Ordering Municipalities by Medical Cost Efficiency Under the Japanese National Health Insurance System using the Stochastic Cost Frontier Model

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Abstract: We applied the stochastic cost frontier model (SCFM) to evaluate whether Japanese municipal national health insurances (NHI) are efficiently managed by their insuring municipalities. A linear regression structure is assumed for the cost efficiency term in the SCFM and the best set of explanatory variables in SCFM was selected by minimizing the Bayesian information criterion (BIC). The optimized SCFM clarified the factors associated with inefficiency and the degree of NHI inefficiency. The NHI subsidy system is likely to incur soft budget problems, since financial deficits are covered ex post by subsidies from the central government. The results obtained using the optimal SCFM show that the greater the financial support is from the central government, the more inefficiently a municipality administers its NHI.

Keywords: Bayesian information criterion, Cost efficiency, Japanese national health insurance, Selection of variables, Skew normal distribution, Soft budget problem, Stochastic cost frontier model.

1. Introduction

In Japan, the health insurance is regulated by the central government which provides universal coverage. Insurers administer their health plans independently under central government controls. The plans can broadly be classified into two categories, the national health insurance (NHI) and the employee health insurance (EHI). The NHI is administrated independently by individual municipalities, which include cities, towns, villages, and Tokyo's 23 wards. In 2007, there were a total of 1,834 insurers. The municipality administers the NHI separately from other public activities and thus has an NHI account in addition to a general account. Unemployed citizens who are not dependent on family members, such as elderly or retired members of households, employees of family-operated businesses or self-employed business people, and part-time workers are covered under NHI.

From the insurers perspective, the NHI account is under continual financial pressure as most of the insured are elderly, who use numerous costly medical services. The NHI is thus primarily designed to service citizens who are unemployed or who live on their pension. However, since insurance tax does not provide sufficient revenue cover for insurance expenses, the cost difference between insurance payments and tax revenues is offset by subsidies, mainly from the central government. The amount of each subsidy is calculated by considering the context of financial revenue and service delivery; however, the values of some financial subsidies are ultimately decided after assessing total medical costs, such a system is susceptible to a soft budget problem.

The soft budget problem was introduced as an economic model to identify situations under which there exists an incentive for an agent to complete his or her work inefficiently if he or she knows ex ante working, that subsidies from the principal will make up the deficit of the work. The details of the soft budget problem have been discussed in Sato (2002) and Kornai, Maskin and Roland (2003). The soft budget problem associated with the NHI system is that knowledge of the central government subsidy that is paid after the total medical cost is determined provides incentive to the municipality to administer the NHI inefficiently ex ante. Tajika and Yui (1999) discussed the possibility that a NHI fiscal grant policy under which the central government assesses subsidies each time the NHI incurs financial trouble results in inefficient administration of the NHI by the municipality. By applying the stochastic cost frontier model (SCFM) originally proposed by Battese and Coelli (1995), Yamashita, Akai and Sato (2002) also found that the allocation of central government tax subsidies to a municipal general account creates the soft budget problem.

A basic SCFM consists of a cost frontier and a cost efficiency term. In the estimation of an ordinary cost function, the difference between the actual cost value and the estimated cost value is represented by the error term, while the SCFM deals with this error term including cost efficiency effect. Battese and Coelli (1995) estimated the technical inefficiency effect by assuming that the technical inefficiency term has a linear regression structure in stochastic production function model, an application that distinguishes their study from other methods (see e.g., Kumbhakar and Lovell (2000)). The production function can be changed to create a cost function. Hence, in the stochastic production function model, cost efficiency is referred to as technical inefficiency. In order to estimate the SCFM for the municipal general account, Yamashita, Akai and Sato (2002) used the amount of the financial subsidy from the central government as an explanatory variable in the cost efficiency term, and determined the existence of the soft budget problem due to the subsidy. In addition to estimating the SCFM for the municipal general account, they illustrated the degree of efficiency for each municipality by calculating cost efficiency using the method of Battese and Coelli (1993). The calculated degrees of municipal efficiency were listed in order, identifying which of the municipal administrations analyzed were efficient or inefficient. We applied the Yamashita, Akai and Sato (2002) study to the NHI account to see whether an NHI soft budget problem exists, and to identify which of the municipal NHI administrations were efficient or inefficient.

The general increase in medical costs has recently become a serious fiscal problem in many countries, and has lead to a search for methods for increasing efficiency. Illustrating the extent of municipal efficiency or inefficiency for NHI administration in this study will help reduce the potential of the soft budget problem in the subsidy system. The central government can also identify inefficient municipalities and urge them to improve NHI management efficiency, and the disclosure of the cost efficiency ranking may increase the efficiency of medical services.

The aim of the present study was therefore to apply the SCFM to evaluating the efficiency of Japanese municipal NHI management under the existing central government NHI subsidy system. To select optimal expletory variables in the SCFM, we used the Bayesian information criterion (BIC) proposed by Schwarz (1976). The optimized SCFM clarifies the factors affecting inefficiency and evaluates each municipality's degree of NHI inefficiency. This paper is organized as follows: in Section 2, the NHI system and fiscal subsidies from the central and prefecture government are introduced, and the existence of the soft budget under this subsidy system is explained. Section 3 describes the SCFM, and the data used in the SCFM analysis is shown in Section 4. Section 5 describes the analysis results, and our conclusions are presented in Section 6.

2. National Health Insurance System in Japan and the Soft Budget Problem

Medical services in Japan can be accessed freely and patients can visit the medical institutions of their choice at any time. Payment for medical treatment reflects the medical and technical service fee, which is decided by the central government once every two years, and medical institutions are then paid their fee-for-service by insurers. The NHI cost-sharing system creates a medical cost pool, which includes the insured, insurer, and the central government. The insured patient contributes to medical costs through out-of-pocket payments at the medical institution. Insurer municipalities contribute a portion of NHI fiscal revenues toward the medical costs incurred by insured citizens. The NHI fiscal revenues are primarily derived from insurance tax and the central government's contribution, which includes medical costs for the elderly and the retired employees in the elderly health care system and the retiree health care system, respectively. Additional subsidies from the central and prefecture government are paid directly into the municipal NHI account. However, the magnitude of the prefecture subsidy is at the prefecture's discretion, which means that there may not be any prefecture subsidy if the prefecture decides not to subsidize the NHI account. There are three main types of central government subsidies: the general subsidy, the specific subsidy, and money transferred from a municipal general account (MGA).

General subsidies are provided when insurance tax revenues are insufficient to cover medical costs, such as when medical costs are too high or tax revenues are too low. In such instances, people without regular employment are insured under the NHI as their insurance tax is not sufficient to cover medical costs. The medical costs covered by the NHI are high because the elderly are not usually employed and subsist on pensions and frequently use medical services. The general subsidy covers the part of medical costs that should be absorbed by insurance tax, and is capped. The specific subsidy is a subsidy provided to a municipality for unpredictably high medical costs in events such as natural disasters and epidemics. The money from MGA is transferred into the NHI account to cover the remaining costs, after NHI revenue and subsides have been used for health cost payments. While municipalities administer their own general accounts, Tajika and Yui (1999) demonstrated that the money transferred from MGA is mostly raised by the central government through a local allocation tax.

The amounts of the subsidies, with the exception of the prefecture subsidy, are decided once the total medical cost and the insurance payment from the NHI are complete, potentially causing the soft budget problem. The reasons for the soft budget problem developing under the NHI subsidy system can be attributed to two municipal and central government conditions. First, the NHI is publicly owned and is subsidized by the central government in order to prevent bankruptcy when the insuring municipalities face financial collapse. Second, the central government cannot monitor the performance of each municipal NHI administration and thus subsidizes municipalities without evaluating their administrative efficiency. Given a knowledge of these conditions, the municipality may fail to administer the NHI efficiently, resulting in the soft budget problem and inefficient management of medical costs.

