**Winners in the urban champions league**
**- A performance assessment of Japanese cities by means of dynamic and super-efficient DEA**

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**Abstract**
This paper aims to provide an advanced assessment methodology for city performance strategies, based on an extended Data Envelopment Analysis (DEA). The use of novel efficiency-improving approaches based on DEA originates from the so-called Distance Friction Minimisation (DFM) method. To design a feasible improvement strategy for low-efficiency Decision-Making Units (DMUs), we develop a Target-Oriented (TO) DFM model on top of a Super-Efficiency model, in order to generate an appropriate efficiency-improving projection model. The TO approach specifies a target-efficiency score (TES) for inefficient DMUs. This approach is able to compute an input reduction value and an output increase value in order to achieve a TES. To include a dynamic DEA perspective, we develop next a new model from a blend of the TO-DFM approach and a Time-Series (TS) approach which incorporates a multi-temporal time horizon and a stepwise target score to achieve a final target efficiency score in order to generate a more appropriate efficiency-improving DEA projection. This model is able to incorporate a catch-up effect in the efficiency projection. However, this TS approach assumes that the efficiency frontier is fixed at any time parted. However, in reality, efficiency frontiers vary from year to year. That is to say, the TS approach does not incorporate a frontier shift effect in setting the target improvement level. Therefore, it is necessary to develop a more realistic efficiency improvement projection which includes a dynamic system of target-settings to achieve a target improvement level in order to programme more realistic policy initiatives. In this paper we develop a new multi-period model from a blend of the TO-DFM and the dynamic approach.

The above-mentioned Dynamic TO-DFM model will be applied to an efficiency assessment of Japanese cities. In this study, due to comparative data limitations, we consider two inputs (population and city budget) and two outputs (GDP and tax revenues). Based on these items, this study assesses the relative economic performance of Japanese big cities (i.e., government-ordinance-designated cities in Japan) by means of a super-efficient DEA model. Finally, we provide an efficiency improvement programme based on the Dynamic TO- DFM model for inefficient cites.

**Extended Abstract**

We live in the '*urban century*'. The role of urban systems is becoming more and more important. The megatrend of population concentration in city areas does not come to a standstill, even not in a depopulating society like Japan. These unprecedented increases in urban population have close links with the economic performance of these cities.

A standard tool which is used to judge the performance or efficiency among different actors is Data Envelopment Analysis (DEA), proposed by Charnes, Cooper and Rhodes (1978). Over the past decades, this has become an established quantitative assessment method in the evaluation literature. Seiford (2005) mentions that these are at least 2800 published articles on DEA in various fields, but nowadays this number is already much higher. Currently, in an urban performance context, there are also several assessment studies that have applied DEA models to measure economic efficiency among cities, which are regarded as Decision Making Units (DMUs). The large number of applied studies shows that efficiency analysis is an important but also intriguing topic.

It should be noted that DEA was originally developed to analyse the relative efficiency of a DMU by constructing a piecewise linear production frontier, and projecting the performance of each DMU onto that frontier. A DMU that is located on the frontier is efficient, whereas a DMU that is below the frontier is inefficient. The wealth of DEA studies has demonstrated that an inefficient DMU can become efficient by reducing its inputs, or by increasing its outputs. In the standard DEA approach, this is achieved by a uniform reduction in all inputs (or a uniform increase in all outputs). However, in principle, there are an infinite number of possible improvements that could be implemented in order to reach the efficiency frontier, and, hence, there are many solutions, should a DMU plan to enhance its efficiency.

