MB

* 1,000won = 1$, MB = megabytes, and GB = gigabytes.

Even though MNOs have three choice variables to segment customers under three-part tariffs, in Korea they use two variables, lump-sum fees and allowances, to segment customers as shown in Table 1. Unit prices do not vary with lump-sum fees and allowances. This means that MNOs use two choice variables both in 2PTs and 3PTs even though allowances instead of unit prices are used to segment customers in three-part tariffs.

Observing the growing use of 3PTs by MNOs, this paper first investigates whether three-part tariffs are as good as or better than two-part tariffs in terms of MNOs' profit. In order to see the difference between 2PTs and 3PTs as clearly as possible, this paper uses a very simple model assuming that a 2PT with a 3PT are available to the profit maximizing monopolist. Under another assumption that consumers' demand curves are linear downward sloping lines, this paper derives the profit maximizing lump-sum fees, unit prices and allowances. This paper also compares the monopolist profits and consumer surplus under a 2PT and a 3PT. Then this paper relaxes single 2PT assumption and allows a monopolist MNO offers two 2PTs. With the relaxed assumption and the same linear demand curve assumption, this paper investigates whether the profit from a three part tariff whose unit price is assumed to be fixed is larger than the profit from two part tariffs. This paper also compares consumer welfares in 2PTs and 3PTs. The last objective of this paper is to examine the role of allowance, based on the outcomes of above analyses, which is the key variable that distinguishes 3PTs from 2PTs. Additional assumptions adopted in this paper are that consumers are uniformly distributed in a closed interval and that there is no uncertainty in the use of data volume in terms of subscribers.

The structure of this paper is as follows. Section 2 reviews previous studies on 3PTs, and Section 3 introduces the assumptions of the analyses. Section 4 finds analytical results for a single 2PT and two 2PTs, and Section 5 reports analytical results for a single 3PT. Section 6

concludes the paper with a brief summary of findings, a few remarks on limitations of this paper and directions of further research.

2. Literature review

Previous studies have mostly focused on 2PTs and there have been only several research papers on 3PTs. Bagh and Bhargava (2008) compared 3PTs with 2PTs and concluded that single three-part tariff beats a menu of 2PTs and a small menu of 3PTs are more profitable than a large menu of 2PTs. Kwon (2011) analyzed theoretically features of a single 3PT when market is monopolized, and reported an outcome that the profit maximizing monopolist has an incentive to set a menu of allowances that are positively correlated with lump-sum fees (membership fees). However, the model used in Kwon (2011) did not consider the possibility that consumers' uncertainty in estimating data use could prevent them from overestimating data use and choosing a 3PT that offers too much allowance. Uncertainty is critical factor that could bias consumers' choices in favor of flat rates in reality. Nunes (2000) found that consumers tend to put more emphasis on the possibility of using more than the average than the possibility of using less than the average. The author argues that this tendency induces customers to prefer a flat rate to a usage rate. Lambrecht, Seim and Skiera (2007) found that demand uncertainty is a key driver of choice among three-part tariffs and higher demand uncertainty is associated with choosing a tariff with a higher allowance. Chao (2013) investigated the incentives of a dominant firm to use a 3PT in vertical business relationship with downstream firms in the oligopolistic market structure.

3. Key assumptions of analyses

Assume that there are numerous consumers and each consumer is differentiated by the preference parameter θ, ranging between 0 and 1. A higher θ implies a higher propensity to consumption. It means that if $\theta_1 > \theta_2$, the demand curve of a θ_1-consumer locates above (or on the right of) the demand curve of a θ_2-consumer. The utility of consumers are assumed to be strictly increasing with θ, and because of this assumption, two demand curves do not cross each other. Let $f(\theta)$ denote the population density of each subscriber type, θ. It is assumed that the monopolist, maximizing profit, knows the distribution of $f(\theta)$, and does not know each consumer's preference index.

Each consumer maximizes his utility for given budget. For the purpose of deriving the individual demand curve, Tirole (1988)'s approach is used. The total utility consists of two parts: the summation of the utility from consumption and the utility from income. Function V(·) represents utility from consumption and U(·) represents utility from income. Now suppose that user whose income is I consumes data service by the amount of quantity q when unit price is p. If communication fee is very small relative to income I (p·q << I), consumer utility can be expressed as follows.

$$\text{Utility} = U[I - p\cdot q] + V(q) \qquad (U'>0,\ U''<0,\ V(0)=0,\ V'>0,\ V''<0)$$
$$= U(I) - (p\cdot q)\cdot U'(I) + V(q)$$
$$= U(I) + U'(I)\ \{\lambda\cdot V(q) - p\cdot q\}$$

If income I is fixed, consumer will choose quantity q^* which maximize the $\lambda \cdot V(q) - (T + p\cdot q)$. From the first-order condition, an optimal amount of quantity is found.

$$\frac{\partial}{\partial q}\{\lambda\cdot V(q) - (T + p\cdot q)) = 0. \qquad \therefore \lambda\cdot V'(q) = p \quad \text{---------- (1)}$$

Let's assume that the utility function from consumption is $V(q) = \theta q - \frac{1}{2}q^2$ in order to obtain linear demand curves. In other words, U(·) function is same for each consumer, but V(·) function changes as consumer index changes. It is readily apparent that the concavity of the utility function is satisfied: $V(0) = 0$, $V'>0$, $V''<0$. Also, this utility function satisfies the assumption that a higher θ implies a higher propensity to consumption. By substituting the function V in to Eq. (1), the following demand curve, shown in Eq. (2) is derived. This demand function will be used in this paper.

$$q = \theta - \frac{1}{\lambda}p \quad \text{---------- (2)}$$

Also, consumer density is assumed to be uniformly distributed. In other words, $f(\theta) = 1$. The cost function C(·) is assumed to have a small constant marginal cost ($\frac{\partial C(Q)}{\partial Q}$) because variable costs in the telecommunications industry are usually very small. Then $C(Q) = mc\cdot Q$, where Q is total consumption and mc is a constant marginal cost.

