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Development of Malaysian Women Fertility Index: Evidence from Shannon's Entropy

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Abstract. A fertility rate is a measure of the average number of children a woman will have during her childbearing years. Malaysia is now facing a population crisis and the fertility rate continues to decline. This situation will have implications for the age structure of the population where percentages of senior citizens are higher than percentages of people aged below 5 years old. Malaysia is expected to reach aging population status by the year 2035. As the aging population has a very long average life expectancy, the government needs to spend a lot on medical costs for senior citizens and need to increase budgets for pensions. The government may be required to increase tax revenues to support the growing older population. The falling fertility rate requires proper control by relevant authorities, especially through planning and implementation of strategic and effective measures. Hence, this paper aims to develop a fertility index using Shannon's entropy method. The results show that Selangor, Johor, and Sarawak are among the states with the highest values of the fertility index. On the other end of the spectrum, Terengganu, W.P. Labuan, and Perlis are ranked in the last positions according to the fertility index. The information generated from the results in this study can be used as a primary source for the government to design appropriate policies to mitigate dwindling fertility rates among Malaysian women.

INTRODUCTION

Women fertility is rated by the mean number of children that a woman will have during her childbearing years. Fertility patterns in the world have changed dramatically over the last few decades. Since the 1970s, a large number of developed countries such as United Kingdom, Canada, Denmark, and Germany have seen their fertility rates below replacement level [1]. In Malaysia during the late 1950s, the total fertility rate was 6.2 children per woman. By 2013, it had fallen below 2.0 children per woman. Malaysia is now facing a population crisis and the fertility rate continues to decline. The total fertility rate has reached the replacement level by year 2010 [2].

The negative influence of low fertility rate is the main cause to further investigate this topic. In society, low level of fertility rate is one of the economic challenges when the population age structure will be affected. In year 2035, Malaysia is projected to reach the status of aging population where 15 per cent of the total population will be at least 60 years old [2]. As the aging population has a very long average life expectancy, the government needs to spend a lot on medical costs for senior citizens and also needs to increase budgets for pensions. The government may be required to increase tax revenues to support the growing older population. The falling fertility rate requires proper control by relevant authorities, especially through planning and implementation of strategic and effective measures.

Therefore, in this study, we present the mathematical development for measuring fertility index to discover the ranking of the women population ability to have children. The women fertility index is perform to demonstrate the rank of each state in Malaysia. To the best of the authors' knowledge, the official report on the Malaysian women fertility index has not yet been studied. For the development of women fertility index, there are several characteristics that potentially related to the fertility behavior can be employed in developing the women fertility

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index based on previous researchers findings. In details, there are seven characteristics that were used in this study as a potential determinant in fertility behavior which are place of living (urban or rural), age at first marriage, female tertiary education attainment, number of divorces, female participation in labor force, family planning methods, and female income.

In this study, the total number of children ever born (CEB) per woman was used as a measure of fertility. CEB is regularly used as proxy for fertility in various studies [3], [4], [5]. The fertility index plays an important role to explain the fertility level for each state in Malaysia from "high fertility" to "low fertility", as it may help the government to design appropriate policies aimed at increasing fertility rates among Malaysian women.

The rest of the paper is structured as follows. The next section defines the methodology which includes the data standardization, weight calculation and index development of the woman fertility for each state. To close the paper, we present the results, and conclusion of the study.

METHODOLOGY

The development of a fertility index requires three main steps; the first involves identification of characteristics related to fertility from comprehensive literature review, the second requires calculation of weighting characteristics, which involves application of Shannon's entropy method, and the final involves building of fertility index using methods of linear combination or weighted arithmetic average [6].

In this study, the data has been obtained from the Fifth Malaysian Population and Family Survey by the National Population and Family Development Board. The data standardization is performed since the measurement units and scales of seven characteristics differ. The standardization is used to transform different scales and units among various characteristics into common measurable units to allow for multi characteristics comparisons [7].

Data Standardization

Let $X = [x_{ij}]$ and $Z = [z_{ij}]$ being the elements of data matrix of number of children ever born (CEB) and standardized data matrix, respectively across all characteristics. Table 1 provides further information regarding the characteristics.

TABLE 1. Description of the Characteristics

No.	Characteristics	Description of characteristics
1	URBAN	Number of females living in urban areas by state
2	AGE	Female age at first marriage (years)
3	EDU	Number of females tertiary education attainments by state
4	DIVORCE	Number of divorces by state
5	EMPLOYED	Number of females employed by state ('000)
6	PLAN	Number of married couples using family planning methods by state
7	INCOME	Median monthly female income by state (RM)
8	CEB	Total number of children ever born per woman by state

In this study, to eliminate anomalies of measurements units and data scales, the data standardization is performed [7] before calculate their weights

$$z_{ij} = \frac{x_{ij}}{\sum_{j=1}^{k} x_{ij}} \tag{1}$$

Weight Calculation

In Table 2, the structure of the matrix is constructed with n number of location (state), i against k fertility characteristics, j and w_j is the weight of fertility characteristics j.

