An Empirical Study of Japanese ADSL Development by Panel Data Analysis on Four Major ADSL Carriers

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Abstract

ADSL (Asymmetric Digital Subscriber Line), which is one of the major technologies of broadband access, showed a remarkable increase in Japan after year 2000, with ADSL representing more than 14.5 million subscribers in 2006. Recently Japan has taken a worldwide lead in FTTH, with 11.3 million subscribers at the end of December 2007. Japan has been the first country to experience this transformation which is referred to as migration from ADSL to FTTH. However, the environments of the Japanese ADSL market were not initially favorable; the ADSL service in Japan was introduced later than in Korea, U.S. and other countries, which caused Japanese ADSL penetration to lag behind. This was considered a symbol of Japan's delay in embracing the so-called IT Revolution. Since then, a lot of effort has been made by both private and public sectors to catch up. Among these were efforts to promote competition in the market, including deregulations such as unbundling, collocation rules, disclosure of ADSL capacity information, and charges for dry copper and dark fiber for interconnection. Because of these deregulations, new entrants emerged in the market, with YahooBB is representing a typical example. When YahooBB entered the market, it offered almost half charges of others. Since them, fierce price competition has been in effect. In addition to charges, competition occurred in various services. It was YahooBB that started free services such as offering modem, on-site installment, and a two-month initial trial. The factors can be summarizes as follows: (a) deregulation (competition policy); (b) market competition among ISPs; and (c) technological development. Regarding to (a), (i) collocation rules; (ii) disclosure of information on capacity for ADSL; (iii) unbundling; and (iv) charges for dry copper and interconnection are examples. New entrants such as YahooBB with extreme cheap charges are representative example of (b). (c) including ADSL speed to access to the Internet. Currently 50Mbps services are offered to the subscribers.

The purpose of this paper is to estimate the effect of deregulation on ADSL carriers. Tsuji and Tomizuka [2006], for instance, analyzed factors promoting ADSL by the AHP analysis, but there are no other analyses which focus on the market and subscribers data of ADSL rigorously. This paper utilizes the panel data analysis and this is the first attempt in this field so far. One result we obtain is that the revision and enforcement of Telecommunications Business Law is mostly contributed to the promotion of Japanese ADSL. This research can be applied to the analysis of FTTH, which shows rapid growth in the broadband market.

1. INTRODUCTION

Broadband access has shown a remarkable increase in Japan after 2000, as it represents 28.3 million subscribers, including ADSL of 13.1 million subscribers (46.3%), and FTTH of 11.3 subscribers (33.9%) as of December 2007. Especially, more than 90% of household can use the ADSL service, and its subscription charge becomes very low. Therefore, Japan can be said as the most developed nation in broadband infrastructures. A factor promoting Japanese broadband lies in deregulations by government, competition among carriers, and technical development. However, there are few researches evaluating these effects rigorously in this field. Also, an evaluation of the deregulation policies is not enough. The regulators need much information on market trends with respect to the change of policies or innovations. An importance of researches in this field will be much higher according to the diffusion of FTTH which is expected to be a next major technology of broadband.

This paper focused on ADSL market, and heuristically analyzes the factors promoting it by using the data of its subscribers. There are few previous researches empirically studying demands of broadband services. This is because it's difficult to obtain an important data such as traffic or subscriber, as broadband market grows so rapidly. Therefore recent researches are represented by individual data based on a questionnaire, and applying a discrete choice model such as logit or probit models. We utilized a panel data analysis on four carriers which dominates over 80% of its share. This is so far the first attempt in this field.

This paper consists of six sections: Section 2 introduces the previous researches and characteristics of our research. In Section 3, a general description on ADSL market is presented. Section 4 formulates our methodology of estimation and results of estimation are presented. The each contribution of factors promoting ADSL development such as deregulation, market competition, and technological development is analyzed. One important characteristic of this paper is to analyze effects of these factors on *indivisual* carriers. We can identify which carriers benefitted most by particular factors. These are presented in Section 5. In Section 6, we discuss how to apply this analysis to the FTTH market, which number of subscribers has been

approaching to those of ADSL due to the recent migration. Brief conclusions are also provided in this section.

2. PREVIOUS RESEARCHES

Though there are many previous researches on broadband technology, we have few researches on empirical studies of its development. Eisner and Waldon [2001], Kridel, Rappoport and Taylor [2001], Sidak, Crandall and Singer [2002] utilized discrete choice methods to analyze competition of broadband market in US. Also, Ida and Kuroda [2006] applied nested-logit model to analyze Japanese market. Tsuji [2003], Tsuji and Tomizuka [2006] analyze Japanese ADSL. Some cases which utilized rigorous data of subscriber can be found in just calculation of supply function of Tanaka, Yazaki and Murakami [2004], calculation of demand function of Tsuji and Tomizuka [2006]. One background of less research utilizing data of subscriber is in its difficulty. Broadband were developed so rapidly in these days that it is difficult to obtain enough data for estimation, and its market would be monopoly or duopoly, so it is also difficult to obtain even cross sectional data. In addition, discrete choice methods applied in researches above require a questionnaire to obtain data, thus there are some problems for bias or reliability of data for estimation.