4. Optimal pricing for the single and multiple two-part tariffs

4-1. Analysis of the single two-part tariff

Carlton and Perloff (1999)'s model is used to analyze the single two-part tariff. A two

part tariff is defined by a lump-sum fee (T) and a unit price (p). The demand function is $q = \theta - \frac{1}{\lambda}p$. If there is no lump-sum fee, a consumer indexed by θ will get surplus by the amount of $\frac{1}{2\lambda}(\lambda\theta - p)^2$. However, a lump-sum fee (T) transfers some consumer surplus to the monopolist. Therefore, only consumers whose surpluses are greater than the lump-sum fee will purchase the service.

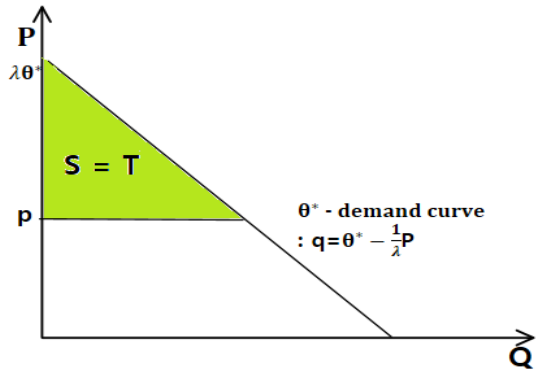
From now on, the index θ^* represents the marginal consumer who is indifferent between purchasing the service and not purchasing it. For a marginal consumer, total surplus should be equal to the lump-sum fee and a usage fee. Fig. 1 shows this relationship and index θ^* satisfies Eq. (3).

$$\frac{1}{2\lambda}(\lambda\theta^* - p)^2 = T \quad \text{---------- (3)}$$

Differentiating partially the both sides of Eq. (3) with respect to T and p results in the following condition.

$$\frac{\partial\theta^*}{\partial T} = \frac{1}{\sqrt{2\lambda T}}, \frac{\partial\theta^*}{\partial p} = \frac{1}{\lambda}$$

Figure 1. Demand curve of the marginal consumer



Consumer surplus increases as index θ increase. Thus, consumers whose index is greater than θ^* will subscribe the service and whose index is less than θ^* will not subscriber it. Then, the total number of subscribers can be obtained by integrating the density function $f(\theta)$ from θ^* to 1. The total subscriber number N is equal to $\int_{\theta^*}^{1} f(\theta)d\theta = \int_{\theta^*}^{1} d\theta = 1 - \theta^*$. The total traffic created by N is Q, which is equal to $\int_{\theta^*}^{1}(\theta - \frac{1}{\lambda}p)f(\theta)d\theta = \int_{\theta^*}^{1}(\theta - \frac{1}{\lambda}p)d\theta = \frac{1}{2}(1 - (\theta^*)^2) - \frac{1}{\lambda}p(1-\theta^*)$.

The monopolist can adjust p and T to maximize her profit. Profit is divided into two

category: profit from lump-sum fees and profit from usage charges as shown in Eq. (4).

$$\Pi = p\cdot Q + T\cdot N - C(Q) = (p-mc)\{\frac{1}{2}(1 - (\theta^*)^2) - \frac{1}{\lambda}p(1-\theta^*)\} + T(1-\theta^*) \text{ ---------- (4)}$$

Taking derivative with respect to T and p results in the following two first order conditions and from which profit maximizing T and p can be found. Table 2 shows that the optimal unit price and lump-sum fees.

$$\frac{\partial \Pi}{\partial T} = 0: \frac{1}{2\lambda}\{2\lambda - 4p + 2mc - 3\sqrt{2\lambda T}\} = 0$$

$$\frac{\partial \Pi}{\partial p} = 0: \frac{1}{2\lambda^2}\{\lambda^2 + 3p^2 - 4\lambda p - 4\lambda T + 2(\lambda - p)\cdot mc\} = 0$$

Table 2: Optimal lump-sum fees and unit price

	Unit price	Lump-sum fee	Marginal consumer index(θ^*)
Single 2PT	$\frac{\lambda + 4mc}{5}$	$\frac{2(\lambda - mc)^2}{25\lambda}$	$\frac{3\lambda + 2mc}{5\lambda}$

The maximum profit and other optimal values of endogenous variables, as shown in Table 3, are derived by plugging these optimal values into the profit function Eq. (4).

