Analyzing the Economic Effect of Mobile Network Sharing in Korea

Young-Keun Song, Hangjung Zo, and Sungjoo Lee

As mobile markets in most developed countries are rapidly coming close to saturation, it is increasingly challenging to cover the cost of providing the network, as revenues are not growing. This has driven mobile operators, thus far mostly involved in facility-based competition, to turn their attention to network sharing. There exist various types of mobile network sharing (MNS), from passive to active sharing. In this paper, we propose a model, based on the supply-demand model, for evaluating the economic effects of using six types of MNS. Our study measures the economic effects of employing these six types of MNS, using actual WiBro-related data. Considering lower service price and expenditure reduction, the total economic effect from a year's worth of MNS use is estimated to be between 513 million and 689 million USD, which is equal to three to four percent of the annual revenue of Korean mobile operators. The results of this study will be used to support the establishment of a MNS policy in Korea. In addition, the results can be used as a basic model for developing various network sharing models.

Keywords: Mobile network sharing, economic effect, site sharing, mast sharing, RAN sharing, core network sharing, national roaming, MVNO.

Manuscript received July 25, 2011; revised Oct. 30, 2011; accepted Nov. 18, 2011.

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http://dx.doi.org/10.4218/etrij.12.0111.0471

I. Introduction

In the past, mobile networks were operated primarily to provide voice services, short message service, and low-capacity data services. Competition among mobile operators took the form of facility-based competition, aimed at expanding service coverage and enhancing network capacity and quality. As a result, most mobile operators in developed countries have established their own mobile networks offering nationwide coverage [1]. At a time when mobile communication service revenues were growing at a rapid pace, the deployment of new networks resulted in a fast return on investment.

Today, the trend is focused on new mobile broadband networks that are capable of satisfying consumer demand for high-speed data. With widespread diffusion, in recent times, of the smartphone and other emerging mobile devices such as tablet PCs, e-books, and smart books, the demand for high-speed mobile data services is rapidly rising, at a higher pace than expected. As a consequence, there is an increasing need for capital investments in the deployment of new mobile broadband networks, as well as in capacity upgrades of existing mobile networks, to cope with the rapid surge in mobile data traffic. However, the problem is that the minimal revenue growth reported by operators does not support the required network investment costs, as the current market has hit a point of saturation. Meanwhile, telecom-related spending by households in developed countries is already quite high. Therefore, raising prices is not really an option for mobile operators [2]. As a consequence of the widespread use of unlimited mobile data plans, an increase in service sales does not automatically lead to an increase in revenue. Moreover, as a result of the progress in the openness of mobile networks, mobile operators no longer have exclusive rights of use over the facilities they own, undercutting their incentive for further facility investments. The burden of investment in new mobile broadband networks faced by operators can also have negative consequences for consumers. A delay in the construction of high-speed mobile networks, which would meet the current consumer demand, would create inconvenience and have a negative impact on the economic development.

This raises the question of whether or not there are ways to ensure that investment in new mobile broadband networks continues without mobile operators being forced to raise prices or place an excessive financial burden on themselves. To avoid incurring these potential financial costs, network sharing has been given serious consideration and has begun to be established around the globe. One implication of this is that the mobile market may have to move past the phase of facility-based competition. Sharing of network elements allows mobile operators to save money by avoiding the duplication of network assets. The traditional model of single network ownership of all mobile network elements is beginning to be challenged. This arrangement in which mobile communications network elements are shared between operators is known as "mobile network sharing (MNS)." MNS can be defined as a cooperative arrangement for mobile network management in which an operator shares its network in part or in entirety with another operator to reduce network deployment and operational costs [3]-[6]. Depending on the level of sharing under an MNS arrangement, MNS can be classified into several types.

To what extent, then, does the introduction of MNS reduce the network investment requirements of mobile operators, and how great are the potential benefits for consumers? Also, what is the extent of the positive effects of MNS by their type? Network cost savings of 20 to 50 percent are mentioned for most types of MNS by some industry analysts and consulting papers [6], [7]. However, despite the importance of a systematic framework existing to help decision makers evaluate policy options relating to the introduction of MNS, there are very few previous studies analyzing the effects of MNS. Therefore, it is essential to develop a model for the effects of MNS, regardless of the type.

To meet this need, this study proposes a model for estimating the economic effect of MNS by type, based on a mathematical model allowing a systematic analysis. For a comparative analysis of MNS according to its type, we propose a model for evaluating economic effects that combines a producer surplus model, measuring the efficiency of network operation by mobile operators and the increase in service revenue, and a consumer surplus model, measuring the increase in service use as a result of the lowering of prices. Meanwhile, using actual data, we measure the economic effect of MNS in WiBro service to test the validity of the model and its suitability for practical application. First, the results will be used to support reasonable decision making related to the introduction of MNS. Second, the results will be used as a basic model for developing various infrastructure-sharing models.