Tsuji and Tomizuka [2006] analyzed factors promoting Japanese ADSL by AHP (Analitical Hierarchical Process) analysis. They divided these factors into three types: deregulation, competition, and technology, then calculated degrees of importance. Finally, they monetarily evaluated factors, in which competition mostly contributed the development of ADSL. AHP is applicable if factors are very complicated and the data is small. However, data for estimation was from questionnaire, so it may be still some problems on bias.

This paper utilizes panel data of monthly subscribers of four ADSL carriers in order to take care of the shortage of data. As noted earlier, the ADSL market has been oligopoly, and Tele-communication Working Group [2005] or some research mentioned difficulty of utilizing the panel data analysis. Many researches which utilize panel data

use yearly data. It is just 5 years since ADSL service has started, so sample would be small even with the yearly panel data. For this problem, however, we can utilize monthly data for estimation, as development of ADSL is so rapid, then we can estimate its effects rigorously and significantly.

This paper utilizes the data of subscriber, but the traffic of connection is also important when we analyze its diffusion. This implication will be more serious if subscription charges are based on the traffic (pay-as-you-go plan), but ADSL carriers charges fixed monthly rates, so we can applied the number of subscriber as an index of the ADSL diffusion.

3. ADSL MARKET

Deregulations of the ADSL market began with the revision and enforcement of Telecommunication Law on September 2000, which includes some political adjustment of unbundling of subscriber lines and collocation rules.[1)] On December 2000, interconnection charges of line-sharing and dry-copper were admitted, which enabled competitors to enter the ADSL market substantially.[2)] In addition, Telecommunication Law and the admission of interconnection charges were revised and enforced again, which mainly included the unbundling of dark-fiber.[3)] However, NTT did not disclose information on collocation related to dry-copper or dark fiber, and intended to delay the competitors' installation of ADSL devices in NTT's telephone offices. NTT was thus enforced to disclose of all information on collocation for free (enactment of notification) on June 2001, and a committee of arbitration on this problem was set up on November 2001. On July 2000, NTT was advised administratively to install competitor's equipment of ADSL within 7 days. In addition, NTT was ordered administratively again to keep the period of installation, which enabled NTT to delay it deliberately. These market developments of ADSL are summarized in Table 1.

As shown in the Table 1, NTT, e-Access, ACCA networks, and YahooBB launched ADSL service consecutively, and these four carriers have been dominating over 80% share of the ADSL market.

Table 1: Implementations and Events of Factors

Time	Events
Dec. 1999	Experimental connection in MDF started.
Sep. 2000	Revision of Telecommunications Business Law enforcement rule (Introduction of regulations concerning unbundling in subscriber's line) (Establishment of regulations regarding collocation)
Oct. 2000	e-Access started its services.
Dec. 2000	Admission of line sharing and dry copper connection charges NTT East and West started its services.
Jan. 2001	ACCA networks started its services.
Feb. 2001	NTT East and West started making the ADSL modem terminal.
Apr. 2001	Revision and enforcement of Telecommunications Business Law Enforcement Rule and connection fee rule (Unbundling of dark fiber)
Jun. 2001	Enactment of notification (Stipulation of information on collocation be disclosed free of charge)
Sep. 2001	YahooBB started its services.
Nov. 2001	Inauguration of the Telecommunications Business Dispute Settlement Commission (The mediation and arbitration became possible.)
Aug. 2002	YahooBB started the two-month free trial campaign.
Oct. 2002	YahooBB formed a business tie-up with Edion and Joshin Denki. (Tie-up with the general merchandising store)

Source: Ministry of Internal Affairs and Communications (MIC)

The trend of subscribers is summarized in Figure 1. There are three big jumps of subscribers; mid-2001, end of 2001, and end of 2002. This paper aims to clarify factors which explain these jumps.

One of the most significant factors promoting Japanese ADSL is continuous decline of its subscription charges as shown in Figure 2. Regarding the definition of subscription charges, we normalize into those per 1Mbps. It should be noted that this construction of charges removes the effect of connection speed from charges. Connection speed is about 1.5Mbps when ADSL started, and currently that is over 50Mbps. The trend of connection speed is describes in Table 2, which shows speed is almost doubled every year. This makes ADSL charges per 1Mbps low substantially.

