Distribution of Population Density and the Cost of Local Public Services: The Case of Japanese Municipalities*

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abstract

We consider the relationship between the cost of public service provision and the distribution of population within a municipality. By making use of small area statistics, we investigate the distribution of population density in Japanese cities. Taking account of the population distribution within a municipality, we estimate the cost function of local public services in the Japanese local public sector. The result shows that compaction of the city reduces per capita cost of public services and that its extent varies across the cities.

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1 Introduction

The purpose of this paper is to examine how the spatial structure of population distribution within a municipality affects per capita cost of providing local public services. It is well-recognized that environmental factors such as size of population and of area are important determinants of the cost of providing public services as well as factor prices and level of output (e.g. Shoup, 1969; Musgrave and Musgrave, 1989). In addition to considering population size, we focus on the distribution of population as a determinant of the cost of local public services. In particular, using small area statistics, we estimate cost function of local public services in Japanese municipalities.

The effect of change in population distribution on the cost of providing public services is an important issue, not only theoretically but also practically. For example, the financial position of the local public sector is anticipated to worsen with urban sprawl, which is a phenomenon commonly observed in both developed and developing countries. In the non-metropolitan area in Japan, both population shrinkage and progress in suburbanization are expected to raise the cost of local public services per capita. In order to improve cost efficiency of public services, Japan's central government has promoted merger of municipalities and has tightened regulation of land use. The merger of municipalities is expected to reduce the per capita expenditure due to economies of scale in population. On the other hand, land use regulation is a policy oriented toward a compact city.[1]

Whether compaction of municipalities brings or not a reduction of the cost is still an open question. In the empirical literature, Ladd (1994) has shown that except for sparsely populated counties, greater population density with population growth has an upward pressure on per capita local public spending. Duncombe and Yinger (1993) have analyzed returns to scale in public production. Distinguishing the between economies of population scale and other dimensions of scale such as quality and technical return, they have shown that fire protection service has slightly decreasing return to scale in population. Hayashi (2002) has investigated the minimum efficient scale (MES) of local public production incorporating the congestion function, and has found that the population attaining MES depends on the socioeconomic and geographic characteristics of the region.

The analyses mentioned so far have focused upon the relationship between the cost of local public services and the total population or the average population density of region. The costs of public service provision depend not only on the size of population and of area but also on the distribution of population within a municipality.[2] Even though both total population and area are

[1] The concept of compact city is a major trend in urban planning not only in Japan but also in the world. It should be noted that urban compactness cannot be characterized only by the population density (e.g. Morrison, 1998: Burton, 2002: and Chen et al., 2008).

[2] In the literature, Elis-Williams (1987) has considered the optimal location of public facilities, taking account of the

the same, a municipality with a densely populated neighborhood may have different cost from that with uniformly populated area. In line with this perspective, using density defined as the number of jobs and people per area of urbanized land, Carruthers and Ulfarsson (2003) estimated the expenditure equations in the US counties and argued that urban sprawl raises the cost of providing public services. Craig (1987) and Craig and Heikkila (1989) have estimated the effects of congestion on the produced output, using the data across neighborhoods within a single city.[3]

These analyses reveal that the cost of providing public services is affected not only by aggregate variables such as population and area but also by the distribution within a municipality. Carruthers and Ulfarsson (2003) have been focused upon the population density in urbanized area, since they are primarily concerned with the relationship between the cost of public services and urban sprawl. However, when we consider the cost of public services of the municipality including rural area, we have to capture the entire distribution of the population including not only urbanized area but also rural area.[4] Craig (1987) and Craig and Heikkila (1989) concentrated on analysis for a specific city. Although their analyses are useful to compare the magnitude of the congestion effects within a municipality, we could obtain a rich policy implication by investigating the relationship between the cost and the population density, taking into account other environmental characteristics.

In this paper, we consider the relationship between the cost of providing public services and the spatial structure of the population within a municipality. By making use of small area statistics, we investigate the distribution of population density in detail. We develop a simple index that represents the distribution of the population density. The index is similar to the familiar Lorenz curve. Using this index, we survey the distribution of the population density in Japanese municipalities. Furthermore, we construct an analytical framework which incorporates the population density within a municipality to the cost function formulated in the previous studies such as Duncombe and Yinger (1993) and Craig (1987). Using this framework, we estimate the parameters of the cost function and consider its implication.

The results obtained in this paper are the following. First, we confirm that the distribution of the population density within Japanese municipality significantly differs across the municipalities. Second, the concentration of population to a particular neighborhood within a city reduces the per capita cost of providing the public service. In contrast, the suburbanization characterized by an expansion of residential area leads an increase in the cost. Finally, the effects of the population distribution on the cost vary among the items of expenses, which reflect the difference in technology and form of provision among the services.

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relationship between spatial population distribution and the cost of providing public services. Shoup (1989) has addressed a normative issue of the rules for sharing the cost of public services within a city.

[3] See also Bennett (1980) and Tao and Yuan (2005).

[4] In the context of regional economics, Ciccone and Hall (1996) considered a relationship between spatial density of employees and productivity at the state level.

The rest of this paper is organized as follows. In section 2, we develop a methodology to analyze the distribution of the population and describe Japanese cities. In section 3, we present an analytical framework which is an extended version of the cost function developed by Craig (1987) and Duncombe and Yinger (1993). Section 4 is devoted for the empirical investigation for Japanese cities. In section 5, we estimate the cost function for towns and villages. Concluding remarks is presented in section 6.

2 Spatial Structures of Japanese Cities

Prior to the estimation of the cost function, we describe the current situation of the population distribution within the municipalities. Fig.1 shows an example of graphical representation of the data used here. In this figure, Toyama-shi, a municipality located in the middle region of Japan, is decomposed into the small areas that consist of several enumeration of population census. In Figure 1, the dark colored pieces represent densely populated areas.

