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Mortality Analysis by Income Group of Civil Servants in Malaysia

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ABSTRACT

This paper presents a study on the mortality trend and its correlation with the income factor for the period of 2009-2018. Income factor is known to affect the social determinant of mortality in many ways. Individuals with higher income are known to experience lower mortality rates as compared to those with lower income. Income inequality promotes higher mortality risks due to limited and imbalance access of healthcare. Eventually, this may lead to social disparity and unhealthy economic situation to the country. This paper aims to further analyse the mortality trend based on the income distribution among civil servants in Malaysia. Future mortality rates are then being estimated for the next ten years, from 2019 and 2028. This study uses Heligman-Pollard model to individualise the age group data of the civil servant income groups. Next, this study applies the Lee Carter Model to fit and estimate the mortality rates which then be forecasted using the ARIMA model. Results show that low income group recorded higher mortality rates than middle and high income groups. Whilst, the high income group provides strongest correlations to mortality rates with the highest positive correlations recorded in 2013. The weakest correlations recorded by low income group with the lowest negative correlations recorded in 2009. The forecasted mortality rates show gradual increased according to each income group of low, middle and high starting from ages 30, 33 and 36 respectively. The increased in mortality rates affects the lower income group earlier than the higher income group. This study provides a customized and accurate mortality forecast by income status that strengthens the social security and public health systems in Malaysia through fair allocation of social funding and welfare.

Keywords: ARIMA, income inequality, Lee Carter Model, mortality by income status.

1 INTRODUCTION

Income falls under socioeconomic status which is the social class of an entire demographic. It is often expressed as a blend of education, employment and income. Current income is commonly predicted by the education level - the higher the education level, the better the salary earned by a person [1]. Meanwhile, the more educated the population is, the lower the unemployment rate of the country. Obviously, positive correlation exists between the three major socioeconomic class factors which are education, employment and income [2].

Income is one of the few variables that almost determines the livelihood of individuals. Income is very significant for every human being and can help in covering the needs of a person such as healthcare, education, lifestyle, and more. Besides income, many previous studies were conducted on understanding the nature of mortality towards other factors like ethnic group [3], age group [4] and locality by states [5]. In this study, we will determine the significant of income towards the mortality rates for civil servants population of Malaysia.

Mortality can be caused by variety of causes such as accidents, illnesses, suicides and many more. Often, people are unconscious that income is also a part of the contributing factors that may lead to death in a population. Trying to understand on how mortality is so closely linked to the income of an individual has been a major concern in demography, epidemiology, and public health for many years and is starting to draw economists' interest [1]. Life expectancy rises continuously with income [6]. Moreover, a study proved that individuals who have higher portion of income tend to have lower mortality rate than those in the lower income group defined by sex and race in United States of America [7].

The problem of income inequality has expanded throughout many parts of the world including in developed and developing countries. In the economics term, income inequality is defined as a disparity of income distribution which portrayed significant social classes among the individuals, groups, populations or countries within their respective ecosystem [8]. In Malaysia, the income gap has widened between the wealthy, middle class and poor since 2008. As reported by Khazanah Research Institute (KRI) in the “2018 State of the Households”, the actual gap of income average between the top 20% (T20), middle 40% (M40) and bottom 40% (B40) of households in Malaysia has doubled the figure recorded in 1998 [9]. Moreover, the average national income standards are different in each state in accordance with the amount of job opportunities offered in the city. For instance, Kuala Lumpur has a total median income of RM9,073 compared to the median income in Kedah, which is only RM3,811 in 2016, this proved that the distinct income disparity has long been experienced by each state in Malaysia long time ago. Hence, it is crucial to study the impact of income disparity that may lead to increase in mortality. A customized and accurate mortality forecast by income status is essential in strengthening the social security and public health systems in Malaysia through fair allocation of social funding and welfare.

1.1 Relationship between Socioeconomic Status and Mortality

The relationship between mortality and the socioeconomic status (SES) has been long studied by numerous researchers, whom attempted to disclose the underlying causes of mortality that contributed by SES. Measures of SES such as income, education, wealth, and occupation have been commonly associated with mortality.