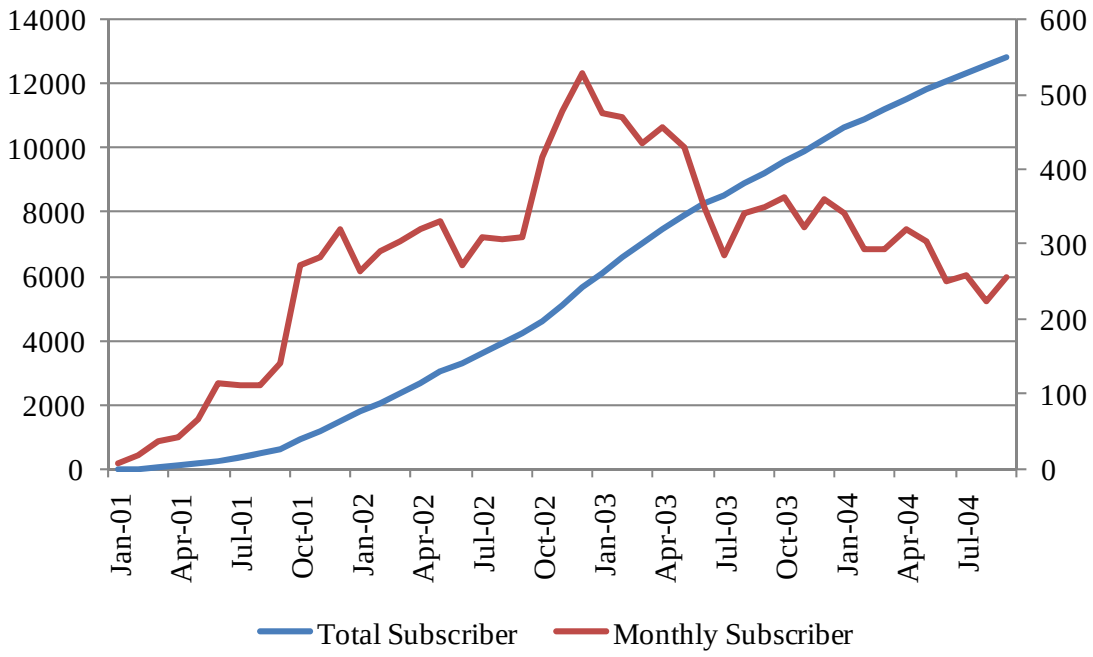

Figure 1: Transition in number of ADSL subscriber (thousand)

Source: MIC

Table 2: Speed of ADSL connection

	NTT	YahooBB	e-Access	ACCA
8Mbps	December-01	September-01	November-01	September-01
12Mbps	November-02	August-02	October-02	October-02
24~26Mbps	July-03	August-03	July-03	August-03
40Mbps	December-03	January-04	November-03	February-04
47~50Mbps	August-04	September-04	February-04	July-04

Source: MIC

Figure 2 presents the trend of charges of each carrier, and it is obvious that competition among ADSL carriers in the market lowers charges. In addition, pricing strategies of each carrier also determine them. According to Figure 2, NTT charged the highest among the carriers, while YahooBB the lowest. This is because NTT has brand image due to not only a member of prominent NTT or Nippon Telephone and Telegraph Corporation before its privatization but also high quality services. On the other hand,

YahooBB is based on the unique business model such as vertical integration management which provides all services from the network to the provision of various contents. In addition to this, YahooBB was the late comer to the market, and this made YahooBB to adopt the above pricing strategy.[4, 5)] The price elasticity is considered to be different from each carrier.

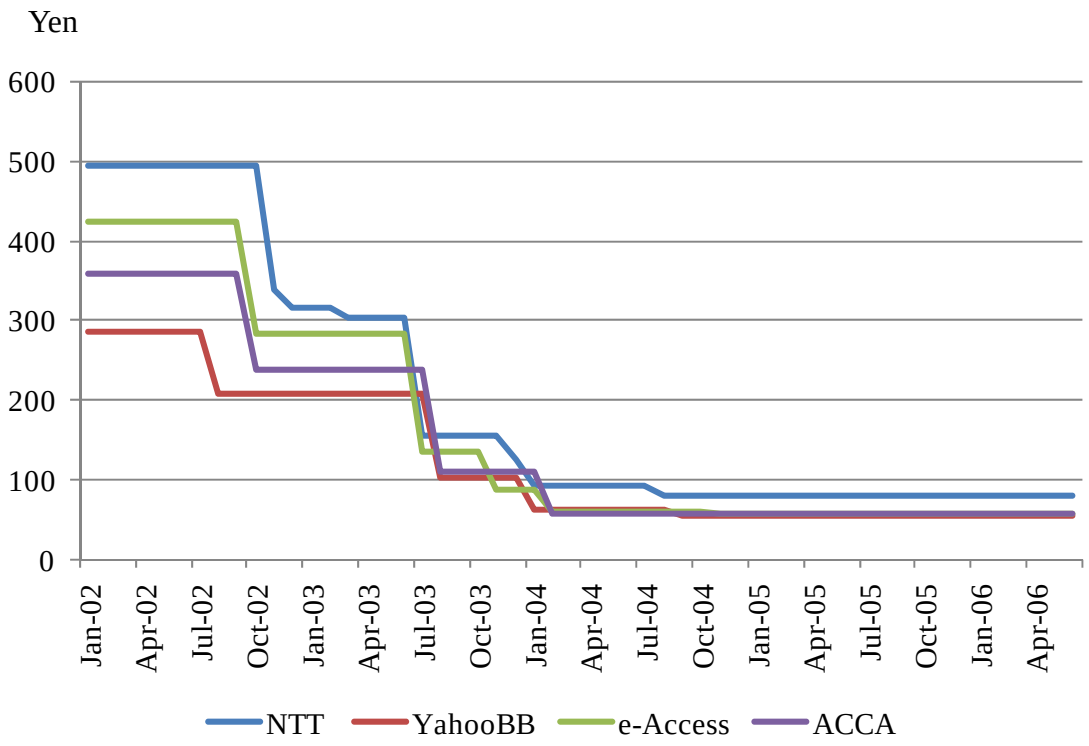

Figure 2: Transition of Subscription Charges of Four Carriers (JPY per 1Mbps)