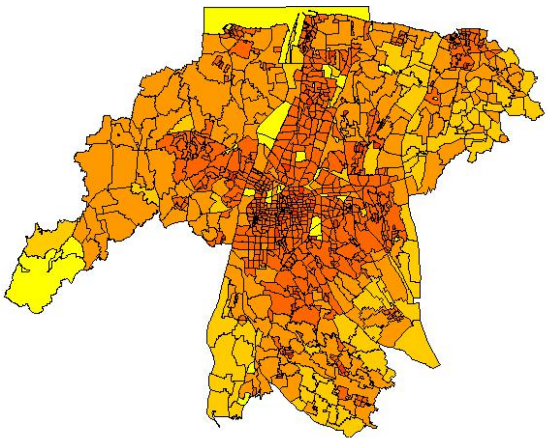

Figure 1 An example of the population density by small areas

In order to capture the distribution of population density, density gradient is most frequently used in the analysis.[5] However, it will be difficult to incorporate density gradients into the analysis of the cost function previously done. Instead of density gradient, we use a index based on the concentration curve.

[5] For example, Sridhar (2007) has considered density gradients in Indian city and its determinants, including public expenditures. Cheng and Masser (2003) also have investigated the pattern of urban growth using an extended model of the density gradient.

2.1 Methodology: Concentration Curve and Concentration Index

In this subsection we will show an index which is based on the familiar Lorenz curve.[6] Consider a municipality of which the population size is *N*. Suppose further that this municipality consists of *K* neighborhoods. For explanatory purpose, in this subsection, each neighborhood is assumed not to vary in size. The distribution of population in the municipality is represented by a vector $\mathbf{n} = (n_1,...,n_K)$, where n_i denotes the population in the *i*th neighborhood. The concentration curve of the population is defined as follows:

$$L_P(p) = \frac{1}{N}\sum_{j=1}^{k} n_j^{\uparrow}\ , \quad for \quad p = \frac{k}{K} \tag{1}$$

where $n_i^{\uparrow}$ denotes the number of the population in the *i*th neighborhood in increasing order such as $n_1^{\uparrow} \leq n_2^{\uparrow},... \leq n_K^{\uparrow}$. By definition, $L_P(p)$ is an increasing convex function in *p* and $L_P(0) = 0$ and $L_P(1) = 1$ hold. The concentration curve represents a relative degree of concentration by its curvature. In Fig. 2, $L_P^A(p)$ and $L_P^B(p)$ represent the concentration curves based on different distribution of population, respectively. We can consider that the $L_P^A(p)$ represents more concentrated situation than $L_P^B(p)$. Such ordering is preserved by a certain class of function. Let consider two distributions of population denoted as $\mathbf{n}^A$ and $\mathbf{n}^B$. From the well-known results of majorization, we obtain the following properties.[7]

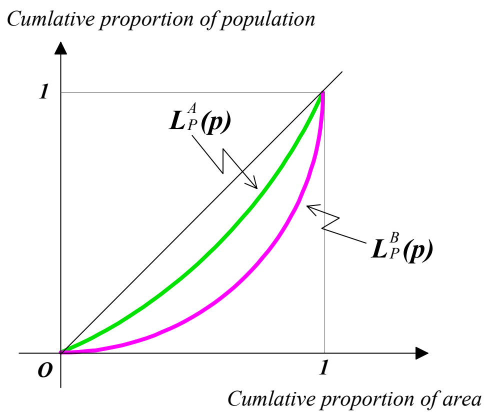

Figure 2 Concentration curve of population

Property 1 Suppose that two distributions such as $\mathbf{n}^A$ and $\mathbf{n}^B$. Let $L_P^A(p)$ and $L_P^B(p)$ as the concentration curves corresponding $\mathbf{n}^A$ and $\mathbf{n}^B$, respectively. If for all $p \in [0,1]$, $L_P^A(p) \geq L_P^B(p)$ is met, then for any symmetric concave function $g(\mathbf{n})$, $g(\mathbf{n}^A) \geq g(\mathbf{n}^B)$.

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[6] For example, see Lambert (1993).

[7] For example, see Marshall and Olkin (1993).

We can reduce the concentration curve to a concentration index which corresponds to the Gini index in the literature of income inequality. The concentration index, *CONC*, can be defined as follows:

$$CONC(\mathbf{n}) = -1 + \frac{1}{K} + \frac{2}{KN}\sum_{i=1}^{K} i n_i^{\uparrow} \ , \tag{2}$$

It can be easily verified that the concentration index is a convex function in **n**. Larger degree of concentration in the sense of the concentration curve means larger concentration index.

Although the concentration index is a simple measure of the distributive properties of the population, it should be noted that we can not capture the distribution of municipality, entirely. First, since the concentration index is a relative measure, we can not distinguish a municipality in a metropolitan area with high population density from one in the hinterland with low population density. Second, unlike the gradient curve of density, the concentration index does not show the geographical correlation among the neighborhoods. However, as shown in the later section, we can easily incorporate the distribution of population density into the analysis by making use of the concentration curve.

2.2 Spatial Distribution of Population: the Case of Japanese Cities

According to the definition described in the previous subsection, we survey the concentration index in the Japanese cities. In Japan, local government is two-tiered: prefectures and municipalities. Prefectures are the higher tier of local government covering wide areas.[8] The municipalities are classified into city, town and village. In this subsection, we concentrate our attention to the city. But “designated cities”, which have population greater than 500,000 and have similar functions with prefecture unlike other cities, are excluded from the observation.[9]

We compiled the data on the neighborhoods in each city from the Toukei GIS Plaza provided by Statistical Bureau, Ministry of Internal Affairs and Communications, which is based on the population census conducted in 2000. The neighborhood is defined as such subdivision of municipalities as *cho* and *aza*. Since the area of neighborhood varies in size, the concentration index defined in (2) is slightly modified. In addition, the small area without population is excluded from the calculation of concentration index, since our concern is the cost of public services which is

[8] For the current state of Japan's local administration, see CLAIR (2005). Recent economic issues on the Japanese local public finance are surveyed by Joumard and Yokoyama (2005).

[9] In FY2000, there were 12 designated cities: Sapporo, Sendai, Chiba, Kawasaki, Yokohama, Nagoya, Kyoto, Osaka, Kobe, Hiroshima, Kitakyushu and Fukuoka. In addition to those cities, five cities have become the designated city by the end of 2007.

mainly provided in the populated area.

Figure 3 shows the distribution of the concentration index. We can see that the calculated value of concentration index considerably varies across the cities. This fact suggests a need for the investigation of the cost of public services taking account of distribution of the density. Most of municipalities with extremely low concentration index are located in Tokyo metropolitan area. Such cities consist of densely populated neighborhoods and show the high density of population as a whole.

