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Procrustes Analysis of Indonesian Mortality Table Iv and Indonesia's Death Rate During Covid-19 Pandemic

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Abstract

The level of accuracy to calculate the premium is one of the main points for an actuary to determine the criteria of product which is offered by an insurance company to customers. The main reference in this accuracy is the mortality table. The last mortality table made by AAJI (Asosiasi Asuransi Jiwa Indonesia or in english is Indonesian Life Insurance Association) was Mortality Table Indonesia (MTI) IV which was published in 2019. However, unexpectedly, the Covid-19 pandemic occurred in early 2020 which caused the death rate to be higher than normal situation. This study aims to compare MTI IV which was made with assumptions before the Covid-19 pandemic according to the death rate in Indonesia during the Covid-19 pandemic. This study uses secondary data, by finding the probability of death in Indonesia by calculating the death rate in Indonesia based on population data according to age group classifications obtained from BPS (Badan Pusat Statistik or in english is Central Agency of Statistics) Indonesia. Furthermore, both data were compared using Procrustes analysis to calculated the level of conformity. The results showed that 75.97% of the data matched MTI IV with the death rate during the pandemic. If the insurance company wants more accurate results, they can be adjusted to the Indonesian Mortality Table using data during the pandemic. If it is quite satisfied with the accuracy of 75.97%, the company can continue to use MTI IV.

Keywords: Covid-19, Death Rate, Mortality Table Indonesia, Procrustes Analysis.

1. Introduction

The number of deaths in Indonesia due to Covid-19 up to of July 25, 2020, was 83,279 people, this fairly large number of deaths due to Covid-19 made most people nervous and resulted in the government treating several of restrictions on social access for the community (Munandar et al., 2020; Suyatna, 2021). The World Health Organization (WHO) defines mortality as an event of the permanent disappearance of signs of life, which usually occurs at any time after a live birth (Maqableh and Alia, 2021). Information about mortality has an important role for the government and private institutions in the context of development planning, evaluation of population policy programs, and as a reference for insurance companies in setting premium prices (Astor et al., 2020; Devereaux et al., 2002).

The death of a person no one knows for sure, but in mathematics, there is something called probability. Opportunity is a possibility that might occur in a problem (Johnson and Wichern, 2014). The probability

of a person aged x dying within a certain age is made in the form of a table based on age called the mortality table. In fact, every country has its own mortality table that describes the distribution of the probability of death in that country. The distribution of the probability of death in each country is different.

The mortality table is used by insurance companies to determine the number of premiums and benefits that must be given to their customer companies. By using the concept of probability, the probability of a person surviving to a certain age can be determined. The Indonesian mortality table is a mortality table compiled and processed by insurance companies and the national insurance whose collaboration with Badan Pengawas Pasar Modal dan Lembaga Keuangan (Bapepam) or in english is Capital Market and Financial Institution Supervisory Agency and the Persatuan Aktuaris Indonesia (PAI) or in english is Indonesian Actuary Association. The results of this mortality table will be disseminated to insurance companies to be applied in their respective companies.

The Indonesian mortality table I was first implemented in Indonesia in 1993, along with the development of science and technology, the population grew, accordingly the table was continuously updated in several years, namely 1993, 1999, 2011, and the last published mortality table was the Indonesian Mortality Table IV which published in 2019. However, with the increase in deaths due to Covid, the number of deaths was higher than the normal situation before pendemi Covid-19. Therefore, the mortality table compiled last, namely the Mortality table IV, needs to be considered for implementation.

Based on this, the authors analyzed the compatibility of Indonesia Mortality Table IV with current real events by comparing the mortality rate in Indonesia during the Covid-19 pandemic using excess mortality. Excess mortality is a term used in epidemiology and public health that refers to the number of deaths from all causing during a crisis and beyond what we would have expected to see under normal conditions. In this case, we are interested in how the number of deaths during the Covid-19 pandemic compares to the death rate in Indonesia (Giattino et al., 2020).

