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Research paper

Malaysian Fertility Transitions: Analyses and Projections of ASFR and TFR by Ethnicity

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Abstract

This paper presents the study of Malaysian fertility transitions: analyses and projections of age-specific fertility rates (ASFRs) and total fertility rates (TFRs) by ethnicity. In this study, the trends of ASFR and TFR were analysed and compared between ethnic groups, and provided insightful explanation behind the fertility transition over the last six decades from year 1958 to 2015. This paper is the first to adopt the functional data model to estimate fertility rates using Malaysia data. The advantage of the functional model over the mathematical curve approaches is that its ability to account for changes in fertility trends over the years. We use the functional data model to estimate future Malaysian ASFRs and TFRs according to three ethnic groups: Malay, Chinese and Indian. Results show that Malaysian total fertility rates (TFRs) have decreased tremendously from 6.28 children for every woman (aged 15 to 49) in 1958 to 2.23 children in 2015. The forecasts of age-specific fertility rates show that the ages of the highest births gradually change to older age, indicate that the trend of Malaysian women delaying their first birth, will continue to happen in the future. The forecasts of Malaysian TFR show that the TFRs of Chinese and Indian record the lowest low fertility, which is below 1.0 by 2027 and 2030 respectively.

Keywords: *Total fertility rate; age-specific fertility rate; functional data model; Malaysian fertility.*

1. Introduction

Over the last few decades, fertility patterns in the world have changed dramatically and reached unprecedented low levels. These changes occurred in many countries especially among developed nations. In Malaysia, total fertility rates (TFRs) have declined tremendously from 6.0 children per woman in 1950 to 2.33 in 2015. Interestingly, the rate of decline were varied according to ethnic groups, in which the TFR of the Chinese and Indian were consistently lower than that of the Malay over the years. According to [1], the variation of fertility rates by ethnicity is due to their different cultural practices and religion beliefs.

A continued decline in fertility gives severe long-term impacts on national socio-economic development [2] as low number of births would have not enough to sustain current populations. This issue will result in a substantial imbalance ratio of elderly dependents to working-age people which will affect the productivity level of the nation. To overcome this problem, new incentives or policies have been implemented to encourage more births. For instance, the Australian government implemented a series of increment to family-related benefits and cuts to personal income tax rates [3]. In Malaysia, the government has recently announced to increase maternity leave from 60 days to 90 days, mandatory to private sectors and introduced a unit trust fund to each newly borne babies, namely *ADAM50*. These policy intervention dependent on the estimation of fertility rates. Hence, a study that can accurately forecast future fertility rates is becoming increasingly important.

This paper presents comparative analysis and forecasts of age-specific fertility rates and total fertility rates by three main ethnic groups in Malaysia including Malay, Chinese and Indian. We compare three ethnic groups' fertility levels and observed the transition of fertility over the fifty-nine-year period from 1958 to 2015. Although [4] has examined the pace of fertility changes in Malaysia from 1970 to 2010, the trends of future fertility rates among the ethnic groups were not estimated. The future trends of fertility are necessary as they will inform the possible changes for national population policy goals. Due to this limitation, it is of interest to this research to model and forecast the age-specific fertility rates and total fertility rates according to ethnic groups in Malaysia.

Methods to estimate age-specific fertility rates have been long established in the literature. Among them include Hadwiger function [5], quadratic spline model [6], cubic spline model [7], Brass procedure [8] and Gompertz curve [9]. See [10] for details of fertility models. These mathematical curve methods have been applied worldwide. For example, a research from [11] used a polynomial model approach to estimate the age-specific fertility rates of Indonesian. A polynomial model is suitable to determine the age-specific fertility rates with respect to different ages in the year. A research from [12] used four mathematical models, which were Hadwiger, Gamma, Beta, and Gompertz models to estimate the age-specific fertility rates in Peninsular Malaysia. All these models were proven to provide excellent fit for the one-year age-specific fertility distributions of populations. It might be possible to fit these models to Malaysia fertility data how-

ever the results obtained would not be accurate as it refers to only one-year age-specific fertility rates, without taking into consideration the change of fertility rates over years.
Therefore, to accurately model fertility patterns in Malaysia, this research adopts a method proposed by [13], so called the functional data model. This model could reveal fertility changes not only by age but also across the years. There are two parameters included in the models which are the age-component and time-component. These age and time parameters undoubtedly would increase our understanding of fertility pattern in Malaysia. The functional data model combines ideas from functional data analysis, nonparametric smoothing and robust statistics which are based on Lee-Carter model framework [14]. Using Australian fertility data, [13] has proved that this technique produced more accurate results that the original Lee-Carter.
Although the functional data method was widely applied in other area of interest such as air quality monitoring [15;16] and mortality, fertility and migration forecasting [17], the application of this model to estimate fertility rates is rather limited. As far as we concern, the functional data method has not been tested to forecast fertility rates in Malaysia. Hence, this research will fill in the gap by extending the application of the functional data model to Malaysian fertility data.