Among the four subsidies mentioned above - prefecture subsidy, general subsidy, specific subsidy, and money transferred from MGA - the current form of general subsidies and money transferred from MGA may exacerbate the soft budget problem. The municipal expectation that money transferred from MGA will make up for the NHI financial shortage creates the soft budget problem. The general subsidy supplies more to a municipality with higher medical costs. As medical costs increase, the insurance tax, which is dependent on medical costs, is set at a higher rate. As the insurance tax is raised, more insured workers will be unable to pay the tax. The financial shortfall, covered by the general subsidy, increases as medical costs increase and cannot be covered by insurance tax revenues. The municipality's anticipation of the general subsidy leads to complacency and thus inefficient insurance administration and the soft budget problem. The prefecture subsidy is not likely to contribute toward the soft budget problem because it is a discretionary fiscal policy, with different criteria determining the contribution to each municipality and cannot be expected to offset financial shortfalls. The special subsidy is applied mainly as recovery costs from unpredictable accidents and is also independent of the soft budget problem.

3. Stochastic Cost Frontier Model

A municipality with high medical costs does not always run the NHI inefficiently. Medical costs increase for two reasons, the high cost of heavy medical treatment required to achieve the wellness of the insured, and wasteful medical expenditure that does not improve health. In the first case, the role of the NHI requires service without attention to commercial gain, and the municipality works toward improving the health of the insured. Thus, although the medical costs are high, treatment and wellness goals are achieved, and the municipality qualifies as a good NHI administrator. Conversely, a poor NHI administrator may cut medical costs, resulting in a deterioration of the health of the citizens. In the second case, a municipality that qualifies as a poor NHI administrator must reduce wastefulness or improve wellness and treatment outcomes. Despite having high medical costs, in the first case, the municipality is considered an efficient NHI administrator, while in the second case, the municipality is considered an inefficient NHI administrator. The central government needs to identify efficient and inefficient medical costs before providing subsidies to a municipality. However, how can the central government distinguish between efficient and inefficient medical costs? Moreover, how can such efficiency be defined? The economic model's cost function can provide an answer and is described concisely together with an estimation method below.

A production cost exists when any outcome is generated. The cost is determined by the outcome of y and k input prices $\boldsymbol{w}=(w_1,\ldots,w_k)'$, such as wages and capital prices for production activity (see microeconomic texts, e.g., Varian (2005)). Suppose that $c(y,\boldsymbol{w})$

denotes the cost function at which cost is minimum or there is no waste associated with achieving the outcome, or the maximum outcome is produced at the achieving cost. Fig. 1 shows the relationship between costs and outcomes. Efficient production is along the cost frontier for the cost function definition at which is there is no waste. Although achieving the cost of inefficient production is higher than that along the cost frontier, costs can be cut or a higher wellness outcome can be produced.

In the case of NHI administration, achieving a combination of higher wellness outcomes and medical costs on the cost frontier qualifies as efficient. Although medical costs are high, the municipality administers NHI efficiently if it achieves the wellness outcomes for its costs on the cost frontier. Conversely, if the achieving medical cost is higher than the efficient cost on the cost frontier, the medical cost is wasteful and the municipality should make an effort to cut costs or increase the wellness outcome. By estimating the cost frontier and comparing the efficient cost on the cost frontier and the achieving medical cost, we can evaluate the efficiency of respective municipal NHI administrations.

To identify the presence of the soft budget problem in the NHI subsidy, Battese and Coelli (1995) proposed a useful method for estimating the cost frontier using the SCFM. Their method empirically analyzes the cost frontier function and quantifies the reasons for the inefficiency with explanatory variables.

Let E_i , y_i and $\boldsymbol{w}_i=(w_{i1},\dots,w_{ik})'$ be the achieving medical cost, outcome and input prices at the i th municipality ($i=1,\dots,n$), respectively, where n is the sample size. Suppose that an unknown parameter vector γ specifies the cost function. Then, the SCFM is defined by

$$E_i = c(y_i, \boldsymbol{w}_i \mid \boldsymbol{\gamma}) \exp(u_i + v_i),\ (i = 1,\dots,n), \tag{1}$$

where v_i and nonnegative u_i are independent random variables, and v_i expresses an error term and u_i denotes the cost efficiency term. The exponential part in (1) indicates the difference between an achieving medical cost and efficient cost in $c(y_i,\boldsymbol{w}_i|\boldsymbol{\gamma})$. In the present paper, we assume that $v_1,\dots,v_n$ and $u_1,\dots,u_n$ are independently distributed according to the normal distribution $\mathrm{N}(0,\sigma_v^2)$ and the truncated normal distribution $\mathrm{N}^+(\boldsymbol{\beta}'\boldsymbol{z}_i,\sigma_u^2)$, respectively, where $\boldsymbol{\beta}$ is a $m\times 1$ unknown parameters vector and $\boldsymbol{z}_i$ is the $m\times 1$ explanatory variables vector expressing the factors of inefficiency for NHI administration. Furthermore, we assume that the cost function can be given by the Cobb-Douglas formula in economics. Then, the SCFM in (1) is rewritten as

$$\log E_i = \gamma_0 + \gamma_y \log y_i + \sum_{j=1}^{k} \gamma_j \log w_{ij} + u_i + v_i = \boldsymbol{\gamma}' \boldsymbol{a}_i + u_i + v_i,\ (i = 1,...,n) \quad (2)$$

where $\boldsymbol{\gamma}=(\gamma_y,\gamma_0,\gamma_1,\dots,\gamma_k)'$ and $\boldsymbol{a}_i=(y_i,1,\log w_{i1},\dots,\log w_{ik})'$. Since u_i and v_i are independent, it is easy to obtain the joint probability density function of u_i and v_i as

$$g(u_i, v_i \mid \boldsymbol{w}_i, \boldsymbol{z}_i, \boldsymbol{\theta}) = \frac{1}{2\pi\sigma_u\sigma_v\Phi(\boldsymbol{\beta}'\boldsymbol{z}_i/\sigma_u)} \exp\left\{-\frac{(u_i - \boldsymbol{\beta}'\boldsymbol{z}_i)^2}{2\sigma_u^2} - \frac{v_i^2}{2\sigma_v^2}\right\}, \quad (3)$$

where $\boldsymbol{\theta} = (\boldsymbol{\gamma}, \boldsymbol{\beta}, \sigma_u^2, \sigma_v^2)'$ and $\Phi(x)$ is the distribution function of the standard normal distribution. Let $\varepsilon_i=u_i+v_i$, we obtain the joint density function of u_i and ε_i by substituting ε_i into the equation (3). Integrating the obtained the joint density with respect to u_i, yields the marginal density function of ε_i as

$$f(\varepsilon_i \mid \boldsymbol{w}_i, \boldsymbol{z}_i, \boldsymbol{\theta}) = \frac{1}{\psi}\phi\left(\frac{\varepsilon_i - \boldsymbol{\beta}'\boldsymbol{z}_i}{\psi}\right) \frac{\Phi((\lambda + \lambda^{-1})\boldsymbol{\beta}'\boldsymbol{z}_i / \psi + \lambda(\varepsilon_i - \boldsymbol{\beta}'\boldsymbol{z}_i) / \psi)}{\Phi((1 + \lambda^2)^{1/2}\boldsymbol{\beta}'\boldsymbol{z}_i / \psi)}, \quad (4)$$

where $\phi(x)$ is the probability density function of $\mathrm{N}(0,1)$, $\psi^2 = \sigma_u^2 + \sigma_u^2$ and $\lambda=\sigma_u/\sigma_v$ (for a detailed derivation of equation (4), see e.g., Battese and Coelli (1993)). Notice that $\varepsilon_i=\log E_i-\boldsymbol{\gamma}_i'\boldsymbol{a}_i$. Therefore, the unknown parameter $\boldsymbol{\theta}$ is estimated by maximizing the log-likelihood based on (4), i.e., the maximum likelihood estimator of $\boldsymbol{\theta}$ is defined by

$$\hat{\boldsymbol{\theta}} = (\hat{\boldsymbol{\gamma}}, \hat{\boldsymbol{\beta}}, \hat{\sigma}_u^2, \hat{\sigma}_v^2)' = \arg\max_{\boldsymbol{\theta}} \sum_{i=1}^{n} \log f(\log E_i - \boldsymbol{\gamma}_i'\boldsymbol{a}_i \mid \boldsymbol{w}_i, \boldsymbol{z}_i, \boldsymbol{\theta}).$$

