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Seeing How the Japan's Quality-of-Life has Changed

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Seeing how the Japan's quality-of-life has changed

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Abstract

This paper presents a DEA/MI (Data Envelopment Analysis/ Malmquist Index) analysis of the change in QOL (Quality Of Life) that is defined as the state of social system measured by multiple social-indicators. Applying the DEA/MI to the panel social-indicators data of the Japan's 47 prefectures for the period 1975-2002, we quantitatively see the QOL transition of Japan using the "cumulative" frontier shift index of the analysis. The results show that the Japan's QOL has risen up for the bubble economy years (the last half of the 1980s) and dropped down for the succeeding lost-decade (1990s). We also find the prefectures responsible to the QOL change. Moreover, the use of the lower-bound DEA together with the ordinary DEA enables the QOL evaluation in the bad respects as well as in the good ones.

1 Introduction

This paper examines how the *QOL (Quality Of Life)* of Japan has changed for the period 1975-2002. QOL, like *well-being* or *social welfare*, would have subjective as well as objective dimensions. However, we here adopt somewhat restricted concept of the QOL as follows, selected from among several QOL genealogies that Mieno [10] lists: the state of social system measured by multiple objective-indicators from the viewpoint of well-being or welfare. To begin with, OECD develops *social indicators* as the measurement of the QOL (OECD [12]). Therefore, we can simply say that the QOL dealt with in this paper is the state of social system as measured by the social indicators.

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To grasp the QOL appropriately, we should view a lot of phases of social system comprehensively, implying the simultaneous use of multiple social-indicators. In this multi-dimensional evaluation, we generally use the indicators' weighted sum as an integrated measure. But it is difficult to define such a weighting a priori, or also difficult to interpret the weighting if it is derived through some multivariate analysis technique.

For such a QOL analysis, we employ *DEA (Data Envelopment Analysis)* (e.g., Cooper et al. [3]) with nonuniform weights, i.e., a flexibly defined weighting system corresponding to each entity called *DMU (Decision-Making Unit)* being evaluated. DEA is a mathematical programming technique for measuring the relative *efficiency* of DMUs with multiple *inputs* and multiple *outputs*. Replacing the inputs with *negative* social-indicators (the smaller the value, the better) and the outputs with *positive* social-indicators (the greater the value, the better), we can relatively evaluate the QOL of DMUs because social indicators are what measure QOL. It is a DEA analysis beyond the standard DEA efficiency analysis. This approach is originally proposed by Hashimoto and Ishikawa [6], which is listed as one of the creative DEA applications (Reisman et al. [13]), and Zhu [16], Murias et al. [11], etc. refer to [6].

Based on this DEA consideration, we examine the time series transition in Japan's QOL by *DEA/MI (DEA/ Malmquist Index)* analysis (e.g., Färe et al. [5], Thanassoulis [14]). DEA/MI measures the *Malmquist index*, i.e., ratio of DEA efficiencies in two different time periods with shifting DEA efficiency *frontiers*. Also, the Malmquist index can be decomposed into two components: "catch-up" and "frontier shift". While the former measures how much closer to the frontier a DMU moves, the latter does the move of the frontier. Since the Malmquist index is as to the production by nature, the DEA frontier in the analysis usually implies the productivity frontier. But in the DEA case having the social indicators as the inputs and outputs, that implies the QOL frontier. Applying the DEA/MI to the panel social-indicators data of Japan's 47 prefectures for 1975-2002 and using the frontier shift index of the analysis, we devise to quite obviously display the Japan's QOL change throughout the period.

Further, we here apply *negative DEA* [15, 4], a variation of DEA, as well. Since the ordinary DEA is an *upper-bound* evaluation focusing on each DMU's superiority, it has a tendency to take no account of the inferiority. It does not seem so appropriate to evaluate the QOL comprehensively. Then, adding the negative DEA, a *lower-bound* evaluation focusing on each DMU's inferiority, we try to view the Japan's QOL in bad respects as well as in good respects. Hashimoto and Kodama [7] try to analyze the Japan's livability change using the time series DEA. This paper takes long strides to evolve [7] by introducing both the Malmquist index and the negative DEA.

2 Methodology

Since we employ DEA as the analytic method in the QOL study, this section concisely describes the DEA concepts used in the methodology.

2.1 DEA

DEA is originally developed by *CCR (Charnes, Cooper and Rhodes)* [2]. The CCR model in its *weak efficiency* and *ratio* form to measure the DEA efficiency score of target DMU

j_0, $g_{j_0}(0 \leq g_{j_0} \leq 1)$, is formulated as the following fractional programming:

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

where n = the number of DMUs, $y_j = [y_{1j}, ..., y_{rj}, ..., y_{tj}]$ = output vector of DMU j, y_{rj} = the amount of output r from DMU j, $u = [u_1, ..., u_r, ..., u_t]$ = weight variable vector of output, u_r = the weight given to output r, t = the number of outputs, $x_j = [x_{1j}, ..., x_{ij}, ..., x_{mj}]$ = input vector of DMU j, x_{ij} = the amount of input i to DMU j, $v = [v_1, ..., v_i, ..., v_m]$ = weight variable vector of input, v_i = the weight given to input i, m = the number of inputs.

This can be converted into the following LP (Linear Programming), the CCR model in its weak efficiency, *input oriented* and *envelopment* form:

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

where θ, λ_j (j = 1, ..., n) = decision variables to LP. We can find DEA scores g_{j_0} (= θ) of all the DMUs by solving LP (2) n times, setting each DMU as target DMU j_0 in turn. Here, DMUs j_0 with the optimum $g^*_{j_0} = 1$ are judged *DEA efficient*, while the other DMUs j_0 with $g^*_{j_0} < 1$ are *DEA inefficient*.

