

Competition in the Japanese Cellular Phone Market

by Sumiko ASAI*

Introduction

Currently, cellular phone services offer a wide range of purposes from business to entertainment, and a mobile handset has become an essential tool. However, as opposed to the major cutbacks in monthly charges seen in the 1990s, the decline in the price index for cellular phone services since 2000 has been small, and the charges remain high in Japan, when compared with rates for the same services in other countries¹.

One factor that contributes significantly to this downward rigidity in prices is the cross subsidization between handsets and monthly service charges². The price of the handset is extremely low in several countries including in Japan, and the resulting deficit is subsidized through monthly charges. This business model limits the extent to which monthly charges could be reduced, although it contributes to promoting new subscriptions or upgrades to more advanced handsets³.

Collusive behavior is another factor that warrants investigation. In Japan, operators providing cellular phone services using their own facilities are limited to four firms at present; NTT DoCoMo, KDDI, Softbank and EMOBILE⁴. However, oligopoly in the cellular phone market is not restricted to Japan, and is common to many countries due to the scarcity of radio frequencies. Thus, whether or not the competitive mechanism works in the oligopolistic market has been one of the top concerns of researchers and regulators. An examination of a few previous studies on this topic reveals some findings. Valletti and Cave (1998) stated that retail prices were extremely stable when the U.K. cellular phone market was the legal duopoly. Stoetzer and Tewes (1996) pointed out that the duopoly cellular market in Germany limited competition, and several market characteristics led to tacit collusion among competitors.

Thus, the cellular phone market is oligopoly worldwide and the relationship between market structure and performance needs to be investigated for policymakers and researchers. In an attempt to address this need, this paper measures the degree of competition in the Japanese cellular phone market in order to examine whether or not its structure causes downward rigidity in prices.

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The remaining sections of the paper are organized as follows. The next section provides an overview of the Japanese cellular phone market, followed by a review of related literature. Following this survey, the model and data are described. The next two sections present the estimation results and policy implications. The final section offers some conclusions.

Overview of the Japanese Cellular Phone Market

As a background to the empirical study in this paper, this section provides an outline of the Japanese cellular phone market⁵. Japanese cellular phone services were introduced by NTT Public Corporation (NTT Public Corp.) in 1979. NTT Public Corp. was a government agency providing domestic telecommunication services and had a monopoly at the time. However, a competitive mechanism was set in motion and NTT Public Corp. was privatized, becoming NTT Corporation (NTT) in April 1985⁶. Although cellular phone services had been monopolistically provided by NTT, the Ministry of Posts and Telecommunications (MPT, the present Ministry of Internal Affairs and Communications: MIC) decided to issue a license to a new operator in 1986. Based on this policy, a new carrier entered the cellular phone business, providing competition for NTT (from which NTT DoCoMo spun off in 1992). At this stage, the market structure moved from a monopoly to a duopoly. When digital services were introduced in 1993, the Ministry issued licenses for the provision of digital cellular phone services to other newcomers. However, as competition developed, a few firms were consolidated and the market became an oligopoly consisting of three firms: NTT DoCoMo, KDDI, and Softbank. In addition to three operators, MVNOs (Mobile Virtual Network Operators), that is, operators providing services for consumers by renting facilities from other operators, exist in the cellular phone market. However, so far, they have not proliferated in Japan and their impact on the market has been limited⁷.

Although competition has existed in the cellular phone market since the late 1980s, it is only since 1996 that there has been a significant increase in the number of subscribers, as shown in Figure 1. The main factors contributing to market growth during the 1990s were the abolition of subscriber charges, a reduction in monthly charges, and technological advances in handsets. By September 2009, the number of cellular phone subscribers had reached 109.6 million, double the number of fixed line subscribers. Recently, the market has almost reached saturation point, judging from the low rate of market growth and high penetration rate of handsets⁸. Furthermore, there has not been any major reduction in prices since 2000, as shown in Figure 2.

