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The Fuzzy Clustering and Logistic Regression based on Medical Service Value Model of Social Security for Informal Workers, Thailand

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Abstract

This study was aimed to find the medical service value model for estimation of hospital medical expenses of informal workers in Thailand for the case that they are admitted to a hospital for treatment without surgery. Using the fuzzy clustering method which is based on fuzzy equivalent relation, the data surveyed from informal workers by Social Security office in year 2010 is analyzed. The data obtained from the fuzzy clustering analysis is used to establish a logistic regression model. Subsequently, the result from this model, which is compensation for medical expenses, will be used to estimate the monetary value of medical services for the informal workers when receive the treatment without surgery.

Keywords: fuzzy clustering, informal workers, logistic regression.

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1. Introduction

Social Security System was firstly established in Germany during the years 1883 and 1889 under the rule of Chancellor Bismarck. It initiated in 1883 starting from the mutual fund to carry insurance case of illness. One year later employment insurance including disability and pension benefits, was born operating by employer associations which was subsequently managed in provincial levels in 1889. The insurance was commonly responsibility of 3 sides: the government, the employer and the employee. Fund management was by collecting subvention which was mandatory for those with income. This is a guarantee of benefits to the project. The successful Germany model has spread to many countries in Europe, Latin America, the United States, Africa, Asia and countries in the Caribbean at a later time.

The rural community in Thailand, mostly agricultural society, is the most freedom of thought, they have their own customs and there needs to be welfare. This is an important principle of life in which the government is trying to provide to society. The social security[15] prescriptive to the employees who have sustained injuries or illness as a result of working for employer should be secured that they would receive compensation money from the employer. The target is to achieve stability in employment, working conditions, labor safety and health, understanding and cooperation between employers and employees in all economic areas. Until 2011 A.D., the Draft of the Social Security Act A.D.2011 was approved and went into force on 2 September A.D.2011. Under this Social Security Act, in the initial stage tentative protection coverage shall be provided to places of business with over 20 employees before it was extended to places of business with at least one employee. However, this system does not cover farmers, employees of the company's crop, fishery, forestry, animal husbandry, workers who are not employed throughout the year, employees of employers who hire them to work in a manner from time to time as temporary or seasonal, employees of employers who are natural persons which the employee is not doing business and employees of the employer engaged in commerce or hawker stalls.

It is well known that the labor force is vital to the national economy but protection coverage has not yet been provided to them. For this reason, the Thai government has realized the importance of such that the coverage of benefits should be expanded to informal workers in Social Security office. In 2010, Pongpullponsak et al.[1], determined four most important benefits for insured persons, including (1) cost of medical treatment, (2) compensation for unemployment, (3) funeral expenses and (4) financial aid. There are several researches documented prediction methods of the medical services expenses. For instance, Baker and Krueger [9] studied medical costs for workers' compensation insurance. Jihong and Minglai [4] reported a theoretical investigation of the reformed public health insurance in urban China. Galbraith and Stone [5] studied abuse of regression in the National Health Service allocation formulae, which responds to the Department of Health’s 2007 resource allocation research paper. In Thailand, Pongpullponsak et al. has attempted to establish a benefit system on medical services to informal workers. Based on treatment of patients, the expenses of medical services can be divided into 3 groups composing of group I where patients are admitted to a hospital for treatment without surgery, group II where patients are admitted to a hospital for surgical treatment and group III where patients receive treatment but are not admitted to a hospital. For this research, the study is focused on patients who are admitted to a hospital for treatment without surgery and for the future work, the medical services values for the other two groups will be studied.

The medical service value where patients are admitted to a hospital for treatment without surgery involves many factors. Nawata [7, 8], introduced that the hospital length of stay can be analyzed using the discrete-type proportional hazard model and the medical service value can be determined by the ordered probit models. Before using in creating a
medical service value model, the data basically appear as diversity and fuzzy data. Integration of
the data to the same group has been introduced by Chen, et al.[6] using fuzzy clustering
analysis. Based on fuzzy equivalent relation they used the method to analyze the flood disaster
linear regression models for fuzzification of indicator variables in medical decision making. In
2010 Stefan [14] studied predictions of the observed variable with fuzzy numbers in
regression models.