From the mechanism of model (1), DEA judges any DMU producing more outputs with fewer inputs relatively efficient (DEA efficient). In the DEA QOL analysis where the inputs and outputs are respectively replaced by the negative and positive social-indicators, any DMU with greater positive- and smaller negative-social-indicators is judged relatively well. That is, the DEA score g_{j_0} in this analysis implies the relative QOL level of DMU j_0 measured by means of DEA, though it is not well-defined a priori unlike efficiency. Therefore, DMUs j_0 with $g^*_{j_0} = 1$ might be judged having *DEA best* QOL and the others with $g^*_{j_0} < 1$, having *DEA not-best* QOL. In the DEA QOL case, there exist no organic relationships between x and y in model (1) unlike production efficiency. Therefore, we need not take the DMU scale measured by DEA inputs or outputs into consideration to compute the QOL ratio g_{j_0}. That is, we may here employ not the BCC (Banker, Charnes and Cooper) model [3], but the CCR model.

2.2 DEA/MI analysis

DEA/MI analysis measures the Malmquist (productivity) index (Malmquist [9]) in the DEA frame:

In Fig. 1, a single input and output DEA case, DMU j_0 being evaluated was at point A in period α and line OCD shows the CCR DEA frontier. Then, the input oriented DEA efficiency of DMU j_0 is measured by PC/PA (< 1, DEA inefficient). When point A is on the frontier, the DEA 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 also shifted to line OEF. DEA efficiency change of DMU j_0 can be measured by the ratio of DEA score in period β to that in period α, but the frontier has shifted, so that we compute the geometric mean of ratios for the two frontiers in periods α and β. This is the DEA (CCR input oriented)/ Malmquist index of DMU j_0 between periods α and β

$$MI_{j_0}[\alpha,\beta] \equiv \left(\frac{QD/QB}{PC/PA}\cdot\frac{QF/QB}{PE/PA}\right)^{1/2}. \tag{3}$$

Here, $MI > 1$ means gain in DEA efficiency of DMU j_0 from period α to β, while $MI = 1$ and $MI < 1$ mean the status quo and loss, respectively.

Transforming formula (3), Malmquist index can be decomposed into two components as follows:

$$\begin{aligned} MI_{j_0}[\alpha,\beta] &= \frac{QF/QB}{PC/PA}\times\left(\frac{PC}{PE}\cdot\frac{QD}{QF}\right)^{1/2} && (4)\\ &= CU_{j_0}[\alpha,\beta]\times FS_{j_0}[\alpha,\beta] && (5)\\ &= \frac{QF/QB}{PC/PA}\times\left(\frac{PC/PA}{PE/PA}\cdot\frac{QD/QB}{QF/QB}\right)^{1/2}. && (6)\end{aligned}$$

As the first term in the right hand side of formula (4) shows, CU expresses *Catch-Up* index, i.e, $CU > 1$ means that DMU j_0 has moved closer to the period β frontier than to the period α one. $CU = 1$ and $CU < 1$ mean that it has the same distance and that it has moved farther, respectively. FS expresses *Frontier Shift* index from the second term in the right hand side of (4), and $FS > 1$ means gain in DEA frontier shift from period α to β measured from the location of DMU j_0, i.e., the frontier has moved *onward* so as to have the more output with the fewer input as shown in Fig. 1. $FS = 1$ and $FS < 1$ mean no change and loss (shift *backward*), respectively.

Since PE/PA in Fig. 1 is, for example, the DEA score θ ($= g_{j_0}$) of the period α DMU j_0 measured by means of the period β frontier, we denote it as $\theta[D^\alpha, F^\beta]$. Then from formula (6),

$$MI_{j_0}[\alpha,\beta] = \frac{\theta[D^\beta,F^\beta]}{\theta[D^\alpha,F^\alpha]}\times\left(\frac{\theta[D^\alpha,F^\alpha]}{\theta[D^\alpha,F^\beta]}\cdot\frac{\theta[D^\beta,F^\alpha]}{\theta[D^\beta,F^\beta]}\right)^{1/2}. \tag{7}$$

In model (2), letting x_j^α, $y_j^\alpha = x_j$, y_j in period α respectively, $\theta[D^\alpha, F^\alpha]$ can be obtained as the optimum of the following LP, the ordinary DEA model:

$$\begin{aligned} \text{Minimize} \quad & \theta \\ \text{subject to} \quad & \sum_{j=1}^{n}\lambda_j y_j^\alpha \ge y_{j_0}^\alpha, \\ & \sum_{j=1}^{n}\lambda_j x_j^\alpha - \theta x_{j_0}^\alpha \le 0, \\ & \lambda_j \ge 0,\ j,...,n, \\ & (\theta \text{ unconstrained}). \end{aligned} \tag{8}$$

$\theta[D^\beta, F^\beta]$ can also be obtained by the LP (8) replaced α by β.

While $\theta[D^\alpha, F^\beta]$ is obtained as the optimum of

$$
\begin{array}{lll}
\text{Minimize} & \theta & \\
\text{subject to} & \displaystyle\sum_{j=1}^{n} \lambda_j y_j^\beta \geq y_{j_0}^\alpha, & (9) \\
& \displaystyle\sum_{j=1}^{n} \lambda_j x_j^\beta - \theta x_{j_0}^\alpha \leq 0, & \\
& \lambda_j \geq 0,\ j, ..., n, & \\
& (\theta \text{ unconstrained}), &
\end{array}
$$

this forms the *DEA exclusion model* (Andersen and Petersen [1]). Finally, we can obtain $\theta[D^\beta, F^\alpha]$ by also the DEA exclusion model (9) exchanged α and β.

In the current QOL study, using the panel social-indicators data of the 47 prefectures of Japan, we obtain the catch-up $CU_{j_0}[\alpha, \beta]$, frontier shift $FS_{j_0}[\alpha, \beta]$ and Malmquist $MI_{j_0}[\alpha, \beta]$ indices from period α to β for prefecture j_0. It should be noted that the catch-up compares the closeness of prefecture j_0 to the QOL frontier in each period, the frontier shift expresses the movement of the QOL frontier between two periods, and the Malmquist measures the change in QOL of prefecture j_0 taking the frontier shift as well as the catch-up into consideration. While the CU_{j_0} and MI_{j_0} express the move of prefecture j_0, the FS_{j_0} expresses the shift of the QOL frontier which is composed by the prefectures having DEA best QOL, not necessarily by prefecture j_0 itself. That is, the FS_{j_0} implies the Japan's QOL frontier shift measured from the location (viewpoint) of prefecture j_0, and the frontier shift onward means moving in the direction of greater positive- and smaller negative-social-indicators. Therefore, we here propose the average frontier shift index of all the prefectures, i.e., the QOL frontier shift measured from the viewpoint of the average prefecture, as an appropriate indicator to view the QOL change at the Japan national level.

