

Department of Social Systems and Management

Discussion Paper Series

No. 1233

**Evaluating Administrative Efficiency Change in the
Post-Merger Period: A Study on Ibaraki Prefecture
(1979–2004)**

by

Shoko Haneda, Akihiro Hashimoto and Takao Tsuneyoshi

May 2009

UNIVERSITY OF TSUKUBA
Tsukuba, Ibaraki 305-8573
JAPAN

Evaluating administrative efficiency change in the post-merger period: A study on Ibaraki prefecture (1979–2004)

Shoko Haneda^{a,*}, Akihiro Hashimoto^b, Takao Tsuneyoshi^c

^a*Faculty of Business Administration, Komazawa University,
Komazawa, Setagaya, Tokyo 154-8525, Japan*

^b*Department of Social Systems and Management, University of Tsukuba,
Tsukuba, Ibaraki 305-8573, Japan*

^c*Doctoral Program in Social Systems and Management, University of Tsukuba,
Tsukuba, Ibaraki 305-8573, Japan*

Abstract

This paper analyzes the change in municipal administrative efficiency in the post-merger period by using the data of 92 municipalities in Ibaraki prefecture for the period 1979–2004. For this purpose, we employ a nonparametric programming method to compute Data Envelopment Analysis (DEA)/Malmquist indices (MI). These indices are decomposed into two component measures, namely, *catch-up* and *frontier shift* indices. We find that the administrative efficiency in Ibaraki prefecture in the post-merger period is monotonically regressed; however, the efficiency scores of merging municipalities are found to be higher than those of nonmerging ones. The contribution of scale change in the post-merger period is notable in Tsukuba city, which was formed by consolidating small-sized municipalities.

Keywords: Municipal mergers; Data envelopment analysis; Malmquist index; Japanese municipal administration

JEL classification: H72, R11, R50

*Corresponding author. Phone: +81-33-418-9782; fax: +81-33-4188-9435; e-mail address: shaneda@komazawa-u.ac.jp.

1 Introduction

The factors affecting municipal administrations in Japan, such as the declining birthrate, aging population, and financial difficulties faced by both the national and local governments, have changed. In order to take advantage of ongoing decentralization and maintain municipal administrative services, the national government revised the Special Law on Municipal Mergers in 1995 with the aim of promoting voluntary municipal mergers. As the law was to remain in effect only until March 2005, over 700 municipalities completed the required procedures for mergers. The total number of municipalities consequently decreased from 3,229 in 1999 to 1,788 in 2008.

Municipal mergers have been surrounded by controversies. Cross-comparisons of populations of varying sizes carried out in the past have revealed economies of scale in areas with a population of 100,000–200,000 (Yokomichi and Okino, 1996; Saito, 1999). This empirical evidence is consistent with the view that mergers improve the efficiency of the administrative operations and financial management systems of small local governments; therefore, evaluation of efficiency in terms of cost minimization is a criterion for mergers.

Although municipal mergers diversify public services, they also lead to the deterioration of these services. This is because the convenience enjoyed by residents is based on geographical conditions and population structure. Kanazawa (1999) and Yokomichi (2003) present essential public services and facilities as a criterion for mergers. These surveys provide some insight into the determinants of efficiency, that is, the evaluation of efficiency in terms of the characteristics of municipalities. Thus, rather than defining administrative efficiency by means of an ordinary cost function (that is, a parametric approach), we define it by means of a nonparametric approach by considering various specifications of municipalities.

This paper examines the changes in the municipal public services in the pre- and post-merger period in 1979–2004. Our purpose is threefold.

First, we measure the administrative efficiency of municipalities and suggest a criterion for mergers. In the current study, we employ Data Envelopment Analysis (DEA) (e.g., Cooper et al., 2000) by considering two dimensions of public services, that is, *scope* and *quality*. DEA is a nonparametric method for measuring the relative efficiency—known as *DEA efficiency*—of *decision-making units (DMUs)* with multiple *inputs* and *outputs*. In this study, we replace the outputs with indicators that represent the scope and quality of public services, thus allowing for an evaluation of the DMUs' administrative efficiency.

Second, we examine the administrative efficiency change following municipal mergers. In this study, we apply the *DEA/Malmquist Index (DEA/MI)* approach (e.g., Färe et al., 1994; Thanassoulis, 2001)—which is actually a DEA time series analysis—to the DMUs' outputs. The MI is decomposed into two component measures: *catch-up* and *frontier shift*. We use the frontier shift and show the chronological changes in Ibaraki prefecture; moreover, we observe the differences between merging and nonmerging municipalities.

Third, we analyze the scale effect of merged municipalities in the post-merger period. We further decompose the catch-up index into two indices related to efficiency

gains and scale gains in order to clarify the source of efficiency change, that is, to identify the factor that contributes to shifting municipalities closer to the frontier. We select two merging cities, Tsukuba and Hitachinaka, and calculate the cumulative indices using the pre-merger and post-merger periods as our reference points. In terms of scale efficiency change, we examine the extent to which an alteration in scale in the post-merger period contributes to the efficiency change in municipalities.

The results show a notable contribution of evaluation for municipal mergers. We find that regardless of the mergers, the overall performance of Ibaraki prefecture is regressed in 1979–2004, mainly in terms of the frontier shift. However, the efficiency scores of the merging municipalities were greater than those of the nonmerging ones. With regard to Tsukuba city, the scale effect in the post-merger period is largely due to efforts to catch up with the frontier.

The paper is organized as follows. Section 2 introduces the data set employed in this study and discusses the approach for applying DEA to the evaluation of the municipalities. Section 3 briefly explains the basis for the computation of DEA and DEA/MI. Our approach maintains the same sample size in the pre- and post-merger periods. Section 4 explains the calculated efficiency scores of the municipalities with two examples; it contains a prefecture analysis and a comparative analysis of merging and nonmerging. Section 5 summarizes the paper and presents the conclusions.

2 Data

In this section, we briefly explain the municipal mergers in Japan, our views on the municipalities' role of providing local public services, and the data employed in this study.

2.1 Merger and dissolution of municipalities in Japan

Municipal mergers take place in the following two ways: the formation of a *newly established* municipality or by *incorporation*. A newly established municipality is formed when more than two existing municipalities amalgamate with a new one, while incorporation involves at least one municipality being absorbed into another city. The difference between the two is with regard to the extent of municipal incorporation. While an absorbed municipality loses its name, members of the municipal assembly, and municipal regulations, a newly established municipality is able to newly establish these.

Municipalities are classified into four categories on the basis of their population: *an ordinance-designated city*, *a core city*, *a city*, and *a town or village*. The enlargement of a city assembly, which can be authorized in order to plan and execute public works related to public health, urban planning, social welfare, and education, depends on the population (Steiner, 1965). The central government thus encourages mergers with the hope of (1) increased convenience for residents and (2) highly specialized and diversified services.

Consequently, besides increasing the diversification in public services, mergers increase the total number of municipal employees. There are approximately 40 public employees per 1,000 residents in Japan; this is a rather small number considering

that Japan is an advanced country (Tachi, 1998); thus, the public employees have to perform several tasks in addition to their regular ones. With an increase in the number of municipal employees, mergers are expected to lead to greater specialized—something that was difficult to achieve earlier.

While the benefits of mergers are generally emphasized, there exists an opposing view with regard to the quality of public services in the post-merger period. Mergers lead to a deterioration in public services since they reduce the number of municipal employees per resident (Konishi, 2003). The central government decides to maintain a certain level of local public services regardless of the population size, and thus, a municipality with a smaller population needs more public employees per resident, for instance, 1,300–1,400 public workers for 200,000 residents as compared with 60–80 for 5,000 residents. As noted here, diversifications and quality of public services are both essential for evaluating administrative efficiency in the post-merger period.

2.2 Input-Output data

We use the data pertaining to 92 municipalities in Ibaraki prefecture for the period 1979–2004. Ibaraki prefecture is the northern part of the Kanto region and is famous for its energy industry, particularly nuclear energy. As Ibaraki is a community suburb located in the Tokyo region, its population is increasing gradually with the expansion of the Greater Tokyo region.