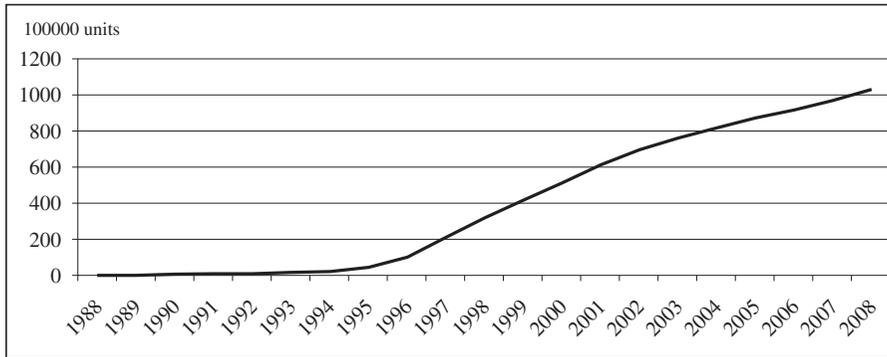


Figure 1: Number of Subscribers of Cellular Phone Services

Data source: Telecommunications Carriers Association

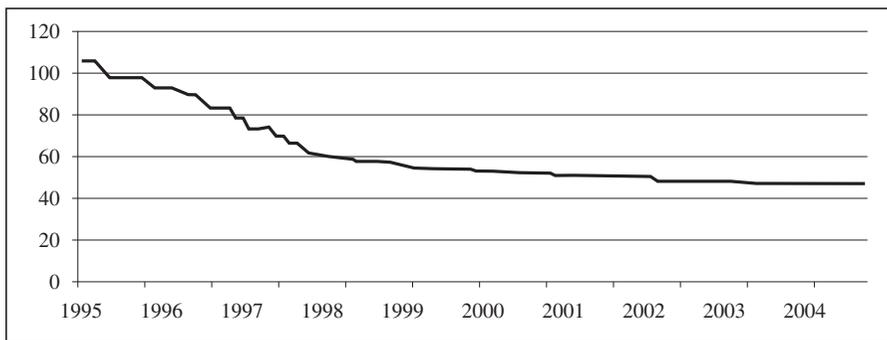


Figure 2: Monthly Charges of Cellular Phone Services (1995 average = 100)

Data source: Monthly Report on Corporate Service Price Index

As for market share, monthly data on subscribers by operator have been published by the Telecommunications Carriers Association (TCA)⁹. These publications showed that NTT DoCoMo's monthly share remained stable at approximately 57 percent in the late 1990s. What had a competitive impact on the cellular phone market was the advent of i-mode service in February 1999. Developed by NTT DoCoMo, i-mode is a service for Internet access using mobile phones. NTT DoCoMo adopted the *de facto* standard HTML (Hypertext Markup Language) for producing content. The adoption of such an open interface enabled a large number of content producers to enter the market. NTT DoCoMo also established criteria for content accessible from i-mode terminals and selected official sites according to the criteria. Content producers have an incentive to produce attractive content in order to be authorized as official sites¹⁰ because users have easy access to official sites, and NTT DoCoMo collects information charges

on behalf of content producers for these sites, As the number of attractive i-mode sites increased, utility also rose for i-mode users, leading to an increase in the number of subscribers. Thus, there was positive feedback between i-mode sites and users¹¹. Furthermore, Internet access through mobile phones became very popular because NTT DoCoMo installed software for i-mode service on standard handsets in June 2000. NTT DoCoMo's share of net additions compared with the previous month reached about 80 percent during the period from July to October 2000. However, NTT DoCoMo's share of net additions decreased and its first mover advantage gradually declined because other operators also started Internet access services promptly.

In October 2001, NTT DoCoMo was also the first operator to establish third generation (3G) services, which enable high-speed transmissions, followed by KDDI in March 2002. However, while NTT DoCoMo needed to construct new base stations for its 3G services, KDDI could provide 3G services by replacing software, thanks to compatibility between the second generation (2G) and 3G services. This helped KDDI rapidly expand its 3G service area. Consequently, NTT DoCoMo did not continue to enjoy an advantage, although it was the first to introduce 3G services.

The market share of NTT DoCoMo peaked at 59.24 percent in March 2001. The share has been on a decline since April of the same year, although it temporarily rose again to 59.2 percent from December 2001 to January 2002, as shown in Figure 3, with the introduction of 3G services and new handsets. That is to say, although the introduction of value added services via advanced handsets temporarily differentiates the operator from other competitors, these competitors soon catch up with the advanced services developed by the first mover. Surveying the market in the long term, services have become almost homogeneous among operators and there is little room for product differentiation in the cellular phone market.

