Telecom Development in Korea: Substitution and Integration of Fixed-Mobile Services and Regulatory Implications

Chang-Ho YOON
Korea University

Young-Woong SONG
National Computerization Agency

The past decade has seen phenomenal growth of mobile service in Korea. Growth in mobile services began to spurt in the late 1990s when all the other sectors of the economy were suffering the effects of financial crises and undergoing a painful restructuring process. Mobile infrastructure facilitated the fast flow of information among workers and investors and helped the economy to get over turmoil by reducing coordination costs among those economic agents. Both the fixed and mobile networks seemed to reinforce each other at the early stages of mobile development, working as vehicles for telecom development in Korea.

By the mid 1990s, fixed line penetration in Korea had already reached a very high level by OECD standards, centering at around 45 percent of total population. Mobile service penetration expanded far beyond fixed line penetration reaching 67.5 percent at the end of year 2002. Along with these developments and great technological achievements in data transmission and fixed-mobile convergence, many important questions arose regarding substitutability and integration between fixed and mobile services and the role of the fixed network in the development of the telecom sector as a whole. Empirical analyses of access to networks have so far suggested complementarity between the stock of fixed lines and mobile subscribers and strong substitutability between new fixed-line and mobile subscribers. However, without further information on substitution and complementarity between the services themselves, it would be difficult to assess the economic impact of changes in mobile technology and regulatory responses in Korea. In fact the rapid development of fixed-mobile convergence and internet business created a new area of competition for both fixed and

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mobile service providers. Traditional regulatory measures on business restriction are thus likely to fade out if substitution and convergence continue in the future.

This paper examines the substitution hypothesis and regulatory implications from a strategic point of view by highlighting that each network provides an intermediate input to the other network to jointly produce fixed-to-mobile (FM) and mobile-to-fixed (MF) services. Both FM and MF traffic have increased from the earliest stages of mobile service development and stayed at such high levels so far. Mobile-to-mobile (MM) calls were initially regarded as complementary to fixed calls in the early stages of development. Only after the nation-wide mobile networks were completed in the late 1990s did MM expanded at an accelerating pace and begin to replace fixed-to-fixed service (FF). Using monthly traffic and revenue data from 1997 to 2002, this paper attempts to estimate a system of demand equations for FF, FM and mobile services originating in mobile networks, MMF (MM plus MF) and claims that all three services show substitutability for each other.

The substitution relationships among telecom services provide a new framework for examining traditional regulatory measures. The effect of price controls, for example, should change substantially once the government lifts restrictions on the line of businesses and allows full competition between fixed and mobile providers. What is more important, however, is that the trend towards substitution and integration challenges traditional legal definitions of markets and regulatory restrictions on lines of business. Competition among fixed and mobile services has accelerated technological convergence towards a so-called NGcN (Next Generation Convergence Network) environment, where operators and service providers can choose any media and device to supply seamless services to consumers whose demands may occur anytime and anywhere. The regulatory policy on tariffs, the structural separation of accounting, restriction on lines of business, access charges and allocation of spectrum resources will certainly influence the pace of convergence in the future. Unless regulatory restrictions constrain business accommodation of new trend, commercialisation of technological convergence seems to be an inevitable investment choice for telecom operators in Korea.

