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DEA AS APPLIED TO PRICE-CAP SETTINGS OF NTT

01302170 National Graduate Institute for Policy Studies TONE Kaoru

1. Introduction

As a part of the deregulation promotion projects of the Japanese Government, the Ministry of Posts and Telecommunications (MPT) has decided to abolish the sanction system for price settings in the telecommunications industry and to shift to a price-cap system starting from October 1, 2000. For the purpose of a smooth transition to the new system, the MPT organized a committee for studying the price-cap system chaired by Professor (Emeritus) Okano. As a member of the committee, the author engaged in the measurement of the cost inefficiency of Nippon Telegraph and Telephone Company (NTT) by using Data Envelopment Analysis (DEA).

2. Price-cap System

There are at least two important factors for deciding the price-cap: the consumer price index (CPI) and the productivity progress index (X-efficiency). The former reflects the trend of consumer prices and the latter relates to price reductions due to advancement in productivity.

The basic formula for deciding the price index in the next year from the current one is as follows.
New Price Index=Current Index $\times(1+CPI-X)$.
Usually we can estimate the CPI from published statistics and the X-efficiency can be obtained by analyzing past performances of enterprises.

3. X-Efficiency

Assume that the update for the price index obtained by the above formula continues for consecutive t years. Then, the revenue at the t-th year will be reduced to $R\times(1+CPI-X)^t$, where R is the predicted revenue at the t-th year. We balance this value with the sum of the cost (C) and reasonable profit (P), the latter including tax for profit, at the t-th year. Thus, we have a balance equation: $R\times(1+CPI-X)^t=C+P$. From this equation we have a formula for determining X-efficiency as,

$$X=1+CPI-\sqrt[t]{\frac{C+P}{R}}. \tag{1}$$

We estimated C, P and R using past data and the medium-range management plan of NTT. The validity of the estimated cost (C) will be checked via DEA as follows.

4. Cost-Efficiency measured by DEA

Suppose that there are n DMUs with m inputs and s outputs. We denote inputs and outputs of DMU_j by $\boldsymbol{x}_j=(x_{1j},\ldots,x_{mj})^T$ and $\boldsymbol{y}_j=(y_{1j},\ldots,y_{sj})^T$, respectively. The input and output data matrices X and Y are defined as $X=(\boldsymbol{x}_1,\boldsymbol{x}_2,\ldots,\boldsymbol{x}_n)$, $Y=(\boldsymbol{y}_1,\boldsymbol{y}_2,\ldots,\boldsymbol{y}_n)$. Let the unit cost of input x_{ij} be c_{ij} and the corresponding cost vector be $\boldsymbol{c}_j=(c_{1j},\ldots,c_{mj})$.

For each DMU_o ($o=1,\ldots,n$), we solve the following LP.

$$\begin{aligned}&\min \boldsymbol{c}_o\boldsymbol{x} \\ &\text{subject to } X\boldsymbol{\lambda}=\boldsymbol{x},\quad Y\boldsymbol{\lambda}\geq\boldsymbol{y}_o,\quad \boldsymbol{\lambda}\geq 0.\end{aligned} \tag{2}$$

With an optimal solution of this LP $(\boldsymbol{x}^*,\boldsymbol{\lambda}^*)$, we define the cost-efficiency τ_o of DMU_o by

$$\text{Cost efficiency } (\tau_o)=\boldsymbol{c}_o\boldsymbol{x}^*/\boldsymbol{c}_o\boldsymbol{x}_o \tag{3}$$

Using the *technical efficiency* θ_o^C, the *allocative efficiency* α_o is defined as the ratio τ_o/θ_o^C. We now define the *scale efficiency* σ_o as the ratio θ_o^C/θ_o^V where θ_o^V is the *pure technical efficiency*. Thus, we have a decomposition of cost efficiency:

$$\text{Cost-efficiency } (\tau_o)=\theta_o^V\times\sigma_o\times\alpha_o \tag{4}$$

Later on we will employ regional adjustments of the cost-efficiency to take account of the scale factor of enterprises. For this purpose, we define the *adjusted cost-efficiency* by dividing the cost efficiency by the scale efficiency as:

$$\text{Adjusted cost-efficiency } (\rho_o)=\tau_o/\sigma_o=\theta_o^V\times\alpha_o \tag{5}$$