2.3 Negative DEA

As the maximization of model (1) shows, the ordinary DEA is an upper-bound evaluation focusing on each DMU's superiority. To evaluate the QOL not only in good respects but also in bad respects, we introduce the following DEA variation as a lower-bound evaluation. The model in its weak efficiency and ratio form in contrast with (1) is

$$
\begin{array}{lll}
\text{Minimize} & f_{j_0} = \dfrac{uy_{j_0}}{vx_{j_0}} & \\
\text{subject to} & \dfrac{uy_j}{vx_j} \geq 1,\ j = 1, ..., n, & (10) \\
& u, v \geq 0, &
\end{array}
$$

and the converted LP form corresponding to model (2) is

$$
\begin{array}{lll}
\text{Maximize} & f_{j_0} = \xi & \\
\text{subject to} & \displaystyle\sum_{j=1}^{n} \lambda_j y_j \leq y_{j_0}, & (11) \\
& \displaystyle\sum_{j=1}^{n} \lambda_j x_j - \xi x_{j_0} \geq 0, &
\end{array}
$$

$$\lambda_j \geq 0,\ j = 1, ..., n,$$
$$(\xi \text{ unconstrained}),$$

where ξ, λ_j (j = 1, ..., n) = decision variables to LP.

This DEA idea focusing on each DMU's inferiority is separately proposed by Yamada et al. [15] and Doyle et al. [4]. The former proposes the "inverted DEA" model exchanging the numerator and denominator in model (1), and the latter does the "exclusion" type of model (10) as one of the three lower-bound DEA models. Following both, we employ the model (10) calling the "negative DEA". Here, the negative-DEA score of target DMU j_0, $f_{j_0} \geq 1$, and DMUs j_0 with $f^*_{j_0} = 1$ are on the DEA *rear* (negative-DEA frontier). In the negative-DEA QOL analysis, any DMU having smaller positive- and greater negative-social-indicators is judged relatively bad. That is, DMUs j_0 with $f^*_{j_0} = 1$ should be judged having *DEA worst* QOL, while DMUs j_0 with $f^*_{j_0} > 1$, having *DEA not-worst* QOL.

We can also describe the DEA$^-$/MI (negative-DEA/MI) analysis using Fig. 1. In this way, we hereafter use superscript "$^-$" as the symbol expressing the negative DEA. Suppose that DMU j_0 being evaluated has moved from point A to B and the DEA rear has also shifted from line OGH to OIJ between periods α and β. Then, the DEA$^-$/ Malmquist index of DMU j_0

$$MI^-_{j_0}[\alpha, \beta] \equiv \left(\frac{QH/QB}{PG/PA} \cdot \frac{QJ/QB}{PI/PA}\right)^{1/2} \tag{12}$$
$$= \frac{QJ/QB}{PG/PA} \times \left(\frac{PG/PA}{PI/PA} \cdot \frac{QH/QB}{QJ/QB}\right)^{1/2} \tag{13}$$
$$= CU^-_{j_0}[\alpha, \beta] \times FS^-_{j_0}[\alpha, \beta]. \tag{14}$$

Here, $MI^-_{j_0}[\alpha,\ \beta] > 1$ means gain, i.e., increase in the DEA$^-$ efficiency score of DMU j_0 from period α to β, $CU^-_{j_0}[\alpha,\ \beta] > 1$ means that DMU j_0 has moved farther from the period β rear than from the period α one, and $FS^-_{j_0}[\alpha,\ \beta] > 1$ means that the DEA rear has shifted onward so as to have the more output with the fewer input as shown in Fig. 1. In the DEA$^-$ QOL analysis, using the average FS^- index, i.e., the QOL rear shift from the viewpoint of the average prefecture, we can see the Japan's QOL change evaluating the QOL in bad respects, i.e., finding fault with the individual prefectures' QOL.

Referring to formula (7) and denoting, for example, PI/PA as $\xi[D^\alpha, R^\beta]$ since it implies the DEA$^-$ score of the period α DMU j_0 measured by means of the period β DEA rear,

$$MI^-_{j_0}[\alpha, \beta] = \frac{\xi[D^\beta, R^\beta]}{\xi[D^\alpha, R^\alpha]} \times \left(\frac{\xi[D^\alpha, R^\alpha]}{\xi[D^\alpha, R^\beta]} \cdot \frac{\xi[D^\beta, R^\alpha]}{\xi[D^\beta, R^\beta]}\right)^{1/2}, \tag{15}$$

where each value of ξ can be computed through the LP transformed from (11) like the ordinary DEA/ Malmquist index.

3 Data to DEA-analyze QOL

For the current QOL study, we provide the following data panels of social indicators. Each panel is 47 prefectures × 28 years. Fig. 2 shows the 47 prefectures of Japan, and the sample period is 1975-2002.

As the negative and positive social-indicators in the DEA QOL analysis, which correspond to the inputs and outputs in the DEA efficiency analysis, we employ the following eight indicators for prefectures:

Health

Suicide† (Suicides per total population)

Hospital bed (Number of hospital beds per total population)

Safety

Crime† (Criminal cases recognized by police per total population)

Traffic accident† (Traffic accident cases occurred per total population)

Economy

Bankruptcy† (Bankruptcy cases per total number of firms)

Income (Per capita prefectural income)

Environment

Water quality (Proportion of water resources achieving national standard)

Sewage (Diffusion percentage of sewers)

(† Negative indicator)

We construct this social indicator system beginning with adopting the four aspects of society, i.e., health, safety, economy and environment, which are used throughout our preceding DEA QOL analyses [6, 7]. Further, we employ suicide, crime, income and water quality as social indicators which straightforward represent the four aspects, respectively, also add another indicator to each aspect as one representing the other side of the aspect.

We collect annual data to the eight social indicators, for the 47 prefectures in the period 1975-2002, from *Min-Ryoku (People Power) Database* (Tokyo: Asahi Shimbun Co.) and *Annual Report on Prefectural Accounts* (Cabinet Office, Government of Japan). Deflating the income indicator to the 2002 value, we obtain eight data panels of four negative and four positive social-indicators. We here employ normalized scores with mean of 100 and variance of 100 by each data panel.