2. Data and Methods

2.1. Data

Data required for this research included age-specific fertility rates for three ethnic groups: Malay, Chinese and Indian. Data were collected from the Department of Statistics Malaysia (DoSM). It is noteworthy that Malaysian age-specific fertility data are in quinquennial ages: 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, and 45-49, starting from year 1958 to 2015.

2.2. The Functional Data Model

The Functional data model deals with multivariate data with an ordering on the dimensions that includes underlying smooth function of age with errors. In this research, the age-specific fertility rates for each ethnic group is defined as follows

$$\boldsymbol{y_{t,i}(x) = f_{t,i}(x) + \sigma_{t,i}(x)\varepsilon_{t,i}}$$

$\boldsymbol{y_{t,i}(x)}$ is the observed fertility rates for age $\boldsymbol{x}$ in year $\boldsymbol{t}$ and for the ethnic group $\boldsymbol{i}$. The $\boldsymbol{f_{t,i}(x)}$ is its respective smoothed fertility rate. The $\boldsymbol{\varepsilon_{t,i}}$ is an iid standard normal random variable and $\boldsymbol{\sigma_{t,i}(x)}$is the error that varies by age. Following [10], the smoothed rate of $\boldsymbol{f_{t,i}(x)}$is estimated using a non-parametric approach which is median smoothing B-spline constrained to be concave. This reflects the patterns of Malaysian ASFR in which the maximum number of births occurred in the middle of woman reproductive age, between 30 to 35 years old.
The smoothed age-specific fertility rates are presented using the Rainbow plots from [18] to uncover the underlying structure of ASFR and reveal other interesting features that may not described by formal statistical model. The rainbow plot displays all the data, with the characteristics represent in a colour palette based on an ordering of the data. In this research the rainbow plot represents multivariate graphs which age and time are the factors. This graphical method summarises the ASFR data in a diagrammatic or pictorial way in which the two-factor interaction and relationship will be explored. In this research, we use 'demography' package for *R* software programming to create the rainbow plots of ASFRs for each ethnic group.
Next, the smoothed age-specific fertility rates will be fitted into the functional data model as described in the following equation

$$\boldsymbol{f_{t,i}(x) = \mu_i(x) + \sum_{k=1}^{K} \beta_{t,i,k}\gamma_{i,k}(x) + e_{t,i}(x)}$$

$\boldsymbol{\mu_i(x)}$ is the average of $\boldsymbol{f_{t,i}(x)}$ across years. The age-component $\boldsymbol{\gamma_{i,k}(x)}$ and the time-component $\boldsymbol{\beta_{t,i,k}}$ are estimated using the principal component decompositions of 2 X 2 matrices of $\boldsymbol{f_{t,i}(x) - \mu_i(x)}$. The age and time components equivalent to the principal components' functions and coefficients respectively. The $\boldsymbol{e_{t,i}(x)}$ is the model's errors. Next is to forecast the coefficients $\boldsymbol{\beta_{t,i,k}}$ for future years from 2016 to 2030 ($\boldsymbol{h}$ =1,2 …. 15), using the fitted time-series models. In this research, we use 'auto.arima' function from the *forecast* package of R programming to choose the best fit time series model for each coefficient. Finally, we multiply the forecast of coefficients with the estimated principal components functions, to obtain the forecast of smoothed fertility rates.