Fig. 1 chronologically presents the municipal mergers in Ibaraki. The years in which the respective municipalities were founded are indicated in parentheses. Ibaraki experienced 17 mergers within the sample period and 13 of them were after the year 2000. Ten of them were incorporations and the rest were newly established municipalities. As a result of the municipal mergers, the number of municipalities decreased from 92 in 1979 to 62 by the end of 2004; moreover, municipalities with populations of 5,000–20,000 grew from 4.4 percent to 27.4 percent, but those with populations under 5,000 decreased from 19.6 percent to 6.6 percent in the same period. The scope of services, that is, services provided by amalgamated municipalities, increased in the post-merger period¹. As was the case with Mito city, which underwent incorporations twice, and Tsukuba city, which was newly founded with five small villages—both cities had a population of over 200,000 in the post-merger period—they were designated as *special cities* (Tokurei-shi in Japanese), which is a subset of core cities².

The total number of public employees increased in the post-merger period. In Mito city, it increased from 1,727 to 1,969 and in Tsukuba city, from 221 on an average to 1,777. On the contrary, the number of public employees per 1,000 residents of Mito city actually reduced by 0.9 percent and that of Tsukuba city by 1.6 percent in the post-merger period. Although residents of the city will enjoy a greater scope

¹According to Jacobs (2004), the primary purposes behind the authorization of municipal consolidation were to (1) ensure that local administration would be well integrated over a broader geographical area rather than one municipality; (2) allow local governments to provide urban services to their residents in a more flexible and effective manner; and (3) better accommodate the planned devolution of power from the central government to municipalities.

²This category was established by the Local Autonomy Law, article 252, clause 26. They are designated by the Cabinet following a request by the city council and the prefecture assembly.

of services in the post-merger period, the number of public employees who provide these services to them is decreasing.

In this section, we evaluate a municipality as an *efficient administration* that produces more public services with fewer production resources, for example, capital, labor, and assets. We propose the following three dimensions as inputs:

Capital

Total current municipal revenue (thousand yen a year, deflated to the 1995 value)

Labor

Number of public employees (thousand a year)

Assets

Area (square kilometer)

It is important to note that our approach measures multidimensional public services. Therefore, we use two outputs as indicators of public services, thus allowing for an evaluation of the municipalities' administrative efficiency:

Scope of services

Population size (thousand a year)

Quality of services

Number of employees (per ten thousand residents)

The data are sourced from the *Annual Report on Municipal Financial Results* (Tokyo: Ministry of Internal Affairs and Communications) for fiscal years (April 1 – March 31).

3 Methodology

Since DEA is employed as the analytical method in the current study, we present a brief discussion of its underlying characteristics.

3.1 DEA

DEA was first presented in a seminal article by Charnes, Cooper, and Rhodes (*CCR*, 1978). For the past 30 years, the method has enjoyed wide acceptance and application (Boisso et al., 2000; Emrouznejad et al., 2008). Mathematically, the CCR model, in its *weak efficiency* and *ratio* form, generates an efficiency score for DMUs of interest j_0 , g_{j_0} ($0 \leq g_{j_0} \leq 1$). It is formulated as the following fractional program:

$$\begin{aligned} \text{Maximize} \quad & g_{j_0} = \frac{uy_{j_0}}{vx_{j_0}} \\ \text{subject to} \quad & \frac{uy_j}{vx_j} \leq 1, \quad j = 1, \dots, n, \\ & u, v \geq 0, \end{aligned} \tag{1}$$

where

n = number of DMUs,

$y_j = [y_{1j}, \dots, y_{rj}, \dots, y_{tj}] =$ output vector for DMU j ,
 $y_{rj} =$ output r from DMU j ,
 $u = [u_1, \dots, u_r, \dots, u_t] =$ vector of output weights,
 $u_r =$ weight assigned to output r ,
 $t =$ number of outputs,
 $x_j = [x_{1j}, \dots, x_{ij}, \dots, x_{mj}] =$ input vector for DMU j ,
 $x_{ij} =$ input i to DMU j ,
 $v = [v_1, \dots, v_i, \dots, v_m] =$ vector of input weights,
 $v_i =$ weight assigned to input i , and
 $m =$ number of inputs.

Model (1) can be converted to the following linear program (LP), which is essentially the CCR model in its weak efficiency, *input-oriented*, and *envelopment* form:

$$\begin{aligned}
& \text{Minimize} && g_{j_0} = \theta_{CCR} \\
& \text{subject to} && \sum_{j=1}^n \lambda_j y_j \geq y_{j_0}, \\
& && \sum_{j=1}^n \lambda_j x_j - \theta_{CCR} x_{j_0} \leq 0, \\
& && \lambda_j \geq 0, \quad j = 1, \dots, n, \\
& && (\theta \text{ unconstrained}),
\end{aligned} \tag{2}$$

where θ_{CCR} , λ_j ($j = 1, \dots, n$) = model's decision variables. We can generate DEA scores g_{j_0} ($= \theta_{CCR}$) for all DMUs by solving (2) n times, setting each DMU as the target DMU j_0 in turn. Here, DMUs j_0 with the optimum $g_{j_0}^* = 1$ are judged *DEA efficient*, while those with $g_{j_0}^* < 1$ are defined as *DEA inefficient*.

While the CCR model assumes a *constant returns to scale* (RTS) with the input and output, the flexible Banker, Charnes, and Cooper (*BCC*, 1984) mode allows *variable* (increasing, constant, or decreasing) RTS by adding the following restriction to (2):

$$\sum_{j=1}^n \lambda_j = 1. \tag{3}$$

We can generate DEA BCC scores (θ_{BCC}) for DMU j_0 by solving (2) with restriction (3), in which θ_{CCR} is replaced by θ_{BCC} . θ_{BCC} measures technical efficiency, and the following is defined as scale efficiency (*SE*):

$$SE_{j_0} = \frac{\theta_{CCR}}{\theta_{BCC}}. \tag{4}$$

We thus view θ_{CCR} as the combined indicator of technical efficiency and scale efficiency. In the input-oriented DEA here, $SE = 1$ implies that the output is of the *most productive scale size* (*MPSS*). Formula (4) thus measures the appropriateness of the production size for a given DMU to the MPSS.

Table 1 summarizes the yearly average of efficiency scores computed under CCR and BCC; the scale efficiency scores, with standard deviations indicated in parentheses; and the number of DMUs below (and above) the average $\pm 2\sigma$ of the SE distribution. The table indicates that there is a heterogeneity associated with municipal size in the sample period 1979–2004. We observe a marginal decrease in SE from a value of 0.962 to 0.922 for 25 years, and find DMUs in excess below (and above) 2σ of the distribution. The municipalities are now positioned farther from the MPSS.

It is important to note that in the current study, we employ the BCC model by considering the DMU scale rather than the CCR model. We thus compute the MI relative to the BCC frontier (Ray and Desli, 1997) in the following subsection.

3.2 DEA/MI analysis

In this subsection, we examine municipal administrative efficiency change by using a DEA/MI approach, which measures the Malmquist (productivity) index within a DEA framework. This allows for the measurement of the ratio of DEA efficiencies in two different time periods with dynamic/moving efficiency frontiers. The details of this approach are given below.

Fig. 3 illustrates a single input and output DEA case where DMU j_0 was at point A in period α and the connected line $x^\alpha RSTy^\alpha$ indicates the BCC DEA frontier. The input-oriented efficiency of DMU j_0 is then measured by PC/PA (< 1 , DEA inefficient). When point A is on the frontier, its score is 1 (DEA efficient). Suppose that in period β ($\beta > \alpha$), DMU j_0 has moved to point B and the frontier itself has shifted to $x^\beta UVWy^\beta$. The efficiency change in DMU j_0 can be measured by the ratio of its DEA score in period β to that in period α ; however, since the frontier has shifted, we must compute the geometric mean of the ratios for the two frontiers in those same periods. The DEA (BCC input-oriented)/MI for DMU j_0 between periods α and β is given in (5):

$$MI_{j_0}[\alpha, \beta] \equiv \left(\frac{QD/QB}{PC/PA} \cdot \frac{QF/QB}{PE/PA} \right)^{1/2}. \quad (5)$$

Here, $MI > 1$ implies a gain in DEA efficiency by DMU j_0 from period α to β , while $MI = 1$ and $MI < 1$ imply the status quo and loss, respectively.