Source: MIC

4. ESTIMATION I: PANEL DATA ESTIMATION

A model for estimation is formulated as follows:

$$\ln S_{it} = \beta_0 + \beta_1 \ln P_{it} + \beta_2 \ln G_t + \sum_j \beta_3^j D_{it}^j + u_{it}$$
$$u_{it} = \lambda_i + v_{it} \qquad (1)$$

where S_{it} denotes the number of subscriber, P_{it} the monthly subscription charge (per

1Mbps), G_t real GDP converted into monthly data by moving average method of 3 quarters, and D_{it} dummy variables attached to factors which take 0 before the events started and 1 after they started. In case of the latter, the effects of the events do not last for ever, and they take 0 if their effect terminated. Let us take example of 26Mbps connection service. The event started in July 2003 according to Table 2, and dummy variables before this time takes 0, and after this they take 1. The new service of 40Mbps started in December 2003, and it is reasonable to consider that subscribers start switching from 26Mbps to 40Mbps, and the effect of the former disappear at that time. The dummy variables attached to 26Mbps take again 0 thereafter. An error term is assumed to consist of one-way fixed effect where λ_t is a fixed effect and $v_{it} \sim iid(0, \sigma_v^2)$.

Table 3: Factors (dummy variables) used for estimation

Time	Dummy	Events
Dec. 2000	d1	Admission of line sharing and dry copper connection charges NTT East and West started its services.
Jan. 2001	d2	ACCA networks started its services.
Feb. 2001	d3	NTT East and West started making the ADSL modem terminal.
Apr. 2001	d4	Revision and enforcement of Telecommunications Business Law Enforcement Rule and connection fee rule
Jun. 2001	d5	Enactment of notification
Sep. 2001	d6	YahooBB started its services.
Nov. 2001	d7	Inauguration of the Telecommunications Business Dispute Settlement Commission
Aug. 2002	d8	YahooBB started the two-month free trial campaign.
Oct. 2002	d9	YahooBB formed a business tie-up with Edion and Joshin Denki.

Source: Author

A data for estimation is unbalanced panel in which *i* indicates four carriers of ADSL, and monthly data from end of 2000 to mid-2006 is utilized, and at that time MIC changed the publication of data and monthly data had not published thereafter. The model is based on a log-linear model, where β_1 shows the elasticity of price. It should be noted that the price data in this equation is that of the highest-speed plan for subscribers, which is normalized into per 1Mbps as explained earlier.[6)] Based on the

formulation of the demand function, we add a monthly smoothed real GDP, and apply constant dummy variables of factors that are most important variables of this estimation. The dummy variable shows 0 before the events started, 1 after they started, and 0 if their effects extinct.

Table 4: Factors of Innovations used for Estimation

	Dummy	NTT	YahooBB	e-Access	ACCA
8Mbps	d10	December-01	September-01	November-01	September-01
12Mbps	d11	November-02	August-02	October-02	October-02
24~26Mbps	d12	July-03	August-03	July-03	August-03
40Mbps	d13	December-03	January-04	November-03	February-04
47~50Mbps	d14	August-04	September-04	February-04	July-04

Source: Author

One of main objectives of this paper is to utilize the panel data analysis, and we assume that carriers and times have slope parameters in common. But the elasticity of price may be different from each carrier as noted in the last chapter. In this case, we have to control it, for instance, by adding cross effect terms of price and individual dummy to the model. This is the same for dummy variables of factors. In this case, however, a serious multicollinearity problem might arise, when using all the factors as the cross effect terms. The panel data analysis ordinarily uses hundreds or thousands number of data, and it is impossible to estimate effects to each individual sample. In this paper, however, since there are only four carriers for the estimation, we can estimate the effects of factors to individual carriers. We thus estimate with the panel data analysis at first, and then estimate effects of each carrier. The summary statistics for the estimation is provided by Table 5.

Table 5: Summary Statistics

Variable		Mean	Std.Dev.	Min	Max	Observations
Subscriber	overall	13.7025	1.8898	4.3694	15.5569	N=236
	between		0.9642	12.9437	14.6626	n=4
	within		1.6952	5.1283	15.1997	T-bar=59
price	overall	5.2318	1.3372	4.0082	9.2904	N=260
	between		0.4185	4.6667	5.5777	n=4
	within		1.2893	3.7875	9.0244	T-bar=65
GDP	overall	12.0610	0.0281	12.0220	12.1142	N=276
	between		0	12.0610	12.0610	n=4
	within		0.0281	12.0220	12.1142	T=69
d1	overall	0.9710	0.1681	0	1	N=276
	between		0	0.9710	0.9710	n=4
	within		0.1681	0	1	T=69
d2	overall	0.9565	0.2043	0	1	N=276
	between		0	0.9565	0.9565	n=4
	within		0.2043	0	1	T=69
d3	overall	0.2355	0.4251	0	1	N=276
	between		0.4710	0	0.9420	n=4
	within		0.1171	-0.7065	0.2935	T=69
d4	overall	0.9130	0.2823	0	1	N=276
	between		0	0.9130	0.9130	n=4
	within		0.2823	0	1	T=69
d5	overall	0.8841	0.3207	0	1	N=276
	between		0	0.8841	0.8841	n=4
	within		0.3207	0	1	T=69
d6	overall	0.8406	0.3667	0	1	N=276
	between		0	0.8406	0.8406	n=4
	within		0.3667	0	1	T=69
d7	overall	0.8116	0.3917	0	1	N=276
	between		0	0.8116	0.8116	n=4
	within		0.3917	0	1	T=69
d8	overall	0.1703	0.3766	0	1	N=276
	between		0.3406	0	0.6812	n=4
	within		0.2334	-0.5109	0.4891	T=69
d9	overall	0.1630	0.3701	0	1	N=276
	between		0.3261	0	0.6522	n=4
	within		0.2386	-0.4891	0.5109	T=69
d10	overall	0.1667	0.3734	0	1	N=276
	between		0.0145	0.1594	0.1884	n=4
	within		0.3731	-0.0217	1.0072	T=69
d11	overall	0.1413	0.3490	0	1	N=276
	between		0.0248	0.1159	0.1739	n=4
	within		0.3483	-0.0326	1.0254	T=69
d12	overall	0.0725	0.2597	0	1	N=276
	between		0.0118	0.0580	0.0870	n=4
	within		0.2595	-0.0145	1.0145	T=69
d13	overall	0.0688	0.2536	0	1	N=276
	between		0.0572	0	0.1159	n=4
	within		0.2487	-0.0471	1.0254	T=69
d14	overall	0.3732	0.4845	0	1	N=276
	between		0.0547	0.3188	0.4203	n=4
	within		0.4822	-0.0471	1.0543	T=69