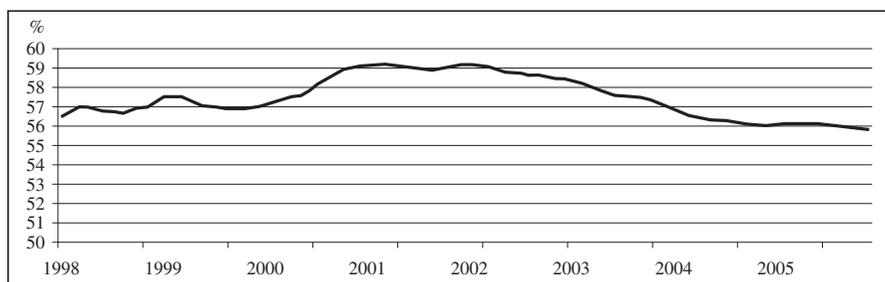


Figure 3: Market Share of NTT DoCoMo
Data source: Telecommunications Carriers Association

Looking over the development of the market, the introduction of Internet access service through handsets which is one of the 2G services brought about a

radical change in the Japanese cellular phone market. On the other hand, although the transfer from 2G to 3G enables high-speed communications, the impact has been smaller than that caused by the transfer from the first generation (analog) to 2G (digital) in Japan¹². It is reasonable to suppose that the cellular phone market has entered the saturation stage from both quantitative and qualitative perspectives.

Related Literature

This section briefly surveys a wide range of literature from demand for the cellular phone services and cost analysis to collusion¹³, because the model adopted in this study involves both demand and cost functions,

Several studies investigated the factors affecting the demand for cellular phones. Gruber and Verboren (2001a) reported that severe competition and a single standard enhance the penetration rate of the service. Furthermore, their study and that of Ahn and Lee (1999) found that countries with high per capital income adopt the 2G service earlier. On the other hand, Gruber (2001), Gruber and Verboren (2001b) and Rouvinen (2006) reported that per capital GDP is not statistically significant for the rate of the diffusion, while market competition promotes diffusion. Lee and Lee (2006) estimated the demand function for Korean cellular phone services and reported that facility-based competition and the reduction in access price play a positive role in the early diffusion of services. These studies show that the factors affecting the diffusion rate of cellular phone services differ depending on the country and life stage of the mobile technology.

Regarding the Japanese cellular phone market, Okada and Hatta (1999) investigated the demand for cellular phone services using the Almost Ideal Demand System and reported that fixed line and cellular telephone services are substitutes for each other. Tsujimura (2006) estimated the demand functions for intra and inter prefecture traffic of cellular and fixed line telephone services, respectively, in order to investigate the relationship between the two telephone services. Tsujimura (2006) stated that the relationship between cellular and fixed line changed from complementarity to substitute. Iimi (2005) analyzed the demand for cellular phone services, using a discrete consumer choice model and measured the price elasticity.

Regarding the cost analysis, two studies present different findings. McKenzie and Small (1997) estimated the cost function for U. S. cellular phone services, using a composite cost function. They reported that the estimation results reject constant returns to scale for all but the smallest firm and the remaining firms exhibit decreasing returns to scale. On the other hand, Foreman and Beauvais (1999) estimated the translog cost function for GTE cellular phone services. They found that scale economies exist at the sample mean.

Another concern of researchers and policy makers is the degree of competition in the oligopolistic cellular phone market. Stoetzer and Tewes (1996) and Valletti

and Cave (1998) pointed out the collusive behavior of operators in Germany and the U.K. Paker and Röller (1997) empirically tested whether cellular phone operators tacitly colluded and investigated the factors that led to tacit collusion, taking into consideration that the U.S. cellular phone market was duopoly in each geographic market, and the same pair of operators competed in the multi-markets. In advance of Paker and Röller's study, Bernheim and Whinston (1990) stated that tacit collusion may be sustainable when the same firms compete in multi-markets (called multimarket contact) because their ability to punish any deviations from tacit collusion is enhanced. Paker and Röller concluded from their empirical study that the multimarket contact and cross-ownership of competitors increase the likelihood of tacit collusion¹⁴. Furthermore, Busse (2000) analyzed how U.S. cellular phone operators coordinate their actions, and asserted that multimarket contact is a necessary, but not sufficient condition for tacit collusion.