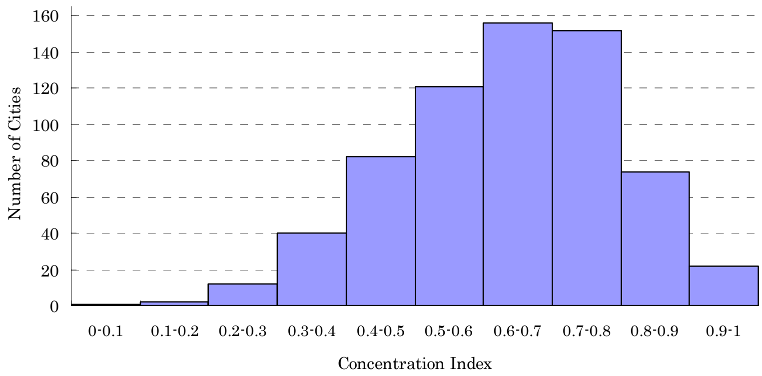

Figure 3 Distribution of the concentration index

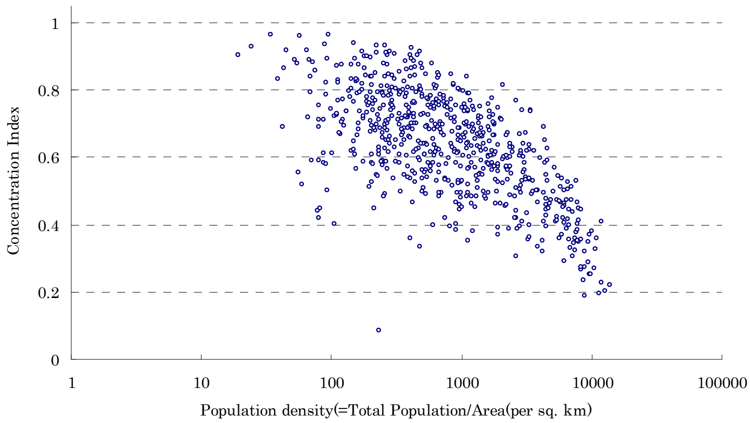

Figure 4 Concentration index by population density by cities

Figure 4 shows that the concentration index is negatively correlated with the average population density. However, in the group of cities with low population density, the concentration index varies across the cities. Hence, it is suggested that the characteristics in the cost of local public services may not be captured by the average statistics such as the population density as a whole.

In the next section, we present an analytical framework to investigate the cost structure of local public services.

3 Analytical Framework

In this section, we develop the model which is an extended version of Craig (1987), Duncombe and Yinger (1993) and Hayashi (2002). In order to focus on the cost structure of the local public service provision, we do not deal with the demand side.

Suppose a municipality which consists of K neighborhoods and of N population. Each neighborhood is assumed to be identical in size. Hence, K is proportional to the area in the municipality. We denote the number of residents in each neighborhood as the vector $\mathbf{n} = (n_1,...,n_K)$. The Municipality regards the distribution of residents as given when they plan the public policy. In each neighborhood, public services are produced by the municipalities and are consumed by the residents. For analytical simplicity, we assume that the benefit of the public services do not spill over the other neighborhood.

Production technologies are assumed to be identical among the neighborhoods. Minimum cost to produce the public service in the ith neighborhood can be written by the cost function, $\hat{c}_i$ as follows:

$$\hat{c}_i(\mathbf{w}, g_i, N) = A(N)c(\mathbf{w}, g_i), \tag{3}$$

where g_i and $\mathbf{w}$ denote the quantity of the public service and the vector of factor price, respectively. In (3), The quantity of the output, g_i, can be interpreted as a direct output. We also assume that the minimum cost is increasing with the factor prices function: $\partial\hat{c}_i / \partial w > 0$ and is increasing with the public services, that is $\partial\hat{c}_i / \partial g_i > 0$. In (3), $A(N)$ denotes a shift parameter resulting from the common cost and has a negative slope in N, that is $A'(N)<0$.

The public service g_i measured by a quantity unit is converted to the service denoted by z_i that is enjoyed by the residents. Thus, z_i is an index of C-output in Bradford et al. (1969). We can write a production function of C-output as follows:

$$z_i = \varphi(g_i, n_i, \mathbf{a}), \tag{4}$$

where $\mathbf{a}$ denotes environmental characteristics other than population. Population in the ith neighborhood is included to take account of the congestion effect. In what follows we assume that $\partial\varphi / \partial g_i > 0$ and $\partial\varphi / \partial n_i \leq 0$. Eq. (4) represents a conceptual process which transforms the output measured in the quantity of products to the services enjoyed by the residents. Solving (4), we obtain,

$$g_i = \phi(z_i, n_i, \mathbf{a}), \tag{5}$$

The Municipality decides the level of C-outputs according to its policy objects. It is a plausible situation that identical levels of service among the neighborhood within a municipality are provided because of equity considerations. That is, denoting Z as a target level of public service chosen by the municipality, we assume z_i=Z for i=1,…, K. Thus, (5) becomes as follows:

$$g_i = \phi(Z, n_i, \mathbf{a}), \tag{6}$$

Inserting (6) into (3), the cost function can be rewritten as follows:

$$\hat{c}_i(\mathbf{w}, g_i, N) = A(N)c[\mathbf{w}, \phi(Z, n_i, \mathbf{a})], \tag{7}$$

The total cost of the municipality J is obtained by aggregating the costs of the neighborhoods.

$$C^J(\mathbf{w}^J, Z^J, \mathbf{n}^J, \mathbf{a}^J, K^J) = A(N^J)\sum_{i=1}^{K^J} c[\mathbf{w}^J, \phi(Z^J, n_i^J, \mathbf{a}^J)], \tag{8}$$

where superscript with capital letter denotes the index of municipality. Using (8), we investigate the determinants of the cost to provide the public services. For analytical simplicity, we make the following assumption:

Assumption 1 The cost function of the small area has the following properties:

(i) $c(\mathbf{w}, g_i)$ is homogeneous degree of λ(>0) in g,

(ii) $\phi(Z, n_i, \mathbf{a})$ is homogeneous degree of δ(>0) in n_i, and

(iii) $A(N)$ takes the form of $A(N) = N^{-\gamma}$.