The equation (1) for estimation is based on “reduced form,” in which factors of both demand and supply are mixed. Then all the variables are assumed to be exogenous, except charges, that is, if charges are lowered, then this leads to increase the number of subscribers, and this leads to lower charges simultaneously, since increase in the number of subscribers reduces costs, and this makes charges lower. Charges thus are considered to be an endogenous variable. To control this endogeneity, we utilize the instrumental variables method in such a way that charges one period earlier are taken to be as an instrumental variable. Since there are many dummy variables and multicollinearity might occur in the estimation, we omit variables from the estimation with correlation coefficient over 0.8. By considering these discussions, the results of estimation are shown in Table 6.

Table 6: Result of Estimation (Panel Data Estimation)

dependent variable: Subscriber of ADSL											
Fixed Effect IV Model						EC2SLS Random Effect IV Model					
	Coef.	Std. Err.	z-value	p-value			Coef.	Std. Err.	z-value	p-value	
price	-0.4635	0.1021	-4.54	0.000	***	price	-0.3673	0.1097	-3.35	0.001	***
GDP	14.4544	4.0703	3.55	0.000	***	GDP	14.6454	4.4626	3.28	0.001	***
d1	0.6867	0.5442	1.26	0.207		d1	0.5570	0.5986	0.93	0.352	
d3	(deleted)					d3	1.4122	0.0950	14.86	0.000	***
d4	1.5998	0.2954	5.42	0.000	***	d4	1.5507	0.3250	4.77	0.000	***
d5	1.1704	0.2669	4.38	0.000	***	d5	1.1906	0.2936	4.05	0.000	***
d6	1.2913	0.2914	4.43	0.000	***	d6	1.6238	0.3133	5.18	0.000	***
d8	0.6919	0.2414	2.87	0.004	***	d8	1.0784	0.1136	9.49	0.000	***
d10	0.0914	0.1812	0.50	0.614		d10	-0.0289	0.1947	-0.15	0.882	
d11	0.6720	0.1549	4.34	0.000	***	d11	0.5369	0.1693	3.17	0.002	***
d12	0.5412	0.1584	3.42	0.001	***	d12	0.4524	0.1740	2.60	0.009	***
d13	0.1651	0.1297	1.27	0.203		d13	0.1287	0.1427	0.90	0.367	
constant	-162.9671	49.7249	-3.28	0.001	***	constant	-166.2991	54.5022	-3.05	0.002	***
R-sq	within	0.9091				R-sq	within	0.9081			
	between	0.4140					between	0.9363			
	overall	0.7922					overall	0.9122			
F test that all u_i=0	F(3,219)	17.11				Hausman Test	chi2(11)	24.63			
	Prob>F	0.000					Prob>chi2	0.010			
Number of obs		234				Number of obs		234			
Number of groups		4				Number of groups		4			

Instrumented: price, Instruments: GDP, d1, d3-d6, d8, d10-d13, price[t-1]

***, **, and * indicate the 1%, 5%, and 10% significant level, respectively.

Source: Author

In the random effect model, we utilized the error component two-stage least squares (EC2SLS) method followed by Baltagi [2005], but it was rejected at 10% level by the Hausman test, and thus the fixed effect model was adopted. The elasticity of charges is significant at a 1% level and this satisfies the sign condition. The estimated coefficient of charges is -0.46, and this is not elastic.[7)] The factor of "NTT's manufacturing modem terminal" is omitted from the list of variables used, because it is completely correlated with its individual effect. In what follows, we discuss the results of identifying factors promoting ADSL according to points such as deregulation, competition, and technology, followed by Tsuji and Tomizuka [2006].

(i) Deregulation

"d1: admission of line sharing and dry copper connection charges (December 2000)," "d4: revision and enforcement of Telecommunications Business Law (April 2001)," and "d5: enactment of notification (June 2001)" are categorized into the factors of deregulation. Except the dummy variable d1, all variables of deregulation are significant. The coefficient of d4 (Revision and enforcement of Telecommunications Business Law) is the largest in comparison with all other factors. It can be said, therefore, that deregulation actually promoted the ADSL diffusion by increasing subscribers.