It is noteworthy that, in the past few decades, the existence of many possible efficiency improvement solutions has prompted a rich literature on the methodological integration of Multiple Objective Linear Programming (MOLP) and DEA models. In particular, Suzuki et al. (2010) proposed a Distance Friction Minimisation (DFM) model. In this approach, a generalised distance indicator is employed to assist a DMU to improve its efficiency by a movement towards the efficiency frontier surface. Of course, the direction of the efficiency improvement depends on the input/output data characteristics of the DMU. It is then appropriate to define the projection functions for the minimisation of distance by using a Euclidean distance in weighted space. As mentioned earlier, a suitable form of multidimensional projection functions that serves to improve efficiency is given by a Multiple Objective Quadratic Programming (MOQP) model, which aims to minimise the aggregated input reductions, as well as the aggregated output increases. Thus, the DFM approach can generate a new contribution to efficiency enhancement problems in decision analysis by employing a weighted Euclidean projection function, and, at the same time, it might address both input reduction and output increase.

The DFM model is able to calculate either an optimal input reduction value or an optimal output increase value in order to reach an efficiency score of 1.000, even though in reality this might be hard to achieve for low-efficiency DMUs. Recently, Suzuki et al. (2015) presented a newly developed adjusted DEA model, which emerged from a blend of the DFM and the target-oriented (TO) approach based on a Super-Efficiency model, in order to generate an appropriate efficiency-improving projection model. The TO approach specifies a target-efficiency score (TES) for inefficient DMUs. This approach can compute an input reduction value and an output increase value in order to achieve a TES. Suzuki et al. (2017) have also developed a new model from a blend of the TO-DFM and a Time-Series (TS) approach which incorporates a multi-temporal time horizon and a stepwise target score to achieve a final target efficiency score in order to generate a more appropriate efficiency-improving projection. This model can incorporate a catch-up effect in the efficiency projection, as shown in Figure 1.

However, this TS approach assumes that the efficiency frontier is fixed at any time period. But, in reality, efficiency frontiers do vary from year to year. That is to say, the TS approach does not incorporate a frontier shift effect in setting the target improvement level. Therefore, it is necessary to develop a more realistic efficiency improvement projection which includes a dynamic system of target-settings to achieve a target improvement level in order to programme more realistic policy initiative, as is suggested in Figure 2.

The aim of this paper is to develop a new multi-period DEA model from a blend of the TO-DFM approach and a dynamic approach which incorporates a dynamic perspective and a stepwise target score to achieve a final target efficiency score in order to generate a more appropriate efficiency-improving projection.

The above-mentioned Dynamic TO-DFM model will be applied to an efficiency assessment of Japanese cities. In this study, due to comparative data limitations, we consider two inputs (population and city budget) and two outputs (GDP and tax revenues). Based on these items, this study assesses the relative economic performance of Japanese big cities (so-called government-ordinance-designated cities in Japan) by means of a super-efficient DEA model. The efficiency evaluation result for the cities concerned from 2007 to 2013 based on the Super-Efficiency CCR model is presented in Figure 3.

