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## TOPICS

### A Study of Efficiency of the Telecommunication Industry in the Asia-Pacific Countries

#### Introduction

It has been a while since the world's major countries introduced privatization to their telecommunications business. At present, it has become widespread, not just in the industrialized countries but also in many developing countries. With these moves towards privatization, have there been improvements in the efficiency of the telecommunications business both in developed and developing countries? With regard to this matter, there are very few actual examples of studies that have analyzed the telecommunication business in developing countries. In looking at efforts in recent years to bridge the digital divide on an international scale as well as developments in ICT technology, and the fact that the business operations of telecommunications operators that provide the core infrastructure for the telecommunications business have a major impact on a country's informatization and its economic growth, the measures that maintain and enable the efficiency and good health of the business become important.\*1 Consequently, it can be concluded that looking at concrete factors that improve efficiency in the

telecommunications business is a useful exercise for investigating such measures.

A study of Efficiency Comparison of the Telecommunications Industry among the Asia-Pacific Region Countries was conducted, based on awareness of these problems, and the results to date were announced in May 2009 as a discussion paper from MIC's Institute for Information and Communications Policy.\*2 This document provides an explanatory outline of this paper.

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A Study of Efficiency of the Telecommunication Industry in the Asia-Pacific Countries

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Waseda University, and the discussion paper referred to above was compiled by all four members. In addition, the original discussion paper was written in English and is aimed at statistical analysis specialists, without taking non-specialized readers into consideration. By offering more detailed explanations than the discussion paper concerning analysis methods and results of estimations, this text aims to broaden awareness of the study results.

**Outline of Goals of Study and Research Methods**

The goals of this study consist of comparing the efficiency of the telecommunications business across Asia-Pacific countries, and analyzing the factors of differences in these efficiencies. In addition to industrially advanced countries such as the United States or Japan, the Asia-Pacific region also includes countries that are still under development. Since the 1990s, elements such as the rapid penetration of mobile communications through mobile phones and the shift to IP in networks have led to rapid changes in the market environment for the telecommunications business. In the light of these changes,

differences may emerge in the measure sought based on each country's economic environment and particular circumstances. For example, whereas there are countries that have already solved all of the peripheral problems (growing period of time from application for the service to actual start of service), others have not and in the countries that have not resolved these issues, dealing with such peripheral problems is probably the key to efficiency in the telecommunication business. In order to conduct a concrete analysis of factors relating to efficiency while taking these variations in market environment into consideration, estimates for production function were obtained using stochastic frontier analysis.

Stochastic frontier analysis is a method that enables the distinction of the degree of efficient usage of the input elements that are required for output, in terms of each entity's economic activity. By using this method, it becomes possible to place a value ranging from 0 to 1 to each entity. The closer the value is to 1, the greater the efficiency, with 1 being the frontier. Shown below is an intuitive explanation of production function as per stochastic function analysis. Firstly, the production function is

shown as this:

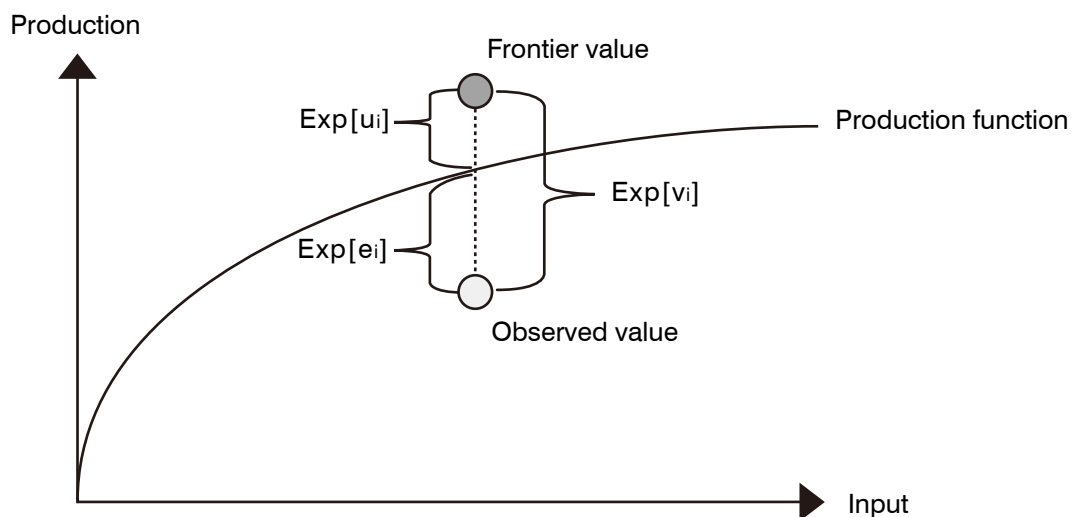
$$\ln Y_i = \alpha + \beta_1 K_i + \beta_2 L_i + e_i \dots (1)$$