Transforming (5), the MI can be decomposed into two components as follows:

$$MI_{j_0}[\alpha, \beta] = \frac{QF/QB}{PC/PA} \times \left(\frac{PC}{PE} \cdot \frac{QD}{QF} \right)^{1/2} \quad (6)$$

$$= CU_{j_0}[\alpha, \beta] \times FS_{j_0}[\alpha, \beta] \quad (7)$$

$$= \frac{QF/QB}{PC/PA} \times \left(\frac{PC/PA}{PE/PA} \cdot \frac{QD/QB}{QF/QB} \right)^{1/2}. \quad (8)$$

In the first term on the right-hand side (RHS) of (6), CU indicates the catch-up index; that is $CU > 1$ suggests that DMU j_0 has moved closer to the period β frontier than to the period α frontier. $CU = 1$ and $CU < 1$ thus indicate that the

same distance or more, respectively, has been covered. We define the second term on the RHS of (6) as the frontier shift (FS) index, where $FS > 1$ indicates a gain in the DEA frontier shift from period α to β as measured from DMU j_0 . In other words, the frontier has moved *onward*, generating more output but with less input (again, see Fig. 3). As in the previous cases, $FS = 1$ and $FS < 1$ imply no change and loss (*backward* shift), respectively.

Since PE/PA in Fig. 3 is, for example, the BCC DEA score θ_{BCC} of the period α DMU j_0 measured by means of the period β frontier, we denote it as $\theta_{BCC}[D^\alpha, F^\beta]$. Then, from (8), we obtain the following:

$$MI_{j_0}[\alpha, \beta] = \frac{\theta_{BCC}[D^\beta, F^\beta]}{\theta_{BCC}[D^\alpha, F^\alpha]} \times \left(\frac{\theta_{BCC}[D^\alpha, F^\alpha]}{\theta_{BCC}[D^\alpha, F^\beta]} \cdot \frac{\theta_{BCC}[D^\beta, F^\alpha]}{\theta_{BCC}[D^\beta, F^\beta]} \right)^{1/2}. \quad (9)$$

By letting $x_j^\alpha, y_j^\alpha = x_j, y_j$ respectively, in period α , we can obtain $\theta_{BCC}[D^\alpha, F^\alpha]$ as the optimum of the following LP, which is the classic DEA model:

$$\begin{aligned} & \text{Minimize} && \theta_{BCC} \\ & \text{subject to} && \sum_{j=1}^n \lambda_j y_j^\alpha \geq y_{j_0}^\alpha, \\ & && \sum_{j=1}^n \lambda_j x_j^\alpha - \theta_{BCC} x_{j_0}^\alpha \leq 0, \\ & && \sum_{j=1}^n \lambda_j = 1, \\ & && \lambda_j \geq 0, \quad j, \dots, n, \\ & && (\theta \text{ unconstrained}). \end{aligned} \quad (10)$$

$\theta_{BCC}[D^\beta, F^\beta]$ can also be obtained by the LP in (10) by replacing α with β .

When $\theta_{BCC}[D^\alpha, F^\beta]$ is obtained as the optimum of

$$\begin{aligned} & \text{Minimize} && \theta_{BCC} \\ & \text{subject to} && \sum_{j=1}^n \lambda_j y_j^\beta \geq y_{j_0}^\alpha, \\ & && \sum_{j=1}^n \lambda_j x_j^\beta - \theta_{BCC} x_{j_0}^\alpha \leq 0, \\ & && \sum_{j=1}^n \lambda_j = 1, \\ & && \lambda_j \geq 0, \quad j, \dots, n, \\ & && (\theta \text{ unconstrained}), \end{aligned} \quad (11)$$

this forms the *DEA exclusion model* (Andersen and Petersen, 1993). Finally, we can obtain $\theta_{BCC}[D^\beta, F^\alpha]$ by once again using the DEA exclusion model of (11) with α and β switched.

The BCC input-oriented MI is computed from (9). However, there is a case in which we cannot necessarily compute the MI . In Fig. 3, suppose that in period β ,

DMU j_0 has moved from point A to point B' ; then the value of $\theta_{BCC}[D^\beta, F^\alpha]$ is infinity. Several studies have touched on this “unbounded” problem. One solution is to replace the value with an output-oriented score (González and Gascón, 2004); another solution is to substitute the unbounded value by 1 and omit the observation in the computation of averages (Coelli et al., 1998).

We found that some observations had values of 1 in both the input- and output-oriented scores. Therefore, we substitute the unbounded value by 1.

3.3 Applying data of municipal mergers to DEA/MI

When applying the DEA panel data to the DEA/MI analysis in our research, we should note that the municipality in each year (DMU) is not completely identifiable in the sample period. When municipalities are consolidated or incorporated, some of them are dissolved, while some are newly established. In this study, we deal with this problem as shown in Fig. 2 with two examples.

Tsukuba city was newly established in 1987 by consolidating five villages/towns (Oho, Sakura, Toyosato, Tsukuba, and Yatabe). Fig. 2(1)*a* illustrates that we do not observe data for the five villages/towns after 1987 nor for Tsukuba city prior to 1987. Shown in Fig. 2(1)*b*, we apply the data for Tsukuba city to each of the five villages/towns after 1987 and thus construct full panel data for the five municipalities.

Fig. 2(2) illustrates the case of incorporation. We complete the construction of the full panel data for the two municipalities by applying data for Mito city and Tsunetsumi village after 1992 in a similar manner.

In this way, we specify five data panels of DEA inputs and outputs, each of which represents the 92 municipalities for 26 years (1979–2004), though there is a decrease the total number of municipalities actually observed in the post-merger period. In our empirical application below, we successfully apply these panels to the DEA/MI analysis.

4 DEA analysis of efficient municipal administration

This section shows the result of the DEA/MI analysis of municipalities. We introduce the average frontier shift index, allowing for an administrative efficiency change in Ibaraki prefecture. In addition, we select two merging cities, Tsukuba and Hitachinaka, and examine the main source of their efficiency changes.

4.1 Cumulative MI

By applying our data to the LPs of (10) and (11) and through formulas (7) and (9), we compute $CU_{j_0}[\alpha, \beta]$, $FS_{j_0}[\alpha, \beta]$ and $MI_{j_0}[\alpha, \beta]$. Normally, these indices for year β would be compared to those in the preceding year, that is, $\alpha = \beta - 1$. However, such annually *successive* indices do not seem suitable when we consider the full sample period. We thus propose an alternative index in the spirit of Hashimoto and Haneda (2008). We therefore employ the following parameters in the current analysis: $CU_{j_0}[1979, \beta]$, $FS_{j_0}[1979, \beta]$, and $MI_{j_0}[1979, \beta]$, where $\beta = 1979, \dots, 2004$. We then compare these values to those in the *standard* year 1979, the beginning

of our sample period. Since these indices measure the successive changes from the standard year to year β , we refer to them as *cumulative* indices. Here, the cumulative index values when $\beta = 1979$ are all 1. Färe et al. (1994) used the sequential product of successive indices to demonstrate the cumulative change from a given year. However, as these authors state, the Malmquist index as well as the frontier shift index does not satisfy the circular test, that is, $MI_{j_0}[\alpha, \alpha + 1] \times MI_{j_0}[\alpha + 1, \alpha + 2] \neq MI_{j_0}[\alpha, \alpha + 2]$. In order to avoid this problem and be able to properly compute the cumulative change, we employ the cumulative indices without using the sequential product.

Fig. 4 shows three cumulative indices for Sanwa village and Edosaki town. We note that the base year 1979 each municipality is treated as a separate DMU indicates that the municipalities were all on the efficient administrative frontier. For Sanwa village, the cumulative CU is 1; this indicates that Sanwa has been on the frontier throughout the sample period. From the relation of formula (7), the MI and FS move together. Since the MI implies the administrative efficiency change by considering the frontier shift, the administrative efficiency in 2004 decreased by 22 percent from the base year due to the FS backward. For Edosaki town, having been on the efficiency frontier in the base year 1979, the CU has frequently been better than the efficiency frontier. The MI , moving backward from the base year, thus moves differently from the FS . Thus, our cumulative indices quantitatively show the chronological changes in municipal administrative efficiency.

4.2 Efficiency changes in Ibaraki prefecture

Recall that CU measures the proximity of a municipality j_0 relative to the efficient frontier in each period, the FS indicates the movement of the efficient frontier between two periods, and the MI measures the change in efficiency of a municipality j_0 by considering the frontier shift index as well as the catch-up index.

While the CU_{j_0} and MI_{j_0} indicate the movement of municipality j_0 , the FS_{j_0} indicates the shift of the efficient frontier, which is composed of the most efficient, that is, DEA efficient, municipalities in administration, but not necessarily of municipality j_0 itself. In other words, the FS_{j_0} indicates Ibaraki prefecture's administrative efficiency change as measured from the location (viewpoint) of municipality j_0 . Therefore, we propose the average frontier shift index of all the municipalities, that is, the efficient frontier shift measured from the viewpoint of the average municipalities, as an appropriate indicator to view the efficiency change in administration in Ibaraki prefecture.