Recently, convergence between fixed line and mobile services has developed. Ida and Sakahira (2008) investigated interdependence on the choice of operators by subscribers between fixed line Internet and mobile services, using a mixed Logit model. They reported that subscribers who select NTT for their fixed line Internet service tend to select NTT DoCoMo for cellular phone services, and vice versa.

There are several methods to measure the degree of competition¹⁵. The traditional approach, often utilized by policy makers, is a structure-conduct-performance (S-C-P) paradigm. This is an indirect approach used to ascertain whether or not a firm exercises market power, and does not model the firm's behavior. In contrast to the traditional approach, there are several other methods collectively referred to as the new empirical industrial organization approach. One of these is the residual demand approach. Kahai, Kaserman and Mayo (1996) investigated whether AT&T is the dominant firm in long-distance telecommunication, using this approach, and concluded that AT&T lacks significant market power after the divestiture. Ward (1999) also analyzed long-distance telecommunications in the U.S., using the residual demand approach. Ward found that there is only modest scope for oligopolistic behavior, although the market is relatively concentrated.

Other than the residual demand approach, we may enumerate the conjectural variation approach and the method proposed by Panzar and Rosse (1987). Iwata (1974) proposed the conjectural variation approach that formulates firm behavior. Since the pioneering study of Iwata (1974), the approach has been applied to a variety of industries. For the telecommunication industry, Taylor and Zona (1997) investigated whether AT&T exercised market power, using this approach. On the other hand, the approach of Panzar and Rosse uses long-term competitive equilibrium. Molyneux, Lloyd-Williams and Thornton (1994) applied the Panzar and Rosse model to banking in European countries. The conjecture approach requires cost data by firm, while input price data are essential for the approach

adopted by Panzar and Rosse. Thus, the fields to which these models may be applied are limited due to the availability of data.

On the other hand, Bresnahan (1982) developed the revised conjectural variation model using a time series of aggregate data, instead of the cost data by firm. Shaffer (1989, 1993) applied the model to both the U.S. and Canadian banking industries. Suominen (1994) extended the Bresnahan model to a multi-products model and measured the degree of competition in the Finnish banking industry. Bresnahan's model enables us to measure the degree of competition using data that is relatively easy to obtain. In the Japanese cellular phone market, while NTT DoCoMo has specialized in cellular phone services¹⁶, KDDI and Softbank have provided more diverse applications over fixed as well as mobile networks, and cost data specific to their cellular phone services are not available. Therefore, this paper adopts the model proposed by Bresnahan in order to measure the degree of competition in the Japanese cellular phone market for reasons of data availability.

Model and Data

This paper measured the degree of competition in the Japanese cellular phone market by Bresnahan's model. The demand function is specified by $Q = D(P, Y)$, where Q is output quantity, P is price, and Y is an exogenous variable which has an impact on Q . When firms are price takers, $P = MC(Q, W)$, where MC is the marginal cost and W indicates input prices. When firms are not price takers, $P = MC(Q, W) - \lambda h(Q, Y)$, where $P + h(Q, Y)$ is the marginal revenue and $P + \lambda h(Q, Y)$ is the marginal revenue as perceived by the firm. When $\lambda = 0$, $P = MC$. Thus, $\lambda = 0$ indicates that the market is in perfect competition. When $\lambda = 1$, $MR = MC$. $\lambda = 1$ describes perfect collusion, and market performance is virtually the same as in a monopoly, even when several firms exist. Thus, the value of λ indicates the degree of competition.

The aggregate demand function is specified by equation (1).

$$Q = \alpha_0 + \alpha_1 P + \alpha_2 Y + \alpha_3 PZ + \alpha_4 Z \quad (1)$$

where Z is also an exogenous variable and PZ is added in equation (1) in order to identify λ in equation (3). Variable Z is often chosen from the prices of related goods. The marginal cost function is specified by equation (2).

$$MC = \beta_0 + \beta_1 Q + \sum_{i=1}^n \gamma_i W_i \quad (2)$$

Equation (3) is given from the first-order condition for profit-maximization.

$$P = -\frac{\lambda}{\alpha_1 + \alpha_3 Z} Q + \beta_0 + \beta_1 Q + \sum_{i=1}^n \gamma_i W_i \quad (3)$$

Equations (1) and (3) are estimated using the two-stage least squares estimation method.