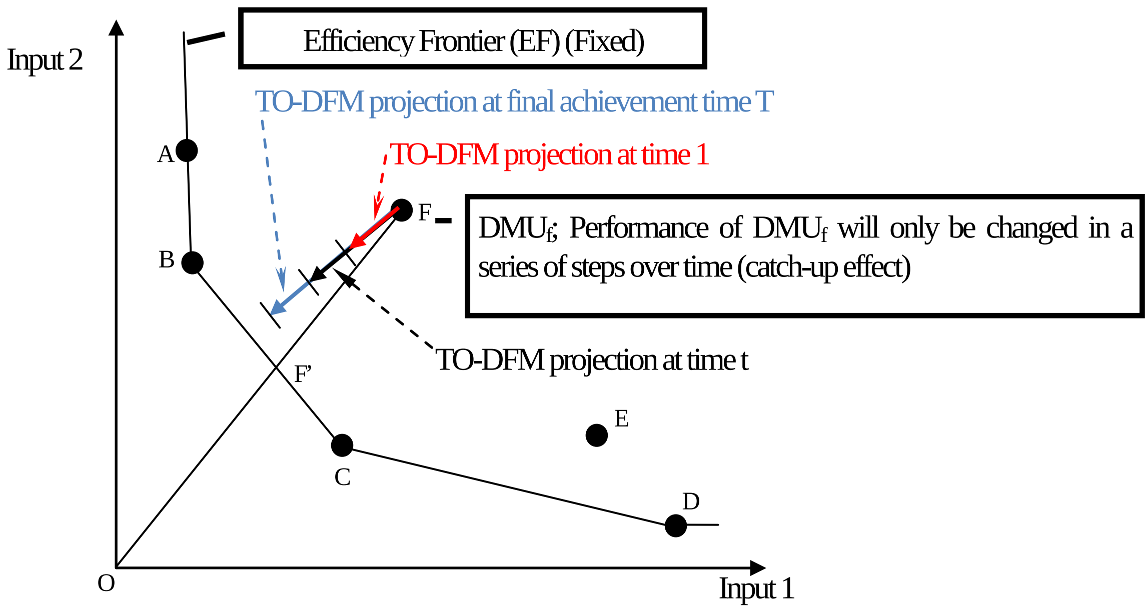



**Figure 1 Illustration of TS-TO-DFM model**