4 DEA analysis of the change in QOL

4.1 Cumulative Malmquist index

Applying the data to LPs (8) and (9), and through formulas (5) and (7), we can compute the catch-up $CU_{j_0}[\alpha, \beta]$, frontier shift $FS_{j_0}[\alpha, \beta]$ and Malmquist $MI_{j_0}[\alpha, \beta]$ indices. These indices for year β are usually compared to the preceding year, i.e., $\alpha = \beta$ - 1. However, such annually *successive* indices do not seem appropriate to see the chronological change throughout the sample period in the wide range of vision. Therefore, we propose to employ another index than the successive one, following Hashimoto and Haneda [8]. We adopt $CU_{j_0}[1975, \beta]$, $FS_{j_0}[1975, \beta]$ and $MI_{j_0}[1975, \beta]$, $\beta = 1975$, ..., 2002. They are all compared to the *standard* year 1975, the start year of the sample period. Since they involve their successive changes from the standard year up to year β, we call them *cumulative* indices. Here, the cumulative index values when $\beta = 1975$ could be all 1. Färe et al. [5] use the sequential product of the annually successive indices to demonstrate the cumulated change from a year. But, as these authors state, the Malmquist index as well as the frontier shift one do not satisfy the circular test: e.g., $MI_{j_0}[\alpha, \alpha+1] \times MI_{j_0}[\alpha+1, \alpha+2] \neq MI_{j_0}[\alpha, \alpha+2]$. Therefore, we adopt the cumulative indices with standard year of 1975 to see the holistic change throughout the period.

Fig. 3 has graphs for three prefectures, Tokyo, Osaka and Tokushima, each of which includes the three cumulative indices CU, FS and MI. Note that the cross-section DEA for the start year 1975 treating each prefecture as a separate DMU tells us the three prefectures were all on the QOL frontier in 1975. For Tokyo prefecture (Fig. 3.1), the cumulative catch-up indices are all 1. That is, Tokyo has been on the frontier throughout the period 1975-2002. From the relation of formula (5), the Malmquist and the frontier shift for Tokyo move together. Since the Malmquist indicates the QOL change of a prefecture taking the frontier shift into consideration, it shows that the QOL level of Tokyo has first risen and reached to its peak (27% better than the start year) in 1989, and since then it has gone down. This also shows the move of the QOL frontier in terms of the points Tokyo located on the annual frontiers.

From the graph of catch-up in Fig. 3.2, we see that Osaka prefecture has frequently gotten out of the QOL frontier though it was on the frontier in the start year. The Malmquist differently moves from the frontier shift, and has reached to its peak in 1990. For Tokushima prefecture (Fig. 3.3), we should watch year 1984. Since Tokushima was on the QOL frontier in 1975 as mentioned above and since $CU(1975,\ 1984) = 1$, it is also on the frontier in 1984. We can see that $FS(1975,\ 1984) < 1$ for Tokushima. But for Tokyo, which has been on the frontier from 1975 to 1984, $FS(1975,\ 1984) > 1$ (Fig. 3.1). That is, comparing two periods 1975 and 1984, their frontiers cross each other. Fig. 4 illustrates such a case. From the period 1975 to 1984, the part of frontier on which Tokyo was has moved onward (towards the origin) in the negative indicator (DEA input) plane, while that on which Tokushima was has moved backward. In this way, the set of three cumulative indices gives us much information about the QOL change for each prefecture.

Fig. 5 shows the moves of three cumulative indices, CU^-, FS^- and MI^-, for Osaka prefecture computed through formulas (14) and (15). It is understood from the cross-section DEA$^-$ that Osaka was on the QOL rear in 1975 and the graph shows that the CU^- indices are all 1, so that Osaka has been on the QOL rear throughout the sample period. Viewing the MI^- graph, the QOL of Osaka even as abused in the bad respects has been about 10% better than the 1975 level in its peak year 1990, but, in 2001, it has dropped to 36% worse QOL level than 1975. Combining Figs. 3.2 and 5, we can see the change in QOL of Osaka prefecture, for example, evaluating the QOL in both the good and bad respects.

4.2 Japan's QOL change, 1975-2002

In order to see how the QOL of Japan has changed for the period 1975-2002, we compute the cumulative frontier shift indices on the average of all prefectures $FS[1975,\ \beta]$, $\beta = 1975, ..., 2002$. They indicate the move of Japan's QOL frontier from the viewpoint of the average prefecture. Note that we should employ geometric means, not arithmetic ones, as the averages of the CU, FS and MI indices because they are all multiplicative by nature.

Fig. 6 shows the average frontier shift FS together with the average FS^-, i.e., average rear shift. In the first half of the period 1975-1990, both the QOL frontier and QOL rear have moved onward, i.e., the Japan's QOL has gotten better even evaluated in either the good or bad respects. The former peak implies 19% better and the latter one does 13% better QOL level than the start year 1975, respectively, and both are in 1990. In the second half of the period 1990-2002, the Japan's QOL has gotten worse. This period almost coincides with the so-called "Japan's lost-decade", i.e., the depression years with the bubble (economy) burst in 1991 at the beginning. Comparing periods 1975 and 2002, the QOL in 2002 focusing on the superiority is still 8% better than 1975, while that on the inferiority is 4% worse than 1975. That is, passing through the bubble economy years (the last half of the 1980s) and the succeeding lost-decade (1990s), the good respects in the 2002 QOL are better, while the bad ones are worse than those in the 1975 QOL, respectively. Thus, we could quite obviously show the time series transition in Japan's QOL, which had been elusive to grasp, throughout the period 1975-2002 using the cumulative FS and FS^- indices graphs.

4.3 Prefecture analysis

For seeing the change in the individual prefectures' QOL, the cumulative MI and MI^- would be the appropriate indicators, whereas we employ the cumulative FS and FS^- to view the QOL change at the national level. It should be reaffirmed that the MI_{j_0} ($MI^-_{j_0}$) implies the QOL change of prefecture j_0 taking the frontier (rear) shift into consideration, evaluating the QOL in good (bad) respects.