As mobile phone usage has changed with the introduction of the Internet access services, we chose the period from January 2000 to December 2005, that is, the period following the introduction of Internet access using mobile phones, for our estimation. The number of subscribers is measured in units of 10,000 for the output variable Q. The data are available from the TCA website¹⁷.

Y is an exogenous variable impacting demand, and income is often adopted as a variable in the studies on the diffusion of cellular phone services. Monthly expenditure for all households in the *Annual Report on the Family Income and Expenditure Survey* published by the MIC, and the index of industrial production measured by the Ministry of Economy, Trade and Industry (METI) were selected as candidates for variable Y¹⁸. However, the two variables and lagged variables were not significant in this study. The finding that income variables were not significant in terms of the demand for cellular phone services was substantiated in the studies conducted by Gruber and Verboren (2001b) and Rouvinen (2006). Therefore, this study did not adopt either monthly expenditure or the index of industrial production as Y.

In this study, the number of websites was adopted as an exogenous variable (Y) that has an impact on the number of subscribers (Q) because there is positive feedback between subscribers and websites. Y is the number of websites and is the total of official sites authorized by NTT DoCoMo plus unofficial sites. Although KDDI and Softbank have also provided Internet access through cellular phones, monthly data on the number of websites are not available for the two companies. Therefore, this study includes only NTT DoCoMo websites. While data on official websites are compiled by NTT DoCoMo, data on unofficial websites were compiled by Digital Street Inc. up until fiscal 2005¹⁹. Data regarding both websites are available on the NTT DoCoMo website.

Furthermore, this study also estimated the demand function, which contains the lagged number of subscribers and its quadratic term in consideration of network effect in the cellular phone market. However, these variables were not used in equation (1) because these lagged values were not significant.

Japanese cellular phone operators initially adopted a two-part tariff consisting of a fixed monthly charge and a usage charge. However, since the mid 1990s, they have offered their users a choice among several package tariff plans, including fixed charge and usage charge. Furthermore, various kinds of discount services have been added to the package tariff plans in an endeavor to target different users groups. Taking the changes in price strategies by operators into account, the Bank of Japan has calculated the price index of cellular phone services, based on both the tariff and discount information. This study adopted the price index for cellular phone services calculated by the Bank of Japan as P, because the index is calculated by a

reasonable method that reflects changes in actual price²⁰.

Regarding variable Z, which is the price of related goods, this study selected the price index for fixed line telephone services because several studies, such as Gruber and Verboven (2001a), Okada and Hatta (1999) and Tsujimura (2006), investigated the relationship between fixed line and mobile telephone services. Z is the price index for fixed line telephone services and is calculated by the Bank of Japan. P and Z are taken from the *Monthly Report on Corporate Service Price Index* issued by the Bank of Japan.

This study used labor price and capital price as input prices W. Labor price W_1 is the wage index taken from the *Monthly Labor Survey* issued by the Ministry of Health, Labor and Welfare. As for capital prices, two indexes are used. One is the price index for capital goods W_2 which indicates the changes in overall capital cost. The other is the price index W_3 which indicates the changes in the capital cost of base stations for providing cellular phone services²¹. The price index for stations and equipment for cellular phones was adopted as W_3 . Both W_2 and W_3 are taken from the *Monthly Report on Corporate Price Index* published by the Bank of Japan. Prices of cellular phone (P) and fixed line telephone services (Z), and the three input prices (W_1, W_2, W_3) are normalized indexes, so that the year 2000 = 100.

Table 1 presents some summary statistics. The price of cellular phone services (P), the price of fixed line telephone services (Z), the price of capital goods (W_2), and the price of stations and equipment for cellular phones (W_3) show downward trends. On the other hand, the number of subscribers (Q) and the number of websites (Y) have consistently risen. Table 1 shows that the decline in the price index for fixed line telephone services was greater than that of cellular phone services for the period.