Under Assumption 1, using the Euler's theorem and rearranging (8), we can represent the per capita cost of local public services as follows:

$$\frac{C^J(\mathbf{w}^J, Z^J, \mathbf{n}^J, \mathbf{a}^J, K^J)}{N^J} = c(\mathbf{w}^J, 1)\{\phi(Z^J, 1, \mathbf{a}^J)\}^{\lambda}(N^J)^{\lambda\delta-\gamma-1}D(\mathbf{n}^J), \tag{9}$$

where

$$D(\mathbf{n}^J) = \sum_{i=1}^{K^J} \left(\frac{n_i^J}{N^J} \right)^{\lambda\delta} , \tag{10}$$

reflects the relative distribution of population. Note that if λδ<1, then $D(\mathbf{n})$ becomes a strictly concave function. In the set-up described above, the cost of local public service per capita also depends on the aggregate population and the number of neighborhoods in addition to the factor prices and the quantity of the public service. Using Property 1, we can state the relationship between the population distribution characterized by the concentration curve and the cost of providing public services as follows:

Property 2. Suppose that λδ<1 hold. Let denote $L_P^A(p)$ and $L_P^B(p)$ as the concentration curves corresponding the population distributions denoted by $\mathbf{n}^A, \mathbf{n}^B \in R_{++}^K$ with $\sum_{i=1}^K n_i^A = \sum_{i=1}^K n_i^B = N$. If $L_P^A(p) > L_P^B(p)$ holds for $p \in [0,1]$, then $C(\mathbf{w}^0, Z^0, \mathbf{n}^A, \mathbf{a}^0, K)/N > C(\mathbf{w}^0, Z^0, \mathbf{n}^B, \mathbf{a}^0, K)/N$ holds for given $\mathbf{w}^0$, Z^0 and $\mathbf{a}^0$.

We turn to the comparative statics. It can be easily seen that $\partial(C/N)/\partial w > 0$, and $\partial(C/N)/\partial Z > 0$. Let us consider the effect of a proportional increase in the population of each neighborhood. That is, $dN = \sum_{i=1}^K dn_i$ and $dn_i / n_i = const$ for i=1,...,K. In this situation, the relative distribution of the population does not change. Differentiating (9), we obtain

$$\left. \frac{d(C/N)}{dN} \right|_{\frac{dn_i}{n_i} = const} = (\lambda\delta - \gamma - 1)\frac{C}{N^2}. \tag{11}$$

Hence, if $\lambda\delta - \gamma - 1 < 1$ is met, the proportional increase in the population reduces the cost per capita.

Second, consider a situation in which the distribution of the population changes due to the migration from the jth neighborhood to the ith neighborhood. That is $dn_i = -dn_j > 0$. Noting that, in this situation, the aggregate population does not alter, we obtain,

$$\left. \frac{d(C/N)}{dn_i} \right|_{dn_i + dn_j = 0} = \lambda\delta \frac{C}{N^{1+\lambda\delta} D(\mathbf{n})} (n_i^{\lambda\delta - 1} - n_j^{\lambda\delta - 1}). \tag{12}$$

Thus, as suggested in Property 2, if $\lambda\delta \in (0,1)$ holds, then the concentration of the population to the *i*th neighborhood from the *j*th neighborhood reduces the per capita cost of the local public services.

Finally, we consider the effects of an increase in the number of neighborhood. In order to separate this effect from other factors, we consider a situation in which *m* neighborhoods with its population of n_k^0/m are replicated from each of *K* neighborhoods, where n_k^0 denotes the initial population in *k*th neighborhood. That is, keeping the total population and the concentration index constant, the populated area in the municipality is increased to *mK* from *K*. The difference before and after the change in the number of neighborhoods can be written as follows:

$$\Delta\left(\frac{C}{N}\right) = \left(\frac{C}{N}\right)(m^{1-\lambda\delta} - 1). \tag{13}$$

where Δ denotes the difference operator defined as after-before. Hence, if $\lambda\delta < 1$, then $\Delta(C/N) > 0$: an increase in the number of the neighborhoods positively affects per capita cost.

In summary, whether the compaction of the municipality is desirable or not depends on the congestion effect represented by $\lambda\delta$.

4 Empirical Analysis

In this section, we estimate the cost function based on the model described in the previous section. As in the previous section, we employ the small area statistics varied in size. An alternative is to use grid square statistics. The latter statistics, where the partition is by essentially equal land areas, corresponds closely to the model in the precious section. However, using grid square statistics makes it extremely complicated to treat a small area that belongs more than two municipalities. Hence, we employ data based on the neighborhood, modifying the model described above.

4.1 Data and Estimation Results

The distribution of population density and area within neighborhoods is obtained from Toukei GIS Plaza based on the 2000 Population Census. Table 1 summarizes the statistics for the neighborhoods.

Table 1. Descriptive statistics of neighborhoods

	Mean	Max.	Min.	Std. dev.
Number of neighborhood within each city	158	2,306	5	192
Total area of neighborhoods by city (in hectares)	13,990	122,153	511	13,781
Area of each city per neighborhood (in hectares)	182	9,264	4	479
Population density by neighborhood (/km²)	1,805	13,900	25	2,450

Source: Toukei GIS Plaza.

In order to avoid the endogeneity problem, for the variables other than the population, we employ the data on FY2002. We compiled the data on local public services other than output from the Survey of Account Settlement in Each Municipality (Shichosonbetsu-Kessan-Joukyo-Sirabe). The specification of C-output is a controversial issue in the literature. In this paper, we compiled the data on the outputs from the level of administration index reported by Nikkei Inc. Research Institute of Industry and Regional Economy. This is a composite index constructed from thirty indicators, including public fees, public welfare, education, and infrastructures etc.

We exclude designated cities from the sample, since these cities are allocated broader administrative authority than other cities, towns and villages.[10] Moreover, several cities are excluded from the sample due to lack of the data on the C-output. As a result, the number of observations is 635 cities.