Fig. 7 shows the graphs for two prefectures, Chiba and Hokkaido. The cross-section DEA and DEA$^-$ analyses for 1975 tell us that, in the start year, Chiba was on the QOL frontier but not on the QOL rear, while Hokkaido was on both the QOL frontier and rear. That is, the QOL "constitution" of Hokkaido 1975 was peculiar because it was having DEA best QOL as well as DEA worst QOL. Also, the cross-section DEA and DEA$^-$ for 2002 reveal that Chiba 2002 is not on the frontier but on the rear, while Hokkaido 2002 is on the frontier but not on the rear.

For Chiba prefecture (Fig. 7.1), in the period 1984-1990 involving the Japan's bubble economy years, the MI index has risen but the MI^- index has not so. After the lost-decade, the QOL of Chiba 2002 in lower-bound evaluation has consequently fallen onto the rear, and that in upper-bound evaluation has also dropped out of the frontier. To the contrary, Hokkaido prefecture (Fig. 7.2) would have improved the QOL inferiority laying stress in the bubble economy years. The MI^- has not decreased even in the second half of the period, and the QOL in lower-bound evaluation could have escaped from the rear in 2002. Although the MI has not so increased throughout the sample period, in 2002, the QOL in upper-bound evaluation is still on the frontier. In this way, the combination of the cumulative MI_{j_0} and $MI^-_{j_0}$ indices enables the deeper analysis of the change in the individual prefectures' QOL.

The Japan's QOL frontier and QOL rear have moved throughout the period as shown in Fig. 6. We here examine what prefectures have caused such shifts. Table 1 shows the prefectures which have shifted the frontier onward and those which have shifted the rear backward every third year. Referring to Färe et al. [5], we employ the following three conditions to designate the prefectures having caused the frontier shift onward from the preceding subperiod:

$$\text{fa) } FS_{j_0}[1975,\beta]/FS_{j_0}[1975,\beta-3] > 1,\ \text{ fb) } \theta[D^\beta, F^\beta] = 1,\ \text{ fc) } \theta[D^\beta, F^{\beta-3}] > 1,$$
$$\beta = 1975 + 3\gamma,\ \ \gamma = 1, ..., 9.$$

That is, those prefectures j_0 in year β exist on the year β frontier judged as "shifted onward from year β - 3" (conditions fa and fb) except for existing on the backward part of the frontier in the crossed-frontiers case as shown in Fig. 4 (condition fc). Likewise, the corresponding three conditions to designate the prefectures having caused the rear shift backward from the preceding subperiod are

$$\text{ra) } FS^{-}_{j_0}[1975,\beta]/FS^{-}_{j_0}[1975,\beta-3] < 1,\ \text{rb) } \theta[D^{\beta},R^{\beta}] = 1,\ \text{rc) } \theta[D^{\beta},R^{\beta-3}] < 1,$$
$$\beta = 1975 + 3\gamma,\ \gamma = 1, ..., 9.$$

In Table 1, much more frontier-onward shifters appear in the first half of the period 1975-1990 than in the second half, 1990-2002. On the other hand, we find many rear-backward shifters in the second half, but there also appear a considerable number of them in the period 1975-1984 (prior to the bubble economy years) of the first half. These back the general tendency of the QOL change at the national level (see Fig. 6). Note that some prefectures appeared as both the frontier and the rear shifters must be said peculiar in the QOL constitution in the subperiod because they are not only on the frontier but also on the rear in the end year of the subperiod.

We obtain the following results of the greatest frequency with which the prefecture appears in the frontier-onward and the rear-backward shifters lists:

As the frontier-onward shifter

7 [Hokkaido], 6 [Nagasaki, Toyama], 5 [Fukui, Iwate, Shizuoka, Tokyo]

As the rear-backward shifter

5 [Akita, Chiba, Fukuoka, Osaka, Shimane, Wakayama]

We can say that the former seven prefectures have been most contributive to the frontier shift onward, while the latter six have been most responsible to the rear shift backward. Altering the conditions above, we can also analyze the prefectures which shift frontier backward and rear onward.

5 Summary and conclusions

This paper presented a DEA methodology to see the change in Japan's QOL for the period 1975-2002. Using the DEA/MI analysis applied to the panel social-indicators data, we could quantify the QOL transition, which had been elusive to grasp. The results show that the Japan's QOL has especially risen up for the bubble economy years, has reached to its peak in 1990, since then, has dropped down for the succeeding lost-decade, and finally in 2002, has been at the roughly same level as the start year 1975. Also, we found the most contributive (responsible) prefectures that had raised and lowered the Japan's QOL level.

From a methodological point of view, this study is unique in that it analyzes the QOL change by means of the Malmquist index that has ordinarily been used in productivity analysis. Moreover, the application of the negative DEA together with the ordinary DEA enabled the QOL evaluation lower-bound as well as upper-bound, and the use of the cumulative indices enabled the obvious display of QOL change in the wide range of vision. In this way, this study, introducing the Malmquist index, the negative DEA and the cumulative indices, would have extended the applicability sphere of the DEA time series analysis and taken long strides to evolve it.

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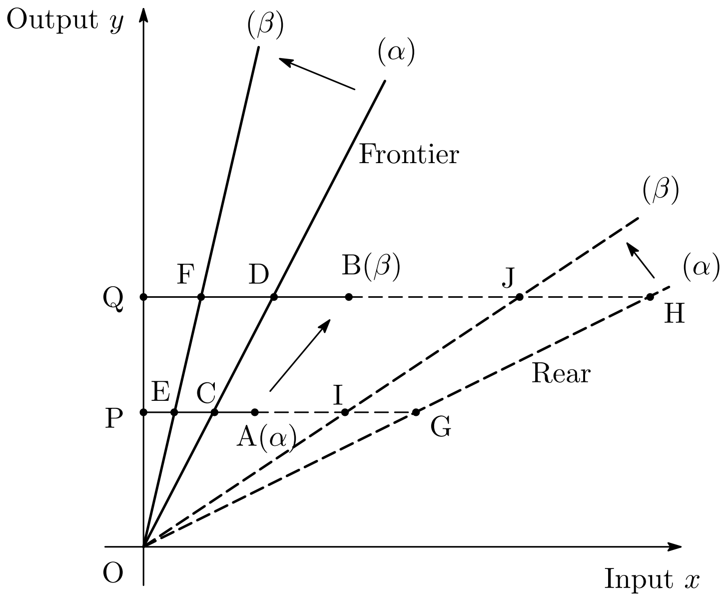

Fig. 1. DEA efficiency changes with the frontier and rear shifting over time.