(ii) Competition

Three carriers NTT locals, e-Access, and ACCA except YahooBB provide network services to ISPs, such as @nifty, Biglobe, and So-net. In stead of these carriers, ISPs compete with each other for obtaining subscribes. Business strategies achieving subscribers are related to ISPs, not three carriers. In this sense, it is not desirable for the estimation to include factors of each ISP's marketing strategies. Only YahooBB, on the other hand, owns ISP services. For this reason, marketing strategies of YahooBB are included among dummy variables. Except factors of carriers' launching new services, all dummy variables related three carriers take 0.

The factors of competition extracted by the estimation are as follows: "d1: new

service launch of NTT east and west," "d6: new service launch of YahooBB," and "d8: two-month free trial campaign by YahooBB". Generally speaking, new service launched by one carrier causes negative effects to subscribers of other carriers. The estimation result, however, shows that the sign of factor d6 (new service launched by YahooBB) is significantly positive. This can be interpreted as follows: the elasticity of charges is low in the ADSL market, and this implies that users rarely change their carriers. The entrance YahooBB into the market expanded and vitalized the whole market, and this leads to other carriers obtaining new subscribers. "d8: two-month free trial campaign by YahooBB" is also positive at a 1% significance level, and it can be said that the campaign was successful. In spite of fact that this dummy variable is attached to only YahooBB, the estimated coefficient is rather large, and this shows strong power of YahooBB at that time.

(iii) Technology

Technological development of ADSL has been occurring continuously, especially those related to connection speed, as shown in Table 2. According to the result, 12Mbps service (d11) has the largest coefficient 0.6920 with the 1% significance level. 24Mbps service (d12) is also large 0.5412 with the 1% significance level, and followed by 12Mbps. 40Mbps service (d13) is not significant. The results related to different connection speed are interesting. Generally speaking, the higher speed of connection service is launched, the number of subscribers of this particular speed increases. The result we obtained, however, is converse. One possible interpretation is that users are not concerned with such high speed connection; since most data can be transmitted smoothly with around 1Mbps.[8)]

5. ESTIMATION II: INDIVIDUAL EFFECTS TO EACH CARRIERS

A problem of estimation in this paper is related to multicollinearity, or correlation of independent variables. As our data covers from its beginning, the effect of trends tend to be dominant. Adopting the panel data analysis is one solution of this problem, but it

is serious in estimation of each carrier due to the shortage of samples. Following the panel estimation, we omitted variables with correlation coefficient over 0.8, and tested whether multicollinearity exists by using VIF (Variance Inflation Factor). Generally speaking, multicollinearity is said to exist if VIF indicates over 10. We omitted variables to an extent that their mean of VIF becomes less than 10 and calculated this for each carrier. The results of estimation are summarized as follows:

Every carrier satisfies the sign condition of their prices significantly, and they are around -0.6 to -0.7. This estimation shows an interesting result. Carrier A provides only network connection services, which is the least elastic in its price. As shown in the Figure 2, its subscription charges are the highest among four. Carrier B, on the other hand, which provides all service has the highest elasticity of price. This is because it serves the lowest subscription charges in contrast with carrier A, since it is of vertical integration.

The number of dummy variables is reduced due to multicollinearity. Almost all variables of the factors of deregulation are significant at a level under 1%, which shows that deregulations promoted Japanese ADSL development. In the panel data estimation, “Revision and enforcement of Telecommunications Business Law (April 2001),” has the largest coefficient, and this policy affected Carrier C and D to increase their subscribers, which do not posse their own ADSL network. This estimation clarifies again that the revision of Telecommunications Business Law including the political settlement of unbundling contributed mostly the diffusion of Japanese ADSL.

Related to factors of innovation, all carriers except Carrier B have positive and the largest coefficients with respect to 12Mbps service significantly. Again, it can be said that connection speed and the number of subscribers are not correlated with each other. Now let us examine the results of each carrier in more detail.

(i) Carrier A

As noted earlier, Carrier A provides only line connection services and is independent of ISPs, and these leads to its subscription charges the highest. Actually it has the least elasticity of price among four carriers. “d6: new service launched by

YahooBB" effected to raise the number of its subscribers, although YahooBB was a new entrant to the market and a new competitor to this carrier. This can be interpreted by the fact that its entry to the market promoted the growth of the whole market and it had the strong synergy effect. Innovation of connection speed seems to have no effect to Carrier A, but only 12Mbps service affected significantly. All these indicated that Carrier A might have strong brand images and this brought the stability of the number of subscribers.