The remainder of this paper is divided into four sections. In section II, we review previous research. Section III describes the process of model development. In section IV, the model is applied to WiBro, using actual data. Finally, section V offers some concluding remarks and future research directions.

II. Literature Review

1. Types of MNS

MNS comes in many shapes and sizes. In previous studies, MNS has been classified in various ways. To accurately classify MNS, it must be determined what components are shared under the current mobile network architecture. In this study, we classify six types of MNS according to the sharing level of network elements. The six types of MNS are defined as follows:

First, site sharing is the least extensive form of MNS. Mobile operators share the same physical compound but install separate masts, towers, antennas, power supply, air conditioning, cabinets, and backhaul [3]. Common use of sites between mobile operators is already a reality in current mobile networks all over the world. The primary reasons are shortage of sites and cost savings [8]. Site sharing can yield capital expenditure (CAPEX) savings of up to 20 percent and operational expenditure (OPEX) savings of up to 15 to 20 percent in Europe [9].

Second, mast sharing is a step up from operators simply co-locating their sites and involves sharing a mast, towers, an antenna frame, or a rooftop [3].

Third, radio access network (RAN) sharing is the most comprehensive form of MNS. It involves the sharing of all access network equipment, such as radio equipment, masts, site compounds, and backhaul equipment. Each RAN is incorporated into a single network, which is then split into separate networks at the point of connection to the core network. Mobile operators continue to keep separate logical networks and spectrums, and the degree of operational coordination is less than what it is for other types of active sharing [3].

Fourth, core network sharing is the most involved and complex form of MNS, in which two separate licensees share both radio and core network elements of the network. This model will logically become a single network company with the licensees becoming roaming or service companies [4].

Fifth, network roaming can be considered a form of MNS although traffic from one mobile operator's subscriber is actually being carried and routed on another operator's network [3]. Users are allowed to roam onto a host network if the home network is not present in a particular region. This is the most realistic and cost-efficient solution in the early new network rollout period.

Sixth, a mobile virtual network operator (MVNO) is a mobile operator that provides mobile communication services but does not have its own radio access network [10], [11].

Site sharing, mast sharing, network roaming, and MVNO are the most common forms of MNS due to their relative technical and commercial simplicity.

2. Effects of MNS

Previous research on the effects of MNS falls into two main categories. Studies belonging to the first category estimate the amount of reduction in the CAPEX and the OPEX of an overall country or an operator under specific scenarios. Siemens [8], for example, estimated the amount of savings that would be earned in terms of CAPEX and OPEX by 3G mobile operators if four types of MNS were introduced in Germany. Barrett and Jackson [12], meanwhile, compared seven types of MNS in terms of reduction size in CAPEX and OPEX. Norman and Viola [9] compared the amount of savings in CAPEX and OPEX that would be realized in developed countries and developing countries, in the case of a joint network rollout. Studies of the second category estimate the economic effect of network sharing, using a supply-demand model. Foros and others [7] proposed a conceptual model for calculating the national roaming-related economic effect of MNS, using four scenarios: two national roaming option scenarios and two investment decision scenarios. Kim and Seol [10] estimated the economic effect expected from the introduction of an MVNO scheme in the mobile communication service market.

The evaluation of the effects of MNS in previous studies mostly consisted of calculating through simulation analysis the amount of reduction in the CAPEX and the OPEX of a specific country or operator under specific circumstances. Few adopted a systematic approach based on a mathematical model. Using a simulation analysis in which the effects of MNS are estimated according to a certain scenario results in case-by-case analysis that does not provide concrete elements of CAPEX or OPEX savings; this makes the results unsuitable for use in other estimations under different circumstances. Kim and Seol [10], a rare example in this regard, presented the components of CAPEX and OPEX that are reduced as a result of the introduction of MNS. However, their analysis was limited to only one type of MNS (MVNO) and, for this reason, cannot be used for other types.

Despite the usefulness of existing studies, they do not propose a systematic framework that can compare MNS types. To overcome this shortcoming, this study strives to develop a generalized model for analyzing the effects of network sharing.

III. Model Development

1. Conceptual Model for Effects of MNS

The most immediate benefit expected from the introduction of MNS is a decrease in the duplication of networks, reducing the CAPEX and the OPEX made by operators. The ability to reduce CAPEX gives a positive incentive to roll out networks in underserved areas and improve the quality of service by reducing black spots. Moreover, it should increase consumer choices as it promotes market entry by new operators facilitating accelerated service expansion, bringing down both wholesale and retail prices. In this study, we distinguish five types of positive effects of MNS, according to the following definition (①-⑤):

① Decrease in duplication of network investment, reducing CAPEX and OPEX [3]-[6], [8]-[10].

② Positive incentive to roll out networks in underserved areas [3], [4].

③ Improved quality of service and capacity, particularly in congested areas [3], [4].

④ Increased consumer choices as entry and expansion become easier and speedier [3], [4], [10].

⑤ Reduction in wholesale and retail prices [3], [10].