Many studies have been carried out to calculate the similarity of two multiple variable data using Procrustes analysis. The Probability function is used to calculate the topological coordinates and then to transform it to physical coordinates using Procrustes analysis (Gunathillake et al., 2016). Transfer learning via Procrustes analysis can be used to improve the prediction performance in a target task via transferring knowledge from auxiliary data of a related task, where the distribution and even the feature space of the data pertaining to the tasks can be different (Turki et al., 2018).

Another research using Procrustes Analysis is estimate ancestry in low-dimensional reference space that is LASER 2.0. LASER 2.0 can accurately estimate fine-scale ancestry within Europe using either exome chip genotypes or targeted sequencing data with off-target coverage as low as 0.05x (Wang et al., 2015) Procrustes analysis can be used to tackle this question by quantifying the match between subsamples and the complete dataset. This research used stream macroinvertebrates to show how sampling design can be optimized by reducing the number of subsamples and increasing the number of sites (Saito et al., 2015). Another research that used Procrustes analysis is assessing the goodness of fit of biplots. This research studied of object and variable matrices employed in biplots analysis, where general matrices can be used in terms of flexibility in selecting distance function (Siswadi and Maharsi, 2012). Based on previous research, the main goal of this research is the goodness of fit between two matrices that can be applied in probability of death in Indonesia and Mortality Table Indonesia IV.

2. Methodology

2.1. Source of Data

The data used in this study is primary data which is data on the total population of Indonesia taken from the BPS. The data represents the population by age group and gender in the data for 2020 and 2019. As a comparison table, the Indonesian Mortality Table IV was used which was compiled by a team of experts (Irsan et al., 2020).

2.2. Data Analysis Technique

There are four stages used to analyse this research, namely:

1. Since we are working with real data, we should know what needs to be done in advance to analyze these raw data in reasonable way. First, we meet to smoot them to even out the most extreme fluctuations. This can be done with a clearing method, such as Whitaker-Henderson. This step is needed if they fluctuate too much or if they contain jumps or error (Binder et al., 2014).

2. Find the excess mortality measure in Indonesia

   The excess mortality can be measure with estimate the expected deaths in 2019-2020 (Giattino et al., 2020). The probability of death of the Indonesian population must consider the following risk notation:

   d_x: number of people expected to die in one year interval at ages x and $x+1$
   q_x: The probability that a person of age x will not last to age $x+1$
   μ_x: The $force\ of\ mortality$ someone aged x (Sutawanir, 2015).
   l_x: number of people living aged x year
   p_x: probability people aged x will live until age $x+1$

   The Estimated time of death using probability theory, using the formula (Carey and Roach, 2020):

   - $d_x = l_x - l_{x+1}$
   - $q_x = \frac{d_x}{l_x} = \frac{l_x - l_{x+1}}{l_x}$
   - $p_x = 1 - \frac{l_x - l_{x+1}}{l_x}$

   The calculation of the death population during Covid-19, namely in 2019 and 2020, is used as the actual calculation of excess mortality.

3. Comparing the probability of death with Indonesia Mortality Table IV using Procrustes analysis

   The results of the actual mortality calculation will be compared with Indonesia Mortality Table IV, where the two mortality rates are two different matrices. With Procrustes analysis, the configuration difference between the two matrices will be known in a numerical value. The numerical value generated by this method can be used to estimate the size of the inter-configuration suitability (Ross, 2004). In Procrustes orthogonal analysis, the order of transformations in the standard order i.e., translation-rotation-dilation gives a minimal distance (Bakhtiar, 2015).

   The procrustes analysis is a shift of configuration matrices to find the parameters $\mathrm{a}_1, \mathrm{a}_2, s$, and $\mathbf{T}$ in $\|s(\mathbf{X} + 1\mathrm{a}_1')\mathbf{T} - (\mathbf{Y} + 1\mathrm{a}_2')\|$ to be maximum. In translation process,