Table 7: Result of Estimation (Carrier A)

dependent variable: Subscriber of ADSL					
	Coef.	Std. Err.	t-value	p-value	
price	-0.5635	0.0839	-6.72	0.000	***
GDP	6.3754	3.7196	1.71	0.092	*
d6	1.1146	0.2007	5.55	0.000	***
d10	-0.0864	0.1526	-0.57	0.574	
d11	0.3382	0.1498	2.26	0.028	**
d12	0.1946	0.1664	1.17	0.247	
d13	-0.0176	0.1218	-0.14	0.885	
constant	-60.2601	45.3545	-1.33	0.189	
	Number of obs		63		
	Adj R-sq		0.9440		
	Durbin-Watson		0.8125		
	Mean VIF		4.61		

***, **, and * indicate the 1%, 5%, and 10% significant level, respectively.

Source: Author

(ii) Carrier B

The elasticity of charges of Carrier B is the largest, and this is because Carrier B was a latecomer to the market and entered the market with far low charges, that is, low charges was its strategy to obtain subscribers. Another reason of its high elasticity is its achieving high efficiency of management due to vertical integration. The factor, "d7: inauguration of Telecommunications Business Dispute Settlement Commission" is strongly significant for carrier B. The aim of the commission at that time was related to interconnection charges of ADSL, which is important for serving low subscription charges. Factors of technological innovation such as connection speed were not significant to Carrier B, which implies that subscribers chose Carrier B mainly from low

charges.

Table 8: Result of Estimation (Carrier B)

dependent variable: Subscriber of ADSL					
	Coef.	Std. Err.	t-value	p-value	
price	-0.7728	0.1268	-6.09	0.000	***
d7	2.0973	0.1828	11.47	0.000	***
d9	0.8012	0.1692	4.73	0.000	***
d11	0.2113	0.1481	1.43	0.162	
d12	0.1491	0.1298	1.15	0.258	
d13	-0.0491	0.1015	-0.48	0.631	
constant	15.5709	0.7333	21.23	0.000	***
	Number of obs		42		
	Adj R-sq		0.9561		
	Durbin-Watson		1.3642		
	Mean VIF		3.11		

***, **, and * indicate the 1%, 5%, and 10% significant level, respectively.

Source: Author

(iii) Carrier C and D

Carrier C and D are referred to as “wholesale type,” and they wholesale their lines to ISPs, which actually engage in marketing to subscribers. In this sense, they are different from Carrier A and B. Another difference can be found in factors of innovation. 12Mbps and 24Mbps services are estimated to be significant to Carrier C and D. The factors of deregulations such as “d4: revision of Telecommunication Business Law,” or “d5: enactment of notification” especially affected on both carriers. Main objectives of deregulation were to promote market competition and encourage new entrants, and in this sense, deregulations on the ADSL market are considered to be successful from our estimations.

Table 9: Result of Estimation (Carrier C)

dependent variable: Subscriber of ADSL					
	Coef.	Std. Err.	t-value	p-value	
price	-0.6854	0.1003	-6.83	0.000	***
GDP	10.6795	4.9282	2.17	0.035	**
d1	2.2211	0.2845	7.81	0.000	***
d4	1.2891	0.2890	4.46	0.000	***
d5	0.5980	0.3000	1.99	0.051	*
d6	0.1624	0.3209	0.51	0.615	
d10	0.1564	0.2041	0.77	0.447	
d11	0.8729	0.1822	4.79	0.000	***
d12	0.5296	0.2143	2.47	0.017	**
d13	0.1832	0.2144	0.85	0.397	
constant	-116.1690	60.0477	-1.93	0.058	
	Number of obs		66		
	Adj R-sq		0.9755		
	Durbin-Watson		1.3576		
	Mean VIF		5.71		

***, **, and * indicate the 1%, 5%, and 10% significant level, respectively.

Source: Author

Table 10: Result of Estimation (Carrier D)

dependent variable: Subscriber of ADSL					
	Coef.	Std. Err.	t-value	p-value	
price	-0.7017	0.1151	-6.10	0.000	***
GDP	7.4192	4.0630	1.83	0.073	*
d4	2.2869	0.3413	6.70	0.000	***
d5	1.3849	0.3344	4.14	0.000	***
d7	2.1145	0.2518	8.40	0.000	***
d10	0.4155	0.2288	1.82	0.075	*
d11	0.9179	0.2149	4.27	0.000	***
d12	0.5446	0.1863	2.92	0.005	***
constant	-78.6117	49.3710	-1.59	0.117	
	Number of obs		65		
	Adj R-sq		0.9727		
	Durbin-Watson		1.8016		
	Mean VIF		4.52		

***, **, and * indicate the 1%, 5%, and 10% significant level, respectively.

Source: Author

6. CONCLUSION

By utilizing the rigorous Panel Data Analysis, we heuristically identified factors promoting Japanese ADSL. Let us describe the brief conclusions of the analysis. The paper shows that the deregulation of "Revision and enforcement of Telecommunications Business Law (April 2001)," which coefficient is 1.5998 with the 1% significance level, mainly promoted Japanese ADSL, and as for factors related to competition, "Entrance of YahooBB into the market" has the important effect with coefficient of 1.2913 at a 1% significance level. Regarding technological factors, "12Mbps services started" is the most effective to the diffusion of ADSL (0.6720 with the 1% significant level), while high-speed services are not necessarily demanded by users. From these discussions, we can interpret Figure 1, in which there are three big jumps in its growth, namely, before June 2001, from September 2001 to January 2002, and from October 2002 to January 2003. From the results of our analysis, three factors occurred in such a way that "Revision and enforcement of Telecommunications Business Law" in April 2001, "Entrance of YahooBB into the market" in September 2001, and "12Mbps services started" in October/November 2002. These factors coincide with three big jumps of increase in ADSL subscribers. It follows thus that the first sharp increase was due to deregulations, the second jump was caused by market competition inspired by previous deregulations, and the third one by technological development.[9)]