Table 1: Sample Summary Statistics

	Q	P	Y	Z	W_1	W_2	W_3
Average	7,290	92.9	63,934	86.6	98.0	91.4	95.2
standard error	1,190	3.8	26,707	7.3	1.5	5.3	2.7
maximum	9,018	101.1	101,976	102.1	101.3	102.2	101.4
minimum	4,910	89.3	5,052	78.7	95.2	84.9	89.6

Q: the number of subscribers measured by 10,000 units

P: the price index for cellular phone services

Y: the number of websites

Z: the price index for fixed line telephone services

W_1 : the wage index

W_2 : the price index for capital goods

W_3 : the price index for station and equipment for cellular phones

P, Z, W_1, W_2, W_3 : 2000 average = 100

Estimation Results

Equations (1) and (3) were estimated, using the two-stage least squares estimation method. Table 2 (a) presents the estimation results for the period from January 2000 to December 2005. α_2 , γ_1 , γ_2 and γ_3 were positive, as anticipated²². Table 2 reports Newey-West heteroskedasticity consistent standard errors, because a positive serial correlation was suggested by the Durbin-Watson test.

Table 2: Estimation Results

	(a): 2000.1~2005.12	(b): 2001.4~2005.12
α_0 (constant)	55987.14 (14271.58)***	34330.11 (18595.29)*
α_1 (P: price)	-537.488 (136.667)***	-325.809 (199.312)
α_2 (Y: websites)	0.0303 (0.0037)***	0.0399 (0.0024)***
α_3 (PZ: mobile price×tele price)	4.9263 (1.5948)***	2.9687 (2.1801)
α_4 (Z: tele price)	-467.230 (164.706)***	-269.010 (201.994)
λ (competition)	0.0347 (0.0131)**	0.0323 (0.0256)
β_0 (constant)	-105.707 (51.398)**	-73.984 (26.192)***
β_1 (Q: subscribers)	0.0045 (0.0019)**	0.0031 (0.0009)***
γ_1 (W ₁ : wages)	0.1723 (0.0725)**	0.1609 (0.0693)**
γ_2 (W ₂ : price of capital goods)	1.4761 (0.3963)***	1.1902 (0.2017)***
γ_3 (W ₃ : price of stations)	0.1208 (0.0993)	0.1717 (0.0742)**
equation (1)	adjusted R ² 0.998 D.W. 0.554	adjusted R ² 0.999 D.W. 1.189
equation (3)	adjusted R ² 0.962 D.W. 0.754	adjusted R ² 0.921 D.W. 0.923
Number of Samples	72	57

Newey-West heteroskedasticity consistent standard errors are in parentheses.

*** 1%, ** 5%, * 10% significance level

instrumental variables: Y (websites), Z (price of fixed telephone services), W₁ (wage), W₂ (price of capital goods), W₃ (price of stations and equipments for cellular phone)

The index of degree of competition λ in Table 2 (a) was positive at the 5 percent significance level. The value of λ was very far from 1, and the hypothesis of collusive behavior was rejected. However, the hypothesis of perfect competition was also rejected. This study calculated the marginal cost based on equation (2), using the estimates in Table 2 (a). Figure 4 shows the price index for cellular phone services as actual price (P), and estimated marginal cost as the price in the perfect competition market. While the disparity between the two indexes in 2000 was comparatively large, it has narrowed gradually since 2001²³.

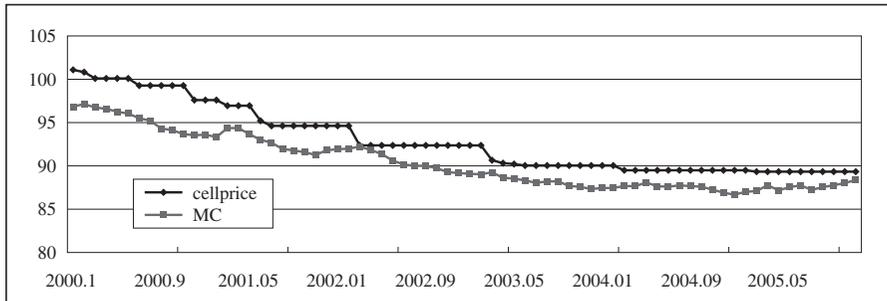


Figure 4: Actual Price and Competitive Price (MC)

This paper also estimated the equations for the period from April 2001 to December 2005, although the number of observations was limited. The estimation results are reported in Table 2 (b). The value of λ in Table 2 (b) was not significant at the 10 percent significance level, implying a competitive market. Since 2001, the first-mover advantage of NTT DoCoMo, brought about by i-mode, has gradually waned, and the company did not have any advantage over its rivals for 3G services. Consequently, the recent market share declined, as shown in Figure 3. The estimation results in this paper are consistent with such background circumstances relating to NTT DoCoMo.