Aichi 23
Akita 5
Aomori 2
Chiba 12
Ehime 38
Fukui 18
Fukuoka 40
Fukushima 7
Gifu 21
Gunma 10
Hiroshima 34
Hokkaido 1
Hyogo 28
Ibaraki 8
Ishikawa 17
Iwate 3
Kagawa 37
Kagoshima 46
Kanagawa 14
Kochi 39
Kumamoto 43
Kyoto 26
Mie 24
Miyagi 4
Miyazaki 45
Nagano 20
Nagasaki 42
Nara 29
Niigata 15
Oita 44
Okayama 33
Okinawa 47
Osaka 27
Saga 41
Saitama 11
Shiga 25
Shimane 32
Shizuoka 22
Tochigi 9
Tokushima 36
Tokyo 13
Tottori 31
Toyama 16
Wakayama 30
Yamagata 6
Yamaguchi 35
Yamanashi 19

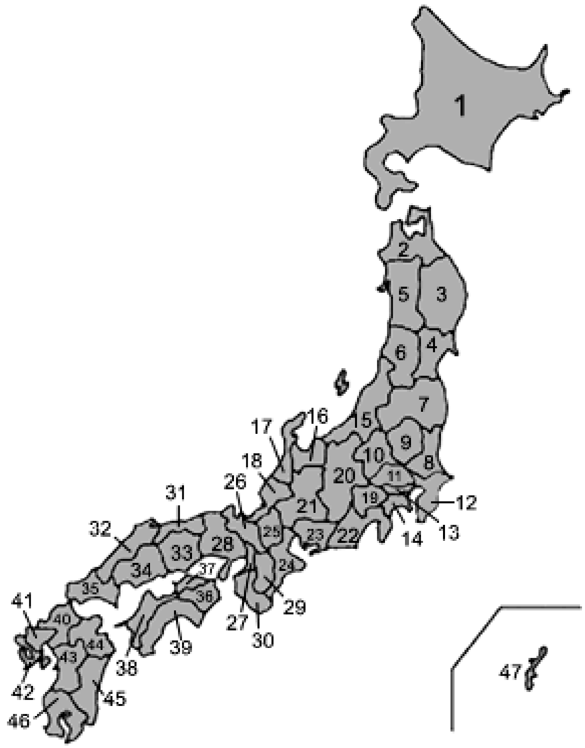

Fig. 2. The 47 Prefectures of Japan.

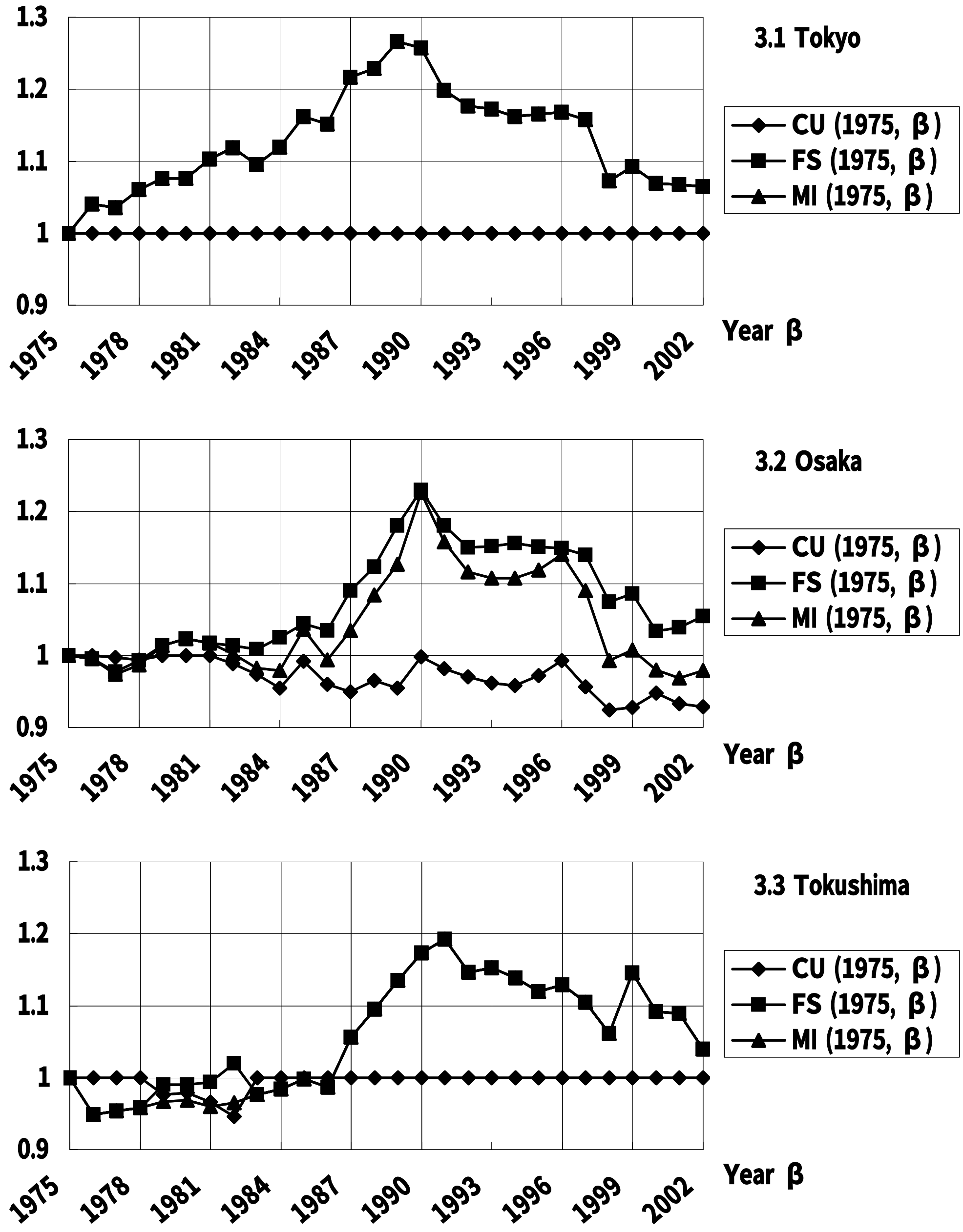

Fig. 3. Cumulative catch-up, frontier shift and Malmquist indices for three prefectures.