Fig. 5 shows the cumulative $FS[1979, \beta]$ on average $\beta = 1979, \dots, 2004$ with base year 1979. It indicates the movement of Ibaraki prefecture's administrative efficiency from the viewpoint of the average municipalities. The administrative efficiency FS backward, the reverse of that shown in Fig. 5, has occurred between 1979 and 2004. Although a recovery is observed in 1984, the administrative efficiency in Ibaraki has almost monotonically been decreasing from 1987 and it finally dropped to 23.1 percent in 2004. This indicates a big loss in the municipal administrative efficiency in Ibaraki for 1979–2004.

In order to examine the impact of municipal mergers, we classify our sample

into merging and nonmerging municipalities and calculate the respective averages. It is important to note that the loss in Ibaraki prefecture’s administrative efficiency regardless of merging is rather apparent. When we consider the average merging municipalities, efficiency shows a marginal regression in the sample period; however, the scores of merging municipalities are slightly higher than those of nonmerging ones.

The CU for merging and nonmerging municipalities explains the difference. Fig. 6 shows the cumulative $CU[1979, \beta]$ on averages $\beta = 1979, \dots, 2004$ with base year 1979. A graph of the merging municipalities indicates that their CU is maintained above 1 in the sample period; thus, they have moved closer to the best practice frontier, which is composed of DEA-efficient DMUs, of period β . The CU for the nonmerging municipalities moved almost the same distance or more relative to the efficient frontier, and the scores are much lower than those of the merging municipalities in the sample period. On the basis of a comparison of their average FS, we conclude, in this regard, that the administrative efficiency of the merging municipalities is better than that of the nonmerging ones for 1979–2004.

4.3 Analysis of merging municipalities

To examine the pattern of administrative efficiency change in both the pre- and post-merger period, we include illustrations of newly established municipalities Tsukuba city and Hitachinaka city (see Figs. 7 and 8, respectively). Tsukuba city was founded in 1987 by consolidating five municipalities with populations under 30,000 (Oho, Sakura, Toyosato, Yatabe, and Tsukuba; Kukisaki was absorbed in 2002). Hitachinaka city was founded in 1994 by consolidating Nakaminato city with approximately 34,000 residents and Katsuta city with 115,000 residents. The population of the two newly established municipalities in 2004 was 191,814 and 151,673, respectively.

Fig. 7 shows Tsukuba city’s cumulative indices relative to the foundation year 1987. A graph after 1987 thus indicates its chronological changes in MI , CU , and FS relative to these values in the foundation year. Since five municipalities were consolidated to form Tsukuba city, five graphs before 1987 show the sequential changes of the three indices using the consolidation as the reference point. Recall that if the cumulative MI or any of its components is less than 1, it indicates a deterioration in the efficiency of a given DMU from the base year; moreover, these indices capture the performance relative to the best practice in the sample, where best practice represents a “a prefecture frontier” in our sample.

Fig. 7 shows that on an average, Tsukuba city’s administrative efficiency regressed slightly in the post-merger period: the cumulative MI was less than 1. The MI indicates Tsukuba’s efficiency change by considering the frontier shift; the figures thus show that the efficiency change was due to FS rather than CU . The cumulative CU was over 1 in the post-merger period, and the merger makes Tsukuba city move closer the yearly efficiency frontier. On the other hand, the cumulative FS was below 1 in the post-merger period. Since frontiers are composed of the most efficient municipalities in the year, Tsukuba city has not been in this list in the post-merger period. From the relation of formula (7), the cumulative MI is almost below 1 in the post-merger period owing to the FS backward.

A comparison with the scores of 1987 reveals that not all the municipalities consolidated into Tsukuba city have improved their administrative efficiency. The cumulative MI was less than 1 for Yatabe and Sakura and above 1 for Toyosato, Tsukuba, and Oho. The CU and FS had marginally increased for Toyosato, Tsukuba, and Oho in the pre-merger period; however, these values had decreased for Yatabe and Sakura. In this regard, Tsukuba city was characterized with administrative efficient and inefficient municipalities. The municipal merger has moved the city closer to the yearly efficient frontier but has not increased the administrative efficiency as compared to the foundation year 1987.

Fig. 8 shows the cumulative indices for Hitachinaka city calculated relative to its foundation year 1994. The values of 1 for cumulated CU imply that Hitachinaka city had been—except for Katsuta in 1979 and Nakaminato in 1992—and has been on the prefecture frontier in the associated year. From the relation of formula (7), MI and FS for Hitachinaka move together. Since the MI indicates its administrative efficiency by considering the frontier shift, the cumulative MI shows that the efficiency first regressed and reached the bottom in a year since the foundation and then it gradually improved. The cumulative MI for Nakaminato and Katsuta gradually decreased but was maintained above 1. We thus note that Hitachinaka city was established after two administrative efficiency cities were consolidated together and that the merger has resulted in much improvement in the administrative efficiency.

4.4 Change in scale efficiency

In this subsection, we assess the impact of municipal mergers on the scale efficiency by applying (4). We compute the DEA CCR/Malmquist index MI^C and decompose the catch-up index CU^C into two components³.

In Fig. 3, line $OC'D'$ and line $OE'F'$ show the CCR DEA frontier in period α and period β , respectively. The MI^C for DMU j_0 between periods α and β is defined as follows:

$$MI_{j_0}^C[\alpha, \beta] \equiv \left(\frac{QD'/QB}{PC'/PA} \cdot \frac{QF'/QB}{PE'/PA} \right)^{1/2}. \quad (12)$$

Likewise from (9),

$$\begin{aligned} MI_{j_0}^C[\alpha, \beta] &= \frac{\theta_{CCR}[D^\beta, F^\beta]}{\theta_{CCR}[D^\alpha, F^\alpha]} \times \left(\frac{\theta_{CCR}[D^\alpha, F^\alpha]}{\theta_{CCR}[D^\alpha, F^\beta]} \cdot \frac{\theta_{CCR}[D^\beta, F^\alpha]}{\theta_{CCR}[D^\beta, F^\beta]} \right)^{1/2} \\ &= CU_{j_0}^C[\alpha, \beta] \times FS_{j_0}^C[\alpha, \beta]. \end{aligned} \quad (13)$$

Here, we enhance the decomposition of CU^C into two components that measure *pure efficiency change (PEC)* and *scale efficiency change (SEC)* (Färe et al., 1994; Ganley and Cubbin, 1992; Ray and Desli, 1997; González and Gascón, 2004). Using (4),

$$SEC_{j_0}[\alpha, \beta] = \frac{\theta_{CCR}[D^\beta, F^\beta]}{\theta_{CCR}[D^\alpha, F^\alpha]} \Big/ \frac{\theta_{BCC}[D^\beta, F^\beta]}{\theta_{BCC}[D^\alpha, F^\alpha]} \quad (14)$$

³Hereafter, we use superscript “C” to indicate CCR and not BCC.

$$= CU_{j_0}^C[\alpha, \beta] / PEC_{j_0}[\alpha, \beta].$$

Therefore,

$$MI_{j_0}^C[\alpha, \beta] = SEC_{j_0}[\alpha, \beta] \times PEC_{j_0}[\alpha, \beta] \times FS_{j_0}^C[\alpha, \beta]. \quad (15)$$

A numerator of the RHS of (14) is $CU^C[\alpha, \beta]$, which is calculated relative to the CCR frontier, and the denominator is $CU[\alpha, \beta]$, which is calculated relative to the BCC frontier, indicating $PEC[\alpha, \beta]$; thus, SEC captures changes in the deviation between the BCC and CCR frontiers. We see a given DMU's SEC between two periods α and β ; for example, $SEC > 1$ suggests that the production size of a interest DMU j_0 moves closer to the MPSS in the sample period. $SEC = 1$ and $SEC < 1$ thus indicate that the same distance or more, respectively, have been covered. In our study, we calculate the cumulative $SEC[\alpha, \beta]$ relative to the foundation year of Tsukuba city and Hitachinaka city, and examine the transition of each city in the post-merger period. The results of the decomposition (15) are shown in Tables 2 and 3.

Table 2 shows the cumulative indices computed under CCR, PEC , and SEC for Tsukuba city. The CU^C and SEC indicate that Tsukuba city has progressed toward the efficiency frontier in the post-merger period, and this was largely due to an enormous increase in the SE . The SEC scores remained above 1 in the post-merger period; this suggests that the merger improved the production size of Tsukuba city and brought it closer to the MPSS. The highest SEC is 1.254 in 1991, which was the fourth year of the merger. This indicates that Tsukuba city was located the closest to the MPSS in the short run.