Table 3: Maximum profit and optimal values of endogenous variables

	Maximum profit	Number of subscriber	Total quantity	Consumer surplus	Social surplus
Single 2PT	$\frac{2(\lambda - mc)^3}{25\lambda^2}$	$\frac{2(\lambda - mc)}{5\lambda}$	$\frac{6(\lambda - mc)^2}{25\lambda^2}$	$\frac{16(\lambda - mc)^3}{375\lambda^2}$	$\frac{46(\lambda - mc)^3}{375\lambda^2}$

4-2. Analysis of two two-part tariffs

4-2-1. The model for two two-part tariffs

Suppose that the monopolist uses two two-part tariffs, (p_1, T_1) and (p_2, T_2), to make subscribers reveal their preference by choosing one out of two choices. Assume that $T_2 > T_1$, $p_2 < p_1$. Henceforth, a two-part tariff (p_1, T_1) is called bundle 1 and another two-part tariff (p_2, T_2) bundle 2.

Each consumer is faced with two bundles and chooses an optimal bundle which generates a greater consumer surplus. Let $S_i(\theta)$ be a surplus function of a θ consumer when the consumer pays p_i, where i = 1 and 2, with no lump-sum fees. When consumers make choices between bundle 1 and bundle 2, they compare the net surplus $S_2(\theta) - S_1(\theta)$ from bundle 2 with the difference in lump-sum fees $T_2 - T_1$. Therefore, if a consumer's net surplus $S_2(\theta) - S_1(\theta)$ is

greater than the net additional cost $T_2 - T_1$ when q is given, the consumer will select bundle 2. If $S_2(\theta) - S_1(\theta)$ is less than the net additional cost $T_2 - T_1$, the consumer will select bundle 1, and if the net surplus is same as the net additional cost, the consumer is indifferent between selecting bundle 1 and bundle 2. Table 4 summarizes this relationship.

Table 4: Consumer choices under two two-part tariffs

	θ consumer's preference
$S_2(\theta) - S_1(\theta) < T_2 - T_1$	Bundle 1
$S_2(\theta) - S_1(\theta) = T_2 - T_1$	Indifferent between bundle 1 and 2
$S_2(\theta) - S_1(\theta) > T_2 - T_1$	Bundle 2

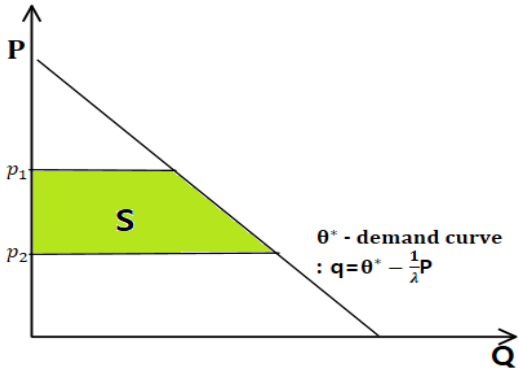
When the linear demand curve shown by Eq. (2) is used, the exact value of $S_2(\theta) - S_1(\theta)$ can be found. Figure 2 depicts $S_2(\theta) - S_1(\theta)$ and the area of the trapezoid is obtained as follows.

$$S_2(\theta) - S_1(\theta) = \frac{1}{2}(p_1 - p_2)(2\theta - \frac{1}{\lambda}p_1 - \frac{1}{\lambda}p_2)$$

For the marginal consumer (θ^*), who is indifferent between bundle 1 and bundle 2, additional surplus is equal to additional cost. Then following equation holds.

$$\frac{1}{2}(p_1 - p_2)(2\theta^* - \frac{1}{\lambda}p_1 - \frac{1}{\lambda}p_2) = T_2 - T_1$$

Figure 2 Consumer surplus between the two bundles



As θ increases, demand curves shift to the right and the consumer surplus increases. Thus, consumers in the interval (θ^*,1) obtain higher surplus than $T_2 - T_1$ and will prefer bundle 2 to bundle 1. By the same logic, consumers in the interval (0, θ^*) will prefer bundle 1 to bundle 2. It can also be proved mathematically. Let $h(\theta) = S_2(\theta) - S_1(\theta) - (T_2 - T_1)$. It is readily

apparent that $\frac{\mathrm{dh}}{\mathrm{d}\theta} = p_1 - p_2 > 0$ and that $h(\theta^*) = 0$. It means that $h(\theta)$ is positive for $\theta \in (\theta^*, 1)$ and negative for $\theta \in (0, \theta^*)$.

However, whether the consumer actually purchases the service or not is a different matter. For example, even though a θ^*consumer is indifferent between bundles 1 and 2, it is possible that the consumer does not want to purchase the service. Even though the consumers in the interval $(0, \theta^*)$ prefer bundle 1 to bundle 2, it is also possible that they do not want to purchase the service if not buying the service is better than buying it.

Suppose that a θ^*consumer does not want to purchase the service. It means that $S_2(\theta^*) - T_2 = S_1(\theta^*) - T_1 < 0$ holds. Note that $S_2(\theta) = \frac{1}{2\lambda}(\lambda\theta - p_2)^2$ and $S_1(\theta) = \frac{1}{2\lambda}(\lambda\theta - p_1)^2$. If we differentiate both equations with respect to θ, $\frac{\mathrm{d}S_1(\theta)}{\mathrm{d}\theta} = \lambda(\theta - \frac{1}{\lambda}p_1) > 0$ and $\frac{\mathrm{d}S_2(\theta)}{\mathrm{d}\theta} = \lambda(\theta - \frac{1}{\lambda}p_2) > 0$. Therefore, both equations $S_1(\theta) < S_1(\theta^*)$ and $S_2(\theta) < S_2(\theta^*)$ hold for all $\theta \in (0, \theta^*)$. It means that all consumers in the interval $(0, \theta^*)$ will not purchase any bundle. Remember that consumers in the interval $(\theta^*, 1)$ at least prefer bundle 2 to bundle 1. It means that no consumer will choose the bundle 1. Therefore, it should be assumed that $S_2(\theta^*) - T_2 = S_1(\theta^*) - T_1 \geq 0$ is satisfied for the analyses of the two 2PT pricing.