NTT DoCoMo's share, and the Herfindahl-Hirschman index (HHI) for the cellular phone market were 55.9 percent and 3,985 respectively, measured by the number of subscribers, as of December 2005. This implies that the market was a highly concentrated one, according to the standard of Horizontal Merger Guidelines issued jointly by the United States Department of Justice and the Federal Trade Commission. Although the reduction in monthly charges in the 2000s has been smaller than that seen in the 1990s, and market concentration has been high, it cannot be concluded from the estimation results that the small-scale reduction in prices was due to collusion among service operators.

Policy Implications

Since the introduction of competition policy in April 1985, the MPT (the present MIC) strictly applied cost-based price regulation to telecommunications providers including cellular phone operators. In December 1996, the MPT recognized that the cellular phone market had become competitive and decided to streamline price regulation for cellular phone services, although some people, especially consumers groups, were concerned that deregulation might be premature and lead to downward rigidity in prices. However, the results obtained in this study

did not support the contention that streamlined price regulation led to tacit collusion in the cellular phone market.

Since 2003, the MIC has conducted an annual analysis of the Japanese telecommunications industry, based on the S-C-P paradigm. The conclusions obtained in the present paper were consistent with those of the MIC. However, while the model adopted in this study evaluates the degree of competition, the focus of attention in MIC's analysis of the cellular phone industry is whether NTT DoCoMo is the dominant carrier, so that the purpose and perspective of the two analyses differ. However, even if a dominant carrier had not existed, tacit collusion among non-dominant carriers may occur and possibly hinder the competitive mechanism. Therefore, it is necessary to monitor not only the conduct of the largest operator but also the activities of all participants and the overall market. Consequently, the approach proposed by Bresnahan is an effective way of analyzing competition policy.

In Japan, number portability for cellular phones started in October 2006, making it easier for consumers to switch operators. Furthermore, the market also saw the entry of a new operator in 2007. The introduction of a number portability system and the new entry are expected to promote competition. On the other hand, the market has transferred from the expansion mode to saturation phase. Price elasticity of demand is supposed to become lower with greater penetration of services²⁴, and inelastic demand is an incentive for collusive arrangements²⁵. Thus, the market power in the cellular phone market will need to be tested again in the future.

Conclusion

This paper measured the degree of competition in the Japanese cellular phone market spanning the period from 2000 to 2005, using Bresnahan's model. This method models firm behavior, and directly evaluates the degree of competition, while the traditional S-C-P paradigm is an indirect approach. From the results obtained from our analysis, while the hypothesis of joint monopoly was strongly rejected, perfect competition for the entire period was also rejected. Moreover, it seems that the market has become more competitive with a decrease in NTT DoCoMo's share, although it is necessary to re-estimate the degree of competition using more up-to-date information²⁶.

This study focused on the cellular phone market to measure the degree of competition. However, convergence between fixed and mobile network services has been developing. It will be necessary to monitor adjacent markets when the degree of competition for cellular business is examined in the future.

Finally, data-related problems remain to be tackled. This paper adopted the number of websites NTT DoCoMo only as Y because monthly data for KDDI and

Softbank were not available. There is room for improvement of Y, an exogenous variable that has an impact on output quantity. Furthermore, data on the number of unofficial websites that is part of Y has not been available since 2006. Therefore, this study could not examine the recent degree of competition in the Japanese cellular phone market.

While NTT DoCoMo has maintained almost the same organization from the beginning, KDDI and Softbank are the result of several corporate mergers. Changes in firm organization of this sort make acquisition of time-trend data difficult. Cellular phone services and firm organization have a rapid rate of change, owing to technological progress. For this reason, policy makers should endeavor to collect data continuously.