In contrast to Tsukuba city, Hitachinaka city is characterized by scale inefficiencies in the post-merger period. Table 3 shows the sources of Hitachinaka city's efficiency change in the post-merger period. The values of PEC and SEC show that its efficiency change CU^C was due to PEC rather than SEC . Scale inefficiencies were realized during the first year of the merger: the SEC scores were monotonically decreased from 0.991 in 1995 to 1.929 in 2004, except for the score above 1 in 1996. The results indicates that in the case of Hitachinaka city, the shift in the production size away from the MPSS over the period of 10 years was attributed to its merger; however, in the very short run, the merger moved close to the MPSS.

From the viewpoint of scale efficiency change in the post-merger period, this finding implies that altering a municipal scale has a more dominant effect on the municipal efficiency for Tsukuba city, which was formed by consolidating small-population municipalities, as compared to that for Hitachinaka city. We add that altering a municipal scale is effective for efficiency change in the short run.

5 Summary and conclusions

Our paper extends the research on municipal mergers and suggests a criterion for mergers. We use the DEA/MI analysis by considering multiple dimensions of public services—the scope and quality of municipal outputs—and apply them to 92 municipalities in Ibaraki prefecture for the period 1979 to 2004. We evaluate a DEA-efficient DMU as an efficient administrative municipality and observe the successive

changes in the efficiency for 92 municipalities from 1979 by using the cumulative MI.

The MI indices are decomposed into two component measures: catch-up and frontier shift indices. Since the FS indicates the shift of the efficient frontier, which is composed of the most efficient municipalities in each year, we introduce the average FS of all the municipalities, that is, the efficient frontier shift measured from the view point of the average municipalities in Ibaraki prefecture. The average FS shows that administrative efficiency in Ibaraki prefecture is marginally regressed in the sample period. Mergers do not improve the efficiency; therefore, we conclude that municipal mergers in Ibaraki prefecture do not contribute to the improvement in the administrative efficiency. However, the score of average FS for merging municipalities was slightly higher than that for nonmerging municipalities; this is because merging municipalities moved much closer to the efficient frontier than nonmerging ones in the sample period. To some extent, a comparative analysis of merging and nonmerging municipalities corroborates the results of general cost-minimization studies.

We further decompose the CU into pure efficiency change and scale efficiency change indices to estimate the sources of the DMUs' efficiency change in the post-merger period. Tsukuba city, which was formed by consolidating five small municipalities in 1984, moves closer to the yearly efficient frontier mainly because of scale efficiency changes. However, Hitachinaka city, which was formed by consolidating two cities in 1994, does not show an improvement in efficiency because of these factors. The results, restricted to our sample, indicate that the scale effect does not necessarily contribute to the efficiency change in the post-merger period.

From a methodological point of view, our research involves a unique analysis of municipal mergers. First, we apply the data of a newly established municipality to all the municipalities that were consolidated to form the former. We are able to hold DMUs in the sample time frame and are able to analyze municipal mergers with DEA/MI analysis. Second, we employ the average FS, which is useful for a prefecture analysis. The FS graphically represents the shift in administrative efficiency at a prefecture level. Third, we calculate the cumulative indices using the pre-merger and post-merger periods as our reference points. These indices obviously display the administrative efficiency change of the given merging DMUs and allow for a comparative analysis of municipalities in the pre- and post-merger periods. We especially believe that the cumulative indices in an analysis of municipal mergers allows for new directions in the development and application of DEA/Malmquist index-based models. In this regard, our empirical approach of applying the data of municipal mergers to DEA/MI extends the applicability of the DEA time series analysis and is a giant step toward its evolution.

The results of this study are useful to both residents and policymakers for deciding on municipal mergers. A resident uses cumulative indices relative to the foundation year of a municipality and appreciates that administrative efficiency is significantly improved in the pre-merger period; further, a resident realizes that altering the municipal scale is effective for moving the municipality close to the efficiency frontier by observing the cumulative SEC in the post-merger period. At the same time, a policymaker measures the administrative efficiency change using

multiple dimensions of public services. In addition, a policymaker can infer the change at the prefecture level from the average FS, and evaluate the decision on a merger through a comparison of the FS of merging and nonmerging municipalities. Although the evaluation of municipal mergers is performed *a posteriori*, it is, nonetheless, helpful for formulating and revising policy decisions.

It is important to note that our results depend on the nature of the Input-Output data that we employed. This is a common limitation of empirical studies using DEA “data-oriented ” methods. One must therefore select the DEA inputs and outputs carefully and reasonably. On the other hand, the methodology presented here is applicable to all subjects of DEA besides municipal mergers. One could thus extend a proposed approach to the use of DEA time series and related models.

References

- Andersen, P., Petersen, N.C., 1993. A procedure for ranking efficient units in data envelopment analysis. *Management Science* 39(10), 1261–1264.
- Banker, R.D., Charnes, A., Cooper, W.W., 1984. Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science* 30(9), 1978–1092.
- Boisso, D., Grosskopf, S., Hayes, K., 2000. Productivity and efficiency in the US: Effects of business cycles and public capital. *Regional Science & Urban Economics* 30, 663–681.
- Borger, B., Kerstens, K., 1996. Cost efficiency of Belgian local governments: A comparative analysis of FDH, DEA, and econometric approaches. *Regional Science & Urban Economics* 26, 145–170.
- Charnes, A., Cooper, W.W., Rhodes, E., 1978. Measuring the efficiency of decision making units. *European Journal of Operational Research* 2, 429–444.
- Coelli, T., Rao, D.S.P., Battese, G.E., 1998. *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publisher.
- Cooper, W.W., Seiford, L.M., Tone, K., 2000. *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software*. Boston: Kluwer Academic Publisher.
- Emrouznejad, A., Parker, B.R., Tavares, G., 2008. Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-Economic Planning Sciences* 42(3), 151–157.
- Färe, R., Grosskopf, S., Norris, M., Zhang, Z., 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review* 84(1), 66–83.
- Ganley, J.A., Cubbin, J.S., 1992. *Public Sector Efficiency Measurement: Applications of Data Envelopment Analysis*. North-Holland: Amsterdam.
- González, E., Gascón, F., 2004. Sources of productivity growth in the Spanish pharmaceutical industry (1994–2000). *Research Policy* 33, 735–745.

- Hashimoto, A., Haneda, S., 2008. Measuring the change in R&D efficiency of the Japanese pharmaceutical industry. *Research Policy* 37(10), 1829–1836.
- Kanazawa, F., 1999. *Shicyouson Gappei Sokusin to Jyu-min Service no Arikata* (Mergers and public services). *Toshi Mondai* 90(3), 39–53.
- Konishi, S., 2003. *Shicyouson Gappei no Ketsudan* (Decision Making in Municipal Mergers). Japan: Gyousei Publisher.
- Jacobs, A.J., 2004. Federations of Municipalities: A Practical Alternative to Local Government Consolidations in Japan? Paper presented at the annual meeting of the American Sociological Association, Atlanta Hilton Hotel, Atlanta, GA, Aug 16, 2003.
- Malmquist, S., 1953. Index numbers and indifference surfaces. *Trabajos de Estadistica* 4, 209–242.
- Ray, S., Desli, El, 1997. Productivity growth, technical progress, and efficiency change in industrialized countries: Comment. *American Economic Review* 87(5), 1033–1039.
- Saito, S., 1999. *Gyousei Kibo to Keizai Kouritusei* (Scale and efficiency on administration). *Toshi Mondai* 90(3), 27–37.
- Steiner, K., 1965. *Local Government in Japan*. Stanford: Stanford University Press.
- Tachi, Y., 1998. *Zaisei no Genjyou to Tenbou* (Data and Chart on National finance). Japan: Okura Zaimu Kyokai.
- Thanassoulis, E., 2001. *Introduction to the Theory and Application of Data Envelopment Analysis: A Foundation Text with Integrated Software*. Boston: Kluwer Academic Publisher.
- Yokomichi, K., 2003. *Shicyouson Gappei no Hitsuyousei to Kadai* (A requirement and a problem on municipal mergers). *Toshi Mondai* 94(2), 3–12.
- Yokomichi, K., Okino, H., 1996. *Zaisei Kouritusei kara mita Shicyouson Gappei* (Evaluation on municipal administrative efficiency). *Jichi Kenkyu* 72(11), 69–87.