MNS may also produce three other types of positive effects. However, these are excluded from the formal analysis as they are of minor importance compared to the other five types and are difficult to measure objectively:

⑥ Optimization of scarce national resources, such as land or spectrum [3].

⑦ Positive environmental impacts [3], [4].

⑧ Product and technological innovation as operators compete in service differentiation [3].

In this study, we measure the economic effect of MNS by examining the first five listed types of positive effects. We assume that it is through these five types of positive effects that the CAPEX and the OPEX of mobile operators change. In addition, changes occur in retail prices and service revenue (Fig. 1).

Assumption 1. The introduction of MNS produces five types of positive effects that reduce the CAPEX and the OPEX of mobile operators, lower retail prices, and change service revenues.

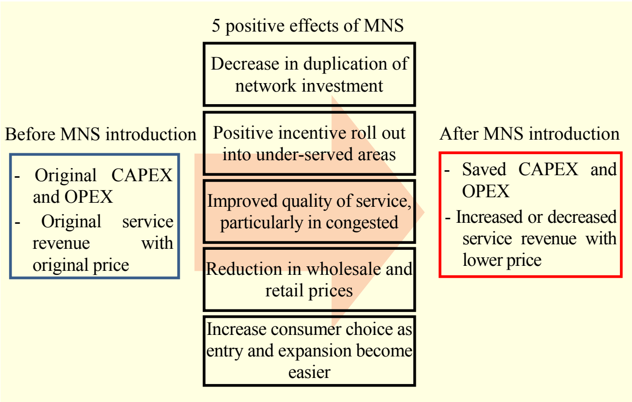

Fig. 1. Conceptual model: positive effects of MNS and variation.

The economic effect of MNS is calculated by adding the consumer surplus variation and the producer surplus variation, the sum of which reflects the decrease in the CAPEX and the OPEX of operators after MNS introduction, as shown in (1).

$$\sum_{t=1}^{n} \Delta TS_{it} = \sum_{t=1}^{n} \Delta CS_{it} + \sum_{t=1}^{n} \Delta PS_{it}, \quad (1)$$

where n is the last period (year) of measuring the effect, ΔTS_{it} is a variation in the economic effect in the t-th year after the introduction of MNS type i, ΔCS_{it} is the consumer surplus variation in the t-th year after the introduction of MNS type i, and ΔPS_{it} is the producer surplus variation in the t-th year after the introduction of MNS type i.

2. Consumer Surplus Variation

In this study, we calculate consumer surplus by employing the technique proposed by Alexander and others [13], which uses the amount of service sales and price elasticity of demand.

The consumer surplus variation is calculated based on a change in service price and traffic volume occurring after the introduction of MNS:

$$\sum_{t=1}^{n} \Delta CS_{it} = \sum_{t=1}^{n} \frac{P_{it}Q_{it} - P_{it-1}Q_{it-1}}{2e}, \quad CS_{it} = \frac{P_{it}Q_{it}}{2e}, \quad (2)$$

where P_{it} is the service price in the t-th year after the introduction of MNS type i (including the basic charge), Q_{it} is the traffic volume in the t-th year after the introduction of MNS type i (Q_{it} represents only the traffic volume in roaming areas if i=5), and e is the price elasticity of demand.

The service price and traffic volume after the introduction of MNS are calculated as

$$P_{it} = P_{it-1}(1 - r_{it}), \quad (3)$$

$$Q_{it} = Q_{it-1}(1 + d_{it}), \quad (4)$$

where r_{it} is the cumulative rate of price drop in the t-th year after the introduction of MNS type i, and d_{it} is the cumulative rate of demand growth in the t-th year after the introduction of MNS type i. The service price and the traffic volume before the introduction of MNS are P_{i0} and Q_{i0}, respectively.

3. Producer Surplus Variation

Producer surplus variation is determined by changes in revenue and cost. Concretely, producer surplus variation is the sum of total service revenue variation and total network cost variation after the introduction of MNS:

$$\sum_{t=1}^{n} \Delta PS_{it} = \sum_{t=1}^{n} \Delta TR_{it} + \sum_{t=1}^{n} \Delta TC_{it}. \quad (5)$$

Total service revenue variation, meanwhile, is calculated based on changes in the basic rate, traffic charge, number of subscribers, and traffic volume since the introduction of MNS:

$$\Delta TR_{it} = \sum_{t=1}^{n} [(1 - r_{it})B(S_t - S_{t-1}) + (P'_{it}Q_{it} - P'_{it-1}Q_{it-1})], \quad (6)$$

where B is the basic rate, $P'_{it}(= P'_{it-1}(1 - r_{it}))$ is the service price in the t-th year after the introduction of MNS type i (excluding basic rate), and S_t is the total number of subscribers in the t-th year after the introduction of MNS. The initial (prior to the introduction of MNS) service price (excluding basic rate) is P'_{i0} and the initial (prior to the introduction of MNS) number of subscribers is S_0.