■ Mobile development and substitution process

Background

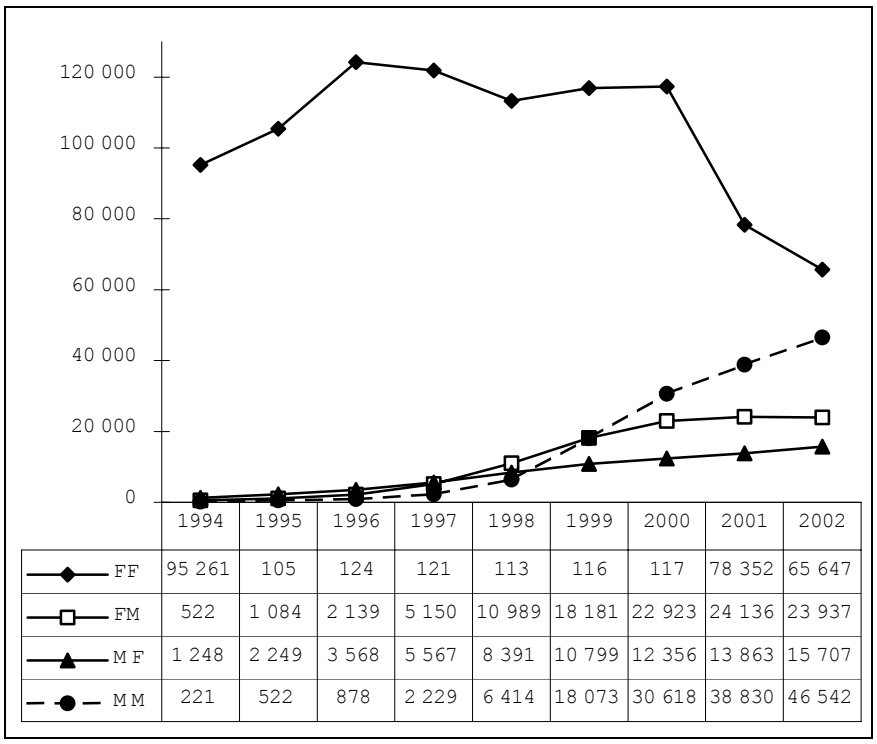
During the 1990s, the number of mobile subscribers in Korea grew at an annual compound rate of 88 percent and exceeded the number of fixed line subscribers in 1999. The number of mobile subscribers reached 32 million at the end of 2002, while the number of fixed subscribers has been stagnant around 22 million for the past few years. One might conjecture that, in the absence of mobile possibilities, the number of fixed subscribers could have been increased further to reach a penetration rate of 60 percent of developed countries in the late 1990s. It was indeed found that throughout the 1990s, the number of mobile subscribers was negatively correlated to the number of new fixed connections implying a certain degree of fixed-mobile substitution at the margin in access to networks (SUNG & KIM, 2002). On the other hand it was observed through cross-country econometric analysis that the demand for mobile phones was positively correlated with the stock of fixed line subscribers (AHN & LEE, 1999). Apparently network externality seemed to play an important role at the initial stages of mobile development. The critical size of demand for mobile services that allows cost effective telephone calls in Korea must have been realized much earlier with the help of the great fixed network that already existed.

Mobile services were relatively expensive compared their fixed rate counterparts and initial transmission quality was poor. The traffic volume of calls that both originate and terminate on the mobile network was much smaller than the volume of traffic that uses both types of lines as complementary inputs. Figure 1 illustrates time trends of four different types of traffic volume, which are produced from fixed and mobile networks. Each type of call traffic is measured in millions of minutes. It shows that introduction of mobile phones increased fixed usage for some time until 1996. Even the volume of FF traffic increased after mobile services were introduced. In fact the share of FM and MF was 3.82 percent and 4.13 percent respectively, while the share of MM was only 1.65 percent. Complementarity and network externality worked in the same direction at the earlier stage.

However, after the government licensed PCS operators in 1997 and allowed competition among mobile operators, the mobile network expanded dramatically and soon covered the whole country. The improved quality of

mobile services was offered at increasingly attractive rates (see Figure 2 for the convergence trend of mobile and fixed prices) and from 1998, the volume of mobile-to-mobile traffic began to exceed both mobile-to-fixed and fixed-to-mobile traffic, thus replacing fixed services gradually over time.

Figure 1: Call Traffic (million minutes)



	1994	1995	1996	1997	1998	1999	2000	2001	2002
FF	95 261	105	124	121	113	116	117	78 352	65 647
FM	522	1 084	2 139	5 150	10 989	18 181	22 923	24 136	23 937
M F	1 248	2 249	3 568	5 567	8 391	10 799	12 356	13 863	15 707
M M	221	522	878	2 229	6 414	18 073	30 618	38 830	46 542

Although fixed traffic has been continuously substituted by mobile communications, it seems likely that it became inelastic over time. The fixed operator was then able to appropriate a part of consumer surplus by offering various packages of differentiated services using discriminatory pricing strategies. In fact, over the past few years, KT (Korea Telecom) has increased fixed rates for local calls and introduced a flat rate system to cope with declining traffic. The changes in pricing policy resulted in an increase in the fixed rate and lessened the burden of otherwise rapidly declining revenues from fixed-to-fixed voice communications.