We specify the cost function as follows:

$$\ln\left(\frac{C^J}{N^J}\right) = \alpha_0 + \beta a^J + \alpha_1 \ln W^J + \alpha_2 \ln Z^J + \alpha_3 \ln N^J + \ln\left\{\sum_{i=1}^{K^J} l_i^J \left(\frac{n_i^J / l_i^J}{N^J}\right)^{\alpha_4}\right\}, \quad (14)$$

where W denotes the wage rate and is defined by,

$$W^J = \frac{\textit{Total wage payments in municipality J}}{\textit{Number of local public employees in municipality J}}.$$

Theoretically, the municipalities produce public services employing capital as well as labor. The price of capital can not be identified when this does not vary across the municipalities.

The per capita cost for each municipality is obtained by

[10] Designated cities are exceptionally authorized to carry out all or part of the functions normally carried out by prefectures in respect of such administrative activities as social welfare, public health, city planning, etc.

$$\frac{C^J}{N^J} = \frac{\textit{Aggregate expenditure in municipality J}}{\textit{Census population in municipality J}}.$$

In (14), $\alpha_3 = \lambda\delta - \gamma - 1$ and $\alpha_4 = \lambda\delta$. In the theoretical model described in the previous section, it is assumed that the area in each neighborhood is identical. Since, we employ the small area statistics varied in size, $D(\mathbf{n})$ is modified as the last term in RHS of (14).

Socioeconomic variables denoted by the vector **a** include the following.

$$\mathbf{a} = (CORE,\ \ SPECIAL,\ \ Merger,\ \ \ln AGE,\ \ \ln IND).$$

The first three elements of **a** are included to control the administrative characteristics of sample. In order to control the difference in the administrative authorities, the dummy variable, *CORE*, which takes the value of one if the sample is the core city, is included.[11] The variable, *SPECIAL*, is a dummy variable which is one if the sample is a special city.[12] *Merger* denotes a dummy variable which is one if the sample is established by the merger during 1997-2002.

Table 2. Descriptive statistics

Variables	Mean	Max.	Min.	Std. dev
ln(*C*/*N*)	3.428	4.007	2.625	0.262
ln*IND*	2.880	3.514	2.034	0.267
ln*AGE*	5.885	7.116	5.414	0.231
ln*N*	8.785	9.080	8.524	0.096
ln*W*	11.229	13.839	8.690	0.823
ln*Z*	4.357	4.543	4.182	0.059
	No. of cities			
Core city	29			
Special case city	35			
Merger during 1997-2002	6			

The last two elements of **a** are socioeconomic variables to control the environmental characteristics. To take account of the difference in age composition, *AGE* denotes the proportion of residents whose age over 65 to the total population is included in the estimation. The difference in the industrial composition is controlled by *IND* which is the proportion of employees working in

[11] Core cities, which have populations of at least 300000 and land areas of over 100 km^2, are permitted to carry out part of the functions delegated to the designated cities.

[12] Special case cities, which have populations over 200000, are authorized to carry out the same functions as core cities with some exceptions.

secondary industry to the total employees.[13] Descriptive data other than the neighborhood used in the estimation is summarized in Table 2.

Using the data set described above, we estimate (14). Since (14) is a non-linear function, the estimation procedure is non-linear ordinary least square (NLS). Because the last term in RHS of (14) is the only nonlinear form, we employ the grid search method to find the sum of square residuals to be minimized. Since Cross-sectional data is used for the estimation, we should take into account the possibility of heteroscedasticity. It may be difficult to specify the property of the error term. Hence, the standard error is calculated by the variance-covariance matrix according to the heteroskedasticity-robust variance matrix estimator for NLS.[14]

Table 3 Estimation results for cost function

Variables	Coef.	Std. error*	t-value
Constant	3.068	0.898	3.417
CORE	0.197	0.035	5.644
SPECIAL	0.088	0.025	3.584
Merger	0.121	0.071	1.692
ln*IND*	-0.164	0.028	-5.861
ln*AGE*	0.343	0.041	8.285
ln*N*	-0.164	0.017	-9.803
ln*W*	0.181	0.085	2.125
ln*Z*	0.510	0.115	4.425
α_4-1	-0.049	0.013	-3.819
R^2	0.573		
adjR^2	0.567		
Number of obs.	635		

*Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

The estimation results are represented in Table 3. In the table, instead of α_4, the results of α_4-1 are reported. From the table, we can find the following facts. First, the estimated coefficient of α_4 is significantly smaller than unity, suggesting that a concentration to densely populated neighborhoods reduces per capita cost of providing public services. That is, the compaction of the city is beneficial for improving the financial position of the local public sector.

Second, the coefficient of the total population is negative and significant, indicating that an

[13] Secondary industry includes mining and quarrying, manufacturing, electricity, gas and water, and construction.
[14] See Wooldrige (2002).

increase in the population keeping the relative distribution of the population density constant reduces the per capita cost of the local public services. This result shows the presence of the economies of population size. It should be noted that the per capita cost may be increased when the population growth is accompanied by suburbanization. We will address this issue in a later subsection. Furthermore, in the case of an increase in the population due to the merger of municipalities, it is ambiguous whether the per capita cost is reduced or not, because the merger implies an increase in the land area.

Third, the coefficients of the factor price and outputs are positive and are significant, which is consistent with the theory. In addition, the coefficient of the output is smaller than unity, suggesting the presence of economies of quality scale.

Fourth, the dummy variables to control the difference in the administrative authorities are positive and significant. The fact that the coefficient of *CORE* is larger than that of *SPECIAL* is consistent with the extent of the administrative authorities allocated to these cities. The dummy variable to control the merger is positive but insignificant. We can not say that the merger of the municipalities immediately reduces the per capita cost.

Finally, the environmental variables, *IND* and *AGE* are significant. The variable *IND* can be interpreted as a proxy variable of urbanization. The result suggests that an increase in the proportion of the employees working in secondary industry reduces the cost of providing public services. The fact that the coefficient of *AGE* is positive partly reflects the difference in the composition of public services. In addition, the cities with aged population are mainly located in rural area. Together with the positive coefficients of *IND*, the results suggest that the cost of providing public services is higher in rural areas than urban areas.