Furthermore, mean and variance of ε_i are given by

$$\begin{aligned} \mathrm{E}[\varepsilon_i] &= \boldsymbol{\beta}'\boldsymbol{z}_i + \frac{\psi}{\lambda_*} D(\lambda_*\boldsymbol{\beta}'\boldsymbol{z}_i / \psi), \\ \mathrm{Var}[\varepsilon_i] &= \psi^2\left\{1 - \frac{\boldsymbol{\beta}'\boldsymbol{z}_i}{\lambda_*\psi} D(\lambda_*\boldsymbol{\beta}'\boldsymbol{z}_i / \psi) - \frac{1}{\lambda_*^2} D(\lambda_*\boldsymbol{\beta}'\boldsymbol{z}_i / \psi)^2\right\}, \end{aligned} \quad (5)$$

where $\lambda_*=(1+\lambda^{-2})^{1/2}$ and $D(x)=\phi(x)/\Phi(x)$. Equation (5) directly implies that the heterogeneity of variances is assumed for distributions of $\varepsilon_1,\dots,\varepsilon_n$ (also distributions of $\log E_1,\dots,\log E_n$) when $\boldsymbol{\beta}\neq\mathbf{0}$. Especially, when $\boldsymbol{\beta}=\mathbf{0}$, i.e., there is no factor of inefficiency for NHI administration, equation (5) becomes the probability density function of the skew-normal distribution, which was proposed by Azzalini (1985), with location parameter 0, dispersion parameter ψ^2 and skew parameter λ (for a detailed description of the relationship between the SCFM and skew-normal distribution, see e.g., Domínguez-Molina, González-Farías and Ramos-Quiroga (2004)).

The estimated result of the SCFM leads us to the degree of cost efficiency for each municipality, which is evaluated by the ratio of the achieving medical cost and the efficient medical cost on the cost frontier. From equation (1), the cost efficiency is defined by

$$CE_i = \frac{E_i}{c(y_i, \boldsymbol{w}_i \mid \boldsymbol{\gamma}) \cdot \exp(v_i)} = \exp(u_i)\,. \tag{6}$$

Since v_i is unobserved, it is appropriate that $\exp(u_i)$ is evaluated by the expected value. This evaluation method was proposed by Battese and Coelli (1993). To evaluate the cost efficiency, first the conditional probability density function of u_i given ε_i by $h(u_i|\varepsilon_i)=g(u_i,\varepsilon_i)/f(\varepsilon_i)$ is calculated, and second, the conditional expectation of exponential u_i given by ε_i is calculated. The cost efficiency is

$$\begin{aligned} \mathrm{E}[\exp(u_i) \mid \varepsilon_i] &= \int_0^\infty \exp(u_i) h(u_i \mid \varepsilon_i)\; du_i \\ &= \frac{1-\Phi(-\sigma - \mu_i / \sigma)}{\Phi(\mu_i / \sigma)} \exp\left(\mu_i + \frac{1}{2}\sigma^2\right), \end{aligned} \tag{7}$$

where $\mu_i = (\sigma_v^2 \boldsymbol{\beta}' \boldsymbol{z}_i + \sigma_u^2 \varepsilon_i) / (\sigma_v^2 + \sigma_u^2)$ and $\sigma^2 = \sigma_v^2 \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$. The cost efficiency is estimated by replacing unknown parameters with their estimators and assigning explanatory variables for each municipality.

4. Setting for Data Analysis

When the SCFM in (1) is used for data analysis, it is necessary to decide the cost E of the independent variable, as an outcome y and input prices $\boldsymbol{w}$ for explanatory variables in the cost frontier term $c(y,\boldsymbol{w}|\boldsymbol{\gamma})$, and explanatory variable $\boldsymbol{z}$ in the cost efficiency term u. Since we empirically analyze the municipal NHI medical cost to see if the municipality administers the NHI efficiently under its subsidy system, the data sample is drawn for the municipality. The input variables, data sources, their mean, standard deviation, minimum and maximum values are shown in Table 1. The data year for 1995 was used together with four additional data sources were matched by municipality to support variables; the 1996 current status of NHI (CSNHI), the 1995 life table (LT) by municipality, the 1995 basic survey on wage structure (WS), the 1996 survey of the medical care institutions (MCI). While the 1995 data values of CSNHI, LT, and WS were utilized, the 1996 MCI data are used as the data for 1995 could not be obtained. The CSNHI is compiled by the All-Japan Federation of NHI organizations (“*kokumin kenkohoken cyuokai*” in Japanese), LT and MCI are compiled by the Health and Welfare Ministry, and the WS by the Labor Ministry. In 2001 the institutions that compiled the LT, MCI and WS were merged as part of central government reforms and are currently called the Ministry of Health, Labor and Welfare. The total number of observations is 3,247, and 5 municipalities are excluded from the analysis due to a lack of data for analysis. In 2005 there were 1,834 municipalities, reflecting that 1,418 municipalities have been merged since 1995.

The municipal medical costs are considered to be cost E. The used medical cost is the insurance payment per NHI insured citizen, for which the value is the total medical cost excluding out-of-pocket payments. Based on the mean medical cost value in Table 1, an insured person spends 323,754 yen per year. Comparing the minimum medical cost, 151,536 yen, and the maximum cost, 688,385 yen, medical costs vary by approximately 4.5 times between municipalities.

The input prices $\boldsymbol{w}$ are divided into two kinds of variables, variable costs and fixed costs. The variable costs are changeable in the short term, like wages and the purchasing price of primary materials, while the fixed costs, like estate or other capital charges, are not changeable. We used hourly wages of male medical doctors, female professional nurses, and female auxiliary nurses as the variable costs. The data source for hourly wages is the WS, and is derived by calculating original data items (dividing the actual number of scheduled hours and over time worked into the contractual and annual special cash earnings). Since the WS reflects prefecture-level data, the municipalities that belong to the same prefecture have the same value. As fixed costs, the number of hospitals, hospital beds, clinics, clinic beds, and dental clinics from the MCI are used for SCFM. For example, the fixed costs have prices for such items as the maintenance and purchase of medical institutions and equipment, however these costs are not straightforward to collect and describe using municipal data, which means that the number of hospitals, clinics, dental clinics and hospital- or clinic-beds are substituted for the capital costs of providing medical services. The central government controls hospital medical services by 345 regulating areas, which are referred to as secondary medical service areas. A municipality is vested in one of 345 secondary medical service areas with neighbor municipalities. The number and type of hospitals and hospital beds are controlled in each secondary medical service areas by the central government to make medical treatment received anywhere, otherwise hospital- or hospital bed-services are provided only in lucrative areas such as populous cities, and citizens in other areas such as depopulated areas can not become to receive medical services in hospitals. Thus, the number of hospitals and hospital beds aggregated within secondary medical service areas that are used for estimating the SCFM, and they are averaged for 100 citizens living in the secondary medical service area. This implies that municipalities within the same secondary medical service area have same data values. Since the number of clinics, clinic beds, and dental clinics are not controlled like they are for hospitals and hospital beds, each municipality has its own per-100-citizen values. In Table 1, the number of hospitals and hospital beds for mental ailments, infectious disease, tuberculosis, and other general disease are shown, with the same data were collected for the clinics. The number of general hospitals was divided by type into the hospitals for long-term care (HLTC), comprehensive hospitals (HCH), and emergency medical services (HEMS). The HLTC has beds for long-term care patients, HCH has more than 100 hospital beds and six departments (internal medicine, surgery, obstetrics and gynecology, ophthalmology, and otolaryngology) and HEMS provides medical care to emergency patients. The number of general hospital beds is also divided by type into beds for long-term care (BLTC) and beds in comprehensive hospital (BCH). The total number of clinics is subdivided into clinic beds and no clinic beds. Clinics licensed by prefecture government that have fewer than 20 beds are included in Table 1.