Table 1. Average DEA scores and scale efficiency

Year	CCR	BCC	Scale	Above 2σ
1979	0.853 (0.092)	0.886 (0.085)	0.963 (0.050)	3
1980	0.859 (0.095)	0.899 (0.081)	0.956 (0.058)	3
1981	0.856 (0.096)	0.886 (0.087)	0.967 (0.043)	1
1982	0.868 (0.099)	0.896 (0.090)	0.969 (0.036)	3
1983	0.847 (0.100)	0.882 (0.090)	0.960 (0.044)	4
1984	0.865 (0.097)	0.887 (0.088)	0.975 (0.040)	3
1985	0.809 (0.104)	0.833 (0.103)	0.970 (0.040)	4
1986	0.870 (0.094)	0.886 (0.089)	0.982 (0.023)	5
1987	0.840 (0.099)	0.873 (0.088)	0.963 (0.044)	6
1988	0.857 (0.093)	0.890 (0.086)	0.963 (0.048)	5
1989	0.857 (0.089)	0.891 (0.084)	0.964 (0.053)	5
1990	0.850 (0.094)	0.881 (0.085)	0.965 (0.048)	7
1991	0.868 (0.085)	0.893 (0.080)	0.972 (0.044)	5
1992	0.876 (0.086)	0.898 (0.078)	0.975 (0.032)	8
1993	0.827 (0.103)	0.853 (0.095)	0.970 (0.043)	7
1994	0.829 (0.107)	0.866 (0.096)	0.957 (0.052)	6
1995	0.835 (0.101)	0.877 (0.091)	0.952 (0.047)	7
1996	0.827 (0.105)	0.874 (0.096)	0.947 (0.050)	5
1997	0.836 (0.103)	0.884 (0.094)	0.946 (0.050)	5
1998	0.861 (0.090)	0.892 (0.086)	0.965 (0.040)	8
1999	0.846 (0.094)	0.884 (0.090)	0.957 (0.045)	10
2000	0.848 (0.093)	0.888 (0.088)	0.955 (0.056)	5
2001	0.840 (0.091)	0.888 (0.090)	0.946 (0.058)	5
2002	0.840 (0.090)	0.893 (0.090)	0.940 (0.065)	7
2003	0.860 (0.088)	0.899 (0.085)	0.956 (0.052)	9
2004	0.826 (0.123)	0.896 (0.095)	0.922 (0.088)	6

Table 2. Decomposition with scale effects for Tsukuba city

<i>Year</i>	<i>MI^c</i>	<i>FS^c</i>	<i>CU^c</i>	<i>PEC</i>	<i>SEC</i>
1987--1988	1.018	0.935	1.089	1.022	1.065
1987--1989	0.980	0.881	1.113	0.982	1.133
1987--1990	0.939	0.870	1.079	0.946	1.141
1987--1991	0.975	0.808	1.206	0.962	1.254
1987--1992	0.938	0.791	1.185	0.947	1.252
1987--1993	0.920	0.910	1.011	0.900	1.113
1987--1994	0.912	0.930	0.980	0.916	1.080
1987--1995	0.880	0.872	1.009	0.892	1.131
1987--1996	0.895	0.882	1.015	0.906	1.121
1987--1997	0.905	0.876	1.033	0.928	1.112
1987--1998	0.933	0.809	1.154	0.964	1.197
1987--1999	0.915	0.825	1.109	0.936	1.185
1987--2000	0.952	0.860	1.107	0.980	1.130
1987--2001	0.977	0.851	1.149	1.000	1.149
1987--2002	0.982	0.820	1.197	0.944	1.186
1987--2003	0.904	0.756	1.196	0.959	1.247
1987--2004	0.935	0.773	1.210	0.967	1.251

Table 3. Decomposition with scale effects for Hitachinaka city

<i>Year</i>	<i>MI^c</i>	<i>FS^c</i>	<i>CU^c</i>	<i>PEC</i>	<i>SEC</i>
1994-1995	0.957	0.989	0.968	0.977	0.991
1994-1996	0.978	0.978	1.000	0.996	1.004
1994-1997	1.004	1.004	1.000	1.018	0.982
1994-1998	1.006	1.006	1.000	1.027	0.974
1994-1999	0.986	1.002	0.983	1.012	0.973
1994-2000	1.011	1.052	0.962	1.009	0.953
1994-2001	0.999	1.043	0.958	1.018	0.941
1994-2002	1.023	1.052	0.973	1.044	0.932
1994-2003	1.032	1.040	0.992	1.065	0.932
1994-2004	1.021	1.052	0.970	1.044	0.929

1. Tsukuba (1987, 2002)
2. Mito (1992, 2005)
3. Hitachinaka (1995)
4. Kashima (1995)
5. Itako (2001)
6. Hitachiomiya (2004)
7. Hitachi (2004)
8. Hitachiota (2004)
9. Naka (2005)
10. Sirosato (2005)
11. Bando (2005)
12. Inashiki (2005)
13. Toride (2005)
14. Chikusei (2005)
15. Kasumigaura (2005)

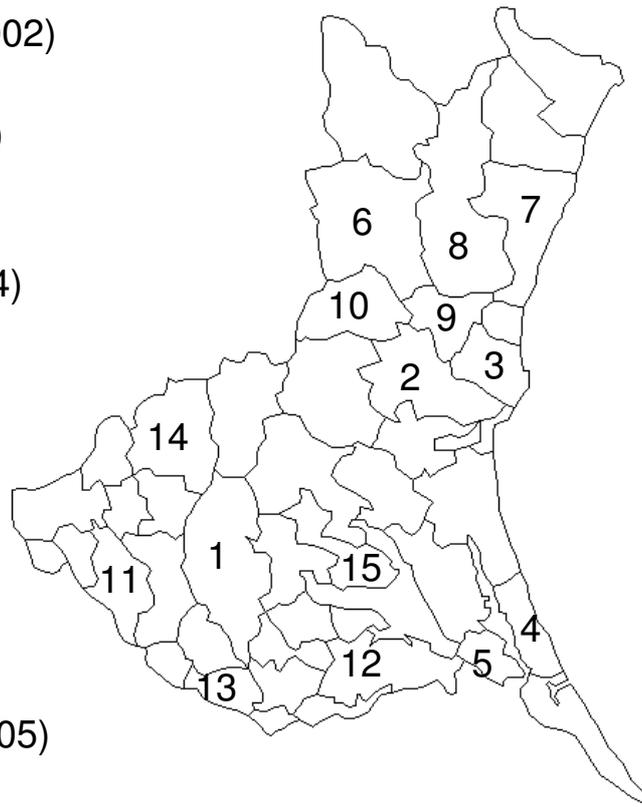


Fig. 1. History of mergers in Ibaraki prefecture

(1) Consolidation

a) Observation

Year	1983	1984	1985	1986	1987	1988	1989	1990
Oho village	○	○	○	○				
Sakura village	○	○	○	○	merger			
Toyosato town	○	○	○	○				
Tukuba village	○	○	○	○				
Yatabe town	○	○	○	○				
Tukuba city					○	○	○	○

b) Our effort

Year	1983	1984	1985	1986	1987	1988	1989	1990
Oho village	○	○	○	○	○	○	○	○
Sakura village	○	○	○	○	○	○	○	○
Toyosato town	○	○	○	○	○	○	○	○
Tsukuba village	○	○	○	○	○	○	○	○
Yatabe town	○	○	○	○	○	○	○	○

(2) Incorporation

a) Observation

Year	1988	1989	1990	1991	1992	1993	1994	1990
Mito city	○	○	○	○	○	○	○	○
Tsunezumi village	○	○	○	○	merger			

b) Our effort

Year	1988	1989	1990	1991	1992	1993	1994	1990
Mito city	○	○	○	○	○	○	○	○
Tsunezumi village	○	○	○	○	○	○	○	○