1.1.1 Income and Mortality

Developments of economic and health statuses are among two aspects being thoroughly presumed as main indicators in assessing countries' financial and social developments for national agenda and policy reforms. Socioeconomic factors such as income status, inflation, GDP and unemployment have distinctly been perceived to have causal effects on mortality experiences. Most of the related studies proved that mortality improvements are parallel to economic growths. [1] found that the income has primary advantage of being a measure for SES as compared to education as it has greater range of variation as compared to education that has a clustering of educational attainment completing high school and college. However, the author further commented that income factor has some analysis limitations on assessing the midlife group's mortality trend as the mortality experienced by this group of people is influenced by reverse causation factor which triggers in later stages of life.

Another study by [11] found that the middle and low income groups have a significant impact on mortality due to cardiovascular disease as compared with high medium income. Based on this trace of reasonings, health status is a causal intermediary between income and mortality. The gap between high income group and low-income group displays the existence of income inequality. Income inequality is defined as the household aggregate income proportion whose income is less than the specified centile of income which lies on the distributions of household income.

1.1.2 Mortality Models

The development of mortality studies has been established ever since the 15th century. In 1693, an English mathematician, Edmond Halley [12] developed the first life table based of life contingencies and its applications. Thereafter, Abraham De Moivre [13] introduced the first formula of mortality modelling in 1725. Later, in 1825 Benjamin Gompertz [14] introduced the new demographical mortality model known as Gompertz Law. Ideally, Gompertz's Law emphasised on the force of mortality that reflects the age dynamics of human mortality which can be precisely modelled as follows:

$$\mu_x = \alpha \exp(\beta_x) \tag{1}$$

where α and β are positive parameters and x denotes age parameter.

In 1992, Lee and Carter [15] introduced the new stochastic mortality model considering the reduction of the annual log age-specific death rates on the time-dependent index. Astoundingly, their model has become most broadly recognised and discussed model in mortality studies until today.

$$\ln(m_{x,t}) = b_x^1 + b_x^2 k_t^1 + \in_{x,t} \tag{2}$$

where $m_{x,t}$ is the rates of central death, that is the fraction of the number of people at age x who died in year t, and the exposure to death of the average population at age x in year t. Element b_x^1 defines the average mortality of age-specific, which certifies the common form of mortality curve over the ages, that is aligned to the past observations, element k_t^1 defines the changes affecting the level of mortality, and element b_x^2 defines the decrease of mortality at age x. It justifies how quickly/slowly mortality rates drop in reacting to k_t^1. The term of error at age x and time t denotes by $\in_{x,t}$. The Lee Carter model has been broadly applied in many studies to further investigate the behaviours and trends of mortality [16,17].

1.1.3 Auto Regressive Integrated Moving Average (ARIMA)

ARIMA is an acronym representing Auto Regressive Integrated Moving Average which is a popular method that has been widely used for time series prediction. Many researchers used Auto Regressive Integrated Moving Average (ARIMA) model along with Lee-Carter model to forecast mortality rates [18]. ARIMA model has been proven to function efficiently and overcome more complex structure models in short-term forecasts. A study has done with the used of Lee-Carter model and ARIMA method to forecast the mortality rates in Norway [19]. They calculated the mortality rates using the

Lee-carter model with parameters of a_x , b_x and k_t included in the model. Various advantages of ARIMA model were found and these have supported ARIMA to be as the most suitable approach particularly in a short-term time series forecasting [20]. Therefore, ARIMA method is able to improve the forecast accuracy even though keeping the minimum parameters.

2 MATERIAL AND METHODS

The mortality rates based on the income groups of public servants from 2009 - 2018 were analysed to observe its trend and characteristics. Then, the relationship between the income groups and mortality is tested using the correlations technique. Finally, the mortality rates are forecasted for the next ten years according to each income group using the Lee-Carter model along with the application of ARIMA model.

2.1 Model and Data

We deployed the Lee-Carter model to fit the mortality rates from 2009-2018. Then, the mortality rates are forecasted from 2019 – 2028 using the ARIMA model. We used the secondary data, which were obtained from the Public Service Department Malaysia (JPA). The range of year of the acquired data is from 2009 to 2018.