The definition of health outcome y has been discussed in the literature, with values for countries, regions, and years having been extensively compared. Murray and Evans (2003) collected these discussions and recommended several health outcomes, such as why health outcomes should not only include expected life or mortality rate, but the quality of life (QOL), which provides information how well patients live, should also be considered. In certain cases, QOL has been a mitigating factor for pain and decreasing operative time. However QOL is not practically used as a health outcome because of the absence of QOL data and only certain data about mortality are available as health outcomes (Zweifel and Friedrich (1997)). The only mortality data available for the current study was expected life data. Here we use the estimated outcome $y{=}y(\boldsymbol{x},r)$ as proposed by Yamashita, Akai and Sato (2002). $\boldsymbol{x}{=}(x_1,\ldots,x_p)'$ is the expected lifespan for 0, 20, 40, 65 and 70 year-old females, which are assumed to be components of the health outcome and indicate medical service at various municipality levels. Female observations are said to reflect more positive health outcomes, because external factors such as smoking, accidental death due to military deployment are less of an influence than with males, and female life expectancy is therefore used for such estimations. r is the ratio of the elderly insured, which reflects the insurance characteristics for respective municipalities. In Table 1, the minimum proportion of elderly insured is 8.1%, while the maximum is 46%. Almost half of the insured are over 70 years old, indicating that considerable variation exists. Since the outcome y is assumed to vary depending on the insured characteristics, the proportion of elderly insured is considered in the outcome. Substituting $y{=}y(\boldsymbol{x},r)$ into (1) and (2) yields the following equations:

$$E_i = c(y(\boldsymbol{x}_i, r_i), \boldsymbol{w}_i \mid \boldsymbol{\gamma})\exp(u_i + v_i),\ (i = 1,\ldots,n)\,, \tag{8}$$

and

$$\log E_i = \gamma_0 + \sum_{j=1}^{p} \gamma_y \log x_{ij} + \gamma_y \log r_i + \sum_{j=1}^{k} \gamma_j \log w_{ij} + v_i + u_i,\ (i = 1,\ldots,n) \qquad .(9)$$

Explanatory variables in $\boldsymbol{z}$ are amounts of financial grants awarded to determine if the soft budget problem is present. The grants are money transferred from MGA, and as general and specific subsidies, and prefecture subsidy. If the parameters of general subsidy and money transferred from MGA are positive, the soft budget problem is present. Specific subsidies may have positive parameters because they are distributed to pay for unexpected medical costs caused by disasters or other events as described in Section 2. Conversely, municipalities with specific subsidies may have unexpected medical costs and that were characterized as cost inefficiency in the model. The parameter of subsidies from the prefecture is not determined because of the discretionary nature of this fiscal policy. The subsidy variables were obtained from CSNHI, and their values are expressed in yen per insured citizen. The mean values of financial grants are listed in Table 1, which shows the values of money transferred from MGA, general subsidy, specific subsidy, and prefecture subsidy were 17,359 yen, 14,699 yen, 7,131 yen, and 568 yen by insured, respectively. The amounts of financial grants differ considerably between municipalities. Some municipalities do not have a general subsidy, specific subsidy, or prefecture subsidy, while others have these respective subsidies at rates of 79,226 yen, 164,849 yen, and 27,868 yen, respectively. The number of insured is also included in the explanatory variable in cost efficiency expression, because the log of medical costs become widely scattered as the number of insured citizens increases. This assumption is supported by Fig. 2, which is a scatter plot of the logarithm of the medical cost and the number of insured citizens. As shown equation (5), the variance associated with the medical cost logarithm in the SCFM is changeable and is dependent upon on the explanatory variable in the cost efficiency term. The heterogeneity of variances in the medical cost logarithm can be expressed by considering the number of insured citizens as the explanatory variable in $\boldsymbol{z}$.

5. Empirical Results

The best set of variables for all variable subsets was difficult to determine because of the number of variables considered in the current analysis. Therefore, we searched for the most suitable set of variables by conducting the following two steps:

(I) We prepared 864 candidate models with different combinations of explanatory variables. The five best models among 864 candidates were determined by minimizing the Bayesian information criterion (BIC) proposed by Schwarz (1978).

(II) By removing variables with p-values above 0.1, we then renewed the five best models and selected the most suitable set of variables among these five models by BIC.

The BIC in the SCFM is defined by

$$\mathrm{BIC} = -2\sum_{i=1}^{n} \log f(\log E_i - \hat{\boldsymbol{\gamma}}_i{}' \boldsymbol{a}_i \mid \boldsymbol{w}_i, \boldsymbol{z}_i, \hat{\boldsymbol{\theta}}) + (k+m+4)\log n\,. \tag{9}$$

In our analysis, Akaike's information criterion (AIC), proposed by Akaike (1973), was not used for the selection of variables, because the aim of our variable selection was not to improve prediction of response variables. This is particularly important given that the AIC is biased toward models with more variables, selecting these as the most suitable when the sample size n is large. We therefore employed BIC, and not AIC, for variable selection

The 864 candidate models had different combinations of 1) to 3) and 0) in the variable set for each variable group in Table 2. The number of hospitals, hospital beds, clinics, clinic beds, and dental clinics are fixed costs; however, these are substitutes for costs, such as the purchase, lease or control costs of land, buildings, medical equipment and so on. In searching for the model having the minimum BIC, the set of explanatory variables that describe fixed costs best, can be determined.

The number of hospitals, hospital beds, and clinics selected variable set 1 from 1) total, 2) breakdown of the total, and 0) nothing. Based on the selection of 1) or 2), we can determine if the total number 1) of variables is sufficient to estimate the medical costs, or if more the detailed numbers contained in 2) should be used. If 0) nothing is chosen, then the variable is not required for estimation. For other hospitals or hospital beds, HLTC & HCH and BLTC & BCH are subdivided according to the same information, substituting the provision of long-term care and medical care in comprehensive hospital for fixed costs, and representing these fixed costs as the number of hospitals or hospital beds. Selection of 1) HLTC, HCH, HEMS or 2) BLTC, BCH by the BIC model will determine which substitute fixed cost variables for long-term care and medical care in comprehensive hospitals are more appropriate for explaining the medical costs. Both substitute fixed costs are necessary for the estimation if 3) is chosen, and additional numbers of hospitals or beds do not affect medical costs if 0) nothing is chosen. For the number of clinic beds and dental clinics, the variable set has choice 1) and 0) nothing, and the BIC will help to evaluate whether these variables are adequate for estimation. In financial grants, 2) includes prefecture subsidies and 1) does not. The prefecture subsidy is not large compared with other subsidies, and as a discretionary fund, it may not be related to medical costs. Using BIC, we can determine if a prefecture subsidy is needed for estimation.

The full model among first 864 candidate models is 1), 1), 2), 2), 3), 2), 1), 1), 2), 1) in each variable group, for outcome, hourly wages, the number of hospitals, the number of hospital beds, additional number of hospitals or beds, the number of clinics, the number of clinic beds, the number of dental clinics, financial grants, other, respectively.

Table 3 shows the combination of variable sets for the five best models in step 1 and the BIC values for the five models at both steps. All candidate models at step 1 have variable set 2) for financial grants; therefore, the prefecture subsidy qualifies as an adequate explanatory variable for the cost efficiency term. 0) nothing is not chosen for the number of hospitals, hospital beds, clinics, and additional number of hospitals or beds, so these variables are expected to decide the medical cost, while the number of clinic beds and dental clinics is not necessarily required since 0) nothing is chosen. From the table, we can see that BIC values of model 1 at both steps are the smallest among the five candidate models and that the BIC value for model 1 is determined by removing insignificant explanatory variables. Therefore, we will use model 1 at step 2 for the following discussion.