In this, Y designates net added value, K is capital stock, L is the number of employees, and e is the error term. Stochastic frontier analysis is an analysis method that also takes into consideration the entities that are conducting inefficient production activities, and makes it possible to conduct relative comparisons of entities conducting frontier production and those not doing so, using as the frontier the efficient entity that is producing the best possible output given the technology against the input. In stochastic frontier analysis, the error term in (1) formula is classified as follows.

$$e_i = v_i - u_i \dots (2)$$

$v_i$  is the error term associated with the regular distribution assumed by the OLS (Ordinary Least Square) method,  $u_i$  is the term that shows deviation from the production frontier that has been obtained by the technical inefficiency. Figure 1 gives an intuitive image of this relationship as an example of cross-section analysis.

**Figure 1: Outline image of stochastic frontier analysis**



The deviation  $\text{Exp}[e_i]$  from the production function is broken down by  $\text{Exp}[v_i]$  and technical inefficiency  $\text{Exp}[u_i]$ . In stochastic frontier analysis, it is possible to estimate the  $u_i$  of each of the economic entities that are being analyzed, and the fact that, through this, it becomes possible to do a comparative ranking of efficiency, can be said to be the advantage of stochastic frontier analysis.  $u_i$  is hereinafter referred to as TE (Technical Efficiency).

In addition, this study used data from 1993 to 2006, and has made estimates according to panel data. Panel data refers to data that has been continuously examining the same target. That is to say, data that records multiple targets at one point in time is cross-section data, whereas time series data is data on a set time period for a single economic entity, and panel data can be said to be a combination of cross-section data and time series data.\*3 This report uses panel data in an ongoing manner in order to estimate stochastic frontier production function.

In terms of similar actual studies that have targeted the telecommunications business, one can start by mentioning Battistoni et al. (2006). Battistoni et al. (2006) targeted the EU countries and estimated the stochastic frontier Translog cost function covering 1995 to 2002, and found that the TE of new EU member countries was rather higher than that of existing members.\*4 In the same way, Erber (2006) estimated the stochastic frontier Translog and Cobb-Douglas production function for four EU countries (Germany, France, the UK and the Netherlands) for the period from 1981 to 2002 and, at that stage, went with carrying out his analysis after breaking down capital stock into ICT capital stock and non-ICT capital stock. According to this, it

became clear that ICT capital stock made a significantly positive contribution to the telecommunications business.

However, many of the existing analyses look at industrialized countries, and one could say that, at this time, very few analyses include developing countries in the field of vision. That is why this study, in looking at the Asia-Pacific region, focuses on the telecommunications business in developing countries and looks to make a comparison between industrialized and developing countries.

### The Data Used and the Analysis Model

First of all, for the estimation, the Cobb-Douglas stochastic frontier production function method was used.\*5

$$\ln Q_{it} = \beta_0 + \beta_K \ln K_{it} + \beta_L \ln L_{it} + \beta_M \ln M_{it} + v_{it} - u_{it} \dots (3)$$

$Q$  refers to output of the telecommunications business,  $K$  is capital stock,  $L$  is labor power, and  $M$  is the raw material, all referring to  $i$  country in  $i$  year.