The aim of this research was to further adapt the model from the work of Pongpulponsak et al. [1]
for estimation of medical expenses of informal workers in Thailand for the case that they receive
treatment without surgery by using logistic regression. Analysis of logistic regression was used
to investigate the relationships between independent variables and dependent variables to the model
in predicting the probability of interest regression analysis. Such that, in 1996 Peduzzi et al. [12]
reported a simulation study of the number of events per variable in logistic regression analysis.
In 2012 McLay et al. [10] used logistic regression method to analyze the volume and nature of
emergency medical calls during severe weather events.

2. Materials and Methods

2.1 The data used in the study

The data used in the study is information of informal workers in year 2010 provided
by Social Security office. The variables in the analysis were sex, age, weight, height,
education, occupation, number of family members, income, number of medical examination,
number of days in a hospital and cost of medical care.

2.2 Fuzzy cluster analysis

Let \( X = \{x_{11}, x_{12}, x_{13}, \ldots, x_{nm}\} \) be the set of informal worker patients, where \( m \) is
the number of the samples and \( n \) is patient characteristics. The fuzzy clustering analysis which
is based on fuzzy equivalent relation includes:

2.2.1 The formula of standardization of matrix \( R' \) is as follows[7]:

\[
Z_{ij} = \frac{x_{ij} - \bar{x}_i}{s_j}
\]

Where \( \bar{x}_j = \frac{\sum_{i=1}^{n} x_{ij}}{n} \), \( s_j = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (x_{ij} - \bar{x}_j)^2} \), \( i = 1, 2, \ldots, n; \ j = 1, 2, \ldots, m \),

\( Z_{ij} \) is standardization of sample \( i \) characteristic \( j \), \( x_{ij} \) is original data of sample \( i \)
characteristic \( j \) and \( R' = (Z)_{n \times m} \) is standardization transformation where the average values
zero and the variable equals 1 in each column.

2.2.2 The formula of correlation coefficient is expressed by the bellowed function:
\[ r_{ij} = \frac{\sum_{k=1}^{m}(x_{ik} - \bar{x}_i)(x_{jk} - \bar{x}_j)}{\sqrt{\sum_{k=1}^{m}(x_{ik} - \bar{x}_i)^2} \sqrt{\sum_{k=1}^{m}(x_{jk} - \bar{x}_j)^2}} \quad (i, j = 1, 2, \ldots, n) \] (2)

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

Thus the fuzzy similar matrix is

\[ R = (r_{ij})_{m \times n} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & r_{nn} \end{bmatrix} \]

2.2.3 The fuzzy equivalent matrix has 3 properties: satisfied reflexivity, symmetry, and transitivity. However, in the case of the fuzzy similar matrix \( R \), it does not satisfy transitivity so we need to generate the fuzzy equivalent matrix on the basis of \( R \). Calculated the transitive closure \( t(R) \) of \( R \) by transitive closure method: from \( R \rightarrow R^2 \rightarrow R^3 \rightarrow R^4 \cdots \) to \( R^{2k} = R^k \circ R^k \), at this time, \( R^k \) is a fuzzy equivalent matrix.

2.2.4 Considering values of \( \lambda \) (0 ≤ \( \lambda \) ≤ 1) to cluster group. Considering values of \( \lambda \) (0 ≤ \( \lambda \) ≤ 1) to cluster the same characteristic data into one group. Each group would contain different characteristic.

2.3 Analysis of Logistic Regression

Analysis of logistic regression was aimed to investigate the relationships between independent variables and dependent variables to the model in predicting the probability of interests (dependent variables are category data and independent variables can be either numerical or category data). Logistic regression analysis is divided into two cases. For case one, binary logistic is used when the dependent variable \( Y \) has only two values; number 0 if the patient has been admitted to hospital for 1 day and number 1 when the patients is admitted into the number 2. Case two is multinomial logistic. It is used when the dependent variable \( Y \) has more than 2 values. For example, the value of the \( Y \) will be 1 when the patient stays in a hospital for 1 day, 2 if the patient is admitted to hospital for 2 days and 3 when the patient is admitted for 3 days.