The best estimation results obtained by BIC are given in Table 4. The dependent variable is the logarithm of the medical cost. Money transferred from MGA, general and specific subsidies, prefecture subsidy, and the number of insured citizens also used logarithmic numbers because they only have positive numbers and large right-skew distributions. Age 0 in the expected lifespan of females, the number of infectious and tuberculosis hospitals, and the number of mental hospital beds were all excluded by carrying out step 2. Focusing on the result of the cost efficiency term to check for the presence of the soft budget problem, all financial grants had a positive coefficient, so that money transferred form MGA is 0.035, general subsidy is 0.118, specific subsidy is 0.021, and the prefecture subsidy is 0.010. The results of money transferred from MGA and general subsidy imply that a soft budget problem exists in these subsidies. Therefore, these subsidies benefit inefficient medical costs, and the more inefficiently municipalities administer the NHI, the larger are the subsidy amounts that are distributed. Based on the specific subsidy results, as we demonstrated in Section 4, municipalities may incur unexpected medical costs and specific subsidies are used to offset these costs. The estimated parameter of the prefecture subsidy was positive, which may occur because prefectures may not help NHI municipalities in good financial condition, and also because inefficient NHI management is a factor of NHI fiscal embarrassment, giving prefecture subsidies to inefficient municipalities.

By estimating the results in Table 4, the degree of cost efficiency (7) was evaluated. The 10 best and worst cost efficient municipalities are listed in Table 5. The 10 best cost efficiencies are approximately 1.002, indicating that there are 0.2 % inefficient excess medical costs above efficient medical costs estimated by SCFM in these municipalities. Correspondingly, the worst cost efficiency is 1.495, which implies that 49.5 % of the medical costs in Sapporo City are inefficient excess. Comparing the subsidy amounts among cities, towns and villages, Tachika and Yui (1999) said that more subsidies are awarded to small municipalities such as villages, however these findings do not consider the efficiency associated with subsidy use. For example, despite having subsidies in both Kitadaito Village and Muroran City amounting to approximately 84,000 yen (Table 5), Kitadaito village is ranked as the 10th best NHI administrator and Muroran City as the 10th worst. Seven of the 10 worst municipalities, Kitakyusyu, Osaka, Hakodate, Mikasa, Otaru, Sapporo City, and Hobetsu Town, were designated high medical cost municipalities (or "*shiteishicyoson*" in Japanese) by the central government in 1995, and their medical costs had been increasing each year. The central and prefecture governments had implemented measures to control these NHI administrators in the next accounting year 1996.

The great Hanshin earthquake, which hit Kobe City on January 17, 1995, killed approximately about 6,500 people and resulted in high, unexpected medical costs as part of the disaster recovery effort. Using the results for the seven worst municipalities and Kobe City, the estimation of SCFM presented here is a good fit to the actual NHI medical cost and fiscal condition data. As in the study of Satoh and Ohtaki (2001), we plotted the distribution of the estimated cost efficiency and the achievement of medical costs for each municipality in Figs. 3 and 4, respectively. In the Kanto area around Tokyo, cost efficiency and medical costs are blue and low, and there are numerous municipalities with efficient NHI administrations, while on Hokkaido, the northernmost island, inefficiency indicated by red and yellow plots are seen. Cost efficiency seems to be regionally correlated, and municipalities with high medical costs can also have high cost efficiency values, and this finding is also reflected in Fig. 5. The mean cost efficiency and medical costs by prefecture are shown in Figs. 6 and 7, which reflect the findings presented in Figs. 4 and 5.

6. Conclusions

We used the SCFM data to assess municipal NHI medical costs to see if the soft budget problem exists in the NHI subsidy system. The results indicated the existence of the soft budget problem for two types of subsidies from the central government. These subsidies are paid ex post, when medical costs are generated, blocking insurer municipalities from exerting efforts toward efficient NHI administration ex ante. The more inefficiently municipalities administer the NHI, the larger their subsidies become until their cap amounts are reached. The degree of cost efficiency is calculated per municipality, clearly showing which municipalities are efficient or inefficient. Also by mapping degrees of cost efficiency and medical costs, regional trends can be observed and it can be shown that high medical-cost municipalities have inefficient medical costs. Future studies could examine the underlying reason for differences in regional tendencies associated with medical costs, which could then be applied to evaluating national health plans for delivering preventive health care services, controlling the number of medical institutions and their beds, and so on; citizens usually have access to medical services from medical institutions that are near their places of residence and medical services are affected by region.

Medical costs are likely to become an increasing fiscal problem in Japan as the baby-boom generation enters retirement in 2007. Increased medical expenditure will therefore be required to serve the larger aging population, while the number of taxpayers declines with the decline in birth rate. Under the Japanese health insurance system, most retired and elderly citizens are insured by the NHI, implying that NHI insurer municipalities will be confronted with fund management issues related to efficient NHI administration in the near future. However, the soft budget problem will exist as long as municipalities do not invoke mechanisms directed at increasing the efficiency of NHI administration, always expecting grants-in-aid from central government, which increase inefficient medical costs. To prevent the soft budget problem, the central government should evaluate whether a municipality’s medical costs are being managed efficiently or inefficiently. In doing so the central government would be in a position to continue subsidizing efficient municipalities and implement disciplinary or control measures against municipalities that administer the NHI inefficiently. The methods for evaluating cost efficiency described in the current paper can help improve NHI administration.

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Table 1. Data source and sample

$n = 3{,}247$

	Data source *			Mean	Std. dev.	Min	Max
Medical cost (yen **)	CSNHI	Mun.	Per ins.	323,754	72,773	151,536	688,385
Expected lifespan of female (Y/O) :	LT	Mun.	-				
0				83.3	0.8	79.4	87.9
20				63.9	0.8	60.7	68.8
40				44.4	0.7	41.6	49.4
65				21.4	0.7	19.3	26.5
70				17.1	0.7	15.1	22.8
Proportion of elderly insured (%)	CSNHI	Mun.	-	24.7	6.2	8.1	46.0
Hourly wages (1,000 yen **) :	WS	Pref.	-				
Medical doctor (m.)***				6.0	0.9	4.1	9.1
Professional nurse (f.)***				2.2	0.2	1.7	2.5
Auxiliary nurse (f.)***				1.9	0.3	1.4	2.5
The number of hospitals :	MCI	Sec.	Per 100				
Total				0.00870	0.00376	0.00198	0.02246
Mental				0.00101	0.00072	0	0.00435
Infectious				0.00001	0.00007	0	0.00097
Tuberculosis				0.00000	0.00002	0	0.00017
General				0.00768	0.00342	0.00177	0.02246
Long term care (HLTC)				0.00050	0.00066	0	0.00383
Comprehensive hospital (HCH)				0.00098	0.00063	0	0.00409
Emergency medical service (HEMS)				0.00391	0.00181	0	0.01404
The number of hospital beds :	MCI	Sec.	Per 100				
Total				1.403	0.484	0.195	3.297
Mental				0.329	0.189	0	1.310
Infectious				0.012	0.010	0	0.057
Tuberculosis				0.029	0.032	0	0.265
General				1.032	0.350	0.164	2.727
Long term care (BLTC)				0.038	0.056	0	0.417
Comprehensive hospital (BCH)				0.382	0.230	0	2.014
The number of clinics :	MCI	Mun.	Per 100				
Total				0.063	0.048	0	1.160
Clinic beds				0.016	0.021	0	0.508
No clinic beds				0.047	0.045	0	1.148
The number of clinic beds	MCI	Mun.	Per 100	0.197	0.226	0	1.971
The number of dental clinics	MCI	Mun.	Per 100	0.034	0.026	0	0.878
Financial grants (yen **) :	CSNHI	Mun.	Per ins.				
Money transferred from MGA				17,359	12,557	1,859	479,065
General subsidy				14,699	10,972	0	79,226
Specific subsidy				7,131	8,195	0	164,849
Prefecture subsidy				568	1,336	0	27,868
The number of insured	CSNHI	Mun.	-	11,828	36,264	93	953,455

*) NHI (current status of National Health Insurance 1996), LT (life table by municipality 1995), WS (basic survey on wage structure 1995), MCI (survey of medical care institutions 1996).
Mun., Pref. and Sec.; data are collected by municipalities, prefectures, and secondary medical service areas.
Per ins.; data values are described per insured in municipalities, per 100; data values are described per 100 citizens in municipalities or secondary medical service areas.