A number of estimation methods are suggested for this type of stochastic frontier production function using a panel data, but these estimates were conducted based on Battese and Coelli (1995). In Battese and Coelli (1995), it is possible to do the estimates while taking into consideration the variables that affect the value of TE, and in that case, the calculation method for TE is as shown below.

$$TE_{it} = \frac{Q_{it}}{\beta_0 K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M} \exp(v)_{iy}} = - \exp(-u)_{it} \dots (4)$$

In terms of generating data, this document applies the semi-macro, or industrial level to data. This means that that it is a value for the entire telecommunications

business in each country. In estimating stochastic frontier production function, the following databases were used. These are the WDI (World Development Indicator), the World Telecommunications / ICT Indicators Database, and PWT (Pen World Table) version 6.2. Using these, the data was organized as shown below.

### (1) Output

Output means actual gross production at year 2000 prices for the telecommunications business. There are countries in the Asia-Pacific region where it is not possible to obtain the deflator, and so the deflators used in constructing actual output were those of the WDI and GDP.

### (2) Capital stock

For capital stock, this was estimated as a rule using the PE (Perpetual Inventory) method. In the PI method, for the level of capital stock at a given point in time, the annual investment amount within the durable years is considered gross capital stock, and the total of the investment amount after deducting the total capital depletion over the durable years becomes net capital stock. This method can be said to be the most widely used in estimating capital stock. The PI method can be also shown as below.

$$\sum_{t=0}^T I_t (1 - \delta)^{T-t} \dots (5)$$

$I$  is actual telecommunications business investment amounts at year 2000 prices.  $\delta$  is the depreciation rate of 0.115 from the KLEMS Database.\*6  $T$  refers to the durable years and has been set at 18 as in "Social Capital of Japan" from the Cabinet Office.

### (3) Labor power

The number of telecommunications business operators was used.

**(4) Raw materials**

Since it is not possible to obtain public data on raw materials data, the total value for fixed telephone subscribers and mobile

communication subscribers was used as a proxy for the raw materials. According to Nemoto and Asai (2002), the expenses for the raw materials vary

proportionally to the subscribers.

The descriptive statistics for the above data are as per Table 1 below.

**Table 1: Descriptive statistics**

	1993	1994	1995	1996	1997	1998	1999	2000	2001
<b>Output (million US\$)</b>									
Mean	16,600	17,082	19,078	21,108	24,105	26,075	28,895	33,521	35,000
Standard deviation	41,095	41,668	43,596	46,839	55,671	59,110	63,871	70,424	71,642
Minimum	11.39	18.28	25.78	37.85	63.04	92.53	127.82	187.18	215.92
Maximum	175,735	182,783	189,782	202,461	242,282	255,401	274,358	292,762	294,701
<b>Capital stock (million US\$)</b>									
Mean	25,019	26,046	28,597	31,104	33,759	37,805	42,290	52,227	56,718
Standard deviation	46,833	46,229	47,965	49,955	52,226	60,159	69,350	92,686	101,599
Minimum	16.22	32.84	34.81	72.18	115.69	113.17	104.27	101.14	99.27
Maximum	185,070	184,899	185,205	184,107	183,693	211,197	244,578	304,349	330,536
<b>Labor power (thousand people)</b>									
Mean	132	132	133	136	136	136	153	157	167
Standard deviation	231	244	246	250	261	269	302	317	330
Minimum	1.01	1.03	0.98	0.99	0.99	0.96	0.96	1.00	1.24
Maximum	879	961	976	997	1,060	1,108	1,180	1,263	1,302
<b>Raw materials (million US\$)</b>									
Mean	16.68	17.87	20.56	24.01	27.69	31.52	37.50	55.28	64.50
Standard deviation	39.49	41.64	45.76	50.89	56.46	62.34	71.02	113.56	136.08
Minimum	0.07	0.07	0.08	0.08	0.09	0.11	0.14	0.27	0.32
Maximum	164.12	177.58	193.44	210.49	229.18	249.06	275.55	420.23	532.70