Figure 2: Real prices of traffic services

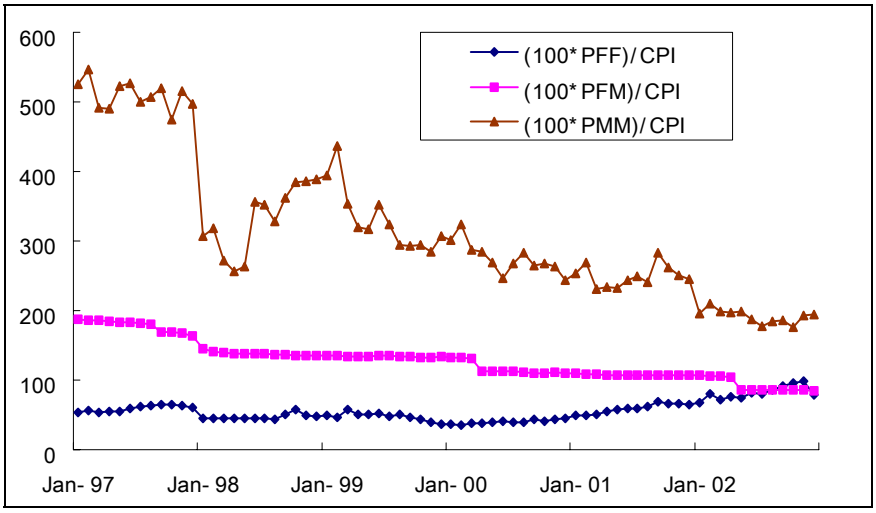
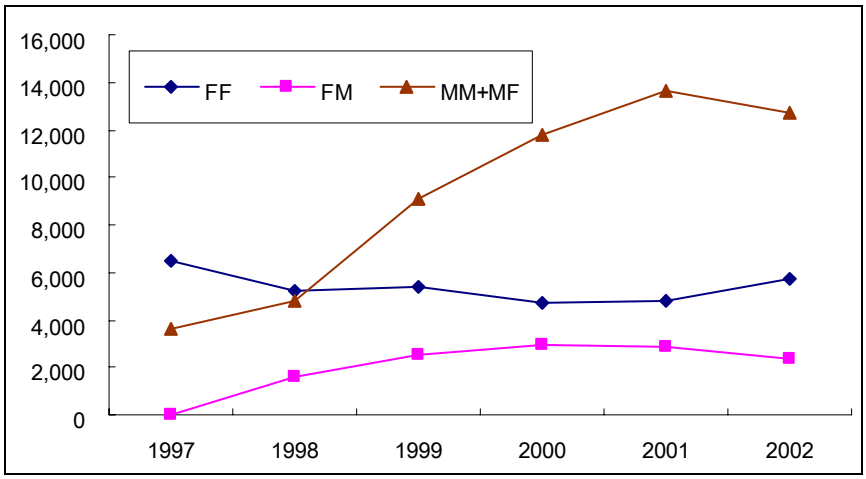


Figure 3: Traffic revenue (billion Won)



Estimating substitutability between fixed and mobile services

Much evidence has been discussed on substitution between fixed and mobile access (see for example, RODINI *et al*., 2003 among others). Substitution in access, however, does not necessarily imply replacement of fixed

communications by mobile phones. The two networks provide intermediate inputs to each other when mobile calls terminate or originate on a fixed line. Unless these calls are substituted by mobile calls that are completed within mobile networks, substitution hypotheses can be misleading and remain confusing. To clarify these issues, we examine substitution possibilities among three different types of calls- FF, FM, and MMF by estimating their demands simultaneously. Notice that we do not differentiate between MM and MF since these services are charged at the same price by the same operators. Let's denote a specific type of call by subscript i = 1, 2, and 3 where 1 = FF, 2 = FM, and 3 = MMF. The demand for each service will generally depend on the prevailing price structure of various services, users' income and the network sizes of both fixed and mobile lines among others. Since the number of subscribers to each network again depends on the distribution of individual consumer surplus derived from subscription decision, which again depends on prices, the individual demand for each service at period t can be expressed as reduced forms as follows.