**) Average of daily currency exchange rates in 1995; $1 = 94.065 yen (National units per US-Dollar, OECD Statistics)

***) (m.) and (f.); male and female

Table 2. The variables set for each variable group

Variable group	Variable set
Outcome :	1) Expected lifespan of femal; 0, 20, 40, 65, 70 years old, Proportion of elderly insured
Hourly wages :	1) Hhourly wages of medical doctor (m.), professional nurse (f.), and auxiliary nurse (f.)
The number of hospitals :	1) Total 2) Mental, Infectious, Tuberculosis, General 0) nothing
The number of hospital beds :	1) Total 2) Mental, Infectious, Tuberculosis, General 0) nothing
Additional number of hospitals or beds :	1) HLTC, HCH, HEMS 2) BLTC, BCH 3) HLTC, HCH, HEMS, BLTC, BCH 0) nothing
The number of clinics :	1) Total 2) Clinic beds, No clinic beds 0) nothing
The number of clinic beds :	1) The number of clinic beds 0) nothing
The number of dental clinics :	1) The number of dental clinics 0) nothing
Financial grants :	1) Money transferred from MGA, General & Specific subsidy 2) Money transferred from MGA, General, Specific & Prefecture subsidy
Other :	1) The number of insured

Table 3. Sets of variables and BIC in the 5 best models

Variable group	Model 1	Model 2	Model 3	Model 4	Model 5
Outcome :	1)	1)	1)	1)	1)
Hourly wages :	1)	1)	1)	1)	1)
The number of hospitals :	2)	1)	2)	2)	2)
The number of hospital beds :	2)	1)	2)	2)	1)
Additional number of hospitals or beds :	2)	2)	2)	3)	2)
The number of clinics :	2)	2)	2)	2)	1)
The number of clinic beds :	1)	1)	0)	1)	0)
The number of dental clinics :	0)	0)	1	0)	0)
Financial grants :	2)	2)	2)	2)	2)
Other :	1)	1)	1)	1)	1)
BIC for 1st estimation	-4555.94	-4549.73	-4534.94	-4532.73	-4517.72
BIC for 2nd estimation	**-4586.01**	-4557.44	-4564.74	-4539.66	-4525.42

The best model is bolded.

Table 4. The estimation result in the best model

Log likelihood $= 2{,}402.1593$

	Coefficient	Standard error	p -value
Cost frontier (normal) term			
Expected lifespan of female (Y/O) :			
20	0.066	0.013	0.000
40	-0.078	0.016	0.000
65	-0.104	0.021	0.000
70	0.108	0.018	0.000
Proportion of elderly insured (%)	0.018	0.000	0.000
Hourly wages :			
Medical doctor (m.)*	-0.011	0.002	0.000
Professional nurse (f.)*	-0.102	0.019	0.000
Auxiliary nurse (f.)*	0.116	0.014	0.000
The number of hospitals :			
Mental	27.394	3.354	0.000
General	6.040	1.084	0.000
The number of hospital beds :			
Infectious	-0.914	0.214	0.000
Tuberculosis	0.308	0.073	0.000
General	0.074	0.011	0.000
Additional Number of hospitals and beds :			
BLTC	0.249	0.041	0.000
BCH	0.075	0.011	0.000
The number of clinics :			
Clinic beds	-0.873	0.146	0.000
No clinic beds	-0.189	0.047	0.000
The number of clinic beds	0.089	0.015	0.000
Constant	11.643	0.338	0.000
Cost efficiency (truncated-normal) term			
Money transferred from MGA	0.035	0.008	0.000
General subsidy	0.118	0.011	0.000
Specific subsidy	0.021	0.004	0.000
Prefecture subsidy	0.010	0.001	0.000
The number of insured	0.041	0.003	0.000
Constant	-1.935	0.145	0.000
σ_u^2	0.002	0.001	
σ_v^2	0.012	0.000	

*) (m.) and (f.); male and female

Table 5. Ranking cost efficiency by municipality

	Municipalities	Prefecture	Medical cost (Per ins. Yen)	Subsidies (Per ins. Yen)	Cost efficiency
Best 10	Azumi village	Nagano	187,692	8,208	1.001771
	Yamagata village	Nagano	204,630	8,234	1.001824
	Hakuba village	Nagano	195,582	5,958	1.001847
	Asahi village	Nagano	229,061	13,089	1.001860
	Tomika town	Gifu	210,425	5,091	1.001868
	Otari village	Nagano	226,052	10,958	1.001869
	Nakaizu town	Shizuoka	232,568	9,887	1.001875
	Nanmoku village	Nagano	203,064	13,119	1.001876
	Minamiminowa village	Nagano	222,551	11,022	1.001880
	Kitadaito village	Okinawa	165,792	84,118	1.001881
Worst 10	Muroran city	Hokkaido	518,626	84,897	1.395205
	Kitakyusyu city	Fukuoka	435,255	67,041	1.415823
	Kobe city	Hyogo	375,568	60,121	1.421949
	Tagawa city	Fukuoka	493,887	86,722	1.422113
	Osaka city	Osaka	353,609	56,785	1.423461
	Hobetsu town	Hokkaido	539,066	105,506	1.423498
	Hakodate city	Hokkaido	490,743	67,623	1.436701
	Mikasa city	Hokkaido	645,896	120,333	1.441603
	Otaru city	Hokkaido	618,210	84,659	1.494560
	Sapporo city	Hokkaido	481,710	86,422	1.495036