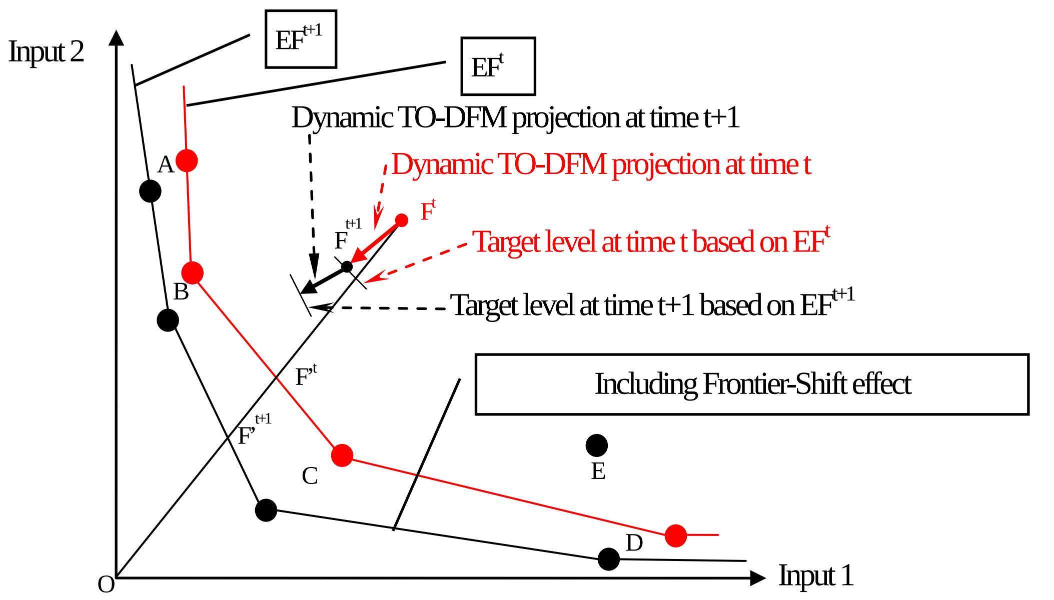
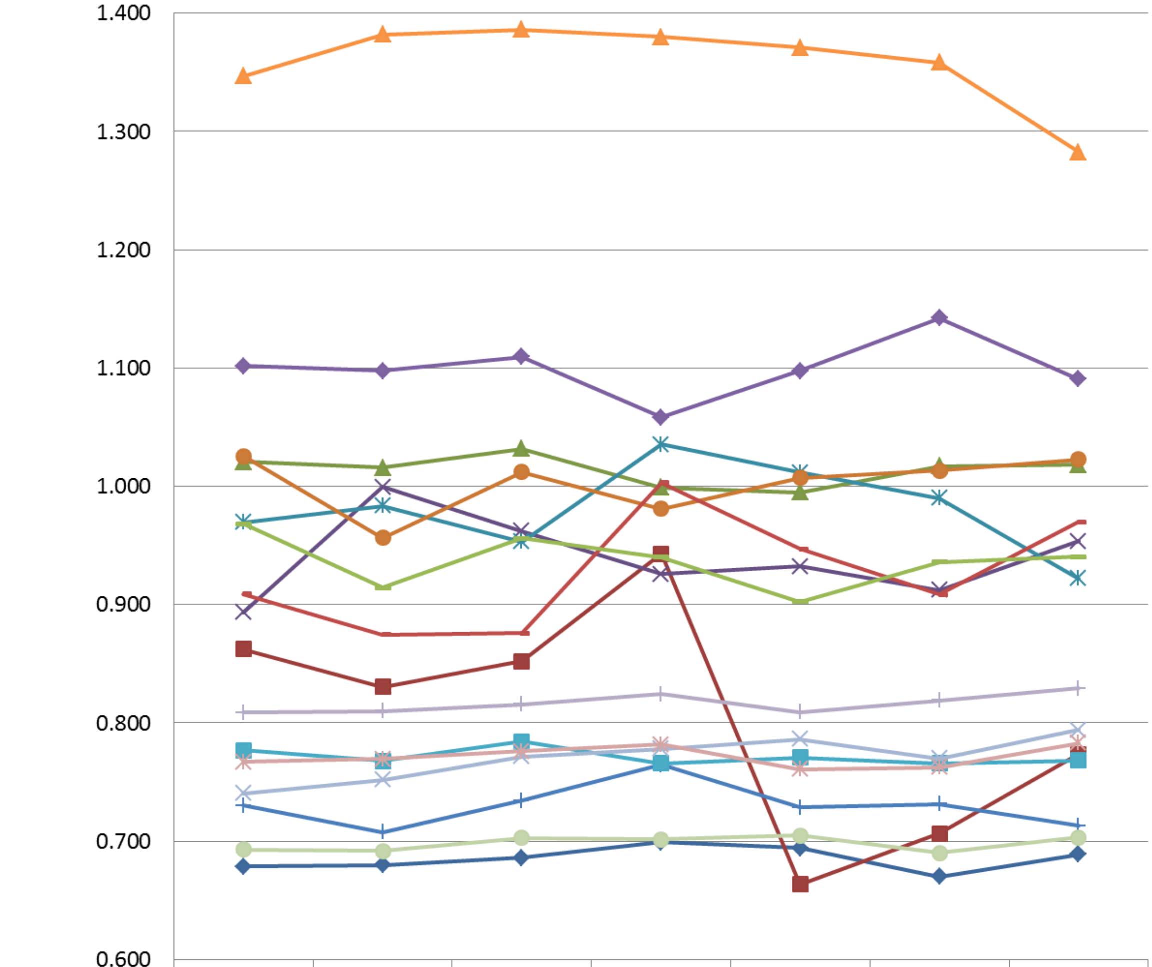



