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The Linear Regression and Fuzzy Logistic Regression based Medical Service Value Models for Informal Workers in Thailand

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Abstract

The purpose of this research is to develop an estimation model for non-surgical medical service value of informal workers for the social security system in Thailand. In the study, the data of workers in year 2010 provided by the Social Security Office was analyzed and used to create the medical service value model. Two methodologies, linear regression and fuzzy logistic regression have been chosen to develop the model, and then the estimates obtained from each model are compared to the actual costs from hospitals. The results demonstrated that the medical service value model established from fuzzy logistic regression method gave the closest estimates to the real expenses.

Keywords: fuzzy clustering, informal workers, fuzzy logistic regression, medical service value

1. Introduction

The social security system is established to insure employers in case of illness, retiring and disability from work. The insurance is commonly involving with 3 sides: government, employer and employee. Fund management will be collected through subvention which is mandatory for persons who have income. The social security system in Thailand has initiated since 1952 administrating employees' compensation in case of illness or accident due to work. Until 1990, the House of Representatives has approved and confirmed the Social Security Act draft resulting in the Social Security Act A.D. 1992. It defines the mutual fund to carry employment insurance for illness, disability, death which does not be work-related, parturition, child allowance, and unemployment and pension benefits. Social security outset in the project usually provides protection limited only for some certain employments such as manual labors in establishments with more
than 20 employees. In the present days, the system has been expanded into various public sectors in order to cover benefits of the social security to workers who receive regular incomes and members in family during working age as well as out of work, disability or elderly. The project is planned to primarily carry out as mandatory until it has been successfully settled down and the performance reaches acceptable level, the system will be extended to form a voluntary social security scheme, where the weaver freelance can be included in this program.

In Thailand, informal workers such as workers in fishing, forestry and agricultural services, part-time workers, sweatshop, hawkers etc. are as vital to the national economy as those labors whose are covered under the social security program. Nevertheless, the social security or any protection coverage has yet not been provided for these informal workers which in turn the burden of welfare of these workers falls to the government in different ways. For example, informal workers and members in families receive medical and health treatment under the universal coverage health insurance system, although they are able to pay social security contributions to get medical benefits from the social security system. For this reason, the government of Thailand has attempted to extend the social security program to informal sector workers covering 4 benefits, (1) costs of medical treatment, (2) compensation for unemployment, (3) funeral expenses and (4) financial aid. The study has started by a study of Pongpulpansak et al. (2010) who defined target groups that should be included in the program. The researchers have subsequently determined a model for estimating costs of medical treatment without surgery for informal workers.

Several studies have reported for an appropriate medical benefit for informal sector workers. For instance, Baker and Krueger (1995) established a model for estimating medical and health compensation for insured persons under the social security system. Ding and Zhu (2009) employed controlling of medical service value in revolution of health insurance system in China. In 2011, Galbraith and Stone proposed the abuse of regression in the National Health Service allocation formulae which is in response to the Department of Health's 2007 resource allocation research paper. Kazumitsu and Navata (2008, 2009) analyzed hip fracture treatments in Japan by using discrete-type proportional hazard and probit models. One year later, they developed the discrete-type proportional hazard model for estimating duration of hospital stay for cataract patients. From their reports, it is found that duration of hospital stay should be taken into account for medical service value model.

We have previously developed a methodology, the linear regression based medical service value without surgery model, used for estimating medical costs of informal workers for the social security system in Thailand. Since the information used in the previous study are high variation and ambiguous, this study is aimed to analyze the data as in the previous study by fuzzy clustering method before using to establish a new method. The efficiency of a newly constructed model will then be compared with the previous model in order to select the most appropriate estimation method. Fuzzy clustering method is an effective methodology that has been popularly used to deal with fuzzy or ambiguous data. Chen et al. (2011) used fuzzy clustering method in clustering the data of flood damage into dependent variables and independent variables, where they were subsequently analyzed to construct a logistic regression based risk analysis model. Peduzzi et al. (1996) conducted a simulation study of the number of events per variable in logistic regression analysis using fuzzy clustering method for data allocation. McLay et al. (2012) used logistic regression method to analyze the volume and nature of emergency medical calls during severe weather events.