NOTES

1. The Ministry of Internal Affairs and Communications (MIC) investigated the rates charged for telecommunications services in the United States, South Korea, four countries in Europe, and Japan in 2009. While digital subscriber line (DSL) service rates for Internet access using fixed networks in Japan were remarkably low, Japanese cellular phone service rates ranked in the middle. In addition, they were significantly high for heavy users. The details of the report on telecommunication service rates are available on the MIC website, http://www.soumu.go.jp/johor_tsushin/eidsystem/market01_06html.
2. The Study Group on Mobile Business established in the MIC recommended that the monthly communication charge and handset cost should be separated in 2007 to secure fairness of burden across consumers. Following this recommendation, Japanese cellular phone operators revised their tariff plans and increased the price of handsets. However, they also constructed several self-selecting tariff plans to keep the price of handsets low at the request of consumers.
3. Albon and York (2008) evaluated the effect of subsidization in the cellular phone market.
4. Although EMOBILE started operation at the end of March 2007, the other three firms have substantially occupied most of the market. Three firms excluding EMOBILE operated during the estimation period in this study.
5. For further details on the Japanese cellular phone market, see Funk (2006).
6. For details on the regulatory reform in the Japanese telecommunications market, see Asai (2006).
7. The ratio of MVNO subscribers to total subscribers was only 0.27 percent as of September 2005, according to *the Market Analysis on the Telecommunications Business 2006* published by the MIC.

8. The ratio of the number of subscribers to total population in Japan reached 83 percent as of September 2009.
9. The data are available at the TCA website, <http://www.nttdocomo.co.jp/corporate/ir/finance/subscriber/imode.html/>.
10. The differences between official sites and unofficial sites, however, have recently tended to become blurred, due to an increase in the websites providing free information and the development of search tools such as Google.
11. Tanaka (2002) showed that positive feedback between NTT DoCoMo subscribers and i-mode websites exists, using the vector auto-regression model.
12. As Tilson and Lyytinen (2006) stated that the transition from 2G to 3G promotes new entry from the computing and content sectors and has a great impact on the cellular phone market. However, in Korea and Japan, data communication services via handsets had already penetrated and influenced a wide range of industries such as content and banking during the 2G stage. It is unique to Korea and Japan that the introduction of 2G services had a great impact on the cellular phone and relevant markets.
13. Gans, King and Wright (2005) provided a useful survey of the cellular phone industry.
14. Multimarket contact is observed not only in the cellular phone market but also in the airline and banking industries in the U.S. For the impact of multimarket contact on the degree of competition in the airline industry, see Evans and Kessides (1994).
15. For a survey on empirical studies, Bresnahan (1989) and Torii (2005) have provided useful reviews.
16. Strictly speaking, NTT DoCoMo had also provided personal handy-phone systems (PHS) and paging services. However, paging services and PHS services were terminated in 2007 due to a decrease in the number of subscribers.
17. If monthly data on traffic for voice communication and packet communication were available, we could adopt a multiple-product model, which would have two outputs such as voice and packet communications. However, since such data are unavailable, this study adopts the single-product model, which sets the number of subscribers as output.
18. Data on industrial production is available from METI's website <http://www.meti.go.jp/statistic/index.html/>
19. The number of unofficial websites has not been investigated since April 2006.
20. For the calculation method of price indexes for fixed line and cellular phone services, see "The Explanation of Corporate Service Price Index" issued by the Bank of Japan, <http://www.boj.or.jp/type.exp/stst/pi/data/ecsp2k1.pdf>.
21. The specific capital in this study is the base stations. The price of overall capital goods is also included in this estimation because cellular phone business needs not only base stations, but also a wide range of facilities.

22. This study also estimated the equations using either W_2 or W_3 , because the value of γ_3 in Table 2 (a) was not significant. As a result, a model using both W_2 and W_3 as variables was adopted from the viewpoint of fitness. However, conclusions about market power drawn from these cases were the same.
23. This paper defined the ratio of disparity between actual price and estimated marginal cost to estimated marginal cost as the disparity rate. The average disparity rate in 2000 was 4.45 percent, while the average in 2005 was 2.11 percent.
24. Okada and Hatta (1999) and Tsujimura (2006) calculated price elasticity of cellular phone demand for several years and found that absolute values gradually became smaller as the penetration advanced.
25. For the effects of the collusive agreement, see Church and Ware (2000), Chapter 10.
26. Data on the number of unofficial websites have not been available since 2006. Therefore, the number of websites as variable Y should be replaced by some other variable to measure the degree of competition using post-2006 data.

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