**Figure 2 illustration of Dynamic TO-DFM model**



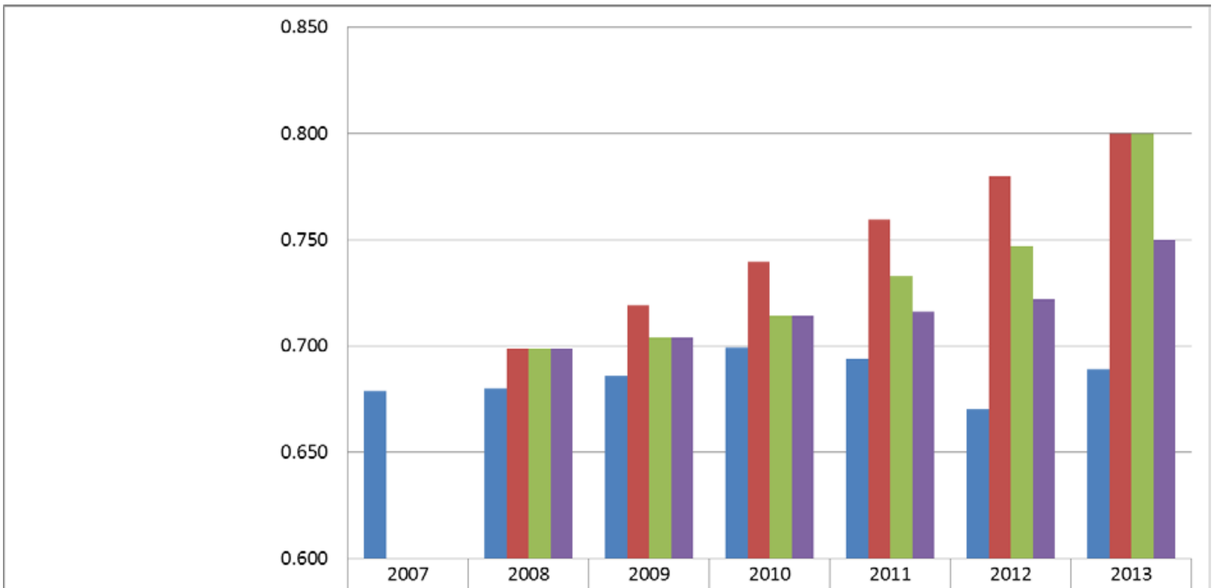

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|
| Sapporo | 0.679 | 0.680 | 0.686 | 0.699 | 0.694 | 0.670 | 0.689 |
| Sendai | 0.862 | 0.831 | 0.852 | 0.943 | 0.664 | 0.707 | 0.774 |
| Saitama | 1.021 | 1.016 | 1.032 | 0.999 | 0.995 | 1.017 | 1.018 |
| Chiba | 0.894 | 0.999 | 0.962 | 0.926 | 0.932 | 0.912 | 0.954 |
| Yokohama | 0.969 | 0.983 | 0.953 | 1.035 | 1.012 | 0.990 | 0.922 |
| Kawasaki | 1.025 | 0.957 | 1.012 | 0.981 | 1.007 | 1.014 | 1.023 |
| Niigata | 0.730 | 0.708 | 0.734 | 0.765 | 0.729 | 0.731 | 0.713 |
| Shizuoka | 0.909 | 0.875 | 0.876 | 1.003 | 0.947 | 0.909 | 0.970 |
| Hamamatsu | 0.968 | 0.914 | 0.956 | 0.940 | 0.902 | 0.936 | 0.941 |
| Nagoya | 1.102 | 1.098 | 1.109 | 1.058 | 1.098 | 1.142 | 1.090 |
| Kyoto | 0.777 | 0.768 | 0.784 | 0.766 | 0.771 | 0.766 | 0.768 |
| Osaka | 1.347 | 1.382 | 1.386 | 1.380 | 1.371 | 1.358 | 1.283 |
| Kobe | 0.741 | 0.752 | 0.771 | 0.778 | 0.786 | 0.770 | 0.794 |
| Hiroshima | 0.767 | 0.769 | 0.776 | 0.782 | 0.761 | 0.763 | 0.783 |
| Kitakyushu | 0.693 | 0.692 | 0.703 | 0.702 | 0.705 | 0.690 | 0.703 |
| Fukuoka | 0.809 | 0.810 | 0.816 | 0.824 | 0.809 | 0.819 | 0.829 |

**Figure 3 Efficiency scores for Japanese big cities based on the SE-CCR-I model**

From Figures 3, it can be seen that Osaka, Nagoya, Kawasaki and Saitama in 2013 may be regarded as super-efficient cities. It also can be seen that the efficiency scores of Sendai 2011 decline drastically compare to their 2010 score. It is plausible that this reflects the direct influence of the Tohoku earthquake in 2011. We also notice that Sapporo city has the lowest efficiency scores. Sapporo city may also suffer from an indirect influence of the earthquake from 2011, though it seems necessary to make a serious effort to improve the urban economic performance of this city. We will now address in particular the city of Sapporo.