In estimation of medical service costs, it is found that if the ambiguous data has been used in the study, this might yield inaccurate results. To avoid such a problem, several researchers have adapted the principle of fuzzy for data analysis in their studies. Ho (2011) developed a method for optimal evaluation of infectious medical waste disposal companies using the fuzzy analytic hierarchy process. Bolotin (2005) studied fuzzification of linear regression models with indicator variables in medical decision making. Stefan (2010) defined three types of fuzzy predictions of the observed variable in the classical regression model where unknown parameters and observations are crisp. Therefore, the aim of this study is to develop a non-surgical medical service value estimation model of informal workers for the social security, Thailand
using the fuzzy logistic regression analysis method. Subsequently, the estimates obtained from using the newly constructed model will be compared with the results from our previous model.

2. Methods
2.1 The medical service value model

The data used in the study, is obtained from the surveys of informal workers of the social security, Thailand in 2010, included sex, age, weight, height, education, occupation, number of family members, income, number of medical visiting, length of hospital stay, costs of medical care.

Estimation of non-surgical medical expenses of patients can be done from analysis of length of illness and hospital stay, which is discrete random variable, where it equates to 1, 2, 3 etc. Nawata et al. (2008, 2009) analyzed the length of stay in hospital, which is depending on the severity of the case, using the discrete-type proportional hazard model. Thus, let the leaving rate, designated as \( h_i(t) \), be a conditional probability that the \( i^{th} \) patient staying in a hospital on the \( t^{th} \) day will leave the hospital on that day. Therefore, the probability of the \( i \) patient to leave hospital on the \( t \) day is a function of \( h_i(t) \) and give by

\[
p_i(t) = \frac{h_i(t)}{\prod_{s=1}^{t} (1 - h_i(s))}, \quad t \geq 2, i = 1, 2, ..., n
\]

where \( n \) is number of patients, \( s \) is number of days staying in the hospital an \( s = 1, 2, ..., t - 1 \). According to health benefits of the social security system, Thailand, the patient can claim for reimbursement at actual payment but not exceed 12,000 baht per days and not more than twice a year. Given that there is no limitation of the length of hospital staying for insured person. Let \( T \) is the maximum number of days that patient could stay in a hospital, and let \( p_i(T+1) \) is the probability that the patient \( i^{th} \) will stay in hospital more than \( T \) days. Then,

\[
p_i(T+1) = \prod_{s=1}^{T} (1 - h_i(s)), \quad t \geq 2, i = 1, 2, ..., n
\]

Let \( V_i \) is random variable of medical expenses of patients \( i^{th} \). From the continuous proportional hazard models by Nawata et al. (2008, 2009), we obtain an equation of risk incidence for various characteristics of patients as below;

\[
h_i(t) = d_i \exp(v_i \beta), \quad t = 1, 2, 3, ..., T,
\]

when \( d_i \) is the rate of patient staying in a hospital on day \( t^{th} \), and \( \beta \) is regression coefficients of patient condition.

2.2 Analysis of Regression

The aim of regression analysis is to estimate the parameters on the basis of empirical data. The linear form of regression analysis can be written as
where $y$ is an output variable, $x_i$ is input variable, and $\beta_i$ is parameter of the most frequent mathematical form use in regression analysis. Then, the equation of linear regression will be

$$y_j = \beta_0 + \beta_{ij}x_{ij} + \varepsilon_{ij}; \quad i = 1, 2, \ldots, n \quad \text{and} \quad j = 1, 2, \ldots, m.$$  

(5)

If $m$ is sample size, $n$ is number of variables and $\varepsilon_{ij}$ is error of the equation.

In 2004, Dennis and Wage (2000) studied health insurance and pension plans to investigate the relationship between employee compensation and small business owner income by using regression analysis. From the equation 3 of Pongpuponsak’s report (2010), estimation of $\nu'\beta$ using regression method and expected value of non-surgical medical service of patients when they are not admitted to a hospital for treatment can be expressed by

$$E(C_{ji}(t)) = \int_0^\infty \nu'h(t)dv = d_0 \int_0^\infty \nu' \exp(\nu'\beta)dv.$$  

(6)

2.3 Fuzzy cluster analysis

Let $X = \{x_{i1}, x_{i2}, x_{i3}, \ldots, x_{in}\}$ be the set of patients in case of informal workers, where $m$ is the number of sample size and $n$ is patient characteristics. The fuzzy clustering analysis which is based on fuzzy equivalent relation, includes 4 steps as described below.