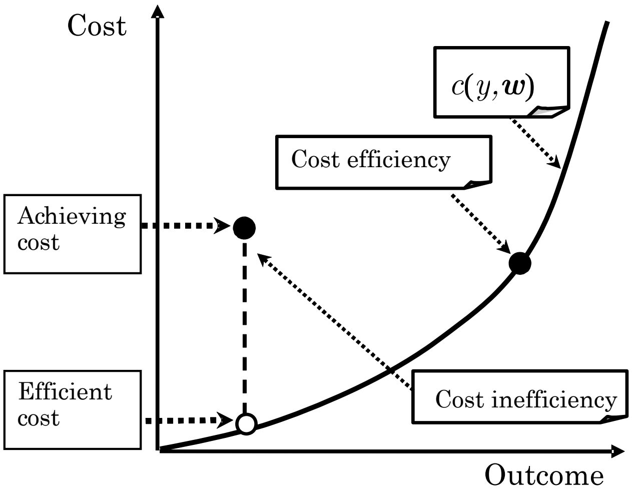

Fig. 1. Relationship between costs and outcomes

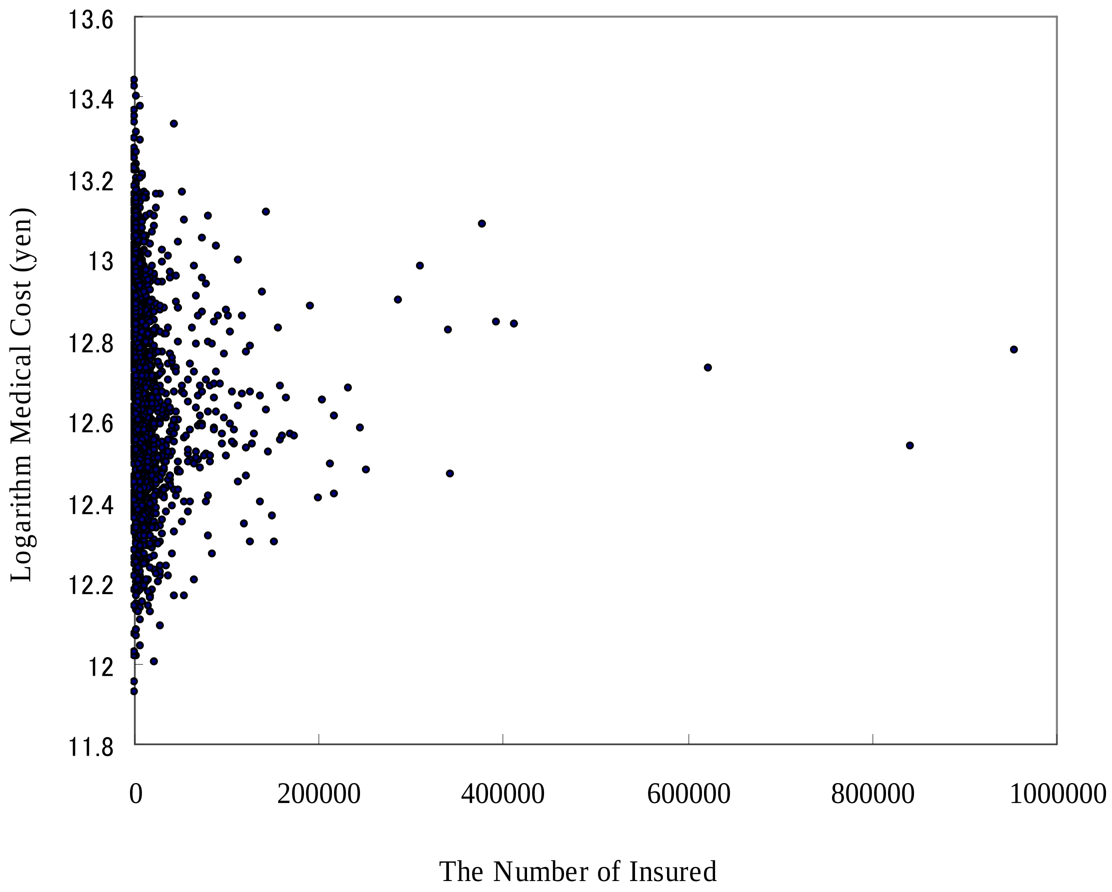

Fig. 2. The scatter plot of the medical cost logarithm and the number of insured

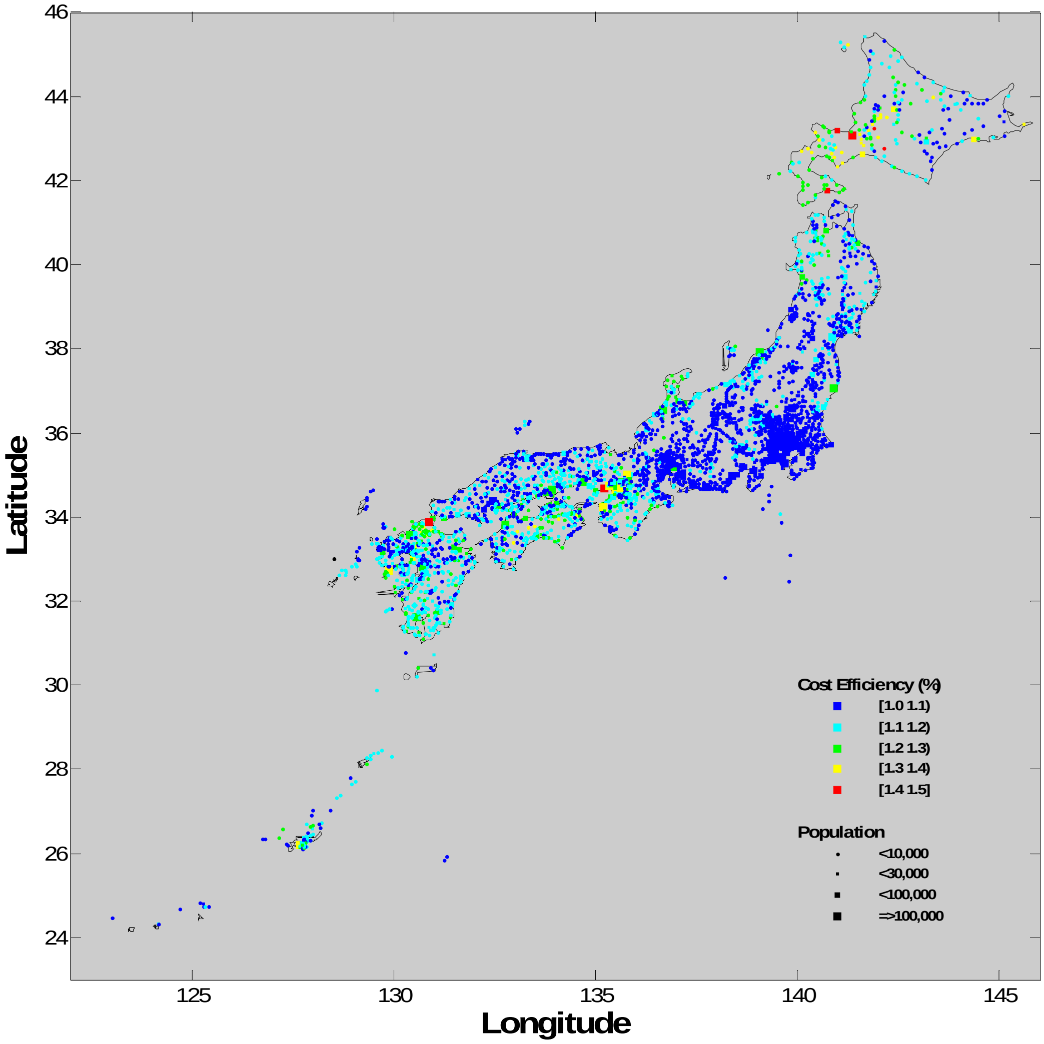

Fig. 3. A distribution map of estimated cost efficiency in Japan

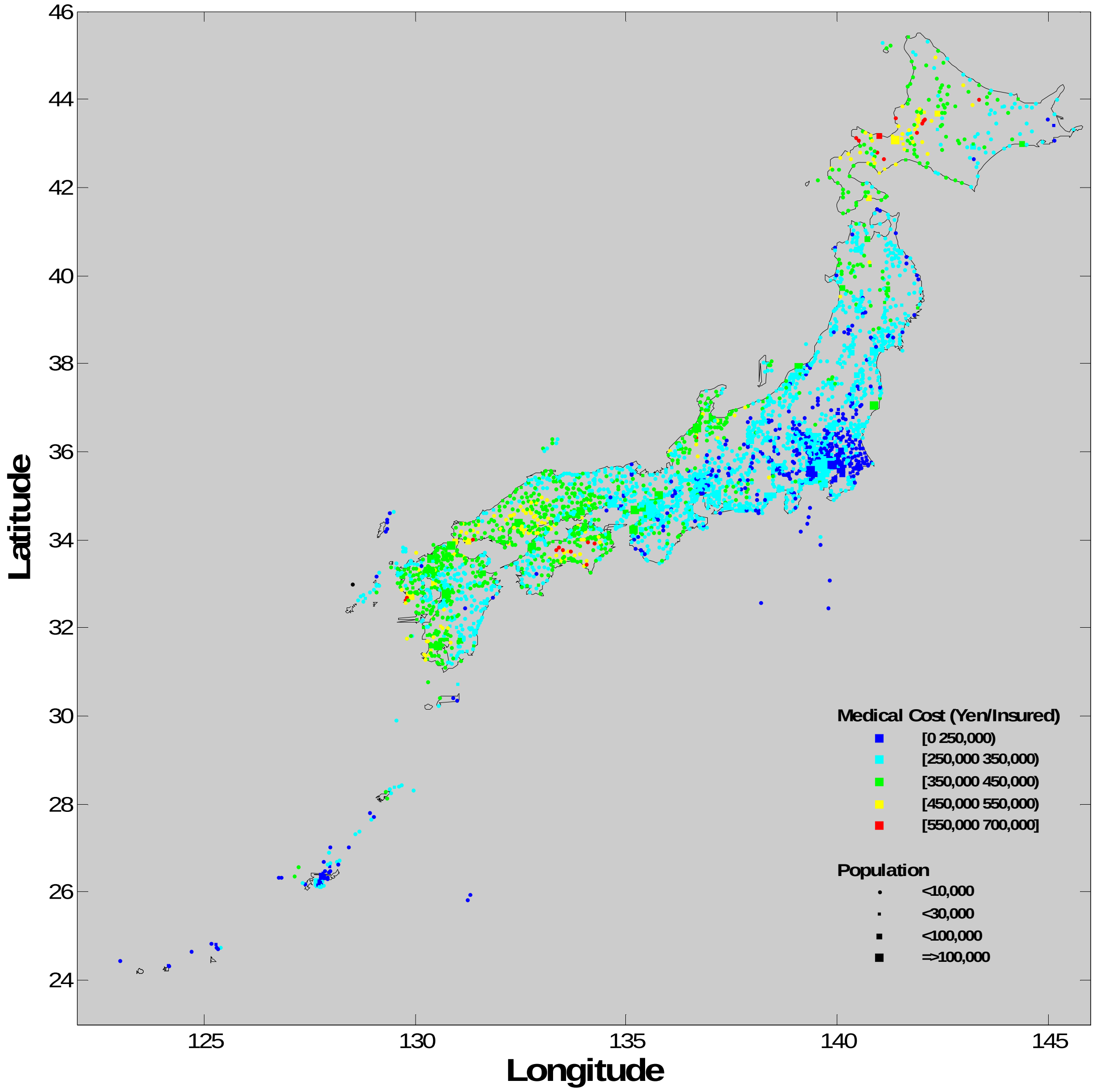