The Statistics used in logistic regression analysis consists of;

2.3.1 Chi – square
It is the test for the suitability of the model, where the hypothesis is

\( H_0: \) Appropriate model
\( H_1: \) Inappropriate model

The statistical equation is

\[ X^2 = \sum_{i=1}^{k} \frac{(O_i - E_i)^2}{E_i} \] (3)

2.3.2 Maximum likelihood estimate
Maximum likelihood is a method for parameter \( \beta \) estimation.

\[ G^2 = -2[\ln L_p - \ln L_q]; df = p \] (4)

Where \( L_p \) is likelihood of constant value of the independence \( P \) value group.
L₀ is likelihood of constant value when there is only one group.

2.3.3 Relationship between independence value and dependence value (Wald test)

Given the hypothesis as

\[ H_0: \beta_j = 0 \]
\[ H_1: \beta_j \neq 0 \]

Statistics analysis of Wald test is

\[ Wald = \left[ \frac{b_i}{SE(b_i)} \right]^2 \] (5)

Where \( SE(b_i) \) is the standard of the maximum likelihood function, estimate is standard of error.

2.3.4 Deviance test (D) is goodness of fit test:

\[ D = -\sqrt{-2 \log(\hat{Y})} \] (6)

2.3.5 Logic Model

2.3.5.1 Binary logistic regression is a logistic regression analysis used when dependent variable has only two choices or two categorical variable. Logistic response function is written as:

\[ \pi = \frac{e^{\beta_0 + \sum \beta_i x_i}}{1 + e^{\beta_0 + \sum \beta_i x_i}} \] (7)

or

\[ 1 - \pi = 1 - \frac{e^{\beta_0 + \sum \beta_i x_i}}{1 + e^{\beta_0 + \sum \beta_i x_i}} \]

Where \( \pi \) is the probability that the event of interest has occurred. \( \beta_0 \) is the intercept of the regression line and \( \beta_1, \beta_2, \beta_3, ..., \beta_n \) are the logistic regression coefficients of \( x_i \).

Odd ratio is used to compare the probability between the interested event and disinterested event. The form of the model in general is

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

2.3.5.2 Multinomial logistic regression is the logistic regression analysis used when dependent variable Y has more than two 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 logit will equal to \( k - 1 \).

The form of the model in general is

\[ \log\left(\frac{p_i}{p_k}\right) = \beta_{0j} + \sum_{i=1}^{n} \beta_{0j} x_i, j = 1, 2, ...k - 1. \] (9)
Where $p_j$ is the probability of interested event of $j$ compared to the baseline category as $k$, $\beta_{0j}$ is a constant of category as $j$ and $\beta_{ij}$ is coefficients of parameters $i$ Category $j$

\[
p_j = \frac{\beta_{0j} \cdot \sum_{k=1}^{j} \beta_{ik}}{1 + \sum_{j=1}^{k-1} e^\beta_{0j} \cdot \sum_{k=1}^{j} \beta_{ik}} \quad ; \quad j = 1, 2, \ldots, k - 1 \quad \text{and} \quad p_k = 1 - \sum_{j=1}^{k-1} p_j \quad (10)
\]

2.4 The medical service value model

For medical expenses of patients who is admitted to a hospital for treatment without surgery, it can be estimated from the length of stay in a hospital (number of days staying in hospital). The length of stay is discrete random variable where number of days equates to 1, 2, 3 ... The length of stay in hospital depends on the severity of the case.

In 2009, Nawata et al. analyzed the length of stay by the discrete-type proportional hazard model. Let $h_i(t)$ 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. We call $h_i(t)$ the leaving rate. Therefore, the probability of the $i$ patient to leave hospital on the $t$ day is a function of $h_i(t)$ and given by

\[
p_i(t) = \begin{cases} h_i(t), & t = 1 \\ \prod_{s=1}^{t-1} (1 - h_i(s)) h_i(t), & t \geq 2, i = 1, 2, \ldots, n \end{cases}
\]