**Step 1:** Estimation of the default value is by using the following equation (1993):

$$Z_{ij} = \frac{x_{ij} - \bar{x}_{ij}}{s_j},$$

where $\bar{x}_j = \frac{1}{n} \sum_{i=1}^{n} x_{ij}$, $s_j = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2}$, $(i = 1, 2, \ldots, n; j = 1, 2, \ldots, m)$. $Z_{ij}$ is standardization of patient $i$ characteristic $j$, and $x_{ij}$ is original data of patient $i$ characteristic $j$. $R' = (Z_{ij})_{n \times m}$ is standardization transformation where the average and variation values of each column equate 0 and 1, respectively.

**Step 2:** The coefficient of the fuzzy similar matrix $R'$ will be calculated by

$$r_{ij} = \frac{\sum_{k=1}^{m} (x_{ik} - \bar{x}_i)(x_{jk} - \bar{x}_j)}{\sqrt{\sum_{k=1}^{m} (x_{ik} - \bar{x}_i)^2} \sqrt{\sum_{k=1}^{m} (x_{jk} - \bar{x}_j)^2}}; \quad i, j = 1, 2, \ldots$$

where $\bar{x}_i = \frac{1}{m} \sum_{k=1}^{m} x_{ik}$ and $\bar{x}_j = \frac{1}{m} \sum_{k=1}^{m} x_{jk}$.

Hence the fuzzy similar matrix is
\[ R = \begin{pmatrix} r_{11} & r_{12} & \ldots & r_{in} \\ r_{21} & r_{22} & \ldots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \ldots & r_{nn} \end{pmatrix} \]

**Step 3:** The Fuzzy equivalent matrix obtained from the equation above contains 3 characteristics which are reflexivity, symmetry and transitivity. In case that the fuzzy similar matrix \( R \) does not satisfy transitivity, the fuzzy equivalent matrix on the basis of \( R \) will be generated by calculating transitive closure \( n(R) \) of \( R \) using transitive closure method by \( R \to R^2 \to R^4 \to \cdots \to R^{2k} = R^k \odot R^k \) at this time \( R^k \) is a fuzzy equivalent matrix.

**Step 4:** Clustering the data can be done by considering the values of \( \lambda \) at \( 0 \leq \lambda \leq 1 \). The data with the same characteristic will be categorized into one group so each group would contain different characteristics.

2.4 Analysis of Logistic Regression

The aim of analysis of logistic regression is to determine the relationship between independent variables and dependent variables for establishing a model used to predict the probability of event of interest to be occurred, where the dependent variable is category data and independent variables can be either numerical or category data. Logistic regression analysis is divided into 2 cases. For case I, binary logistic is used when the dependent variable \( Y \) has only 2 values; \( Y = 0 \) if a patient stays in a hospital only 1 day, and \( Y = 1 \) if a patient stays in a hospital for 2 days. The case II is multinominal logistic, it is used when the dependent variable \( Y \) contains more than 2 values. For example, \( Y = 1 \) when a patient stays only 1 day in a hospital, \( Y = 2 \) if a patient is admitted to hospital for 2 day and \( Y = 3 \) when stays in a hospital for 3 days.

The statistics used in logistic regression analysis consists of;

2.4.1 Chi − square: used to test for the suitability of the model, where the hypothesis is

\[
\begin{align*}
H_0: & \quad \text{the model is suitable;} \\
H_1: & \quad \text{the model is not suitable.}
\end{align*}
\]

The statistical equation is

\[ \chi^2 = \sum_{i=1}^{n} \left( \frac{O_i - E_i}{E_i} \right)^2. \]

2.4.2 Maximum likelihood estimate; a method for estimating parameter \( \beta \)

\[ G^2 = -2 \left[ \ln L_p - \ln L_0 \right] \quad df = p, \]

where \( L_p \) is likelihood of constant value of independent \( P \) value group and \( L_0 \) is likelihood of constant value when there is only 1 group.

2.4.3 Relationship between independent value and dependent value (Wald test)

Given the hypothesis as
H₀: β₁ = 0 ;  
H₁: β₁ ≠ 0 .

Statistical analysis of Wald test is by

$$Wald = \left( \frac{h_i}{SE(h_i)} \right)^2,$$

where $SE(h_i)$ is the standard of the maximum likelihood function, estimate is standard of error and $df$ is degree of freedom.