Total network cost variation is the sum of network equipment cost variation, network operation cost variation, and transaction cost variation occurring since the introduction of MNS:

$$\Delta TC_{it} = \sum_{t=1}^{n} [\Delta NC_{it} + \Delta OC_{it} + \Delta IC_{it}], \quad (7)$$

where ΔNC_{it} is the network equipment cost variation, ΔOC_{it} is the network operation cost variation, and ΔIC_{it} is the transaction cost variation.

The details of each component of the network cost variation according to MNS type follow in this section (A, B, and C).

A. Network Equipment Cost Variation

Network equipment cost variation (ΔNC_{it}) caused by the introduction of MNS is the sum of land lease cost variation (ΔC_{site}), tower construction cost variation (ΔC_{mast}), access equipment cost variation (ΔC_{access}), core equipment cost variation (ΔC_{core}), and spectrum license fee variation ($\Delta C_{license}$) occurring as a result of the introduction of MNS. The land lease cost and spectrum license fee, although treated in the

Table 1. Cost-saving status of detail components of network equipment costs by type of MNS.

Type of MNS	Network equipment costs				Spectrum license fee
	Land lease cost	Tower construction cost	Access equipment cost	Core equipment cost	
Site sharing (i=1)	O	X	X	X	X
Mast sharing (i=2)	O	O	X	X	X
RAN sharing (i=3)	O	O	O	X	X
Core network sharing (i=4)	O	O	O	O	X
Network roaming (i=5)	Δ	Δ	Δ	Δ	X
MVNO (i=6)	O	O	O	O	O

Δ: only shared in roaming areas.

account books of mobile operators as an OPEX item, is included in the network equipment costs in this study, for the ease of reasoning.

The amount of network equipment cost variation varies according to the type of MNS, as the level of sharing of network equipment is not the same from one type to another. Table 1 lists detailed components of network equipment costs along with their cost-saving status. If savings occur as a result of the introduction of MNS, the cost component is marked "O," and if not, "X." When the sharing of network elements occurs only in certain areas during national roaming, resulting in partial savings of network equipment costs, such equipment cost components are marked "Δ." Finally, network equipment cost variations can be calculated according to the type of MNS as

$$\Delta NC_{it} = (a\Delta C_{\text{site}} + b\Delta C_{\text{mast}} + c\Delta C_{\text{access}} + d\Delta C_{\text{core}} + e\Delta C_{\text{license}})(n_c - 1), \tag{8}$$

where n_c is the number of operators participating in MNS and the a, b, c, d, and e for each i are as follows:

$$\begin{cases} a=1,\ b=0,\ c=0,\ d=0,\ e=0\ (\text{for } i=1), \\ a=1,\ b=1,\ c=0,\ d=0,\ e=0\ (\text{for } i=2), \\ a=1,\ b=1,\ c=1,\ d=0,\ e=0\ (\text{for } i=3), \\ a=1,\ b=1,\ c=1,\ d=1,\ e=0\ (\text{for } i=4), \\ a=1*rr,\ b=1*rr, c=1*rr,\ d=1*rr,\ e=0\ (\text{for } i=5), \\ \quad rr = \text{area of roaming service/total area serviced} \\ a=1,\ b=1,\ c=1,\ d=1, e=1\ (\text{for } i=6). \end{cases}$$

Assumption 2. n number of mobile operators are sharing one facility, equally splitting the network equipment costs.

B. Network Operation Cost Variation

According to Woo and others [14], network operation cost can be divided into direct cost and indirect cost. Direct operation cost refers to the cost incurred for monitoring the network and both analyzing and repairing malfunctioning components. As for indirect operation cost, it is the cost incurred by such activities as strategy development, planning, personnel management, and R&D, which support direct activities. In this study, network operation cost is defined as the sum of direct cost, indirect cost, and the network fee.

The network operation cost variation (ΔOC_{it}) resulting from the introduction of MNS is the sum of the direct operation cost variation (ΔC_{direct}), the indirect operation cost variation ($\Delta C_{\text{indirect}}$) and the network fee variation (ΔC_{fee}), attributable to the introduction of MNS, as shown in (9).

$$\Delta OC_{it} = (j\Delta C_{\text{direct}} + k\Delta C_{\text{indirect}} + l\Delta C_{\text{fee}})(n_c - 1), \tag{9}$$

where the j, k, and l for each i are as follows:

$$\begin{cases} j=1*rs,\ k=0,\ l=1*rs, \quad (\text{for } i=1), \\ \quad rs = c_{\text{site}}/NC, \\ j=1*rm,\ k=0,\ l=1*rm, \quad (\text{for } i=2), \\ \quad rm = (c_{\text{site}}+c_{\text{mast}})/NC, \\ j=1*ra,\ k=0,\ l=1*ra, \quad (\text{for } i=3), \\ \quad ra = (c_{\text{site}}+c_{\text{mast}}+c_{\text{access}})/NC, \\ j=1,\ k=1,\ l=1, \quad (\text{for } i=4), \\ j=1*rr,\ k=1*rr,\ l=1*rr, (\text{for } i=5), \\ \quad (rr = \text{area of roaming service/total area serviced}) \\ j=1,\ k=1,\ l=1, \quad (\text{for } i=6), \end{cases}$$

where $NC = C_{\text{site}} + C_{\text{mast}} + C_{\text{access}} + C_{\text{core}}$.