Not all consumers in the interval $(0, \theta^*)$ purchase the bundle 1. Only consumers whose surplus is greater than T_1 will actually select the bundle 1. So, there are another marginal consumers for purchasing bundle 1. Let this consumer's index be a θ_k and $S_1(\theta_k)$ be equal to T_1. Then the following equation holds.

$$\frac{1}{2}\lambda(\theta_k - \frac{1}{\lambda}p_1)^2 = T_1$$

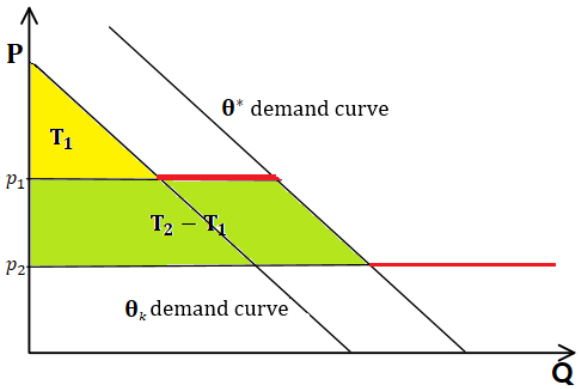


Figure 3. Demand curve of a marginal consumer

Figure 3 shows the demand curves of a θ^*-consumer and a θ_k-consumer. The area of the yellow triangle represents the lump-sum fee of bundle 1. The area of trapezoid represents difference in lump-sum fees between bundles 1 and 2. Red lines represents the consumer demand of different consumers with different consumer indexes. All consumer in the interval (θ_k, θ^*) choose the bundle 1 and consume along the interval shown by the thick red line. All consumer in the interval $(\theta^*,1)$ choose the bundle 2 and consume along the thin red line. Let N_i be the number of subscribers which joins to bundle i (i=1,2). Then N_i is expressed as follows.

$$N_1 = \int_{\theta_k}^{\theta^*} f(\theta)\, d\theta = \theta^* - \theta_k,\ N_2 = \int_{\theta^*}^{1} f(\theta)\, d\theta = 1 - \theta^*$$

Let Q_i be the total consumption which the subscribers of bundle i uses. Then Q_i is expressed as follows.

$$Q_1 = \int_{\theta_k}^{\theta^*} (\theta - \frac{1}{\lambda} p_1) f(\theta)\, d\theta = \frac{1}{2}(\theta^*)^2 - \frac{1}{2}(\theta_k)^2 - \frac{1}{\lambda} p_1 (\theta^* - \theta_k)$$

$$Q_2 = \int_{\theta^*}^{1} (\theta - \frac{1}{\lambda} p_2) f(\theta)\, d\theta = \frac{1}{2} - \frac{1}{2}(\theta^*)^2 - \frac{1}{\lambda} p_2 (1 - \theta^*)\}$$

Profit is divided into two categories: the profit from lump-sum fees and the profit from usage revenue. Then, the aggregated profit is shown as Eq. (5).

$$\Pi = (T_1 \cdot N_1 + T_2 \cdot N_2 + p_1 \cdot Q_1 + p_2 \cdot Q_2) - \mathrm{mc}(Q_1 + Q_2) \quad \text{---------- (5)}$$

Next section derives the conditions for profit maximization by partially differentiating the above profit function Eq. (5) with respect to T_1, T_2, p_1 and p_2.

4-2-2. Profit maximization in the two two-part tariffs

The four equations below show the first derivatives with respect to T_1, T_2, p_1 and p_2.

(1) $\frac{\partial \pi}{\partial T_2}$ **= 0:** $1-\theta^* = \frac{1}{2\lambda}p_1 + \frac{1}{2\lambda}p_2 - \frac{mc}{\lambda}$

(2) $\frac{\partial \pi}{\partial T_1}$ **= 0:** $\theta^* - \frac{3}{2\lambda}p_1 + \frac{1}{2\lambda}p_2 = \frac{3}{2}\sqrt{\frac{2T_1}{\lambda}}$

(3) $\frac{\partial \pi}{\partial p_2}$ **= 0:** $1-\theta^* = \frac{1}{\lambda}p_1 - \frac{1}{\lambda}p_2$

(4) $\frac{\partial \pi}{\partial p_1}$ **= 0:** $\frac{\partial \theta^*}{\partial p_1}(p_1\text{-}p_2)(-1+\theta^*) + \frac{1}{2}(\theta^*)^2 - \frac{1}{2}(\theta_k)^2 - \frac{1}{\lambda}p_1(\theta^* - \theta_k) + (p_1 - \mathrm{mc})\left(\frac{1}{\lambda^2}p_1 - \frac{1}{\lambda}\theta^*\right) = \frac{1}{\lambda}T_1$

Solving the above equations simultaneously results in the optimal unit price, lump-sum fees and maximized profits as shown in Table 5. By plugging these values into the profit function, Eq. (5), maximized profit and optimal values for other endogenous variables are found and shown in Table 6.