Another result is related to the elasticity of price of the carriers, which are different among carriers, that is, Carrier A has the smallest elasticity (-0.5635) with the 1% significance level, while Carrier B the largest (-0.7728) with the 1% significance level. This difference might come from their pricing, and marketing strategies and the managerial organization such as whether they provide ISP services or not. Although these results are reliable because they are based on the data of actual subscribers, this analysis does include all factors related to the ADSL diffusion in the model mainly due to multicollinearity. In addition, ADSL developed quite rapidly in the short period, and the effect of trends seems be strong and might affect our results. Some new idea such as utilizing time difference data might be required. As mentioned earlier, FTTH and CATV affect ADSL development, and the estimation of whole broadband subscribers is

required to conduct, which is one aim of the future research. [10)]

One of the issues related to Japanese FTTH is dominance of NNT in the market. There are two sub-markets of FTTH, namely, that of condominium and single house. In the former market, the share is as follows: NTT locals (52%), Power companies (20%), KDDI (5%), and USEN (7%), as of December 2006, while as for the latter market, NTT locals (76%), Power companies (22%) and KDDI (4%). NTT's share is gradually increasing, and there is an anxiety on NTT to hold a market control. There is one big difference regarding competition in the FTTH market in comparison with ADSL, that is, basically carriers have to deploy optical fiber to single houses or condominiums by themselves, since there was no line sharing like ADSL. This is the reason why carriers other than NTT locals target mainly condominium. In 2005, the "shared access system" was in effect, in which carriers can barrow NTT locals' optical fiber. This system, however, does not work well like the line sharing of ADSL. Thus, more deregulations are required for promoting competition in the FTTH market. The Japanese success of ADSL development is because of good cycle of deregulations and market competition: deregulations caused competition, while competition requested further deregulations. After all, subscribers (consumers) can obtain economic benefits. This is an exactly lesson learned from the Japanese ADSL experience. The lessons learned from ADSL are not fully applied for this market.

Finally, when we consider an application of this analysis on ADSL to FTTH, the number of major FTTH carriers is four, that is, NTT locals, Power Companies, USEN and KDDI, which is not so different from that of ADSL. But NTT's share is much larger, and the same estimation might not apply. In this case, one alternative method is to estimate the broadband market as a whole, as Tanaka, Yazaki, Murakami [2004]. All related carriers and operators in telecommunications market such as ADSL, FTTH, and CATV must be included.

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NOTES

1) ADSL is required to connect to local subscriber's line, which is owned by NTT locals. ISPs have to install ADSL equipment at NTT's telephone offices. The NTT locals have advantages as incumbent operators. Moreover, NTT had a strategy to promote ISDN instead of ADSL, and claimed that the latter disturbed the former. Thus, it took a time to settle this technological problem, and it is said that this made delay in starting Japanese ADSL services. Almost all deregulations regarding ADSL were related to restrict NTT locals to enforce fair competition.

2) The charge of dry copper is calculated by historical costs, not by long-run incremental costs. NTT locals claim that those are set too low to cover actual costs. But it is true that ADSL development became possible because of this, as we can analyze in this paper (see Tsuji [2005] in more detail)

3) The charge of dark fiber is based on the long-run pricing, that is, the time period of pricing is set to be several years and future demand for optical fibers will be increasing. Again, NTT locals claim that the charge is too low to cover actual costs.

4) Regarding the business strategy of Yahoo! BB, extensive analysis can be found in Tsuji [2003], for example. ADSL services were the company's first business in the telecommunications market.

5) Even Yahoo! BB has been suffering negative profit from the beginning. It is only recent that its profit turned to be positive.

6) There are always problems regarding charges for empirical studies, since telecommunications carriers tend to have various charges plan to enclose customers. The weighted average of different charges is theoretically desirable, but pricing plans are so complicated and no data for the share of different services are published. Due to these reasons, we assume that subscribers choose the highest speed services.

7) MIC [2007] obtains elasticity of price based on the discrete choice model such that 0.289 in 2003, 0.439 in 2005, and 0.763 in 2006. The average of these three is 0.497,

which is similar to our result (0.464).

8) This result reveals one of the week points of ADSL, that is, transmission loss. The farther a distance from home to the Telephone office becomes, the weaker transmission signals become, which causes decline in connection speed. Therefore, such high-speed services benefit only a part of users near the base station. Another reason for this result is considered as follows. When we need high speed connection, we had better select FTTH which is more stable in connection speed than ADSL.

9) See Tsuji and Tomizuka [2007].

10) In Japan, the number of FTTH subscribers has been increasing rapidly. In this section, we will discuss issues related to its diffusion and the Next Generation Network (NGN). The number of FTTH subscriber of NTT locals, which is referred to as "B Flet's," exceeded that of their ADSL in December 2006. The number of Their ADSL subscribers, on the other hand, has been decreasing since June 2006 when it reached the peak, and these indicate that so-called migration from ADSL to FTTH has been occurring. A migration analysis by MIC [2005] revealed that most of subscribers of narrowband such as ISDN as well as the most of ADSL heavy users have a strong intension to change to FTTH and actually had migrated. Since FTTH can transmit and receive a large volume of data at one time, it is suitable to the NGN.

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