Just as for the calculation of the network equipment cost variation, the amount of network operation cost variation also differs according to the type of MNS, due to differences in the levels of operation cost that may be reduced. Listed in Table 2 are the detailed components of the network operation cost along with their cost-saving status.

Assumption 3. n number of mobile operators are sharing one facility, equally splitting the network operation costs.

C. Transaction Cost Variation

To implement an MNS system, the parties must link their networks together, which entails cost. This cost includes regulatory costs incurred by the government, including costs related to establishing technical standards and other rules, and costs of mediation between operators [15]. These two types of costs are together defined as the transaction cost of MNS, and the related variation is reflected in the total network cost. The

Table 2. Cost-saving status of detailed components of network operation costs by type of MNS.

Type of MNS	Network operation costs		
	Direct operation costs	Indirect operation costs	Network fee
Site sharing (i=1)	O*	X	O*
Mast sharing (i=2)	O*	X	O*
RAN sharing (i=3)	O*	X	O*
Core network sharing (i=4)	O	O	O
Network roaming (i=5)	Δ	Δ	Δ
MVNO (i=6)	O	O	O

*: Applied at a certain rate according to the type of MNS (the share in total network equipment cost accounted for by a given component).
Δ: Only shared in roaming areas.

Table 3. Korean operator A's service plan.

Flat rate tariff	Free data	Monthly basic rate	Traffic charge per MB
1G tariff	1 GB	USD 10	USD 0.025
30G tariff	30 GB	USD 19.8	USD 0.01
50G tariff	50 GB	USD 27	USD 0.01

Note: USD 1 = KRW 1,000

Table 4. Maximum cumulative rate of price drop by type of MNS.

Type of MNS	Maximum cumulative rate of price drop ($MAXr_{it}$)
Site sharing	12.55%
Mast sharing	16.78%
RAN sharing	29.45%
Core network sharing	38.85%
Network roaming	9.71%
MVNO	40.20%

amount of transaction cost variation (ΔIC_{it}) varies according to the type of MNS, and it is difficult to estimate it before the actual implementation of MNS. Therefore, in this study, we increase the total network operation cost (ΔOC_{it}), calculated earlier, by an incremental amount, to account for the transaction cost variation (ΔIC_{it})

Assumption 4. Transaction cost variation (ΔIC_{it}) increases network operation costs (ΔOC_{it}) by some amount.

IV. Model Application

1. Estimation of Economic Effect of MNS for WiBro in Korea

WiBro is the Korean service name for the IEEE 802.16e (mobile WiMAX) international standard. It is considered an innovative mobile broadband Internet technology in that it overcomes the data-rate limitation of mobile communications and adds mobility to broadband Internet access. Two mobile incumbents have been providing commercial service, but the network deployment and service adoption are much slower than expected [16]. Although WiBro is a new mobile broadband service capable of satisfying the high-capacity (high-speed) data needs of consumers, incumbents have been rather reticent about offering it, as the revenue increase expected from the construction of new networks is less than the increase in related investments [16]. Therefore, the Korean government is examining several policy options to promote the service, including selecting new operators and introducing MNS or, specifically, MVNO. In this study, using the model described above, we estimate the economic impact of the introduction of MNS, considering the case scenario in which two mobile operators share network elements with each other. Given that the depreciation cycle of mobile communications equipment is six years for accounting purposes, the effect is measured for a six-year period.

A. Estimation of Consumer Surplus Variation

Described as follows are the input values used to calculate the service revenue before and after the introduction of MNS and the price elasticity of demand. The service price before the introduction of MNS (P_{i0}) is set to USD 0.035 per MB, taking into consideration the monthly basic rate (USD 10 with 1 GB free data) of a 1 GB plan among WiBro service plans and the associated traffic charge (USD 0.025 per MB) (Table 3). The traffic volume prior to the introduction of MNS (Q_{i0}) is set to 1,421,000 GB, which is the traffic volume of the Korean operator A in January 2011.

Now, to estimate the rate of the price drop following the introduction of MNS (r_{it}) according to its type and the rate of demand growth (d_{it}), the maximum cumulative rate of the price drop ($MAXr_{it}$) is calculated, as in Assumption 5, by multiplying the rate of decrease in the network cost (network equipment + network operation) by type of MNS with the percentage share of network-related expenses in the total expenses (40.2%) of a mobile operator. The maximum cumulative rate of a price drop, thus calculated, is listed in Table 4. The rate of a price drop for each year since the introduction of MNS is calculated using the formula shown in Assumption 6; in other words, the cumulative rate of a price drop in the t-th year following

Table 5. Forecasted cumulative number of WiBro subscribers (S_t) after introduction of MNS in Korea.