2.1.1 Computation of death rates by range of age

The death rate is calculated following the given range of age which are 21 to 25, 26 to 30, 31 to 35, 36 to 40, 41 to 45, 46 to 50, 51 to 55 and 56 to 60, using the following formula:

$$Death\ Rate = \frac{Number\ of\ Death}{Number\ of\ Population} \tag{3}$$

2.1.2 Conversion of probability of death of a group age to the individual age

The data obtained from the JPA are sorted in a range of age group. Therefore, to calculate mortality rates for each age, Heligman-Pollard [21] has introduced a model to convert the death rates from a range of age group to a single age using this formula:

$$q_x = A(x+B)C + De^{-E(\ln(x)-\ln(f))^2}\,\frac{GH^2}{1+GH^x} \tag{4}$$

where A, B, C, D, E, F, G and H are parameters representing three different terms of mortality components. The first component consists of parameters A, B and C which describing the infant and early child mortality below 10 years of age. The second component consists of parameters D, E and F, illustrating the middle life mortality from ages from 10 to 40. This component is also known as accident mortality for males and females and is always being referred as the “accident hump”. The last component of parameter G and H are following the Gompertz’s Law which reflects the steep increase of mortality in adult ages of more than 40 years old.

However, since this study is only focusing on the civil servants’ group, hence we omit the first component of infant and early child, which are parameters A, B and C. Thus, the simplified version of the formula is as follow:

$$q_x = De^{-E(\ln(x)-\ln(f))^2} \frac{GH^2}{1+GH^x} \tag{5}$$

2.1.3 *Mortality rates based on income groups*

In order to investigate the trends of income mortality based on income groups, mortality rates need to be calculated based on each income group using this formula:

$$q_x = \frac{d_x}{l_x} \tag{6}$$

where q_x is the probability of death at age x, d_x denotes the number of deaths at age x, and l_x denotes the number of people alive at age x. From these calculations, the trends can be depicted in graph where the mortality rates act as dependent (y) and age groups act as independent (x). The graph is computed from 2009 to 2018 represented by each income group.

2.1.4 *Relationship between income groups and mortality*

Correlations are statistical techniques that show the extent of two or more variables fluctuate collectively in describing the level of relative strength between or among those variables. A positive correlation implies the degree of which those variables increase mutually, in corresponding to each other whereas negative correlation indicates the degree to which those variables respond distinctively between or among each other. The degree of correlations effect is called correlation coefficient (r), ranging from values of -1 to 1. The closer the r value to either +1 or -1, denotes the strong relationship between those variables. However, the closer the r value to 0, denotes the weak relationship between those variables. The formula of correlation coefficient is:

$$r = \frac{cov(x,y)}{s_x s_y} \tag{7}$$

where;

$$Cov(x,y) = \sum_{i=1}^{n} \frac{(x_i - \bar{x})(y_i - \bar{y})}{n-1} \tag{8}$$

In addition, the positive values of r means that those variables react mutually in a same direction. Otherwise, the negative values of r means that those variables react in an opposite direction towards each other. This relationship is also known as an "inverse" correlation.

The variables used are age groups, mortality rates and the median of income. The independent variable is the age groups and the dependent variables are mortality rates and income rates. Each income group of low, middle and high will be examined respectively in assessing their correlations with the mortality rates. Based on our data, the median of income needs to be converted to per 100,000 so that the scale of income rate in a graph is tally with the mortality rates. To distinguish the correlations between the mortality rates and the level of income, we applied the Pearson Coefficient of correlation technique using the Pearson Chi-Square test.

2.1.5 Forecasting the mortality rates for the next 10 years (2019-2028)

In forecasting the values of mortality rate for the next 10 years, with respect to different income groups of the civil servants in Malaysia, we used the Lee-Carter model. The formula of the Lee Carter model is:

$$\ln\left(m_{x,t}\right) = b_x^1 + b_x^2 k_t^1 + \epsilon_{x,t} \tag{9}$$

Similar to other mortality models, this Lee Carter model is also experienced identifiability issue, which different parametrisations conclude to identical values of $\ln\left(m_{x,t}\right)$. This issue can be resolved by setting up certain constraints on the parametrisations. Hence, we apply the constraints as below:

$$\sum_x b_x = 1 \tag{10}$$

and

$$\sum_t k_t = 0 \tag{11}$$

The age group specific central deaths rates $\ln\left(m_{x,t}\right)$ are then fitted into the Lee-Carter Model. The Lee-Carter Model parameters are estimated using the Singular Value Decomposition (SVD) method. The average values over times of logarithm of central deaths are denoted as the estimated parameters vector $\hat{a}_x$ followed by estimating parameters of $\hat{b}_x$ and $\hat{k}_t$ through the application of the SVD method on the matrix Z in fitting the mortality rates, where the decomposition parameters are achieved.