$$\frac{Q_{it}}{S_{kt}} = f_i(P_{0t}, P_{1t}, P_{2t}, P_{3t}, Y_t)\ ,\ i = 0,1,2,3\ ,\ k = \begin{cases} \text{F, if } i = 1,2 \\ \text{M, if } i = 3 \end{cases}$$

where Y denotes income, S, the number of subscribers and 0, the composite good consisting of all other goods and services except communications services. In this paper we specify demand functions with constant elasticity as follows.

$$q_{it} = \frac{Q_{it}}{S_{kt}} = A_i P_{0t}^{b_{i0}} P_{1t}^{b_{i1}} P_{2t}^{b_{i2}} P_{3t}^{b_{i3}} Y_t^{\eta_i}\ ,\quad i = 0,1,2,3\ ,\ k = \begin{cases} \text{F, if } i = 1,2 \\ \text{M, if } i = 3 \end{cases} \qquad [1]$$

To estimate a system of demand functions properly, we impose zero-degree homogeneity and symmetricity of Slutsky substitution matrix. Since zero-degree homogeneity implies

$$\sum_{j=0}^{3} b_{ij} + \eta_i = 0\ , \qquad [2]$$

we can apply equation [2] to equation [1] to denote every variable in real terms. In fact, equation [1] reduces:

$$
\begin{aligned}
q_{it} &= A_i P_{0t}^{b_{i0}} P_{1t}^{b_{i1}} P_{2t}^{b_{i2}} P_{3t}^{b_{i3}} Y_t^{\eta_i} \\
&= A_i P_{0t}^{-b_{i1}} P_{0t}^{-b_{i2}} P_{0t}^{-b_{i3}} P_{0t}^{-\eta_i} P_{1t}^{b_{i1}} P_{2t}^{b_{i2}} P_{3t}^{b_{i3}} Y_t^{\eta_i} \\
&= A_i \left(\frac{P_{1t}}{P_{0t}}\right)^{b_{i1}} \left(\frac{P_{2t}}{P_{0t}}\right)^{b_{i2}} \left(\frac{P_{3t}}{P_{0t}}\right)^{b_{i3}} \left(\frac{Y_t}{P_{0t}}\right)^{\eta_i}
\end{aligned}
$$

We now express demand equations as follows.

$$
\begin{aligned}
\log q_{it} &= a_i + b_{i1} \log P_{1t}^* + b_{i2} \log P_{2t}^* + b_{i3} \log P_{3t}^* \\
&\quad + \eta_i \log Y_t^* + e_{it}, \qquad i = 1,2,3
\end{aligned}
\qquad [3]
$$

where $P_{it}^* = P_{it} / P_{0t}$, $i = 1,2,3$, $Y_t^* = Y_t / P_{0t}$, $e_{it} \sim N(0, \sigma_i^2)$. Under the symmetricity restrictions, we have

$$
\frac{b_{ij}}{w_{jt}} + \eta_i = \frac{b_{ji}}{w_{it}} + \eta_j, \; i, j = 1,2,3, \; i \neq j, \text{ where } w_{it} = \frac{P_{it} Q_{it}}{Y_{it}}. \qquad [4]
$$

To esitimate equations [3] we adopted consumer price index (CPI) as a proxy for the price of composite goods and industrial product (IP) for monthly income. As we cannot manipulate time-variant restrictions technically, we have to calculate the average of w_{it} instead. Table 1 shows the average ratio of telecom service revenue to GDP.

Table 1: Average ratio of telecom service revenue to GDP (%)

Sample period	*FF*	*FM*	*MMF*
97-02	1.07	0.40	1.74
98-02	0.99	0.44	1.94

Since the disturbance terms of the three equations are likely to be correlated, we employed the SUR estimation method under constraints. The regression results are illustrated in the first column of table 2. Own price elasticities are all negative as expected, while the income elasticity of the fixed service turns out to be negative. Cross elasticities show that there are also complementary relationships between FF and FM, and FM and MMF. Substitution effects only appears between FF and MMF. However, the above estimation does not take into account the nation-wide introduction of PCS in 1997. The mobile network expanded discontinuously from 1997 and intense competition among mobile operators upgraded transmission quality and

lowered prices. The network effect among mobile subscribers thus made mobile subscription more attractive than before.