Fig. 2. Data set of merging municipalities applied to DEA/MI

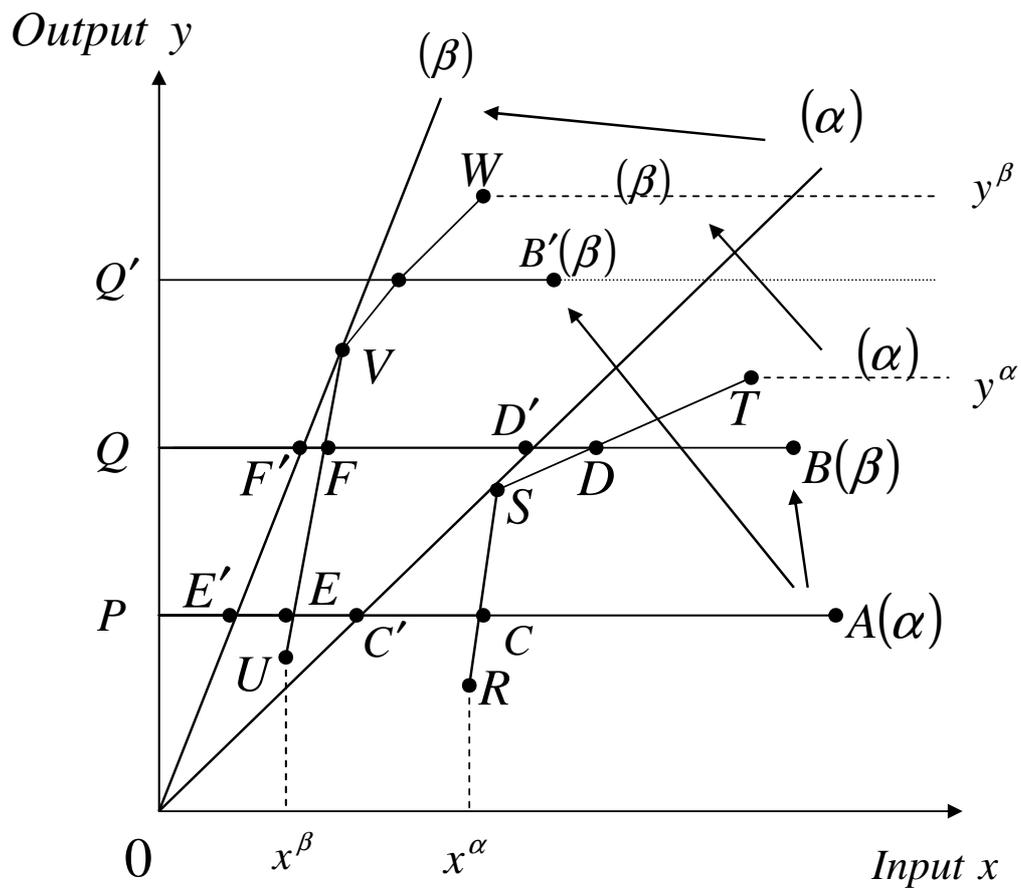


Fig. 3. DEA efficiency changes with the frontier over time

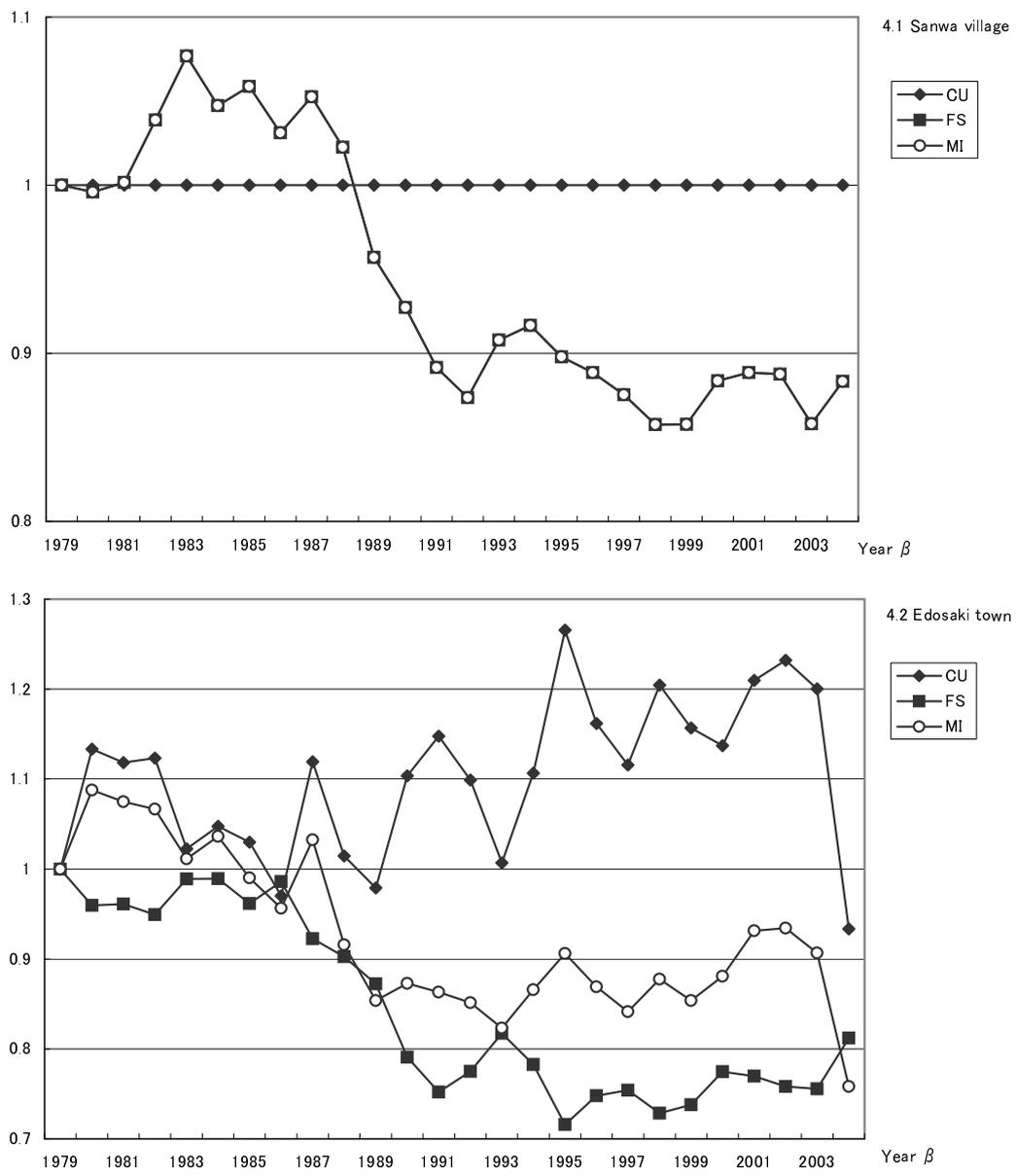


Fig. 4. Cumulated indices for two municipalities

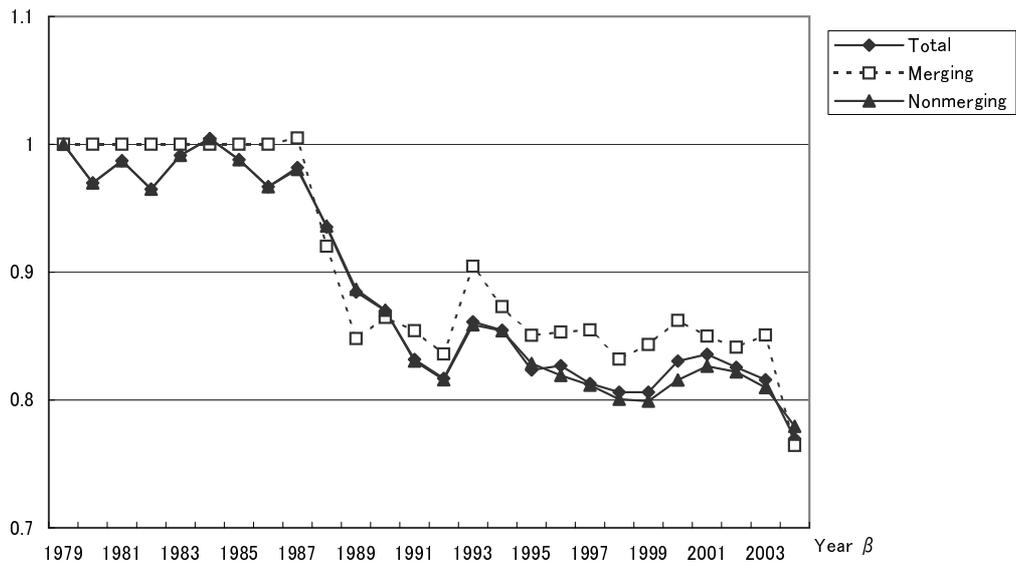


Fig. 5. Administrative efficiency change in Ibaraki prefecture (1979–2004)