The values of the Lee Carter Model's time dependent parameter are forecasted for the next ten years by applying the best fitted autoregressive integrated moving average (ARIMA) model:

$$ARIMA\ (p, d, q) \tag{12}$$

where this linear model of stochastic series is derived from the autoregressive model AR (p), the moving average model MA (q), ARMA (p, q) model. We predict the movement of the k_t values by using the ARIMA (p, d, q) model. The formulation of ARIMA model is a difficult process, but overall, it includes four steps:

i) Identifying the (p, d, q) structure.

ii) Estimating the coefficients formulations.

iii) Selecting the model and diagnostic testing the estimated residuals.

iv) Forecasting the future values.

Minitab software is used to forecast the mortality rates for the subsequent years. We forecast the m_x using the estimated values of a_x , b_x and the forecasted values of k_t. After calculating the values of a_x and b_x, the ARIMA model is then used to forecast values of k_t. Finally, the forecasted mortality rates can be generated by filling in the values of a_x , b_x and the forecasted values of k_t in $\hat{a}_x$.

3 RESULTS AND DISCUSSION

3.1 Analysis of Trends by Income Groups

Figure 1 depicts the trends of mortality rates by low, middle and high income groups respectively for 2009 - 2018. The mortality rates for low income group recorded the highest as compared to middle and high income groups. Also, the trends of mortality for middle and high income groups are following the common trends that they should behave, the lower the level of income, the higher the mortality rates. Typically, the graph also illustrates that as age increases, the mortality rates will increase too.

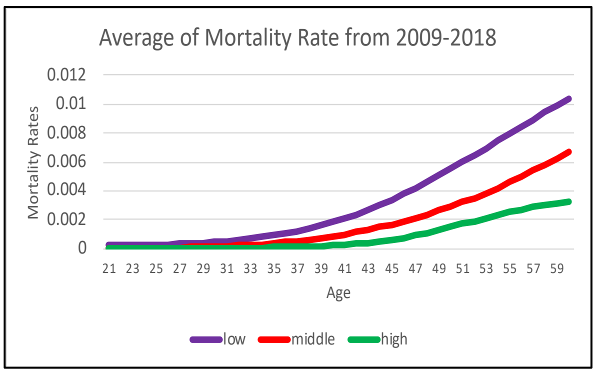

Figure 1: Trends of mortality rates by income groups.

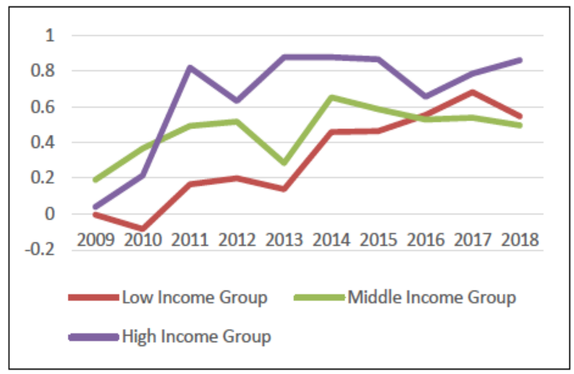

Figure 2: Correlations between income groups and mortality.

3.2 Relationships between Income Groups and Mortality

Based on Figure 2, the correlations for high income group shows the strongest. The positive correlation is recorded between mortality rates and the median of high income group in 2013 with the correlation value of 0.87751. Meanwhile, the weakest correlation is recorded between mortality rates and median of low income group in 2009 with the negative correlation value of -0.00456. The result proves that the high income group affects the mortality rates more as compared to the other groups of income. Nonetheless, all income groups are affecting the mortality rates based on their respective correlational behaviours, higher income will affect the mortality rates more.