2.4.4 Deviance test (D): a test for goodness of fit

$$D = -\sqrt{-2 \log(F)} .$$

2.4.5 Logic Model

2.4.5.1 Binary logistic regression is a logistic regression analysis used when dependent variable contains only 2 choices or 2 categorical variables. The function logistic response $f$ can be written as

$$\pi = \frac{e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}}{1 + e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}} ,$$

or

$$1 - \pi = 1 - \frac{e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}}{1 + e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}} ,$$

where $\pi$ is probability of the event of interest to be occurred, $\beta_0$ is the intercept of the regression and $\beta_i$ is logistic regression coefficient of $X_i$. The odd ratio is used to compare the probability between the occurrence of event of interest and non-interest disinterested. The form of the model is generally

$$y = \log\left(\frac{\pi}{1 - \pi}\right) = \beta_0 + \sum_{i=1}^{n} \beta_i x_i .$$ (8)

2.4.5.2 Multinomial logistic regression is a logistic regression analysis used when dependent variable Y has more than 2 categories. Each value will be compared to the baseline category logit, where $p_j = P(Y = j |X), j = 1, 2, ..., k$. For instance, if $k > 2$ so the logit will be equal to $k - 1$. The form of the model is generally as fellows:

$$\log\left(\frac{p_j}{p_k}\right) = \beta_{0j} + \sum_{i=1}^{n} \beta_i x_i , \quad j = 1, 2, ..., k - 1 ,$$ (9)

where $p_j$ is the probability of occurrence of interested event $j$ compared to the baseline category $k$, where $\beta_{0j}$ is a constant of category $j$ and $\beta_i$ is coefficients of parameter $i$ category $j$.

Thus, $p_j = \frac{e^{\beta_{0j} + \sum_{i=1}^{n} \beta_i x_i}}{\sum_{j=1}^{k-1} e^{\beta_{0j} + \sum_{i=1}^{n} \beta_i x_i}} ; j = 1, 2, ..., k - 1$ and $p_k = 1 - \sum_{j=1}^{k-1} p_j . $
2.5 The fuzzy logistic regression

From the equation (8), the fuzzy logistic regression model with fuzzy variables can be expressed as

\[
\tilde{y} = \log \frac{\alpha}{1-\alpha} = \beta_0 + \sum_{i=1}^{n} \beta_i \tilde{x}_i
\]

(10)

\(\tilde{y}\) is fuzzy number obtained from interval estimation. From the equation (10), interval estimation is fuzzy number \(T\) at \(\alpha - \alpha/2\), then

\[
\tilde{x}_i \pm S.D. \tilde{T}_{\alpha-\alpha/2}.
\]

(11)

3. Results

3.1 Model 1 by regression method

From Pongpullponsak et al. (2010), \(\nu' / \beta\) can be estimated by regression method.

\[
\nu' / \beta = 3.812 - 0.209x_1 - 0.374x_2 - 0.00000004605x_3 - 0.007x_4.
\]

(12)

where \(x_1\) is number of family members, \(x_2\) is sex, \(x_3\) is income, \(x_4\) is weight.

Substituting (12) into (6), where d1, d2, d3 are equal to 0.11, 0.08 and 0.19 day/person/year, so if a patient stays in a hospital for 1, 2 and 3 days, the medical costs will be 1405, 2763 and 3410 baht, respectively.

3.2 Model 2 by fuzzy logistic method

The expected value of non-surgical medical service cost of patient (\(E(C_m)\)), since the variable in this study, the number of days staying in a hospital, which is dependent variable, is category data, logistic regression analysis will be used in estimation of \(\nu' / \beta\). As mentioned previously, using fuzzy clustering method the data can be divided into 3 groups, where each group contains small data numbers. Therefore, distribution of data is carried out among each group before using in simulation for about 10,000 times by using Minitab.

The next step is to establish the medical service value model by using the data from a questionnaire surveying the medical care of informal workers. We hypothesize that there are several factors related to medical care of informal workers including age, weight, height, education, occupation, number of family members, income of the family, number of receiving medical examination and number of days staying in a hospital. All these factors have been used in finding of \(\nu' / \beta\) by fuzzy logistic regression. So we obtain

\[
\tilde{y} = (\nu' / \beta) + \left( \sum_{i=1}^{n} \beta_1 \tilde{x}_1 \right) + \left( \sum_{i=1}^{n} \beta_2 \tilde{x}_2 \right) + \left( \sum_{i=1}^{n} \beta_3 \tilde{x}_3 \right),
\]

\[
\tilde{y} = (\nu' / \beta) + \nu_2 + \nu_3
\]

(13)

Then
\[ \bar{y}_1 = (\beta_1 \bar{\kappa} = [1.223 - 0.003221] + [0.00000046699223 - 0.109243] + [0.006352 - 0.065235], \]

\[ \bar{y}_2 = (\beta_2 \bar{\kappa} = [-0.27822 + 0.000000575723 - 0.12124] + [1.026 + 0.007251], \]

\[ \bar{y}_3 = (\beta_3 \bar{\kappa} = [1.461 - 0.17322 + 0.000000575723] + [-0.945 + 0.000000319232], \]

where \( x_{i1} \) is age, \( x_{i2} \) is sex, \( x_{i3} \) is income, \( x_{i4} \) is number of medical examination and \( x_{i5} \) is number of family members, when \( i \) is groups 2, 1 and 3.