4.2 Population Size, its Distribution and the Cost of Providing Public Services

In the estimation results of the cost function, it is suggested that an expansion of the urban area accompanied by lowering density raises the cost of public services while population growth in the city as a whole reduces the cost. In this subsection, based on the estimation results in a previous subsection, we investigate the relationship between population growth and concentration.

Consider a hypothetical change in the population such that for an initial distribution of the population, $\mathbf{n}^{(1)} = (n_1^{(1)},\dots,n_K^{(1)})$, the distribution of the population after the change is $\mathbf{n}^{(\beta)} = (n_1^{(\beta)},\dots,n_K^{(\beta)})$, where $\beta > 0$ and

$$n_i^{(\beta)} = \left(n_i^{(1)}\right)^{\beta} \frac{\sum_{j=1}^{K} n_j^{(1)}}{\sum_{j=1}^{K} \left(n_j^{(1)}\right)^{\beta}}.$$

By this modification of the initial population distribution, the total population is not changed, while the concentration index becomes higher than the initial distribution under the condition of β>1 due to the downward expansion of the concentration curve. For various values of the β, we calculate the concentration indices. Using the concentration index, we calculate the total population in which the per capita cost of public services remains the same as the initial situation. Thus, the isocost curve, which is written as isocost, is defined as the locus of the combinations of the population and the concentration index along which per capita cost remains constant.

$$iso\cos t^J = \{(CONC(\mathbf{n}^{(\beta)}), N) \in R^2_{++} \big| C/N = C^J / N^J\}.$$

From the estimation results, it can be shown that the isocost curve has a negative slope.

Figure 5 shows two examples of isocost curve. One of two isocost curves is that of Nishitokyo-shi located in the Tokyo metropolitan area. The other is that of Shibata-shi located in non-metropolitan area. In Figure 3, the square and circle dots on isocost curves show the present combination of the population and the concentration index. The total cost is increased if the dot moves toward the origin. But, since the output and other factors affecting the per capita cost are different across the cities, we can not compare the isocost curves of different cities, directly.

Figure 5 suggests the following facts. First, the concentration of the population within a city can mitigate the pressure on increasing the per capita expenditure arising from population declining. Second, the cost reduction by an increase in the population is more remarkable in the rural area than urban area, since the isocost curve is concave toward the origin.

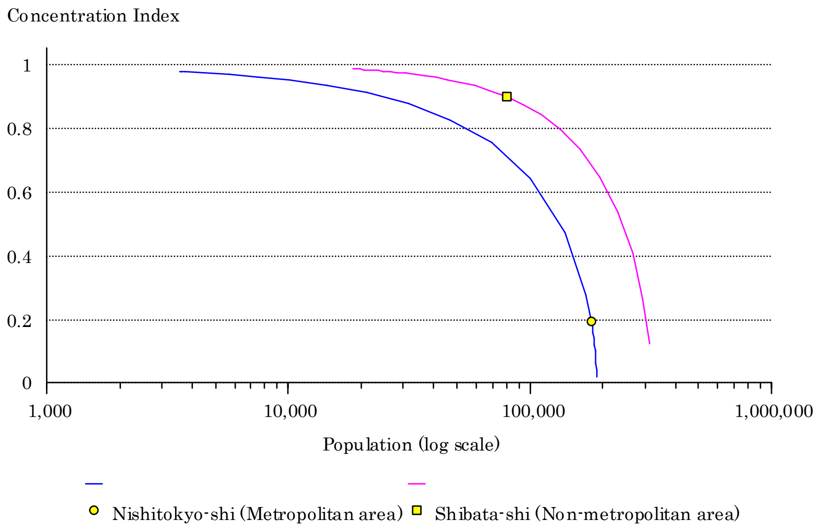

Figure 5 A comparison of isocost curves: metropolitan and non-metropolitan area

Table 4 Elasticity for the concentration of the population

Highest 20 cities				Lowest 20 cities			
	Elasticity	*CONC*	Density (/ km^2)		Elasticity	*CONC*	Density (/ km^2)
Yokosuka**	-1.695	0.692	4,258	Matsu-ura**	-0.082	0.085	231
Yamagata*	-1.593	0.845	670	Hatogaya**	-0.111	0.190	8,765
Ohita*	-1.540	0.751	1,209	Nishitokyo**	-0.151	0.195	11,412
Maizuru	-1.487	0.848	2758	Warabi**	-0.156	0.220	13,934
Asahikawa	-1.451	0.916	481	Siki**	-0.190	0.307	7,183
Komatsu	-1.381	0.843	293	Chikugo	-0.202	0.354	1,131
Kouriyama	-1.380	0.869	442	Utashinai	-0.206	0.402	106
Chitose	-1.356	0.941	149	Kodaira**	-0.209	0.234	8,730
Hakodate	-1.307	0.847	829	Musashino**	-0.212	0.202	12,651
Kanazawa*	-1.276	0.800	976	Gushikawa	-0.214	0.393	1,906
Fukui*	-1.251	0.782	741	Komae**	-0.214	0.230	11,848
Yamaguchi*	-1.246	0.734	394	Mitaka**	-0.236	0.270	10,401
Okinawa	-1.230	0.631	2,443	Muroto	-0.239	0.442	78
Iida	-1.227	0.731	330	Higashikurume**	-0.242	0.272	8,770
Houfu	-1.208	0.751	624	Tomishiro	-0.242	0.386	2,693
Monbetsu	-1. 207	0.964	34	Wako**	-0.245	0.388	6,356
Sizuoka*	-1.206	0.927	410	Iwai	-0.247	0.336	479
Eniwa	-1.204	0.933	221	Yashio**	-0.250	0.320	4,157
Rumoi	-1.203	0.964	95	Isezaki**	-0.252	0.369	1,930
Hunabashi**	-1.203	0.473	6,417	Higashimurayama**	-0.254	0.274	8,287

* Prefectural capital

** Cities located in the metropolitan area

Next, in order to investigate the impact of change in population density on the cost of public services, suppose a migration of residents from the most sparsely populated neighborhood to the most densely populated one. We represent the effect of this concentration on the per capita cost by the form of elasticity. The elasticity of per capita cost to the concentration of population is defined as follows:

$$\left.\frac{d(C/N)/(C/N)}{dn/N}\right|_{dn=dn_{i\max}=-dn_{i\min}} = \alpha_4 N^{1-\alpha_4} \frac{(n_{i\max})^{\alpha_4-1} - (n_{i\min})^{\alpha_4-1}}{\sum_{i=1}^{K} (n_i / N)^{\alpha_4}}.$$

where $n_{i\max}$ ($n_{i\min}$) denotes the population of the small area whose population density is maximum (minimum) within the city. This elasticity means the percentage change in the per capita cost induced by a concentration of residents corresponding to one percent of the total population.