5. Data and Results

We utilized data from five branches: Hokkaido, Tohoku, Tokyo, Kanto and Shin-Etsu belonging to NTT East, and six branches: Hokuriku, Tokai, Kansai, Chugoku, Shikoku and Kyushu belonging to NTT West, for the period 1994-1997. Thus, we have 44 (= 11 branches × 4 years) DMUs for our study. The inputs, outputs and price factors are as follows:
Input(1): Labor, Input(2): Capital, Input(3): Material,

Output(1): Voice transmission, Output(2): Leased lines
Cost(1): Labor, Cost(2): Capital, Cost(3): Material

From these data, we obtained, for each DMU, four efficiency measures: technical (θ^C), pure technical (θ^V), cost (τ) and adjusted cost (ρ).

After adjusting cost efficiency by scale, we find that Hokuriku and Shikoku's positions are considerably advanced, while Tohoku, Chugoku, Hokkaido and Shin-Etu still remain inferior even in scale-adjusted scores.

We obtained the average of the adjusted cost efficiency scores using the cost of branches in NTT East (West) as weight. Table 1 exhibits the inefficiency (= 1− efficiency) of NTT East and West thus obtained.

Table 1: Adjusted Cost-inefficiency through 1994-1997 (%)

	1994	1995	1996	1997	Average
East	15.9	16.8	13.0	6.5	13.0
West	13.4	14.8	12.6	8.3	12.3

6. Cost Reduction Plan by NTT

On November 17, 1999, NTT East and West outlined and announced the "Medium Range Management Improvement Plan." In this plan they tried hard to reduce labor costs, capital investment, material costs and cosigned works consecutively over three years from 2000 to 2002. If this plan is successfully executed, they will have estimated total cost reduction at the fiscal 2002 year as follows: NTT East will reduce costs by about 160 billion yen and NTT West by about 190 billion yen. Adding the cost reductions already attained to these figures, it would be possible for them to reduce costs by about 250 billion yen for NTT East and 300 billion yen for NTT West. These figures are equivalent to 8.7% of NTT East's current costs and 10.1% of NTT West's.

By looking into the adjusted cost inefficiencies scores in Table 1, we can conclude that the above cost reduction plans by the two NTTs are within the range of cost inefficiencies measured by the DEA cost model, and will be attainable by eliminating the cost inefficiencies of both companies.

7. Determination of Price-cap

In order to determine the price-cap we first calculate X-efficiency by using equation (3) that contains CPI (consumer price index), C (cost), P (profit), R (revenue) and t (year) as parameters. For this purpose, we utilized the following values for voice transmission (subscriber line and ISDN) of the NTT East case:

1. CPI=−0.3%
2. t=3 years
3. R=1489.8 billion yen
4. C=1330.8 billion yen that came from the Medium Range Management Improvement Plan by NTT and is ascertained as attainable by DEA as mentioned above.
5. P=84.3 billion

Putting these values in (1), we have

$$X = 1.9\% \quad \text{(for voice transmission of NTT East.)} \tag{6}$$

Thus, we have, for the voice transmission service of NTT East,

$$\text{New Price Index} = 100 \times (1 + CPI - X) = 97.8\%. \tag{7}$$

In the same way, we calculated the price index for the leased line service of NTT East and obtained the new price index 97.6% for this service.

NTT East and West set up their new price system on August 31, 2000 and this system is scheduled to come into effect from October 1, 2000.

The contents of the new price system have the following characteristics: (1) the two companies employed the same price level, (2) they reduced the price gap due to distance differentials and (3) they set a special low rate price for internet service for educational usage.

Table 2 exhibits a summary of the prices employed by NTT East and West, and the price-caps proposed by MPT.

Table 2: Price-cap Indices vs. New NTT Indices

	Voice		Leased line	
	Price-cap	NTT	Price-cap	NTT
East	97.8%	97.4%	97.6%	95.8%
West	97.8%	97.8%	97.6%	96.3%

8. Concluding Remarks

Several remarks will be given at the presentation.

References

[1] Asai, S. and Nemoto, J., "Measuring the Efficiency of Regional Telecommunication Enterprises," (in Japanese) Discussion paper No. 1998-08, Institute for Posts and Telecommunications Policy, 1998.

[2] NERA, *BT Comparative Efficiency Study*, Report prepared for Office of Telecommunications, UK, December 1995.