Table 5: Market outcomes of the two 2PTs

p_1	p_2	T_1	T_2	θ_k	θ^*
$\frac{\lambda + 2mc}{3}$	$\frac{\lambda + 8mc}{9}$	$\frac{2(\lambda - mc)^2}{81\lambda}$	$\frac{4(\lambda - mc)^2}{27\lambda}$	$\frac{5\lambda + 4mc}{9\lambda}$	$\frac{7\lambda + 2mc}{9\lambda}$

Table 6: Optimal values for endogenous variables under two 2PTs

	Profit	Number of subscriber	Total quantity	Consumer surplus	Social surplus
Two 2PT	$\frac{20(\lambda - mc)^3}{243\lambda^2}$	$\frac{4(\lambda - mc)}{9\lambda}$	$\frac{20(\lambda - mc)^2}{81\lambda^2}$	$\frac{92(\lambda - mc)^3}{2187\lambda^2}$	$\frac{272(\lambda - mc)^3}{2187\lambda^2}$

4-3. Comparison of market outcomes under the single and two two-part tariffs

Table 7 presents the comparison of the market outcomes under the single 2PT and two 2PTs. Most of the market outcomes of two 2PTs are greater than those of the single 2PT. Only consumer surplus decreases in two 2PTs. Both profit and total social surplus increase in two 2PTs and this result is consistent with the theory of the second-degree price discrimination in microeconomics.

Table 7: Comparison of market outcomes under the single and two 2PTs

	Profit	Number of subscriber	Total quantity	Consumer surplus	Social surplus
Single 2PT	$\frac{2(\lambda - mc)^3}{25\lambda^2}$	$\frac{2(\lambda - mc)}{5\lambda}$	$\frac{6(\lambda - mc)^2}{25\lambda^2}$	$\frac{16(\lambda - mc)^3}{375\lambda^2}$	$\frac{46(\lambda - mc)^3}{375\lambda^2}$
Two 2PT	$\frac{20(\lambda - mc)^3}{243\lambda^2}$	$\frac{4(\lambda - mc)}{9\lambda}$	$\frac{20(\lambda - mc)^2}{81\lambda^2}$	$\frac{92(\lambda - mc)^3}{2187\lambda^2}$	$\frac{272(\lambda - mc)^3}{2187\lambda^2}$

5. Optimal pricing for the single three-part tariff

5-1. The model for the single three-part tariff

Suppose that monopolist uses the single three-part tariff, which means that the monopolist applies one single three-part tariff, composed of a lump-sum fee (T), a unit price (p) and an allowance (q_0), to all consumers. The same demand function $q = \theta - \frac{1}{\lambda} p$ is used for analyses and three customer groups can be formed under the single 3PT according to the indexes shown in Table 8.

Table 8: Customer indexes for the single 3PT

Index	Characteristic	Value of index
θ_1	Quantity demanded is q_0, if both fixed fee and unit price is zero	$\theta_1 = q_0$
θ_2	Quantity demanded is q_0, if fixed fee is zero and unit price is p_0	$\theta_2 = q_0 + \frac{1}{\lambda} p_0$

The monopolist has three choice variables under the 3PT and lump-sum fees are used to extract consumer surpluses. Some users will not purchase the service if lump-sum fees are greater than their consumer surpluses that they obtain from consumption. The monopolist will adjust lump-sum fees, allowances, and unit price to maximize its profit.

Consumers can be categorized into three groups as shown in Figure 4. The first group is the consumers in the interval $(0, \theta_1)$ who consume less than an allowance (q_0). The first group members consume less than the allowance even when unit price is zero. Therefore, even though they can use the allowance without any additional charge, these consumers consume less than the