$$\begin{aligned}\|s(\mathbf{X} + 1\mathrm{a}_1')\mathbf{T} - (\mathbf{Y} + 1\mathrm{a}_2')\| &= \|s\mathbf{X}\mathbf{T} + s1\mathrm{a}_1'\mathbf{T} - \mathbf{Y} - 1\mathrm{a}_2'\| \\ &= \|s\mathbf{X}\mathbf{T} - \mathbf{Y} + \mathbf{1}(s\mathrm{a}_1'\mathbf{T} - \mathrm{a}_2')\| \\ &= \|s\mathbf{X}\mathbf{T} - \mathbf{Y} + \mathbf{1}\mathrm{a}'\|\end{aligned}$$

   where translation configuration will get

$$\mathrm{a}' = \frac{1'(\mathbf{Y} - s\mathbf{X}\mathbf{T})}{n}$$

   Rotation process can be done with find a $\mathbf{T}$ that assumed $\mathbf{T}$ is an orthogonal matrix, where $\mathbf{T}'\mathbf{T} = \mathbf{T}\mathbf{T}' = \mathbf{I}$. Suppose matrix $\mathbf{T}$ is configuration with ordo $n \times 2$ will be get with matrix

$$\boldsymbol{T} = \begin{pmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{pmatrix}$$

where θ is a rotation degree;

Dilation can be done with find a s, where;

$$s = \frac{tr\ (\mathbf{Y}^{c\prime}\mathbf{X}^{c}\mathbf{T})}{tr\ (\mathbf{T}'\mathbf{X}^{c\prime}\mathbf{X}^{c}\mathbf{T})}$$

with $\mathbf{X}^{c} = \mathbf{C}.\mathbf{X}$ and $\mathbf{C} = \mathbf{I} - \frac{11\prime}{n}$ (Maqableh and Alia, 2021).

The three transformations can be used to determine the optimal fit measure. The suitability is expected to get a conformity value that can provide recommendations whether during the pandemic the TMI used is still relevant.

4. Get a conclusions

The conclusion is obtained based on the similarity value from the Procrustes analysis. The range of values in Procrustes Analysis is 0-100%, the closer to 100%, the more similar it will be. The results of the similarity level in this study will provide suggestions on how to use Indonesia Mortality Table IV in life insurance companies in making product calculation decisions.

3. Results and Discussion

This study compares the probability of death of the Indonesian population during the Covid-19 pandemic with the Indonesian Mortality Table IV. The first step is to calculate the probability of death in each age group based on the sex of the population in 2019 and 2020 to get the value d_x and q_x. The results of these calculations are in Table 1.

Table 1 Probability of Death of Male and Female by Age Group

Age Clasification	Male	Female
	q_x	q_x
0-4	0.062359	0.067586
5-9	0.076744	0.08013
10-14	0.031713	0.043294
15-19	-0.00785	0.00653
20-24	-0.0416	-0.02792
25-29	-0.06734	-0.03873
30-34	-0.07642	-0.05201
35-39	-0.04956	-0.01437
40-44	-0.03466	-0.02487
45-49	-0.01679	-0.02031
50-54	-0.0225	-0.01744
55-59	-0.03666	-0.02168
60-64	-0.20876	-0.03955
65-69	-0.10307	-0.11145
70-74	-0.07472	-0.00747
75+	0.03518	0.093334

From the Table 1, a matrix measuring 16×2 was made, then from the Indonesia Mortality Table IV also made in the form of a matrix with the same size and then these two matrices were analyzed using Procrustes. The application used in the calculation is MATLAB. The results of the Procrustes value describe the suitability of the two data. Based on the Procrustes score, it was obtained that 75.97% of the Indonesian Mortality Table IV had similarities with the probability of death in Indonesia. This means that the mortality rate which has increased drastically compared to the normal situation does not affect the validity of the mortality table. This means that the Indonesia IV mortality table is not vulnerable to a large enough mortality rate.

4. Conclusion

The Indonesian Mortality Table IV published in 2019 is not vulnerable to changes in the death rate in Indonesia due to Covid-19. Based on the results obtained that 75.97% of the Indonesia Mortality Table IV have a match with the death table that the author has calculated. A shift of around 24.03% is not a strong reason to refuse to apply the Indonesia Mortality Table IV in the Covid-19 pandemic situation. However, if it is deemed necessary to have conformity that is close to 100%, it is necessary to update the Indonesian Mortality Table.

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