TABLE 2. Structure of the Matrix

	Characteristics 1	**Characteristics 2**	…	**Characteristics *k***
Location 1	x_{11}	x_{12}	…	x_{1k}
Location 2	x_{21}	x_{22}	…	x_{2k}
⋮	⋮	⋮		⋮
Location *n*	x_{n1}	x_{n2}	…	x_{nk}
	w_1	w_2	…	w_k

Since different characteristics have different meaning, it is not appropriate to assume that they all have equal weights. Methods for finding weights for each characteristic can be classified into two groups which are subjective and objective weights [7]. Subjective weights are determined only according to the preference off decision makers such as rank- based method, pair wise comparison method [8], Analytic Hierarchy Process (AHP) method, weighted least squares method, and Delphi method [9]. The objective methods determine weights for each characteristic by solving mathematical models without any consideration of the decision maker's preferences. The examples of objective weights are correlation method, entropy method, multiple objective programming, and principle element analysis [7]. Subjective weighting may be preferable in the most real problems, since the decision maker's expertise and judgments are taken into account. However, the use of objective weights is practical when obtaining such reliable subjective weights is difficult [7]. In this study, we proposed to implement Shannon's entropy method for determining the characteristics weight.

Entropy Method

The concept of entropy was introduced by [10] in communications theory and the concept is now widely used in many different fields. The concept put forward by Shannon entropy is based on statistical theory. The method of entropy can be used in identifying objective weight which is based on the degree of uncertainty of the information as employed in probability theory [8], [11]. The entropy measure for the j^{th} characteristics is given by the following formula:

$$E_j = -\frac{1}{\ln n}\sum_{i=1}^{n} z_{ij} \ln(z_{ij}) \tag{2}$$

Entropy measures the size of uncertainty information contained in a decision characteristics, i.e. the larger the size, the lower the condition. The weight for the j^{th} characteristics is

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{k} 1 - E_j} \tag{3}$$

Index Development

This step is also known as aggregation method, which involves the process of combining a set of values into a single value. In this study, a linear combination method or weighted arithmetic average is used. Mathematically, the fertility index can be written as follows.

$$FI_i = w_j z_{ij} + w_j z_{ij} + \ldots + w_j z_{ij} = \sum_j w_j z_{ij}, \quad \sum_j w_j = 1, \quad w_j \geq 0 \tag{4}$$

Where,

FI_i = Fertility index for location i.
w_j = weight for characteristics $j, j = 1, 2, 3, \ldots, k$.
z_{ij} = normalized value of location $i, i = 1, 2, 3, \ldots, n$, with respect to characteristics j.

RESULTS

The results in Table 3 show the entropy value, weighted value and rank of each characteristic. The characteristics of EDU, DIVORCE, and PLAN, which have the highest weight, can be considered as important characteristics of fertility, followed by URBAN, EMPLOYED, INCOME, and AGE.

TABLE 3. Entropy Value, Weighted Value, and Characteristics Rank for Fertility Using Entropy Method

Characteristics	**Entropy value,** E_j	**Weighted value,** w_j	**Characteristics rank**
URBAN	0.9347	0.1802	4
AGE	0.9996	0.0012	7
EDU	0.9156	0.2328	1
DIVORCE	0.9327	0.1857	2
EMPLOYED	0.9401	0.1652	5
PLAN	0.9338	0.1825	3
INCOME	0.9810	0.0524	6
		$\sum w_j$ = 1.0000	

After the $FI_i, i = 1, 2, 3, \ldots, n$ are calculated, the state can be ranked from the highest index to the lowest index. The state with the highest values of index presents better conditions for childbirth and childbearing.

TABLE 4. Women Fertility Index by State Using Entropy Method

Index	Rank	State
0.1444	1	Selangor
0.1268	2	Johor
0.1051	3	Sarawak
0.0779	4	W.P Kuala Lumpur
0.0701	5	Sabah
0.0651	6	Kedah
0.0587	7	Perak
0.0585	8	Pahang
0.0576	9	Melaka
0.0480	10	Kelantan
0.0476	11	Negeri Sembilan
0.0407	12	Pulau Pinang
0.0297	13	W.P Putrajaya
0.0266	14	Terengganu
0.0235	15	W.P Labuan
0.0197	16	Perlis

The results in Table 4 show that the state with the highest fertility index is Selangor, followed by Johor, and Sarawak. On the other end of the spectrum, Terengganu, W.P. Labuan, and Perlis are ranked in the last positions according to the fertility index.

CONCLUSION

For the calculation of weighted, it appears that much weight is given to the female tertiary education attainments, number of divorces, and family planning methods. These three characteristics can be considered as important characteristics in explaining fertility behavior in Malaysia.

The results of the fertility index based on entropy method as proposed in this study show that Selangor has the highest fertility index. The reason for the high index in Selangor might be because the state government offer schemes to alleviate lower fertility amongst Selangor women [12]. These schemes includes allocation of RM1500 for newborn babies, parents that are eligible will receive financial help to pay for nursery or daycare centers registered with the Department of Social Welfare amounting to about RM100 every month, and payment aids of RM50 every month for children in pre-school education.

In addressing the problem of low fertility in Malaysia, all parties must play their role. The information generated from the results in this study can be used as a primary source for the government to design appropriate policies to mitigate dwindling fertility rates among Malaysian women. These policies include income supports for families with children, affordable or quality child care and early childhood education, flexible working hours, parental leave, family leave, and reasonable working hours.

The findings from this study make several contributions to the current literature. Based on certain crucial factors that influence the fertility rate in Malaysia, we propose the women fertility index as an indicator for verifying and measuring the degree of ability of the women population in Malaysia to have children. However, we accept that the choice to bear children is personal decision. However, this issue supposed to be taken seriously, with full of responsibility. Thus, it is important for married couples to motivate themselves to have more children with good quality of education as it can enhance the economic productivity in our country.

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