Source: ITU World Telecommunication/ICT Indicators Database

### Estimation Results for Stochastic Frontier Production Function

The estimation results for the stochastic frontier Cobb-Douglas production function using the panel data as referenced in Battese and Coelli (1995) are as

shown in Table 2.\*7 As shown in Table 2, the estimated production factor parameters are all significantly positive, and the estimated value of capital stock shows a value higher than those of other elements. This was also consistent with the feature that the

telecommunications business is a capital intensive industry. And the total of the estimated value of all the parameters ( $\beta_K + \beta_L + \beta_M$ ) being under 1 ( $0.6535 + 0.1200 + 0.1222 = 0.8957$ ), showed diminishing returns. These results are consistent with Erber (2006).

**Table 2: Estimation results for stochastic frontier production function**

Parameters	Coefficient	t value
$\beta_0$	5.1024	8.0177
$\beta_K$	0.6535	16.3889
$\beta_L$	0.1200	2.5238
$\beta_M$	0.1222	2.4604
$\delta_s^2$	0.0989	4.9028
$\gamma$	0.7038	22.0077
$\mu$	0.5277	3.3337
$\eta$	0.0377	3.2291
log likelihood function	27.5221	

Next, Table 3 shows the results of hypothesis testing concerning stochastic frontier analysis. By rejecting the null hypothesis (1) (the hypothesis that must ultimately be rejected) in Table 3,

a result was obtained showing that it was desirable to conduct the stochastic frontier analysis that was shown in Battese and Coelli (1995). And so, by rejecting the null hypothesis (2), it became

clear that  $u_{it}$  follows the half normal distribution or truncated normal distribution. Finally, by rejecting the null hypothesis (3), the result indicates that  $u_{it}$  varies over an estimated period of time.

**Table 3: Hypothesis testing**

Null hypothesis	$X^2$ statistics	Critical $X^2_{v, 0.95}$	
(1) $H_0: \gamma = \mu = \eta = 0$	148.0372	$X^2_{3, 0.95} = 7.045$	Rejecting $H_0$
(2) $H_0: \mu = 0$	5.9961	$X^2_{1, 0.95} = 3.841$	Rejecting $H_0$
(3) $H: \eta = 0$	6.5076	$X^2_{1, 0.95} = 3.841$	Rejecting $H_0$

NB: Kodde and Palm (1986) Table 1 was used for the  $X^2_{v, 0.95}$  values.

**Efficiency Analysis**

Since the estimation results for stochastic frontier production

function that were obtained this time from panel data were valid, the TE for each year and each

country was calculated based on formula (4) and shown in Table 4.