Table 2: Estimation results of naive model

*Dependent variable$**	*Explanatory variable*	*Sample period*	
		97:01~02:12	*98:01~02:12*
FF (log q_1)	Constant	8.111	9.023
		(0.669)	(0.589)
	log P_1*	-0.139	-0.291
		(0.058)	(0.042)
	log P_2*	-0.244	0.026[n]
		(0.038)	(0.032)
	log P_3*	0.592	0.238
		(0.045)	(0.044)
	log Y*	-0.889	-0.809
		(0.110)	(0.084)
R-squared		0.823	0.872
FM (log q_2)	Constant	11.340	-5.425
		(1.620)	(1.429)
	log P_2*	-1.791	-0.138[n]
		(0.325)	(0.189)
	log P_3*	-0.121[n]	0.223
		(0.208)	(0.103)
	log Y*	1.061	2.000
		(0.218)	(0.134)
R-squared		0.865	0.876
MMF (log q_3)	Constant	1.619	4.711
		(0.498)	(0.448)
	log P_3*	-0.007[n]	-0.370
		(0.047)	(0.040)
	log Y*	0.462	0.348
		(0.073)	(0.053)
R-squared		0.737	0.899

Note: Numbers in parentheses are standard deviations. Every estimated coefficient without any superscript is statistically significant at the 1-percent confidence level. Superscripts * and ** denote that the estimated coefficient is statistically significant at the 5 and 10-percent confidence levels respectively. Estimated coefficient with superscript n is not statistically significant. Superscript 1) means dependent variable.

To examine effects of PCS policy in 1997, we estimated the same equations only using data from 1998. The results are shown in the second column of table 2. Substitution effects are now dominant among all three services. From these estimations, we may conjecture that the fixed service FF has always been substituted by mobile service MMF, although it (FF) showed complementarity with FM at an earlier stage of mobile development. However, the complementary effect soon disappeared as the competing mobile networks covered the whole country. The estimation results confirm the hypothesis proposed earlier in the literature on sequential substitution (see for example SUNG & KIM, 2002; SONG, YOON & JUN, 2002).

Table 3: Estimation results using dummy variables

Dependent variable	*Dummy in scale variables*		*Dummy in own price variables*	
	Explanatory variables	*Coefficient*	*Explanatory variables*	*Coefficient*
FF (log q_1)	Constant (a_1)	9.440 (0.570)	Constant (a_1)	9.114 (0.549)
	$A_1 dd$	-0.323 (0.036)	log P_1*	-0.226 (0.038)
	log P_1*	-0.303 (0.041)	*dd* log P_1*	-0.080 (0.009)
	log P_2*	0.036[n] (0.037)	log P_2*	0.040[n] (0.036)
	log P_3*	0.214 (0.040)	log P_3*	0.211 (0.040)
	log Y*	-0.800 (0.078)	log Y*	-0.798 (0.078)
R-squared		0.928		0.928
FM (log q_2)	Constant (a_2)	-6.065 (2.024)	Constant (a_2)	-5.187 (1.893)
	a_2 *dd*	1.186 (0.101)	log P_2*	-0.669 (0.245)
	log P_2*	-0.493 ** (0.262)	*dd* log P_2*	0.232 (0.019)
	log P_3*	0.449 (0.141)	log P_3*	0.433 (0.138)
	log Y*	1.941 (0.173)	log Y*	1.961 (0.169)
R-squared		0.945		0.947
MMF (log q_3)	Constant (a_3)	4.583 (0.486)	Constant (a_3)	4.358 (0.465)
	A_3 *dd*	-0.252 (0.029)	log P_3*	-0.338 (0.041)
	log P_3*	-0.378 (0.044)	*dd* log P_3*	-0.041 (0.005)
	log Y*	0.381 (0.053)	log Y*	0.379 (0.053)
R-squared		0.875		0.875