	Initial number	1st year	2nd year	3rd year	4th year	5th year	6th year
Number of subscribers	432,940	919,571	1,273,476	1,532,576	1,703,644	1,839,638	1,984,008

the introduction of MNS (r_{it}) is "(40%+10%×year t) × the maximum cumulative rate of the price drop ($MAXr_{it}$)."

Assumption 5. The maximum cumulative rate of a price drop by type of MNS ($MAXr_{it}$) = Rate of network cost decrease by type of MNS × Share of network-related expenses in total expenses.

Assumption 6. During the first year (t=1) after the introduction of MNS, the price decreases by about 50 percent of the maximum cumulative rate of the price drop, and the price gradually declines further with its rate finally becoming equal to the maximum cumulative rate of the price drop by the sixth year (t=6).

The price elasticity of demand (e) is estimated using past data and is tested and modified through documentary research and the survey of experts to obtain an appropriate value for WiBro. However, as has been pointed out by Kim and Seol [10], the actual impact of the price elasticity of demand on consumer surplus is rather negligible. Therefore, in this study, we decided to apply the price elasticity of demand of mobile services in Korea used by Kim and Seol [10]; namely, –1.02. The cumulative rate of demand growth (10) is obtained by adding the increase in demand attributable to the price drop and the increase in demand resulting from the rise in the cumulative number of subscribers.

$$d_{it} = r_{it} \times e + \frac{S_t - S_0}{S_0}. \qquad (10)$$

The number of subscribers prior to the introduction of MNS (S_0) was set to 432,940, which is the total number of WiBro subscribers in Korea as of January 2011. For the cumulative number of subscribers in the t-th year after the introduction of MNS (S_t), the estimated number of WiBro subscribers by Song and others [16] is used. The actual implementation of MNS in Korea is possible only with the entry of new operators. Therefore, we use the estimate made by Song and others [16] for the case in which new operators enter the market, raising the total number of participants to three (see Table 5). The forecasted number of subscribers in [16] is one of the most realistic forecasts among the various WiBro subscriber forecasts and is acknowledged as such. In reality, the figure is being officially used in the policy documents of the Korea Communications Commission.

B. Estimation of Producer Surplus Variation

For the WiBro service plan for estimating the producer surplus variation, we also use the tariff for 1 GB in Table 3. In the formula used for the estimation of producer surplus variation (6), a monthly basic rate and traffic charge are needed. Therefore, the monthly basic rate under the 1 GB plan (USD 10) and the associated traffic charge (USD 0.025 per MB) are used respectively as the monthly basic rate (B) and service price before the introduction of MNS (P'_{i0}). The same values as those used for the estimation of consumer surplus variation are used with regard to the total number of subscribers around the time of the introduction of MNS (S_t) and traffic volume (Q_{it}), rate of price drop following the introduction of MNS by type of MNS (r_{it}), and the rate of demand growth (d_{it}).

Concerning the network equipment cost variation by type of MNS (ΔNC_{it}), the network equipment cost variation during the 1st year following the introduction of MNS (ΔNC_{i1}) is estimated based on land lease costs, tower construction costs, access equipment costs, and core equipment costs, as reported in the business plan of Korean operator B [17]. The network equipment cost variation in the t-th year after the introduction of MNS (t≥2) is calculated as in Assumption 7. For the rate of roaming service area (rr), we use 25 percent, corresponding to the population coverage nationwide, excluding Seoul and other metropolitan cities and Gyeonggi-do.

Assumption 7. The network equipment cost variation in the t-th year after the introduction of MNS (t≥2) is the network equipment cost variation during the first year after the introduction of MNS (ΔNC_{i1}) multiplied by the cumulative rate of the price drop (r_{it}): $\Delta NC_{it} = \Delta NC_{it-1} \times (1 - r_{it})$.

In the estimation of network equipment cost variation by type of MNS (ΔNC_{it}), the cost-saving status of detailed components of WiBro's network equipment cost is shown in Table 6. For example, when RAN sharing is introduced, the base station site, wireless connection system (except the one for moving base stations and power supply), and other equipment are shared. Therefore, the network equipment cost variation, in this case, is estimated based on the sharing occurring with regard to all of these network elements. The network element names in Table 6 are slightly different from those of the mobile communications network. Because the WiBro system uses an IP-based network structure to accommodate the fixed line broadband Internet service in the wireless network, and its protocol adopts the MAC layer that supports TCP/IP. The WiBro access network configuration is basically composed of a radio access station (RAS) and an access control router (ACR), which are connected to IP routers. An RAS is a base station in the mobile network. An ACR, which has a similar role to the base station controller/radio network controller in the mobile network, provides functions related to IP routing,

Table 6. Cost-saving status of detailed components of WiBro network equipment costs by type of MNS.