Substituting the values from equation (14) into \( E(C(t)) = t \cdot H_0(t) dt = d \int_0^t \exp(\bar{y}_i \beta_i) dt \) yields the expected value of medical expenses for patient who receives treatment without surgery at registered hospital per day, where \( d_1, d_2, d_3 \) are equals to 0.11, 0.08 and 0.19 day/person/year, respectively. Hence, at significant level (\( \alpha = 0.01 \)) when a patient stays in a hospital for 1 day the estimate of medical costs will be 1021 to 1023 baht. If a patient stays in a hospital for 2 and 3 days, the estimate of medical cost at \( \alpha = 0.01 \) will be 3342 to 3345 baht and 7232 to 7259 baht, respectively.

4. Conclusion and discussion

In this study, we develop the medical service value model for estimating non-surgical medical expenses, including admission to a hospital and medical treatment, of informal workers in Thailand. Using the regression method (model 1) where \( d_1, d_2, d_3 \) are equal to 0.11, 0.08, 0.19 day/person/year, respectively, the expected medical costs for the length of hospital stay at 1, 2 and 3 days are 1405, 2763 and 3410 baht, respectively. Instead of the fuzzy logistic regression method (model 2), it started from data clustering using the fuzzy clustering method on the basis of fuzzy equivalent relation, which results in 3 data groups. Each data group is then used in establishing a logistic regression model. It is found that binary logistic regression should be used for analysis of group I data, while multinomial logistic regression is suitable for groups 2 and 3 analysis. The results obtained from the fuzzy logistic regression model or model 2 is then used to estimate the medical value of informal workers in case of treatment without surgery. At \( \alpha = 0.01 \) where \( d_1, d_2, d_3 \) are equal to 0.11, 0.08 and 0.19 day/person/year, respectively, the medical costs of the length of hospital stay at 1, 2 and 3 days are estimated at 1021 to 1023, 3342 to 3345 and 7232 to 7259 baht, respectively. From figure 5, comparisons of the estimated medical values from each method with the actual expenses from data hospitals in Thailand revealed that using the model 2, the fuzzy logistic regression method, gives the medical values closer to the actual costs than those of the model 1. This is because the model 2 is established from the data that have been dealt with fuzzy clustering method to solve the problem of data ambiguity. This leads into no outliers in the data, there by the model yields more accurate estimated values. For the future work, the overview of the medical service value will be considered for the most suitable medical service value model including expenses of medical treatment with surgery. This information will be contributed in setting up the social insurance of informal workers by the Social Security Office in Thailand.

5. References


MINITAB 16 Order Number 100004968850, Single License, MINITAB Thailand. , February 02, 2010.


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In this part we give the result calculating using Matlab 7.6.0 and the dendrogram by using Minitab version 16. Figure 1 demonstrates data clustering from using the fuzzy clustering method. When $\lambda = 0.7$, It is found that the samples can be divided into 3 groups, composing of group 1 as 1, 35, 3, 9, 13, 16 and 31; group 2 as 6, 10, 17, 20 and 21; group 3 as 2, 4, 5, 7, 8, 11, 12, 14, 15, 18, 19, 22, 23, 24, 25, 26, 27, 28, 29, 30, 33, 34, 37, 38, 39, 40, 32 and 36.

From Figure 2 at $\alpha = 0.01$ when a patient stays in a hospital for 1 day the estimate of medical costs will be 1021 to 1023 baht.
Figure 3 the estimate of medical expenses of a patient when stays in hospital for 2 days

From Figure 3 at $\alpha = 0.01$ when a patient stays in a hospital for 1 day the estimate of medical costs will be 3342 to 3345 baht.

Figure 4 the estimate of medical expenses of a patient when stays in hospital for 3 days

From Figure 4 at $\alpha = 0.01$ when a patient stays in a hospital for 1 day the estimate of medical costs will be 7232 to 7259 baht.