Note: same as table 2

To estimate demands for traffic services properly taking into account structural changes that were brought forth by PCS liberalization policy in 1997, we introduce two kinds of dummy variables as follows.

$$dd_t = \begin{cases} 0, & \text{if } t < 98:01 \\ 1, & \text{otherwise} \end{cases}$$

$$\begin{aligned} \log q_{it} &= a_i + a_{id} dd_t + b_{i1} \log P_{1t}^* + b_{i2} \log P_{2t}^* \\ &\quad + b_{i3} \log P_{3t}^* + \eta_i \log Y_t^* + e_{it} \qquad i = 1,2,3 \end{aligned} \tag{5}$$

$$\begin{cases} \log q_{1t} = a_1 + b_{11}\log P_{1t}^* + b_{11d}\,dd_t \log P_{1t}^* \\ \qquad + b_{12}\log P_{2t}^* + b_{13}\log P_{3t}^* + \eta_1 \log Y_t^* + e_{1t} \\ \log q_{2t} = a_2 + b_{21}\log P_{1t}^* + b_{22}\log P_{2t}^* \\ \qquad + b_{22d}\,dd_t \log P_{2t}^* + b_{23}\log P_{3t}^* + \eta_2 \log Y_t^* + e_{2t} \\ \log q_{3t} = a_3 + b_{31}\log P_{1t}^* + b_{32}\log P_{2t}^* \\ \qquad + b_{33}\log P_{3t}^* + b_{33d}\,dd_t \log P_{3t}^* + \eta_3 \log Y_t^* + e_{3t} \end{cases} \quad [6]$$

The new estimation results are shown in table 3. Estimated coefficients for dummy variables are all statistically significant, implying that there was a structural change in the market environment in 1997. The estimation results are also improved with dummy variables in terms of the statistical significance of estimated coefficients, R-squared. They strongly support the hypothesis that all three services are substitutes for each other.

We can conduct the hypothesis test of structural change with Wald statistic, λ, which is asymptotically distributed as chi-square distribution with J (the number of restrictions) degrees of freedom under the following null hopothesis.

$$H_o : a_{1d} = a_{2d} = a_{3d} = 0$$

$$H_o : b_{11d} = b_{22d} = b_{33d} = 0$$

Under the null hypothesis we can obtain test statistic, i.e. $\lambda_1 \approx 276.74$ for the scale dummy case, $\lambda_2 \approx 282.80$ for the price dummy case. If we further assume that the error terms are independent and identically normally distributed, we can calculate an exact, finite sample F-statistic, g, as follows.

$$g_1 = \lambda_1 / J \approx 92.25\,,\ g_2 = \lambda_2 / J \approx 96.29$$

With associated 1% significant level, the critical value of chi-square statistic is $\chi^2(3) \approx 11.35$ and that of F-statistic is $F(67,3) \approx 4.13$ indicating that we can decisively reject the null hypothesis.

Omitted coefficients in table 2 and table 3 are easily calculated from constraints [4] and the average ratio in table 1. For example, b_{21} is about -0.674 in the case of the naïve regression model, including 1997 samples and 0.077 in the case of introducing dummy variable in own price.

■ Regulatory implications

Access charge regulations

We now examine the effects of regulating access charges and the fixed rate when all the other services are competitively provided. Following the stylized models in the regulatory literature [1], we may visualize pricing as a two-stage process where the government decides on the fixed rate and access charges in the first stage and, based upon the regulated prices, private operators compete in their prices in the next stage.

The prices for FM and MMF are then determined in duopoly equilibrium. When the government increases access charges for the fixed network, it will effectively increase the cost of MF (and hence MMF). Since FM and MMF are substitutes for each other, demand for FM is likely to increase as the price for MMF is pressured upward. As a result, the new equilibrium price for FM is likely to increase. It then follows that, under the substitution hypothesis, an increase in each type of access charges will unambiguously increase the market prices of FM and MMF. The same effects are seen when the government increases a fixed rate. Apparently in each case consumer welfare will decrease, at least in the short-run.