WiBro network facility		Site sharing	Mast sharing	RAN sharing	Core network sharing
Base station site		O	O	O	O
Access network	Base station (RAS)			O	O
	Remote radio head			O	O
	Repeater			O	O
	EMS			O	O
	Antenna		O	O	O
	Construction costs		O	O	O
	Moving base station				
	ACR			O	O
	IP equipment			O	O
	Transmission equipment			O	O
Core network	IP router				O
	Transmission equipment				O
	mVoIP platform				O
	Applied service platform				O
	Network server				O
	Service security equipment				O
	Operation support system				O
	Business support system				
Power supply and other equipment	Power supply equipment		O	O	O
	Incidental equipment		O	O	O

mobility management, authentication, and security. The IP routers in the WiBro service provider's IP networks perform the roles of a mobile switching center, a cellular gateway switch, and a Gateway GPRS (general packet radio service) Support Node/Serving GPRS Support Node, and so on, in the mobile core network. The network equipment cost variation during the 1st year following the introduction of MNS by its type (ΔNC_{i1}), estimated using the above method, is given in Table 7.

Similarly, concerning the network operation cost variation (ΔOC_{it}) by type of MNS, the network operation cost variation during the 1st year upon the introduction of MNS (ΔOC_{i1}) is estimated based on the direct operation cost and indirect operation cost of the investment cost reported in operator B's business plan [17]. Meanwhile, the network operation variation

Table 7. Initial network equipment cost variation (ΔNC_{i1}) upon introduction of MNS (unit: USD 1 thousand).

Initial network equipment cost variation	Estimate
Land lease cost variation (ΔC_{site})*	179,884
Tower construction cost variation(ΔC_{mast})*	60,693
Access equipment cost variation(ΔC_{access})*	181,585
Core equipment cost variation(ΔC_{core})*	110,666
Spectrum license fee variation($\Delta C_{license}$)*	21,275

* Estimated based on business plan of Korean operator B

Table 8. Initial network operation cost variation (ΔOC_{i1}) upon introduction of MNS.

Initial network operation cost variation	Estimate
Direct operation cost variation* (ΔC_{direct})	53,293 thousand USD
Indirect operation cost variation* ($\Delta C_{indirect}$)	26,646 thousand USD
Network fee variation (ΔC_{fee})	MVNO (i=6) = 2.31 cent/MB (Retail-minus discount set to 36%)
	Other types of MNS (i=1 to 5) = 2.1 cent/MB (Retail-minus discount set to 40%)

* Estimate based on business plan of Korean operator B

in the t-th year (t≥2) after the introduction of MNS is calculated as in Assumption 8. The network operation cost variation during the 1st year upon the introduction of MNS (ΔOC_{i1}) by type of MNS, thus calculated, is listed in Table 8.

Assumption 8. The network operation cost variation in the t-th year after the introduction of MNS (t≥2) is the network operation cost variation during the 1st year upon the introduction of MNS (ΔOC_{i1}) multiplied by the cumulative rate of the price drop (r_{it}): $\Delta OC_{it} = \Delta OC_{it-1} \times (1 - r_{it})$.

The network fee is calculated using the retail-minus method, currently employed in Korea to set wholesale prices. The retail-minus discount is set to 36 percent for MVNO and 40 percent for all other types of MNS. Finally, in this study, the transaction cost variation (ΔIC_{it}) is set to 10 percent of the network operation cost.

2. Estimation Results

Table 9, Table 10, and Fig. 2 show the results of estimating the producer surplus variation, consumer surplus variation, and economic effect variation of WiBro if two mobile operators were to have an MNS arrangement for a six-year period, Although the results vary depending on the type of MNS, the annual economic effect of MNS is estimated to be between513 million and 689 million USD, on average. This represents

Table 9. Producer surplus variation following introduction of MNS by type of MNS (unit: USD 1 thousand).

	1st year	2nd year	3rd year	4th year	5th year	6th year	Cumulative surplus
Site sharing	560,085	483,503	374,725	278,268	239,053	233,198	2,168,833
Mast sharing	693,180	547,140	451,967	367,994	333,130	336,118	2,729,529
RAN sharing	711,924	570,008	493,639	428,676	396,419	387,716	2,988,382
Core network sharing	739,309	582,345	509,692	448,505	413,495	396,480	3,089,827
Network roaming	692,253	538,077	426,117	324,138	283,562	292,449	2,556,596
MVNO	908,099	684,312	582,549	496,570	450,183	431,109	3,552,821

Table 10. Consumer surplus variation following introduction of MNS by type of MNS (unit: USD 1 thousand).

	1st year	2nd year	3rd year	4th year	5th year	6th year	Cumulative surplus
Site sharing	306,865	239,021	158,525	86,765	59,166	58,984	909,327
Mast sharing	298,900	207,988	143,235	85,730	61,546	62,901	860,299
RAN sharing	271,528	181,427	115,861	59,701	34,869	32,493	695,879
Core network sharing	254,906	165,963	99,841	44,335	19,040	14,468	598,553
Network roaming	312,465	221,782	157,371	99,048	75,117	78,388	944,170
MVNO	251,864	163,179	96,950	41,552	16,167	11,199	580,911

about three to four percent of the annual revenue of Korean mobile operators.