Where $n$ is number of patients, $s$ is number of days staying at the hospital and $s = 1, 2, \ldots, t - 1$. The patient can claim for reimbursement at actual payment amount but does not exceed 1200 bath per days and not exceed 2 times in a year. Given that the length of hospital stays of patient is unlimited. Let $T$ is the maximum number of days that patients could stay in the hospital. And let $p(T + 1)$ is the probability that the patient $i$-th will stay in the hospital more than $T$ days. Then

\[
p_i(T + 1) = \prod_{s=1}^{T} (1 - h_i(s)), \quad t \geq 2, i = 1, 2, \ldots, n \quad (11)
\]

Let $v_i$ is random variable of medical expenses of patients $i$-th. From the continuous proportional hazard models Nawata et al. [7, 8], we obtain

\[
h_i(t) = d_i \cdot \exp(v_i/\beta) \quad t = 1, 2, 3, \ldots, T. \quad (12)
\]

d_i is rate of patient staying in a hospital on day $t$-th, $\beta$ is regression coefficients of patient condition. Expected value of medical service value of patients that is not admitted to a hospital for treatment without surgery can be expressed by

\[
E(C_{ni}(t)) = \int_0^t v_i h_i(t) dv_i = d_i \int_0^t v_i \cdot \exp(v_i/\beta) dv_i \quad . \quad (13)
\]

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Figure 1. The dendrogram representing the fuzzy clustering method

Figure 1 demonstrates the fuzzy clustering method, when $\lambda = 0.70$ . As seen in the figure, the samples are divided into three groups, composing of group 1: 1, 35, 3, 9, 13, 16 and 31; group 2: 6, 10, 17, 20 and 21; and group 3: 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, 42 and 36.

In 2004, William J. and Dennis, Jr. [13] studied wages, health insurance and pension plans to investigate the relationship between employee compensation and small business owner income by using regression analysis. Since the number of the days staying at the hospital which is dependent variable is category data-logistic regression analysis is used in the study. From using the fuzzy clustering method, the data can be divided into three groups and each group contains small numbers. Therefore, distribution of data in each group is taken into account before using in simulation for about 10,000 times. The next step is to establish the medical services value model, the data used in establishing the model obtained from a questionnaire to survey the medical care of informal workers. We hypothesize that there are several factors involving 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 $v' \beta$ by logistic regression method as follows:

$$\log(v'\beta) = \sum_1 \beta_1 X (1) + \sum_2 \beta_2 X (2) + \sum_3 \beta_3 X (3)$$

(14)
\[
= \{1.223 - 0.003(age)\} + \left[ \begin{bmatrix} 0.00000046699 \times (\text{income}) - 0.109(\text{health}) \\ -0.27(\text{sex}) + 0.0000005757 \times (\text{income}) - 0.121(\text{health}) \\ +1.461 - 0.173(\text{sex}) + 0.0000005757 \times (\text{income}) \end{bmatrix} \right]
\]

\[
\left[ 0.587 - 0.065(\text{number}) + 0.006(\text{age}) \right] + [1.026 + 0.007(\text{age})] + [-0.945 - 0.000000319 \times (\text{income})] \]

\[(15)\]

Substituting the values from equation 15 into will yield the \(E(C_{\text{h}}(t)) = \int_{0}^{\infty} \nu \cdot h(t) dv\), expected value of medical expenses for patient who receives treatment without surgery at registered hospital per day, where \(d\) equals to 0.19 day/person/year. Hence, the estimate of medical expenses for patient who stays in a hospital for one day is 1508 bath and for the length of two day stay the expected medical expenses equal to 2903 bath.

4. Conclusion

In this study we develop the medical service value model for estimation of hospital medical expenses of informal workers in Thailand for the case that they are admitted to a hospital for treatment without surgery. Using the fuzzy clustering method which is based on fuzzy equivalent relation, the data can be divided into three groups in which each data group is used in establishing a logistic regression model. It is found that in the analysis, binary logistic regression is used for group 1, while multinomial logistic regression is required for groups 2 and 3. The result obtained from the logistic regression models is the estimated medical service value of informal workers in case of treatment without surgery. For the future work, the overview of the medical services value will be considered for the most suitable medical service value model. This information will be contributing data in setting up the social insurance of informal workers by Social Security Office in Thailand.

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References