To examine issues related to the trade-off between investment incentives and consumer surplus, we need to examine the effects of access charges on the profits of the fixed operator. For example, if the price elasticity of mobile demand is sufficiently small, an increase in fixed access charges will provide greater profit incentives for the fixed operator to upgrade its network facilities. The fixed access charge will then be determined at the level that provides a fair return above the acess costs.

Substitution and convergence

As the demand for fixed service decreased, the service providers began to switch some of their resources to broadband data transmission and related businesses. The share of voice revenue for KT (Korea Telecom) has fallen from 70.3 percent in 1998 to 40.5 percent in 2002. The internet business has

[1] See for example, SONG, YOON & JUN (2002) for a more rigorous analysis.

been the most rapidly growing alternative area for KT and high speed internet services as a share of total revenues have increased from 0.9 percent to 17.1 percent over the past 5 years. The broadband internet backbone has already been established to cover the whole country and the number of subscribers has reached more than 10 million. The home diffusion rate is almost 70 percent and has grown most rapidly among OECD countries.

The mobile data communications market has also become lucrative. According to a recent survey (ATLAS Research Group, 2003), the proportion of APRU of mobile companies accounted for by data services increased from 6.5 percent to 10.1 percent in the year 2002 alone. Although the continued penetration and sophistication of mobile system in voice and data communications brought forth various types of fixed applications through mobile networks (see for example, CIANCETTA *et al*., 1999), convergence would not be widespread and far reaching in the absence of a broadband internet network.

In the early stages of convergence, KT marketed wireless LAN, and later via its subsidiary, KTF, introduced so called Netspot Swing, which combines the wireless internet network of the mobile provider with the fixed provider's wireless LAN. They are also targeting more appealing mobile internet businesses by exploring new bandwidth such as 2.3GHz that can be bundled with 2.4GHz wireless LAN. It has been considered as essential for the home networking of consumer electronics. KT has also been searching for possibilities to license new fixed-mobile integrated services including a multimedia messaging service and one-phone service. The one-phone service requires a system of billing various converged services together and has to pass regulatory monitoring. Since KT monopolizes the local fixed network covering the whole country, the bundling of fixed-mobile converged services at attractive rates may be regarded as involving unfair tie-ins and is subject to regulatory scrutiny.

Converged services are also provided by mobile providers. The infomobile service is offered by applying CDMA-RF technology to PABX. It is considered as a wireless phone within the limited specified zone and serves as a typical mobile phone outside of the zone. Mobile Centrex attempts to offer communication services through a mobile-based system replacing PABX. The dominant mobile provider, SK Telecom, has been investing aggressively to prepare for MVPN (mobile virtual private network) and unified messaging services.

The convergence process is likely to continue in the near future and the government is moving towards reassessing ongoing technological development to reconsider traditional regulatory paradigms on business restrictions. The government may also arrange an information sharing mechanism for unified messaging and billing services and demand greater transparency in providing access to local networks. Spectrum resources for converged services have to be allocated in an efficient manner. A competitive business environment for reselling converged services may establish many niche markets in the future.

■ Concluding comments

This paper examines complementarity and substitutability between fixed and mobile networks. As far as voice communications are concerned, mobile calls seem to substitute telephone calls originating on the fixed network. The shift from fixed to mobile services has been driven by network externalities and competitive forces in the telecom market. It suggests that the traditional regulatory practice of controlling access charges and fixed rates needs to be re-examined to accommodate new market forces. The paper claims that an increase in access charges to the fixed network is likely to increase the price of all competitive services and reduce consumer welfare in the short term. However, proper incentives need to be provided to the fixed operator to keep access facilities in good shape.

Substitution effects seem to have grown stronger over time and the fixed operators have responded to worsening business climates by introducing fixed-mobile converged services. Although the converged solutions at the initial stages were mainly fixed applications using mobile networks, mobile operators later introduced converged services that could replace fixed communications equipment and enhance both transmission quality and mobility. The regulatory authority needs to rebalance the social benefits of adopting technological progress against the potential for unfair practice on the part of dominant telecom operators, who may attempt to supply converged services through sophisticated bundling strategies. The regulator, however, should not hold back the tide of technological progress.

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