Fig. 4. A distribution map of achieving medical cost in Japan

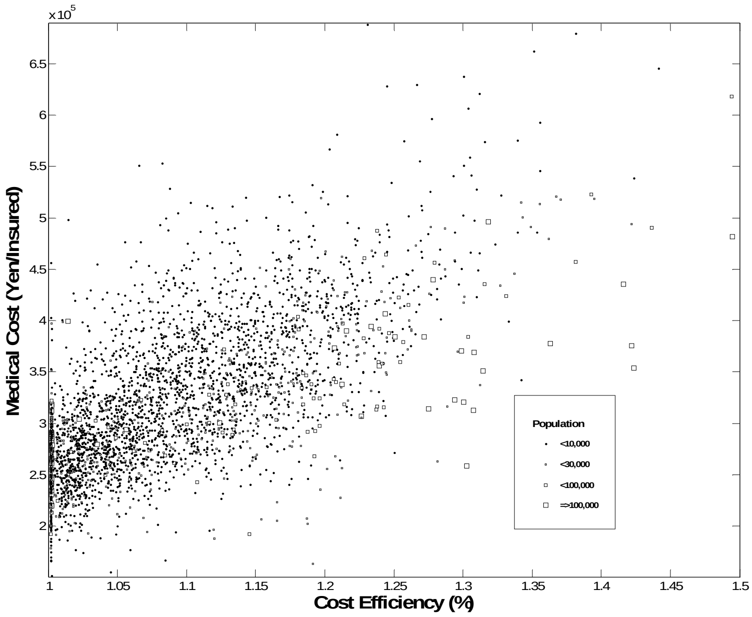

Fig. 5. Scatter plot of achieving medical cost and estimated cost efficiency

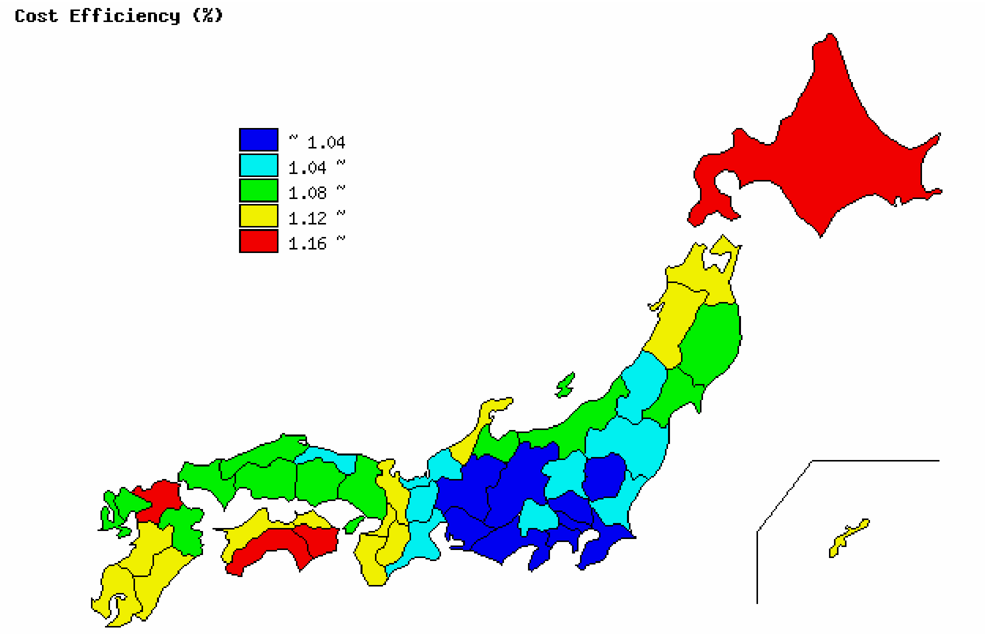

Fig. 6. Municipal average estimated cost efficiency

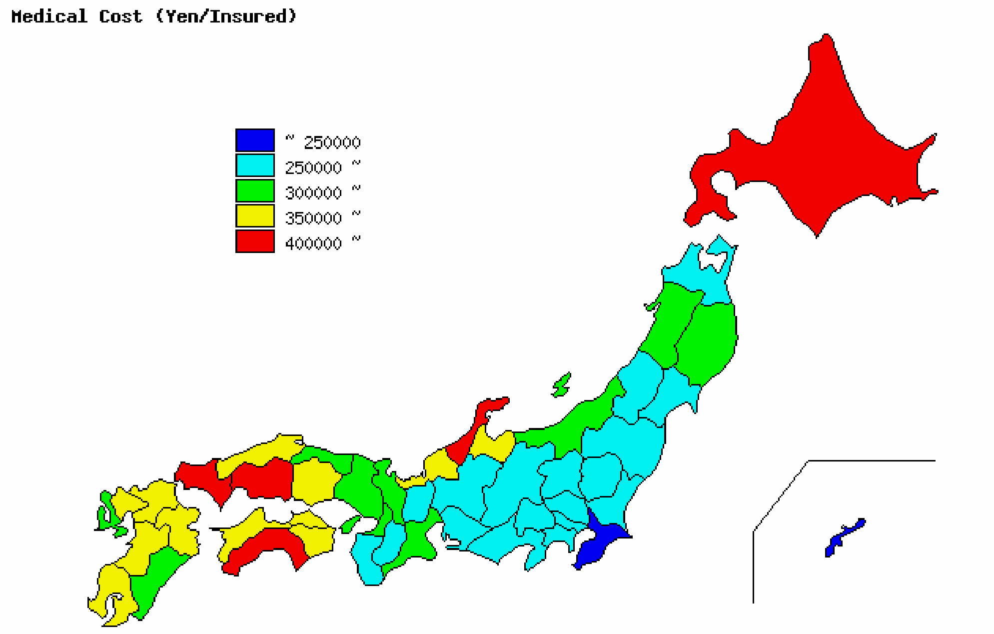

Fig. 7. Municipal average achieving medical cost