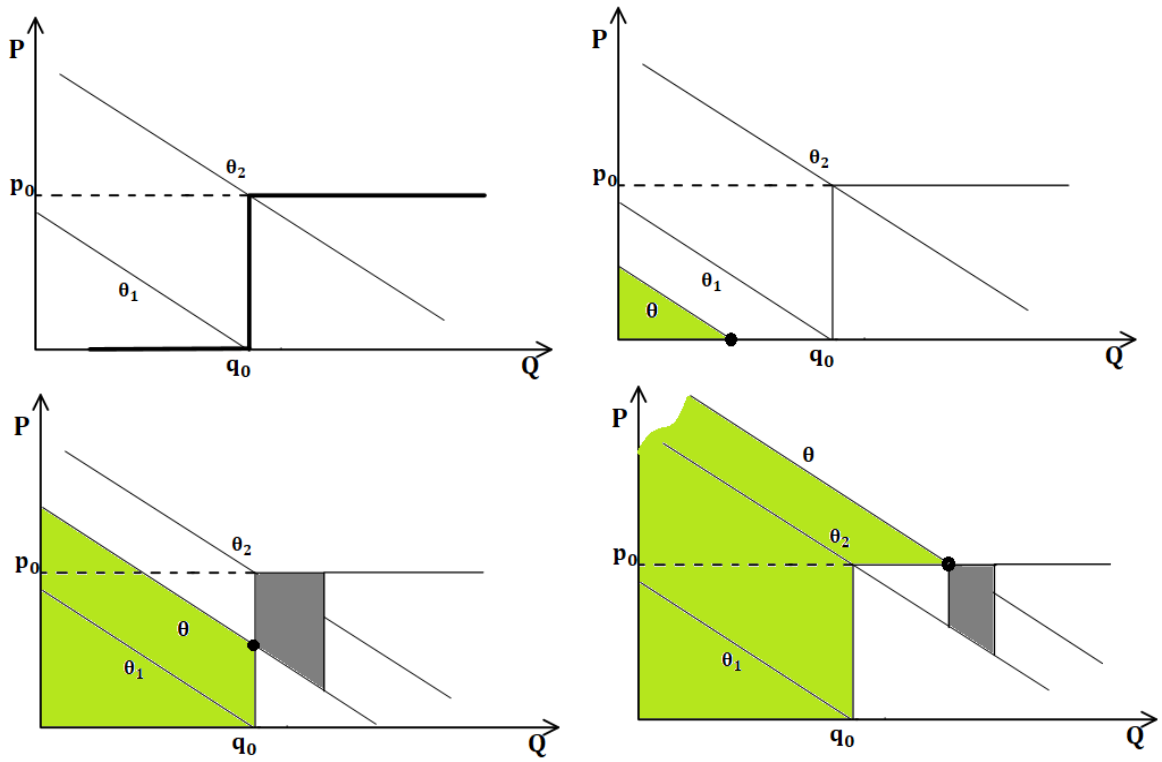


Figure 4: Quantity distribution and consumer choices when θ changes

allowance. The second group is the consumers in the interval (θ_1, θ_2) who consume exactly by the amount of the allowance. They consume no more than the allowance because additional surplus consumers can obtain from the usage in excess of allowance is less than unit price. The third group is the consumers in the interval $(\theta_2, 1)$ who consume more than the allowance. Because additional surplus these consumers receive from the usage in excess of the allowance is greater than the unit price. They consume until marginal benefit is equal to unit price. Following figures show how the quantity demanded changes as consumer index changes. Green areas represent each consumer's consumer surplus and grey area represents a loss in surplus if a consumer uses more than the optimal quantity.

Let $S(\theta)$ be a surplus function of θ consumer under a three part tariff. $S(\theta)$ is an area of triangle, trapezoid and concave pentagon in turn. Especially, $S(\theta_1) = \frac{1}{2}\lambda(\theta_1)^2$ and $S(\theta_2) = \lambda\theta_2 q_0 - \frac{1}{2}\lambda(\theta_1)^2$. The size of fixed fees determines whether θ_1 and θ_2 consumer purchase the service or not.

Suppose T is less than $S(\theta_1)$. A θ_1 consumer purchases the service and a marginal consumer's index θ^* is less than θ_1. All consumers which purchase the service still can be categorized into three parts. Consumers in the interval (θ^*, θ_1) consume by the amount of θ, the quantity when unit price is equal to zero. Consumers in the interval (θ_1, θ_2) consume exactly by the amount of allowance and consumers in the interval (θ_2, 1) consume by the amount of $\theta - \frac{1}{\lambda}p_0$, the quantity when unit price is equal to p_0.

If T is greater than $S(\theta_1)$ and less than $S(\theta_2)$, θ_1 consumer will not purchases the service and a marginal consumer's index θ^* is in the interval (θ_1, θ_2). It means that only two groups of consumer remain. Consumers in the interval (θ^*, θ_2) consume by the amount of allowance and consumers in the interval (θ_2, 1) consume by the amount of $\theta - \frac{1}{\lambda}p_0$.

If T is greater than $S(\theta_2)$, θ_1 consumer will not purchases the service and a marginal consumer's index θ^* is in the interval (θ_2, 1). Only one group of consumer remain. All consumer will consume by the amount of $\theta - \frac{1}{\lambda}p_0$. Next section derives profit maximizing choice variables based on the three possible cases.

5-2. Profit maximization in the single three-part tariff

Profit is composed of two parts: lump-sum fees and usage fees. Let N be the total number of subscribers. Then N is equal to $\int_{\theta^*}^{1} f(\theta)d\theta = \int_{\theta^*}^{1} d\theta = 1 - \theta^*$. Let Q be a total consumption and Q_{excess} be the consumption in excess of allowance. The exact value of Q_{excess} and Q changes by the size of the lump-sum fees. Then, profit function is shown in Eq. (6).

$\Pi = p_0 \cdot Q_{excess} + N \cdot T - mc \cdot Q$ ---------- (6)

5-2-1. Profit maximization when T is less than $S(\theta_1)$

If T is less than $S(\theta_1)$, θ^* is less than θ_1 and surplus of marginal consumer is $\frac{1}{2}\lambda(\theta^*)^2$. Thus, $T = \frac{1}{2}\lambda(\theta^*)^2$. All consumers in the interval (θ^*, 1) purchase the service and therefore, Q is expressed as follows.

$$Q = \int_{\theta^*}^{\theta_1} \theta f(\theta)d\theta + q_0 \cdot \int_{\theta_1}^{\theta_2} f(\theta)d\theta + \int_{\theta_2}^{1} (\theta - \frac{1}{\lambda}p_0) f(\theta)d\theta$$

$$= \frac{1}{2}\{\theta_1{}^2 - (\theta^*)^2\} + q_0(\theta_2 - \theta_1) + \frac{1}{2}(1 - \theta_2{}^2) - \frac{1}{\lambda}p_0(1 - \theta_2).$$