Table 4 shows 20 cities with highest elasticity and 20 cities with lowest elasticity. The cities with high elasticity include those of prefectural capitals such as Yamagata-shi and Ohita-shi. In these cities, where urbanized area and rural area coexist within the city, an expansion of the residential area with decreasing population is expected to raise the cost of public services, remarkably. On the other hand, many of the cities with low elasticity are located in the Tokyo metropolitan area.

5 Analysis Including Towns and Villages for Specific Expenditures

5.1 Cost Structures in Towns and Villages

In the previous section, we concentrate our attention to cities, that is to relatively large populated municipalities. However, more than half of municipalities in Japan are classified into towns and villages other than cities. It is interesting whether the similar relationship between the distribution of the population within a municipality and the cost of local public service provision is observed in the case of towns and villages.

Unfortunately, we could not analyze the case of towns and villages in entire region due to lack of downloadable data. Instead, we estimate the cost function for the towns and the villages in the Kinki region, including six prefectures. The number of towns and villages in Kinki is 228. We compile the data from Statement of Accounts for each municipality.

In addition, we estimate the cost function for the specific item according to the classification by function of the expenditures. Functional form of the cost is the same as that of cities. The definition of the C-output is altered according to the characteristics of the expenditures. Due to data availability, 228 towns and villages are used for the sample. We focus on education expenses and sanitation expenses, using FY2000 data.

For the education expenses, we summarize the estimation results in Table 5 and find the following facts. First, both coefficients of population and distribution of population have negative sign, which suggests that the cost of providing educational services is reduced when the distribution of population is concentrated. Second, the wage rate is not significant. It may be because that the wage rate adopted here is not that of teacher but average wage of local public employees in each municipality. Finally, the coefficient of the variable representing the level of output, Z, has a negative sign. This may be because the teacher-pupil ratio is an environmental variable, not a characteristic of the output.

Table 5 Estimation results of towns and villages in Kinki region

Variables	Education expenses[a]			Sanitation expenses[b]		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	5.869	0.555	10.580	3.817	0.792	4.820
lnAGE	-0.459	0.181	-2.536	0.411	0.235	1.749
ln$N$	-0.438	0.075	-5.868	-0.150	0.084	-1.786
ln$W$	0.077	0.077	0.999	0.026	0.039	0.666
ln$Z$	-0.071	0.130	-0.569	0.176	0.081	2.167
α_4-1	-0.162	0.033	-4.945	-0.127	0.052	-2.418
R^2	0.353			0.250		
adjR^2	0.336			0.229		
No. of obs.	228			182		

[a] The level of the output of education services is defined by Z=(Number of pupils)/(Number of teachers).
[b] The level of the C-output is defined by Z=Waste emission in metric tons per thousand people
* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

The estimation results for sanitation expenses are summarized in Table 5.[15] In the estimation of sanitation expenses, the amount of waste emission per capita is used as a proxy variable of the output. The results are similar to those of the education expenses. That is, both coefficients of population and distribution of population, which is our main focus, have negative sign. Unlike education expenses, the coefficient of the output is positive, which suggests that the cost of the service in increasing with the level of the service.

In the analysis so far, we have used the data on FY2002. In recent years, the central government promotes the merger of municipalities. As a result, the number of municipalities rapidly declined from 3229 in 2000 to 1822 in 2005. In particular, the number of towns and villages declined from 2558 to 1044. In order to investigate whether similar properties are observed after the merging process during the first half of 2000s, we estimate the cost function for towns and villages using the fiscal data on FY2005.[16]

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[15] The number of observations is 182 due to lack of the data on the amount of waste emission per capita in several towns and villages.
[16] The data based on 2000 population census is used for the estimation.

Table 6 Estimation results of towns and villages in Kinki region: FY2005

Variables	Public welfare expenses			Sanitation expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	13.282	0.946	14.036	12.414	0.534	23.251
ln*IND*	0.144	0.141	1.024	-0.812	0.166	-1.097
ln*AGE*	0.542	0.212	2.557	0.695	0.240	2.894
ln*N*	-0.085	0.133	-0.638	-0.195	0.067	-2.920
ln*W*	-0.110	0.099	-1.113	0.012	0.027	0.463
ln*Z*	0.066	0.077	0.860	0.037	0.027	1.351
α_4-1	-0.023	0.029	-0.803	-0.102	0.038	-2.671
R^2	0.199			0.673		
adjR^2	0.146			0.651		
No. of obs.	98			98		

Note: For the sanitation expenses, the definition of variable is the same as FY2002. In the estimation of the public welfare expenses, the output is defined as *Z*=(Sum of the number of child care centers and nursing home)/Population(in million).

* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

Table 6 cont.

Variables	Civil engineering expenses			Education expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	11.662	0.924	12.621	13.612	0.670	20.308
ln*IND*	-0.450	0.200	-2.257	0.270	0.176	1.532
ln*AGE*	-0.556	0.391	-1.422	0.205	0.314	0.651
ln*N*	-0.348	0.113	-3.068	-0.306	0.095	-3.235
ln*W*	0.072	0.055	1.132	0.105	0.501	2.073
ln*Z*	-0.108	0.062	-1.732	-0.067	0.041	-1.628
α_4-1	-0.171	0.065	-2.623	-0.072	0.046	-1.561
R^2	0.292			0.496		
adjR^2	0.245			0.463		
No. of obs.	98			98		

Note: For the education expenses, the definition of variables is the same as FY2002. In the civil engineering expenses, road density, municipal road (km)/area(km^2), is used for a proxy variable of the C-output.

* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

We take the four items of expenses by function, namely, public welfare, sanitation, civil engineering and education. Table 6 shows the estimation results. Similar results are observed as in the previous estimation. In the two items of expenses, α_4, is not significant. It can be seen that since large part of public welfare expenses is a transfer payment from the government to the household, the per capita cost does not depend on the distribution and the total number of the population.