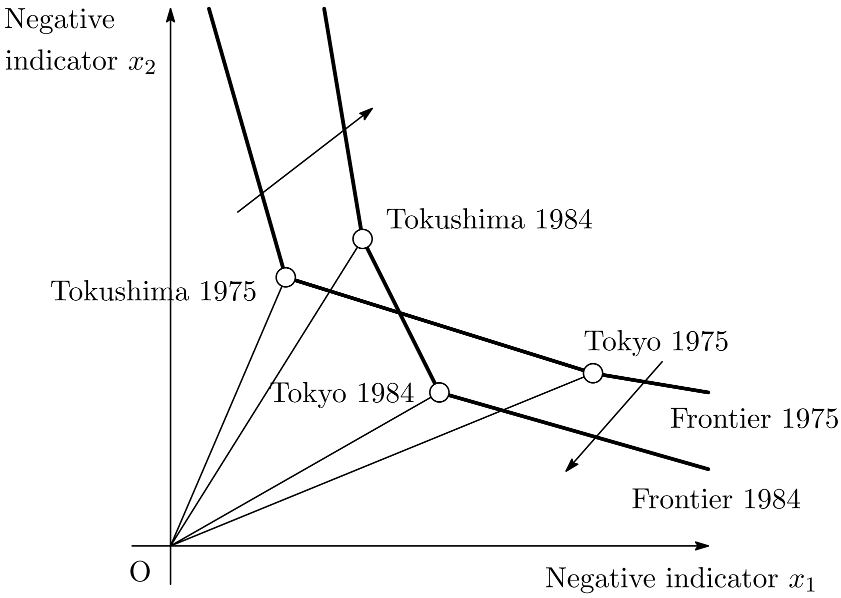

Fig. 4. Crossed frontiers case.

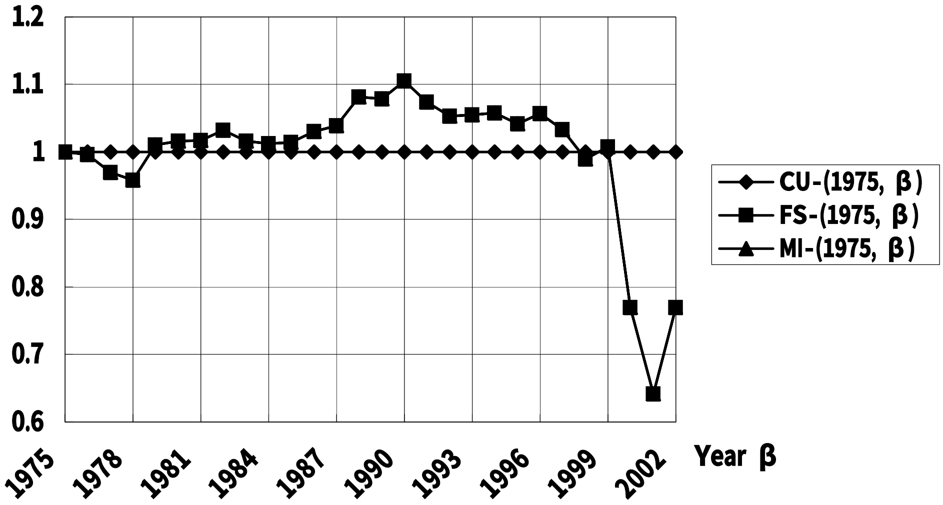

Fig. 5. Cumulative CU^{-}, FS^{-} and MI^{-} indices for Osaka prefecture.

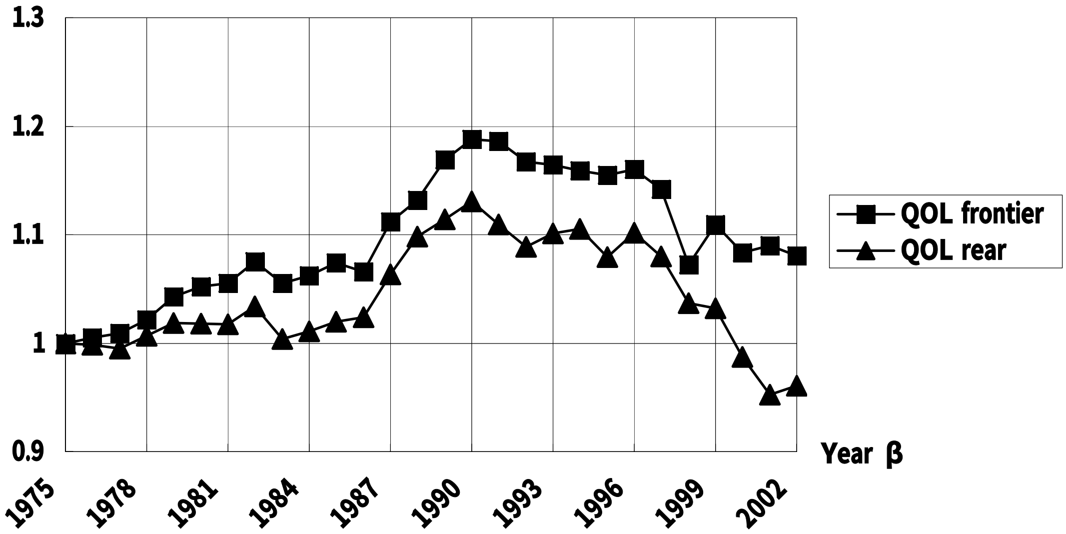

Fig. 6. The change in Japan's QOL for 1975-2002.