Only consumers in the interval (θ_2, 1) consumes greater than the allowance and thus Q_{excess} is

expressed as the following equation.

$$Q_{excess} = \int_{\theta_2}^{1}(\theta - \frac{1}{\lambda}p_0 - q_0)f(\theta)d\theta = \int_{\theta_2}^{1}(\theta - \theta_2)d\theta = \frac{1}{2}(1-{\theta_2}^2) - \theta_2(1-\theta_2).$$

Differentiating the profit function with respect to q_0 to find the optimal value of allowance leads to the following equation. Note that the equations $\frac{\partial\theta_1}{\partial q^0} = \frac{\partial\theta_2}{\partial q^0} = 1$ and $\frac{\partial\theta^*}{\partial q^0} = 0$ hold.

$$\frac{\partial\Pi}{\partial q^0} = -p_0(1 - \theta_2 + \frac{2mc}{\lambda}) < 0$$

It can be easily noted that the above equation has a negative value. It means that profit is increased as allowance decreases. This means that the monopolist can increase profit by reducing the allowance quantity. Reducing allowance will be continued until θ_1 is equal to the marginal consumer's index θ^*. When θ_1 is equal to θ^*, there are no consumers who consume less than the allowance. This fact is inconsistent with our assumption that T is less than $S(\theta_1)$ and this case cannot exist in the model of this paper.

5-2-2. Profit maximization when T is greater than $S(\theta_1)$ and less than $S(\theta_2)$

If T is in the interval $(S(\theta_1), S(\theta_2))$, index θ^* is in the interval (θ_1, θ_2) and the surplus of marginal consumer is $\lambda\theta^* q_0 - \frac{1}{2}\lambda(\theta_1)^2$. Thus, $T = \lambda\theta^* q_0 - \frac{1}{2}\lambda(\theta_1)^2$. All consumers in the interval $(\theta^*, 1)$ purchase the service and therefore, Q is expressed as following.

$$Q = q_0 \cdot \int_{\theta^*}^{\theta_2} f(\theta)d\theta + \int_{\theta_2}^{1}(\theta - \frac{1}{\lambda}p_0)f(\theta)d\theta = q_0(\theta_2 - \theta_1) + \frac{1}{2}(1-{\theta_2}^2) - \frac{1}{\lambda}p_0(1-\theta_2).$$

The amount of Q_{excess} is the same as *5-1-2-1* because there is no change in the interval $(\theta_2, 1)$

$$Q_{excess} = \int_{\theta_2}^{1}(\theta - \theta_2)d\theta = \frac{1}{2}(1-{\theta_2}^2) - \theta_2(1-\theta_2).$$

To obtain profit-maximizing values for endogenous variables, differentiate the profit function with respect to T, p_0 and q_0. Note that the equations $\frac{\partial\theta^*}{\partial T} = \frac{1}{\lambda q^0}$, $\frac{\partial\theta^*}{\partial p} = 0$ and $\frac{\partial\theta^*}{\partial q^0} = 1 - \frac{\theta^*}{q^0}$ hold. Below equations represent first-derivative conditions.

① $\frac{\partial\Pi}{\partial T} = 0 \rightarrow 2T = \lambda q^0 + mc\cdot q_0 - \frac{1}{2}\lambda(q_0)^2$

② $\frac{\partial\Pi}{\partial p} = 0 \rightarrow 3p_0 = \lambda + 2mc - \lambda q_0$ or $\theta^{**} = 1$

③ $\frac{\partial\Pi}{\partial q^0} = 0 \rightarrow 2T^2 - \lambda(q_0)^2 T = 2p_0\lambda(q_0)^2 - 2p_0\lambda(q_0)^3 - 2{p_0}^2(q_0)^2 + 2mc\cdot p_0(q_0)^2$

Substituting equations ① and ② into ③ results in the optimal value of q_0.

$$q_0{}^* = \frac{2(\lambda - mc)}{5\lambda} \text{ or } \frac{2(mc-\lambda)}{\lambda}.$$

If $q_0 = \frac{2(mc-\lambda)}{\lambda}$, a marginal consumer's index θ^* is equal to $1 + \frac{1}{2}q_0$ and this is a contradiction because the index is greater than 1. Therefore, q_0 is $\frac{2(\lambda-mc)}{5\lambda}$. Unit price, lump-sum fees and other variables can be calculated by using $q_0{}^*$value. Table 9 shows optimal values, which are also compared with those of the single 2PT.

Table 9: Comparison of optimal values between single 2PT and 3PT

	p_0	T	q_0	θ^*	θ_2	Π
Single 3PT	$\frac{\lambda + 4mc}{5}$	$\frac{2(\lambda - mc)(2\lambda + 3mc)}{25\lambda}$	$\frac{2(\lambda - mc)}{5\lambda}$	$\frac{3\lambda + 2mc}{5\lambda}$	$\frac{3\lambda + 2mc}{5\lambda}$	$\frac{2(\lambda - mc)^3}{25\lambda^2}$
Single 2PT	$\frac{\lambda + 4mc}{5}$	$\frac{2(\lambda - mc)^2}{25\lambda}$	-	$\frac{3\lambda + 2mc}{5\lambda}$	-	$\frac{2(\lambda - mc)^3}{25\lambda^2}$