5.2 Cost Structure in Specific Prefectures

In the analyses so far, we have estimate the cost function of the cities and of towns and villages, separately. In this subsection, we estimate the cost function for the specific services in the municipalities, including city, town and village, located within a prefecture. In particular, we address the municipalities located in two prefectures: Hyogo prefecture and Osaka prefecture. Hyogo prefecture is a neighbor of Osaka prefecture.

First, we estimate the cost function of the municipalities located in the Hyogo prefecture. Kobe-shi which is the only designated city in Hyogo prefecture is excluded from the sample. In the estimation, we consider only the basic variables including population, wage rate, output and the distribution of population denoted by α_4.[17]

Table 7 summarizes the estimation results. Similar results as that in the previous section are observed. First, the estimated coefficients of α_4 are negative except for the civil engineering expenses. Second, the impact of an increase in the total population is negative except for the public welfare expenses. Third, the coefficient of the output is positive although the estimated values are not significant.[18]

Table 7 Estimation results of municipalities in the Hyogo Prefecture

Variables	Public welfare expenses			Sanitation expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	-16.948	2.845	-5.957	3.406	6.166	0.552
ln$N$	0.886	0.056	15.804	-0.101	0.068	-1.498
ln$W$	0.870	0.345	2.523	-0.047	0.766	-0.061
ln$Z$	0.156	0.081	1.933	0.104	0.086	1.203
α_4-1	-0.146	0.049	-2.969	-0.157	0.084	-1.866
No. of obs.	87			87		

Note: The definitions of variables are the same as previous analysis.
* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

[17] The definitions of variables are the same as previous analysis.

[18] When we focus on the specific service, the assumption of equal provision across the neighborhoods may be inappropriate. In the literature, for example, Ajwad (2006) considered the determinants of resource allocation within jurisdiction for education expenditures and argued that the allocation of resources is not equitable depending on economic and socio-demographic characteristics in the neighborhood.

Table 7 Cont.

Variables	Civil engineering expenses			Education expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	-5.355	6.342	-0.844	5.159	0.419	12.327
ln*N*	-0.189	0.098	-1.969	-0.117	0.040	-2.970
ln*W*	1.175	0.810	1.451	-	-	-
ln*Z*	0.251	0.157	1.601	0.248	0.205	1.210
α_4-1	0.228	0.088	2.570	-0.070	0.046	-1.516
No. of obs.	87			87		

Note: The definitions of variables are the same as previous analysis.
* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

In the case of the municipalities located in Osaka prefecture, the estimation results are summarized in Table 8. Again, Osaka-shi which is a designated city is excluded from the sample. Table 8 shows similar results to those of the Hyogo prefecture.

Table 8 Estimation results of municipalities in the Osaka Prefecture

Variables	Public welfare expenses			Sanitation expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	1.406	7.559	0.186	15.315	8.606	1.780
ln*N*	-0.409	0.055	-7.394	-0.573	0.053	-10.843
ln*W*	0.242	0.903	0.268	-1.300	0.993	-1.310
ln*Z*	0.127	0.161	0.785	0.161	0.113	1.433
α_4-1	-0.469	0.027	15.841	-0.566	0.034	-16.573
No. of obs.	41			41		

Note: The definitions of variables are the same as previous analysis.
* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

Table 8 Cont.

Variables	Civil engineering expenses			Education expenses		
	Coef.	Std. error*	t-value	Coef.	Std. error*	t-value
constant	25.262	12.980	1.946	10.895	7.494	1.454
ln$N$	-0.531	0.122	-4.357	-0.598	0.071	-8.413
ln$W$	-2.274	1.462	-1.555	-0.658	0.840	-0.783
ln$Z$	0.001	0.000	1.485	0.069	0.346	0.200
α_4-1	-0.318	0.076	-4.191	-0.515	0.041	-12.530
No. of obs.	41			41		

Note: The definitions of variables are the same as previous analysis.
* Standard errors are calculated by the heteroskedasticity-robust variance matrix estimator for NLS.

6 Conclusion

In this paper, we have investigated the relationship between the cost of local public services and the population distribution within a municipality. We obtained the following results.

First, the concentration of population within a city reduces the per capita cost of providing the public service. This result is consistent with the literature. In addition, a decrease in the total population of a city raises the per capita cost. In this sense, it is understandable that local governments have growing concern about the rise in the expenditure resulting from population decline and expansion of residential area. Furthermore, this result is basically found for the towns and villages as well as the cities.

Second, although the rise in the concentration of population within a municipality reduces the cost of providing public services, its extent can be varied across the municipalities. The municipality with sparsely populated neighborhood can reduce its cost by concentrating the population to the densely populated neighborhoods. In particular, the prefectural capitals in non-metropolitan area could benefit from compaction of the city. On the other hand, the effect of cost reduction by the concentration is relatively small in municipalities with uniformly populated neighborhoods.

Third, the results for the cost by items of expenses are similar to but less obvious than that for the total cost. This may be partly due to the data availability and the definition of the output. In addition, when we consider particular items of public service, the assumption of which the public services are provided equally to any neighborhood within the municipality may be violated.

From the results summarized above, we have the following policy implication. The current public policy oriented toward the compact city is supported in the sense of improving cost efficiency of the local public sector. However, a government intervention such as introducing land use regulation may induce a huge cost to ensure the effectiveness of the regulation, if the public services are equally provided across the neighborhoods. In our analysis, the marginal cost of population increase is higher in the sparsely populated area than in densely populated area. Therefore, one should consider allocating the tax burden according to the marginal cost of population increase if the equal provision of public service is needed.

In our analysis, we have assumed that changes in the population distribution do not alter the other determinants of welfare. However, the distribution of population affects the various aspects of economic activities. As pointed out in much literature, public policies such as investment for public infrastructures affect the spatial structure of regions (e.g. Chen et al., 2008: Cheng and Masser, 2003). Hence, we have to consider not only the effects of spatial population distribution on the fiscal position of public sector but also more comprehensive aspects, including economic growth and intertemporal welfare etc. Accordingly, further research will be needed in both empirical and theoretical fields.

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