3.3 Forecasting the Mortality Rates by Income Groups (2019-2028)

Figure 3,4, and 5 show results of forecasted mortality rates by income groups, where the value of k_t is obtained by applying ARIMA (1,0,2), as suggested by Sarpong (2013) in Minitab software. Each figure of the year is represented by different colours for better explanation and observation of the mortality trends throughout the years. Based on each of the figures above, the forecasted mortality rates for each income group are increasing or decreasing depending on the respective ages of each income group. As depicted by Figure 3 for low income group of the civil servants, the mortality rates are starting to slowly increase at age 30 and keep increasing rapidly after ages 36 to 60. This reflects that the number of deaths for low income group of the civil servants starting at age 36 is observable every year. For low income group, there is an age effect of mortality, whereby greater ages forecasted higher mortality rates. Highest forecasted mortality rates are recorded at 0.110 in 2028.

Subsequently, Figure 4 depicted the forecasted mortality rates for the group of middle income. Following the same manner of the low income group, but this middle income group started to gradually increase a bit later, at age 33 and keeps increasing rapidly after ages 39 to 60. This group of income observes deaths every year upon reaching age 40. Highest forecasted mortality rates are recorded at 0.062 in 2028. As for Figure 5, the forecasted mortality rates for high income group of the civil servants picked up at the latest age of 36 and keep increasing rapidly after ages 39 to 60. Highest forecasted mortality rates are recorded at 0.024 in 2028. Given these scenarios, the level of income has significant impact on mortality, whereby the higher the income, the lower the mortality forecasted. Nonetheless, the trend of forecasted rates keeps increasing every year.

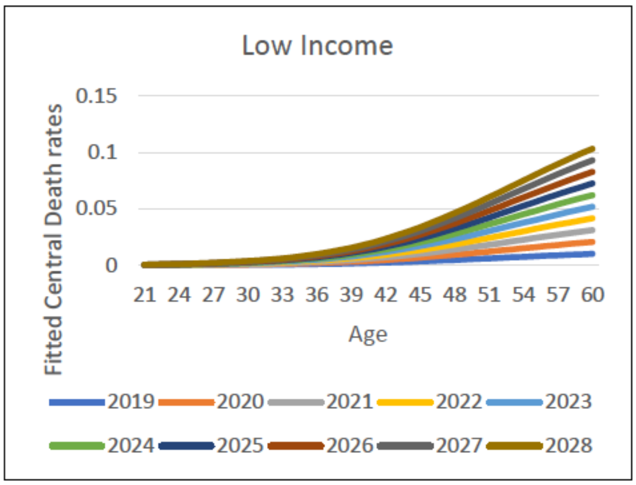

Figure 3: Forecasted mortality rates for low income group (2019-2028).

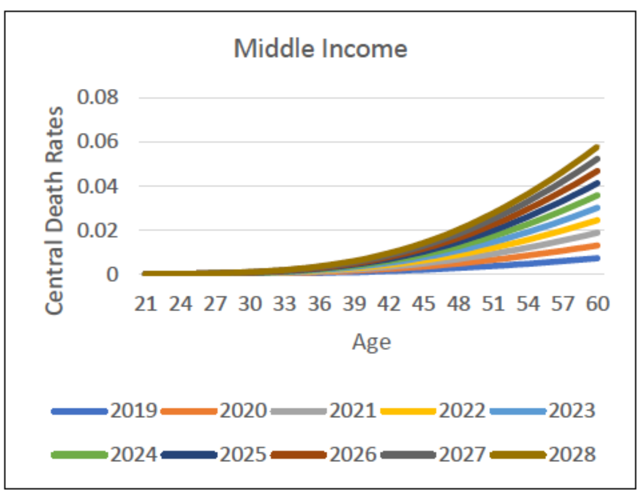

Figure 4: Forecasted mortality rates for middle income group (2019-2028).