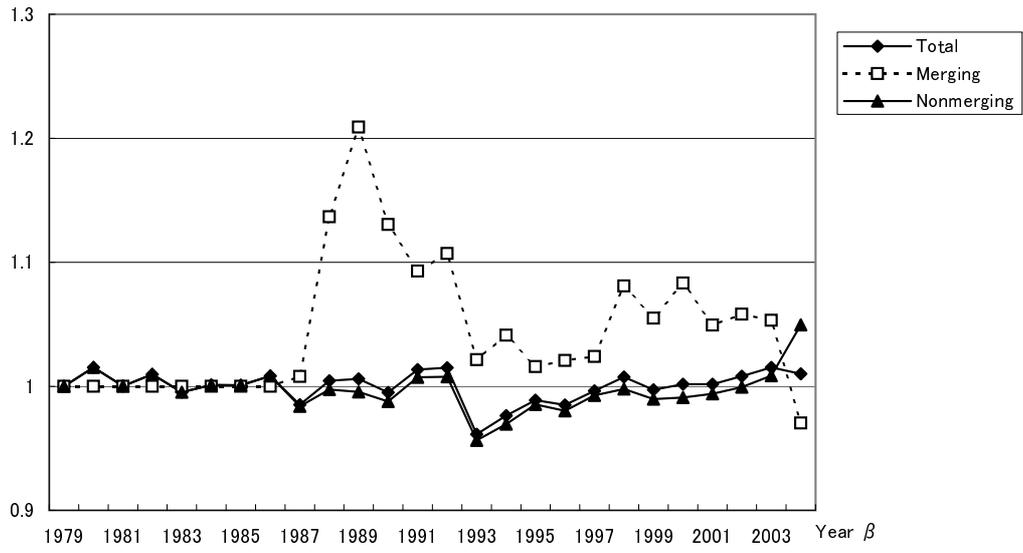


Fig. 6. Average CU for merging and nonmerging municipalities (1979–2004)

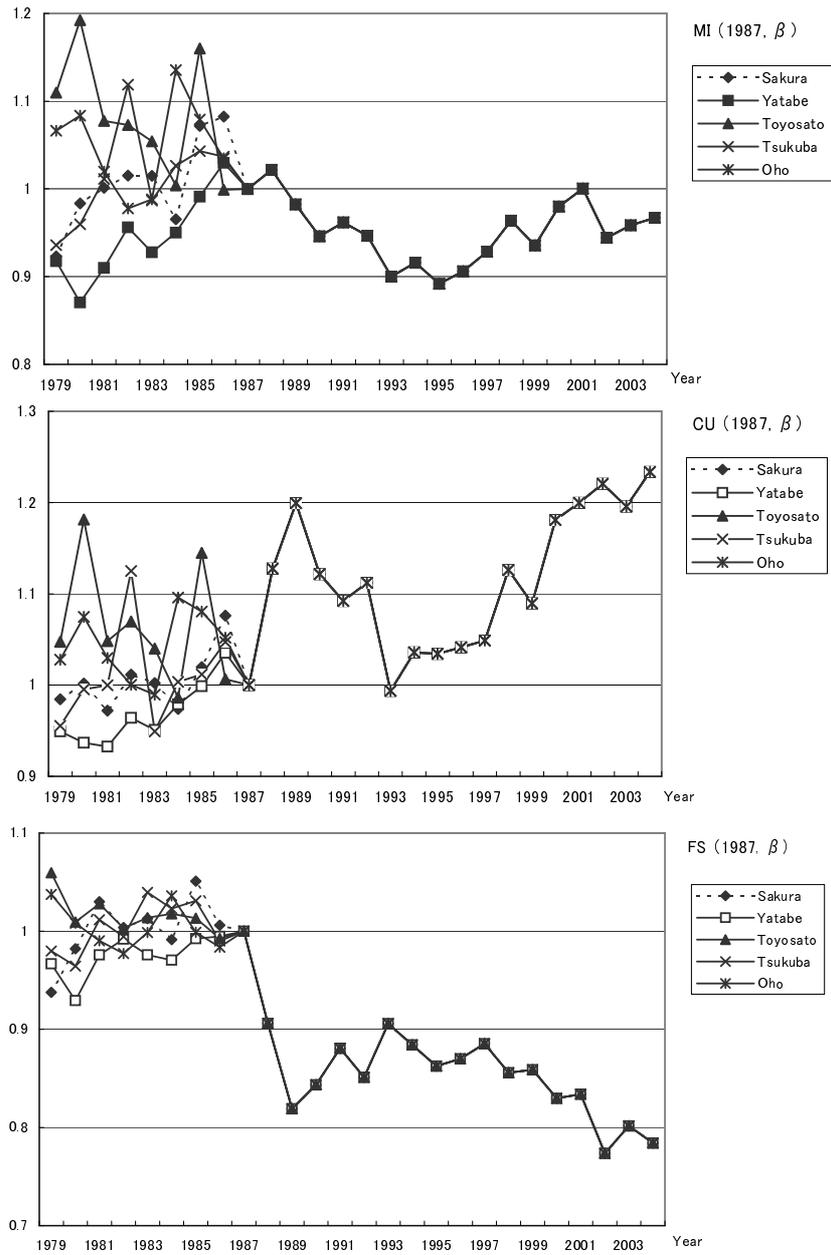


Fig. 7. Cumulative indices for base year 1987 for Tsukuba city

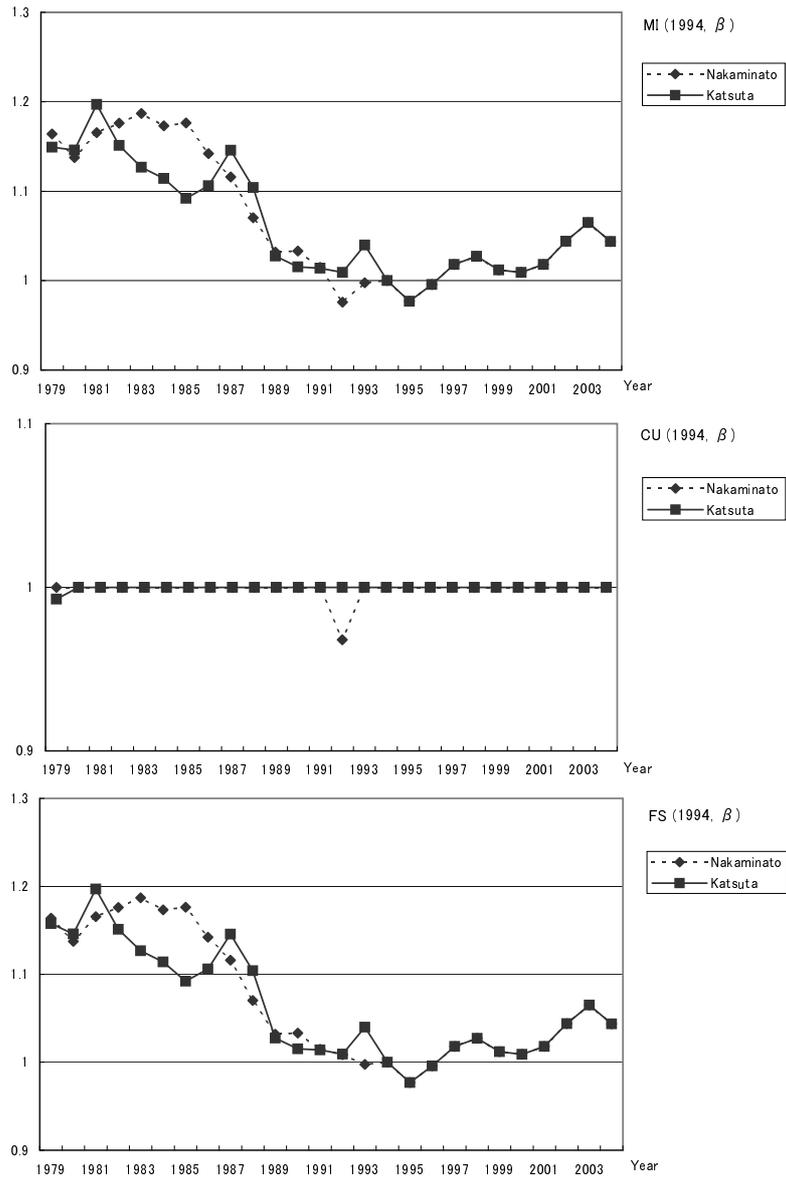


Fig. 8. Cumulative indices for base year 1994 for Hitachinaka city