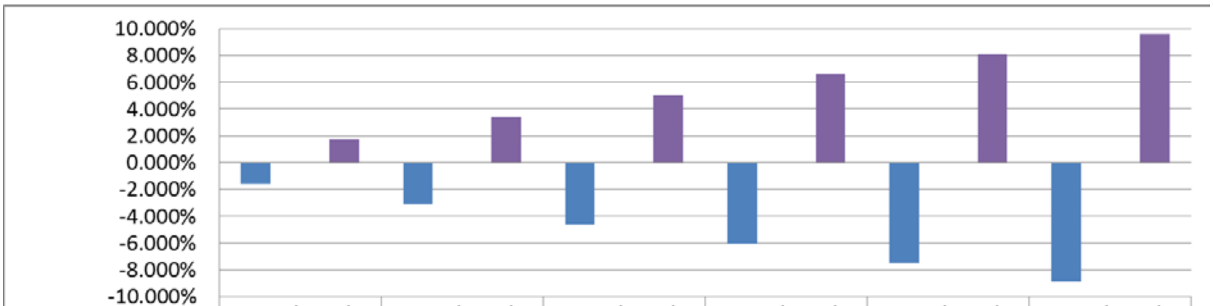
Next, the above-mentioned Dynamic TO-DFM model will be then used to analyse realistic circumstances and to determine the requirements for an operational strategy for a feasible efficiency improvement in Sapporo city. We will use Sapporo 2007 as an illustrative case and point of reference, and present an efficiency-improvement projection result based on the TS-TO-DFM model and Dynamic TO-DFM model. The 2007 efficiency value for Sapporo is 0.679 (see Figure 4). We now consider a target achievement time T of 6(i.e., 2013), while the steps necessary to improve efficiency are given by the time series t = 1, 2, 3, 4, 5, and 6 (i.e. 2008, 2009, 2010, 2011, 2012, and 2013). The final TES for Sapporo 2013 is somewhat arbitrarily set at 0.800. Each TES for each year calculated by the TS-TO-DFM model and the Dynamic TO-DFM model is shown in Figure 4. Especially the TES for each year calculated by the Dynamic TO-DFM model represents a frontier shift effect, as shown in Figure 2. The resulting input reduction values and the output increase values for Sapporo city based on the TS-TO-DFM model and the Dynamic TO-DFM model are presented in Figure 5 and 6.

From Figure 5, we notice that the projection results of the TS-TO-DFM model seem to be linearly increasing values in a rather simplistic form for each year by year. In contrast, from Figure 6, we notice that the projection results of the Dynamic TO-DFM model seem to reflect a frontier shift effect for each year, so as to reach a score of 0.800 in 2013. We also notice that the TES from 2011 to 2013 might represent an unrealistic situation, as is does not incorporate an influence of the Tohoku earthquake in 2011. In fact, the efficiency score of Sapporo from 2011 to 2013 appear to clearly drop to a lower value, as shown in Figure 4. In this regard, the Dynamic TO-DFM model can incorporate a revised TES, based on these facts and real world conditions. In the present study, we assume a revised TES for 2013, set at 0.750, while each target score was set for each year from 2011 to 2013 in Figure 4. The result of this revised target Dynamic TO-DFM model is presented in Figure 7.