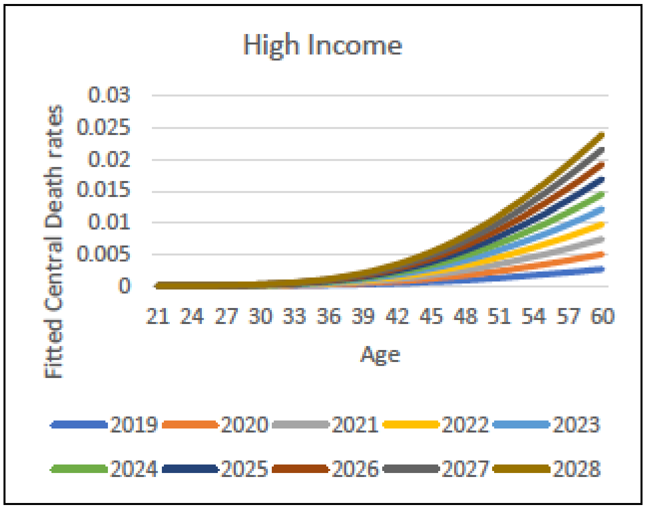

Figure 5: Forecasted mortality rates for high income group (2019-2028).

From all of the earlier findings, the lower income group proves to have significant impact on its mortality experience as compared to the middle and high income groups in particular during younger ages. This may be due to the lower income group tends to have insufficient income to access for their healthcare needs. Moreover, this may also due to unhealthy lifestyle as they are experiencing stress life managing their financial needs and obligations. Most of the low income earners who struggle with their financial and health obligations may find it hard to build wealth, so it is much tougher for them to improve their health. Hence, they are exposed to chronic diseases earlier as compared to high income earners.

On the other hand, the higher income group portrays lower mortality rates as they are expected to have sufficient funding for their healthcare needs and less burden thinking about their financial needs and obligations. However, as much as time is concern, the high income group is somehow also much related to mortality experience together with middle and low income groups due to its exposure of mortality at older workers' age. Relatively, those who are in high income group are mostly those who are in older age, given the situation of them attaining their ceiling salary. To add more point, this group of older workers are prone to associate with aging-related diseases such as diabetes, cancer, heart attack and others. Their immunity also becoming low so they are easily exposed for any infectious diseases. Hence, this group of people is also in a radar of experiencing higher mortality.

The forecasted results show that each income group follows the relative trend of the previous years with only small changes of mortality over the years. Every increment of age will result in higher mortality. If the mortality rates of older workers are compared between each income group, low income group has the highest value of probability of death than other income groups. The number of low income deaths occurs the highest at older age might be due to other associating factors limiting them to take care of their healthcare needs as they have been busy struggling to earn a living. Thus, extra attention also needs to put on this group of income due to its vulnerabilities and uncertainties at older ages.

In short, regardless of any income group, the older workers across each income group face higher risk of death as compared to young workers. Thus, it is more crucial to give more attention to the old age group as we are currently experiencing longevity risks. Government should impose appropriate and effective measures to overcome these issues in particular to those income groups that recorded the highest number of deaths. In addition, the forecasted mortality rates will shed some light to the government or any other responsible parties to spearhead national agenda on pension and savings adequacy for better nation and offspring.

4 CONCLUSION

The association between mortality rates and income has been established before. Different level of income group experiences different pace of mortality transition rates. The mortality transition rates occur earlier for low income group, followed by middle and high income groups. The mortality experiences occur at age 30, 33 and 36 for low, middle and high income groups respectively. The calculated mortality rates for each age of public servants according to their income groups are affected by two significant factors, i.e. the level of income and age. Other contributing factors such as working area, job nature, health conditions and limited access to healthcare may lead to this cause.

Lower income group faces higher mortality rates faster while the higher income group has lower and delayed risk of mortality. However, the impact of mortality on older ages is more significant on high income groups since this group apportions bigger sample size as most of them has attained their ceiling salary. In addition, this group of people is pre-associated with other risk factors of aging like diseases which has led to more vulnerable and critical measures. Above all, the impact of mortality on aging workers are across all levels of income group. The impact is more severe on the low income group as they associate with chronic diseases which have been diagnosed earlier due to limited access of healthcare. Nonetheless, the impact of mortality is major for the high income group as they apportion bigger crowd due to delayed mortality experience of sufficient healthcare access. However, at this juncture, they are also exposed for aging like diseases. Thus, an appropriate measure to manage this mortality experience effectively and efficiently are crucial across all income groups of older ages that aims to strengthen the social security and public health systems in Malaysia through fair allocation of social funding and welfare.

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