3. Discussions

The result of analyzing the WiBro MNS in Korea has the following three implications.

Firstly, the economic effect of each type of MNS clearly shows that the more the network equipment is shared, the greater the economic effect. Meanwhile, MVNO has been proven to produce the highest economic effect of all six types of MNS. We find that site sharing, the least demanding type of MNS, also produces a sizeable economic effect, which makes it a very promising choice.

Secondly, with the above said, the consumer surplus variation tends to be lower with an increase in the amount of equipment shared. This result may be explained by the fact that the extent of a price decline is greater with the types of MNS involving the sharing of an extensive array of equipment. In other words, this is because the maximum cumulative rate of a price drop ($MAX\ r_{it}$) can be greater depending on the rate of network cost reduction, which varies according to the type of MNS, as shown in Table 4. Given the fact that MNS is introduced during a growth phase of WiBro, the rate of subscriber growth and that of traffic growth slows down steadily over time, following the service diffusion pattern in an S-shaped curve. The longer the elapsed time after the introduction of MNS, the smaller the increase in net surplus.

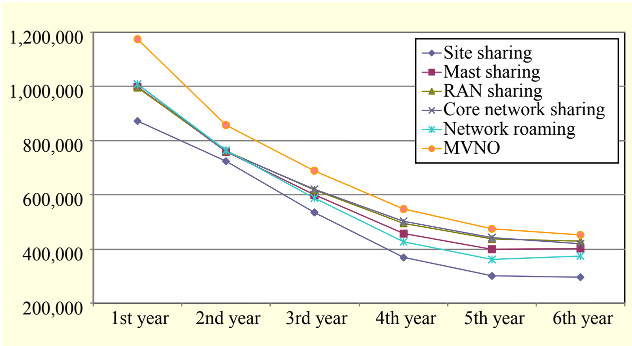

Fig. 2. Economic effect variation following introduction of MNS by type of MNS (unit: USD 1 thousand).

Finally, as a general rule, the greater the global economic effect of MNS, the more advisable is its adoption on a policy level. However, there could be situations in which this may not be the case depending on the estimation results of consumer and producer surplus. For example, even though the total economic effect of MNS is sizeable (+), the positive effects for producers may be negligible. This could lower the incentive of market entry for new operators. If this is the case, even if an MNS scheme is introduced, its initial development in the market could be difficult. On the other hand, there may also be situations in which benefits for consumers may be too insignificant or the MNS scheme suppresses facility-based competition and promotes monopoly or oligarchy, although the overall economic effect is high (+). In such situations, the consumer surplus variation is liable to have a negative (–) value, and the telecom regulator may have to go about the introduction of MNS cautiously.

V. Conclusion

In developed mobile communications markets where operator revenues are not growing, MNS is fast emerging as a core business strategy. The growing interest in MNS is driven by the fact that it is becoming more challenging to fund necessary network investments due to poor cash flow generation. At a time when mobile operators are in the process of examining various types of MNS, a model for analyzing the potential benefits of MNS by their type is likely to prove highly useful. In this study, we proposed a model for estimating the economic effects of six types of MNS, based on the supply-demand model for a more effective and rigorous analysis. Using actual data related to WiBro, we estimated the economic effects of the six types of MNS.

The economic model proposed in this study distinguishes itself from similar models in previous studies in two main ways. First, as previous studies focused primarily on the cost-saving effects of MNS on the producer side, our proposed model considered the surplus on both the producer and the consumer side. Second, this study calculated MNS-related costs in concrete figures, so as to show how the cost components change over time and according to the type of MNS.

The economic effects explored in this paper are expected to be used in the process of Korea's formulation of its MNS policies. Until recently, MNS polices aside from those for site/mast sharing had not been implemented, citing the reason that the effects of MNS had not been verified in Korea. Network roaming under the Telecommunications Business Act, Article 37, enacted in 2001, has yet to provide detailed guidelines. In 2010, the MVNO system was established under the Telecommunications Business Act, Article 38. The results of this research will be utilized as the formulation of government guidelines, as proof of the feasibility of policy implementation and as data for analyzing economic ripple effects, with regard to Article 37 of the Telecommunications Business Act ("Shared Use of Wireless Communications Facilities"), Article 38 of the Telecommunications Business Act (MVNO), and Article 48 of the Wireless Telegraphy Act (site/mast sharing).

This study measured the positive effects of the introduction of MNS while leaving out of the scope of its potentially undesirable side effects. In other words, the long-term competitive harm that may be caused as a result of the introduction of MNS, in the form of a severe suppression of facility-based competition, increase in government regulation, or a deterioration in service quality due to the change in network capacity and reliability, has not been considered in this study. Therefore, the results of this study may be used to support decision making in terms of short-term benefits of MNS, but the final decision on its introduction must not be made without taking into consideration its long-term effects, such as the impact on market structure and service characteristics. Accordingly, future research needs to investigate side effects that MNS can have on competition through a detailed analysis of each of its types.

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