**Table 4: Hypothesis testing**

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Australia	0.454	0.467	0.481	0.494	0.507	0.520	0.533	0.545	0.557	0.570	0.582	N.A	0.605	N.A
China	0.320	0.334	0.348	0.362	0.376	0.389	0.403	N.A	N.A	0.444	0.458	0.471	0.484	0.498
Hong Kong	0.578	0.590	0.601	0.613	0.624	0.635	0.646	0.656	0.666	0.676	0.686	0.696	0.705	0.714
Indonesia	0.296	0.310	0.324	0.337	0.351	0.365	0.379	0.393	0.406	0.420	0.434	0.447	N.A	N.A
Japan	0.564	0.576	0.588	0.600	0.611	0.622	0.633	0.644	0.655	0.665	0.675	0.685	0.695	N.A
Korea	0.386	0.400	0.414	0.427	0.441	0.455	0.468	0.481	0.494	0.507	0.520	0.533	0.546	0.558
Taiwan	0.368	0.382	0.396	0.410	0.423	0.437	0.450	0.464	0.477	0.490	0.504	N.A	N.A	N.A
Malaysia	0.367	0.381	0.395	0.409	0.423	0.436	0.450	0.463	0.477	0.490	0.503	0.516	N.A	N.A
Macau	0.341	0.355	0.369	0.383	0.397	0.410	0.424	0.438	0.451	0.465	0.478	0.491	0.504	N.A
Mongolia	0.229	0.242	0.255	0.268	0.281	0.295	0.308	0.322	0.336	0.350	0.363	0.377	0.391	0.405
New Zealand	0.517	0.529	0.542	0.554	0.566	0.578	0.590	0.602	0.613	0.624	0.635	0.646	0.657	N.A
Philippines	0.271	0.284	0.298	0.311	0.325	0.339	0.353	0.367	0.380	0.394	0.408	N.A	N.A	N.A
Singapore	0.620	0.631	0.642	0.653	0.663	0.673	0.683	0.693	0.702	0.711	0.720	0.729	N.A	N.A
Thailand	N.A	0.358	0.372	0.386	0.400	0.414	0.427	0.441	0.455	0.468	0.481	0.494	N.A	N.A
Bangladesh	0.294	0.307	0.311	0.335	0.348	0.362	0.376	0.390	0.404	N.A	N.A	N.A	N.A	N.A
India	0.273	0.287	0.300	0.314	0.328	0.341	0.355	0.369	0.383	N.A	N.A	N.A	N.A	N.A
Pakistan	0.257	0.270	0.284	0.297	0.311	0.325	0.338	0.352	0.366	0.380	0.394	0.407	0.421	0.435
Sri Lanka	0.232	0.245	0.258	0.271	0.284	0.298	0.312	0.325	0.339	0.353	N.A	N.A	N.A	N.A
United States	0.943	0.945	0.947	0.949	0.950	0.952	0.954	0.956	0.957	0.959	0.960	0.962	N.A	N.A
Mean	0.406	0.415	0.428	0.441	0.453	0.466	0.478	0.494	0.507	0.527	0.550	0.574	0.556	0.522

The TE of the United States is the highest, making it into the technology frontier. Also, the TE of industrialized countries is noticeably higher than that of developing countries pointing to greater efficiency in the telecommunications business in industrialized countries than in developing countries.

In addition, along with the mean value of TE being on a rising trend, the fact that standard deviation is also on a declining trend shows that the TE gap for the telecommunications business in the Asia-Pacific region is shrinking.

And then, TE factor analysis shown in Table 4 is conducted. The estimated model is as follows.

$$TE_{it} = \alpha_0 + \beta_1 \ln(POP_{it}) + \beta_2(YL_{it}) + \beta_3 MB_{it} + \beta_4 INTP_{it} + \beta_5 Dummy_{it} + u_{it} \dots(6)$$

With  $POP_{it}$  being population, and  $YL_{it}$  GDP per person,  $MB_{it}$  is the ratio of taking mobile phone subscriber numbers as the numerator, and the total of mobile phone subscribers and fixed telephone subscribers as the denominator.  $INTP_{it}$  is Internet penetration rate, and  $Dummy_{it}$  is the privatization dummy. This formula (6) was estimated with a pooling model, fixed effect model, and random effect model.

It is possible to separate  $u_{it}$  in the formula (6) like " $u_{it} = a_i + v_{it}$ ."  $a_i$  is the individual effect of each

economic entity and  $v_{it}$  is the error term that complies with standard assumptions. If this  $a_i$  and  $POP_{it}$ ,  $YL_{it}$ ,  $MB_{it}$ ,  $INTP_{it}$  and  $Dummy_{it}$  which are explanatory variables are uncorrelated, estimations are done with the random effect model and with the fixed effect model if  $a_i$  correlates with the above explanatory variables. Also, if all the  $a_i$  are identical, estimations are done with the pooling model to which the ordinary least square method is applied. With regard to whether  $a_i$  is identical or not, there is a model selection with F test, and Hausman test is used in determining whether to use the fixed effect model or the random effect model. In the F test, the  $a_i$  of all the economic entities is identical, which means that the "individual effect" does not exist, and the desirability of pool data is made into a null hypothesis. If the F value is high enough, this null hypothesis is rejected and the existence of the "individual effect" which is an alternate hypothesis is acknowledged. And in the Hausman test, the chi-square test is used to validate the null hypothesis that  $a_i$  and the explanatory variables are uncorrelated, and if the chi-square value is high enough, the null hypothesis is rejected, and the fixed effect model is used.