5-3. Comparison between single 2PT and single 3PT

A few interesting points can be observed from Table 9, comparing the outcomes of the single 2PT and 3PT. Unit price, profit and the number of subscribers are the same in both 2PT and 3PT. The number of subscribers is the same in both rate systems because the marginal consumer's index is the same. Only one difference observed is that lump-sum fees are different between the two rate systems. In order to find the difference in lump-sum fees between the 2PT and the 3PT, the difference is calculated as shown Eq. (7).

$$\frac{2(\lambda-mc)(2\lambda+3mc)}{25\lambda} - \frac{2(\lambda-mc)^2}{25\lambda} = \frac{2(\lambda-mc)(\lambda+4mc)}{25\lambda} = \frac{\lambda+4mc}{5\lambda} \cdot \frac{2(\lambda-mc)}{5\lambda} = \mathrm{p} \cdot \mathrm{q}^0 \text{ ---------- (7)}$$

The lump-sum fees of three-part tariffs are greater than those of two-part tariffs exactly by the amount of the revenue loss caused by an allowance. This is the reason why the profit of the monopolist is the same under the two rate systems. Moreover, because of the same reason, the number of subscribers are the same and total Q (traffic volume) is the same under the two rate systems. The equivalence between the 2PT and the 3PT becomes clearer when the index of the marginal consumer in the 3PT is compared to the marginal index of the third group θ_2. The two indexes are the same as shown in Table 9, implying that the profit maximizing monopolist has an incentive to set T which is making $\theta^* = \theta_2$. In short, when the monopolist utilizes a single three-part tariff, it increases T by the amount of the revenue loss caused by allowance and

chooses the same unit price. Under this single three-part tariff, the marginal consumers' utility is the same as that of the marginal consumer under the single two-part tariff. The relationship shown in Eq. (7) is illustrated in Figure 5, where T3 is the lump-sum fees of the single three-part tariffs and T2 is the lump-sum fees of the single two-part tariff. As long as customers consume more than the allowance, q_0, there is no difference between a 2PT and a 3PT and revenue (and profit) per user is the same in both rate systems.

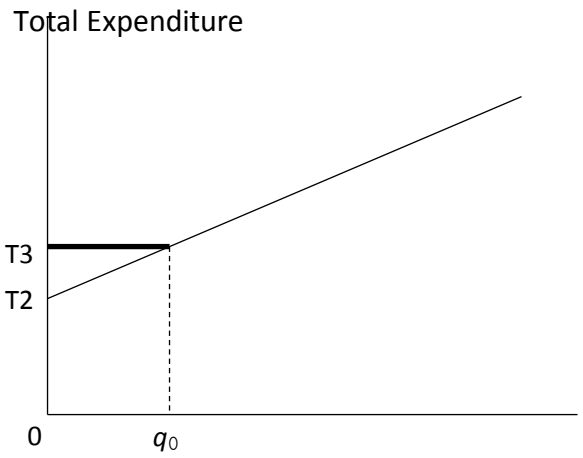


Figure 5. Comparison of allowance in 2PT and 3PT

From Figure 5, at least one role of the allowance can be deduced. The allowance under the single three-part tariff does not generate a revenue and profit loss because according to the analyses up to now, all subscribers use more than the allowance. Then, it may be naturally questioned why the monopolist has an incentive to use a three-part tariff if both 2PT and 3PT result in the same profit as shown in Table 9. Even though the analytical outcomes do not provide a clear answer to the question, one possibility is that when consumers' demand is uncertain, the allowance guarantees the minimum revenue per user as shown in Figure 5. Especially, considering that in reality many mobile communications subscribers do not use up the allowance, a three-part tariff is likely to bring forth more profit to the monopolist than a two-part tariff. In addition, as shown in Figure 5, three-part tariffs can be used a way to raise monthly basic rates (lump-sum fees) while the monopolist keeps existing customers.

6. Results

This paper compares the single two-part tariffs and the single three-part tariffs under the assumption of monopolistic market structure. Demand uncertainty is not allowed and consumers are also assumed to be distributed uniformly in a closed interval. Even though the assumptions are very restrictive, it is found that the market outcomes are the same in both rate systems. In other words, in terms of the monopolist's profit, sales, the number of subscribers, and unit price, a single two-part tariffs and a single three-part tariffs result in the same outcomes. The only difference is the allowance and the lump-sum membership fees. Even though they looks like different, there a special relationship between the lump-sum fees (T3) of the single three-part tariffs and those (T2) of the single two-part tariffs: T3 = T2 + revenue loss caused by the allowance. In short, it can be said that a single two-part tariffs and a single three-part tariffs are identical to the monopolist. Then, why does the monopolist choose three-part tariffs, rather than two-part tariffs? An answer could be that it is a way to increase basic rates without losing customers and profits. It is also possible that three-part tariffs could bring forth more profits to the monopolist than two-part tariffs if customers do not use all allowance or there is demand uncertainty in consumption.

When a single two-part tariffs is compared to two two-part tariffs, as expected and analyzed in previous research, two 2PTs resulted in greater profits, more number of subscribers, and greater social welfare than a single 2PTs.

The outcomes of this paper are based on very restrictive assumptions and the analyses for two 3PTs are not completed and thus the market outcomes of two 3PTs are not compared to two 2PTs. In addition, the market outcomes under the oligopolistic market structure are not analyzed in this paper. Therefore, the analytical results of this paper cannot be generalized. These are the areas of future research.

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