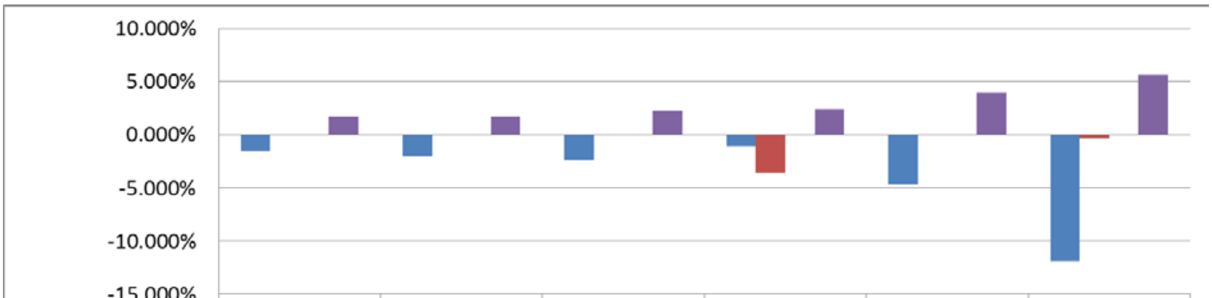

| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|
| real efficiency Score | 0.679 | 0.680 | 0.686 | 0.699 | 0.694 | 0.670 | 0.689 |
| TES for each year by TS-DFM for 2013 | | 0.699 | 0.719 | 0.739 | 0.760 | 0.780 | 0.800 |
| TES for each year by Dynamic-DFM for 2013 | | 0.699 | 0.704 | 0.714 | 0.733 | 0.747 | 0.800 |
| TES(revised in 2011) for each year by Dynamic-DFM for 2013 | | 0.699 | 0.704 | 0.714 | 0.716 | 0.722 | 0.750 |

**Figure 4 Efficiency score and Target Efficiency Score (TES) for each year in Sapporo**



| | TES1(2008) =0.699 | TES2(2009) =0.719 | TES3(2010) =0.739 | TES4(2011) =0.760 | TES5(2012) =0.780 | TES6(2013) =0.800 |
|---|---|---|---|---|---|---|
| (I)Budget | -1.585% | -3.124% | -4.619% | -6.072% | -7.485% | -8.860% |
| (I)Population | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| (O)GDP | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| (O)Tax revenues | 1.711% | 3.373% | 4.988% | 6.557% | 8.083% | 9.567% |

**Figure 5 Efficiency-improvement projection results based on the TS-TO-DFM model (Sapporo)**



| | TES for 2008 =0.699 | TES for 2009 =0.704 | TES for 2010 =0.714 | TES for 2011 =0.733 | TES for 2012 =0.747 | TES for 2013 =0.800 |
|---|---|---|---|---|---|---|
| (I)Budget | -1.585% | -2.037% | -2.408% | -1.121% | -4.638% | -11.894% |
| (I)Population | 0.000% | 0.000% | 0.000% | -3.619% | -0.003% | -0.360% |
| (O)GDP | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| (O)Tax revenues | 1.711% | 1.733% | 2.196% | 2.344% | 3.932% | 5.619% |

**Figure 6 Efficiency-improvement projection results based on the Dynamic-TO-DFM model (Sapporo)**

| | TES for 2008 =0.699 | TES for 2009 =0.704 | TES for 2010 =0.714 | Revised TES for 2011 =0.716 | Revised TES for 2012 =0.722 | Revised TES for 2013 =0.750 |
|---|---|---|---|---|---|---|
| (I)Budget | -1.585% | -2.037% | -2.408% | 0.000% | -2.490% | -7.468% |
| (I)Population | 0.000% | 0.000% | 0.000% | -2.440% | 0.000% | 0.000% |
| (O)GDP | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% | 0.000% |
| (O)Tax revenues | 1.711% | 1.733% | 2.196% | 1.194% | 2.111% | 2.504% |

**Figure 7 Efficiency-improvement projection results based on the revised target Dynamic TO-DFM model (Sapporo)**

From figure 7, it is noteworthy that the Dynamic TO-DFM model shows the characteristics of flexibility and implementability in urban policy programmes.

From the above finding, we note that the Dynamic TO-DFM model is able to present a realistic efficiency-improvement plan which incorporates a stepwise target score in a time-series perspective, frontier shift effects, and real world conditions to achieve a target efficiency score. In conclusion, our Dynamic TO-DFM model is able to programme a more realistic efficiency-improvement urban development plan, and may thus provide a meaningful contribution to decision making and planning for efficiency improvement of Japanese cities.

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