Estimation results based on the above framework are shown in Table 5.

Estimated values are mostly

significant, and since the privatization dummy is significantly correct for all of the estimation methods, this indicates that a strategy of privatization leads to greater efficiency in the telecommunications business. And then, using the F test, the subjective individual effect was verified, and then the null hypothesis that the constant terms of all countries are equivalent was rejected, and in addition, the null hypothesis that the explanatory variables are uncorrelated with the subject individual effect was rejected using the Hausman test, and the fixed effect model was used. Since, according to the fixed effect model, the scale of population, the ratio of mobile phone subscribers, the penetration rate for Internet and the privatization dummy are significantly correct, if one follows these estimation results, should the population scale get larger, the penetration of mobile phones and the Internet advance and the privatization of business occur, one could say that the efficiency of the telecommunications business would increase. Also, since, in the fixed effect model, the GDP per person is not significant, the results in Table 5 show that, even in developing countries, it is possible to obtain increases in the efficiency of the telecommunications business by implementing appropriate measures.

**Table 5: Estimation results of formula (6)**

Parameters	Pooling model		Fixed effect model		Random effect model	
	Coefficient	t value	Coefficient	t value	Coefficient	t value
$\alpha_0$	0.0355	0.6518			0.0337	0.2192
$\beta_1$	0.0148	5.2406	0.2511	6.8674	0.0191	2.1887
$\beta_2$	0.0000	17.2609	-0.0000	-06641	0.0000	3.4569
$\beta_3$	0.0663	2.1439	0.1221	12.5482	0.1668	25.1684
$\beta_4$	0.0012	2.8181	0.0003	2.7501	0.0001	0.5215
$\beta_5$	0.0414	2.9127	0.0182	4.4987	0.0228	5.7339
$\bar{R}^2$		0.7687		0.9930		0.5139
	F(96,126)=4453.8 P-value=[0.0000]		CHISQ(5)=85.278 P-value=[0.0000]			

## Conclusion

With the above analysis, it has been shown that the telecommunications business in industrialized countries, led by the United States, is being operated at a greater rate of efficiency than that of developing countries in the Asia-Pacific region. On the other hand, along with showing that a strategy of privatization is effective

when it comes to increasing the efficiency of the telecommunication business, it has been shown that the scale of population, the ratio of subscribers to mobile phones, and the Internet penetration rate all also have a positive effect. In addition, the size of GDP per person does not necessarily contribute to an increase in efficiency, and it has

been verified that developing countries can achieve levels of efficiency that are equal to those in industrialized countries, depending on the strategies they adopt. Consequently, it is necessary to take these characteristics into consideration when devising policies to maintain the efficiency and good health of the telecommunications business.

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### Notes:

(1) Details can be found concerning the relationship between the progress of ICT development and economic growth in Japan in Takemura (2008).

(2) The complete text of the discussion paper can be found at: <http://www.soumu.go.jp/iicp/chousakenkyu/seika/pdf/DP2009-02.pdf>

(3) For example, the international comparison for GDP per person in 2006 is cross-section data, and the change in GDP per person for Japan alone from 1993 to

2006 is time series data. When the two are combined, the international comparison for GDP per person from 1993 to 2006 that is obtained is panel data.

(4) In the Translog format, there is no need to assume prior specific values concerning the flexibility of substitution between production elements, making it more flexible function type. In this text, the Cobb-Douglas format is used, and in the case of Cobb-Douglas, the substitution flexibility is assumed to be 1.

(5) Since the Translog format is

multicollinear, it has been abbreviated here.

(6) Please refer to the following URL with regard to the KLEMS database: <http://www.euklems.net>

(7) FRONTIER 4.1 was used in these estimates. FRONTIER 4.1 was developed at the Center for Efficiency and Productivity Analysis (CEPA) where Coelli and his colleagues work. It can be downloaded free of charge from the following URL: <http://www.uq.edu.au/economics/cepa/frontier.htm>