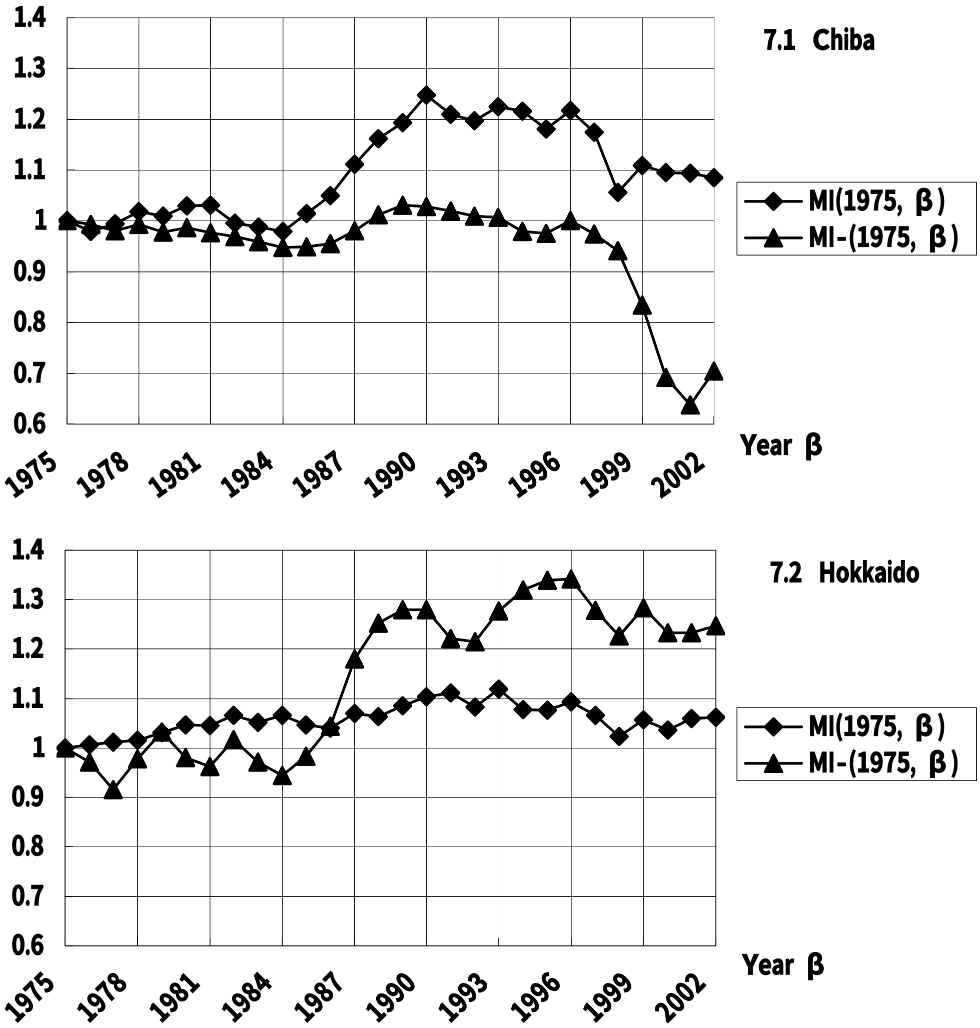

Fig. 7. Cumulative MI and MI^- indices for two prefectures.

Table 1
Prefectures shifting the QOL frontier onward and QOL rear backward

Subperiod	Frontier-onward shifter			Rear-backward shifter		
1975-1978	Aichi	Kagoshima	Shiga	Ehime	Osaka	
	Akita	Kochi	Shizuoka	Fukuoka	Shimane	
	Gifu	Kyoto	Tokyo	Hokkaido	Shizuoka	
	Hokkaido	Nagasaki	Toyama	Kagawa	Tokyo	
	Ishikawa	Nara		Niigata	Tottori	
	Iwate	Okayama		Okinawa		
1978-1981	Aichi	Iwate	Osaka	Ehime	Yamagata	
	Fukui	Kyoto	Shiga	Hiroshima		
	Gifu	Nagasaki	Shizuoka	Hokkaido		
	Hokkaido	Oita	Tokyo	Kochi		
	Hyogo	Okayama	Toyama	Oita		
	Ishikawa	Okinawa		Shimane		
1981-1984	Fukui	Shiga		Akita	Kochi	Shimane
	Gifu	Tokyo		Aomori	Miyazaki	Wakayama
	Hokkaido	Toyama		Chiba	Niigata	Yamagata
	Hyogo			Fukuoka	Okinawa	
	Kochi			Hokkaido	Osaka	
	Nagasaki			Iwate	Saga	
1984-1987	Aichi	Iwate	Tokushima	Akita		
	Fukui	Kanagawa	Tokyo	Shiga		
	Gifu	Kochi	Toyama	Wakayama		
	Hokkaido	Nagasaki				
	Hyogo	Okinawa				
	Ishikawa	Shizuoka				
1987-1990	Aichi	Iwate	Shizuoka	-		
	Akita	Kanagawa	Tokushima			
	Fukui	Kochi	Tokyo			
	Hokkaido	Nagasaki	Toyama			
	Hyogo	Okayama	Yamagata			
	Ishikawa	Okinawa				
1990-1993	Akita	Toyama		Chiba	Kagoshima	Saga
	Hokkaido			Ehime	Kanagawa	Saitama
	Nagasaki			Fukuoka	Miyazaki	Shizuoka
	Oita			Gunma	Niigata	Tochigi
	Okayama			Hyogo	Okinawa	Tokyo
	Okinawa			Ibaraki	Osaka	Wakayama
1993-1996	Fukui			Akita	Shimane	
	Nara			Chiba	Tottori	
	Shizuoka			Gunma		
				Ibaraki		
				Nara		
				Shiga		
1996-1999	Iwate			Aichi	Hyogo	Miyazaki
				Akita	Ibaraki	Niigata
				Chiba	Kagawa	Osaka
				Ehime	Kagoshima	Saitama
				Fukuoka	Kanagawa	Shizuoka
				Gunma	Kyoto	Tokyo
1999-2002	Hokkaido			Aichi	Kanagawa	Saga
	Kanagawa			Akita	Kochi	Saitama
				Aomori	Mie	Shimane
				Chiba	Nara	Shizuoka
				Fukuoka	Okayama	Tokushima
				Hyogo	Osaka	Tokyo

Prefectures appeared as both the frontier-onward and the rear-backward shifters.