3. Analysis of Malaysian Fertility by Age and Ethnicity

Figure 2 shows rainbow plots of the smoothed observed Age-specific fertility rates from year 1958 to 2015 for Malay, Chinese and Indian.
Firstly, we examine changes in fertility rates over the years. The ASFRs of the Chinese and Indian were declined more rapidly than that of the Malay over the years. This is shown by a wider gap between the red curves (early years) and purple curves (latest years) in the figures 2a and 2b compared to the Figure 2c. For example, a Chinese women age 25 can give birth on average 3.7 babies in 1958 and then it declines profoundly by more than half which is only 1.76 babies in 1986. Subsequently, the number continues to decrease, leading to average 0.7 babies in 2015. The birth rates of the Chinese are comparatively lower than the Malay woman of the same age, who can give birth on average 1.59 babies in 2015. According to [4], differentials in fertility by ethnicity and age may lead to changes in the population composition age structure in future.
According to [19], improvements in female education, female employment and gross domestic product per capita are among the factors contribute to a reduction in Malaysian fertility over the years. Moreover, the success of the National Family Planning program introduced by the government in year 1966 also influenced fertility decline in Malaysia [1]. A drastic fall in fertility particularly among the Chinese and Indian is an alarming fact and become a major concern to the government especially when designing new policies related to population, women and family.
Secondly, changes in fertility rates by age were closely observed. In general, the age-specific fertility rates display a bell shape indicating the lowest births occur in the youngest and the oldest age groups whereas the highest fertility rates or the peak of the curves occur in

productive age groups, between 20 to 35 years old. Interestingly, as the colours changed from red to purple, the peak of the curves shifted gradually to the right, that is to older ages. For example, in the Fig 2c, the highest number of births in 1958 were occurred among Indian women age 22 years old which is on average 3.67 babies. Nevertheless, in 2015, the highest number of births declined to 0.97 babies which occurred in later age of 32 years old. This transition may happen due to the increased of the age at first marriage. Statistics showed that the mean age at first marriage for Malaysian women increased from 18.5 in 1947 to 22 in 1970 and increased further to 25.1 in 2000 [20]. Thus, it seems that the age at marriage can affect the level of fertility and subsequently population growth.

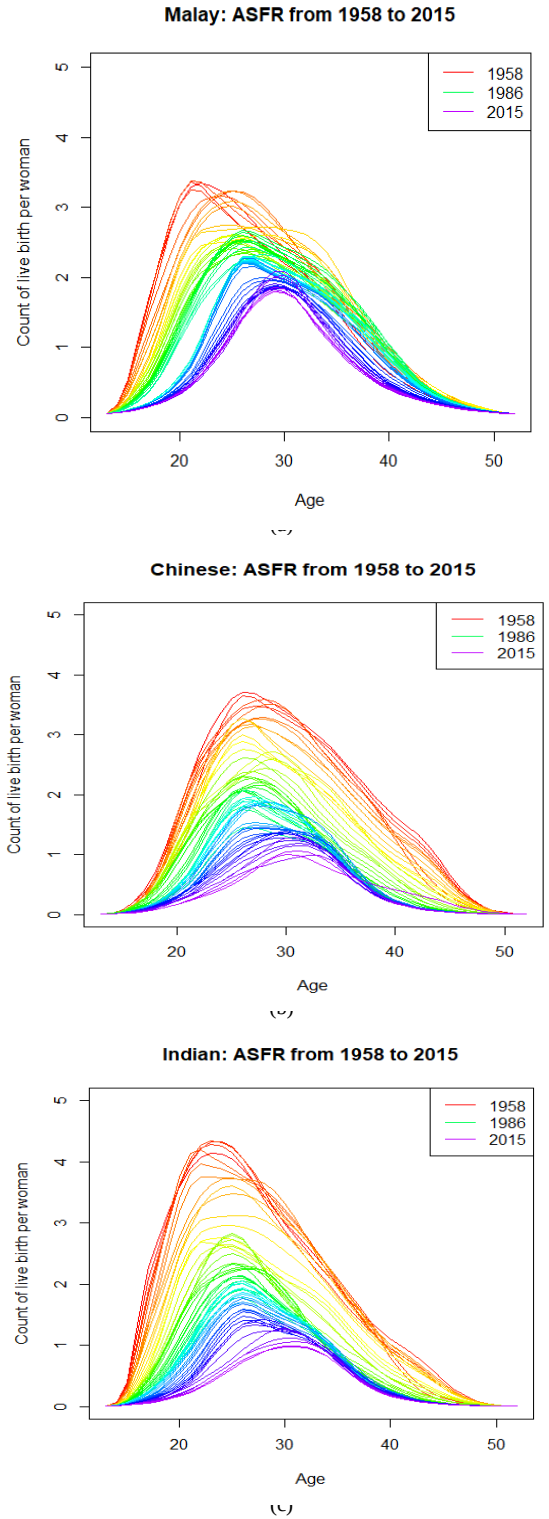


Fig. 2: Rainbow plots of Malaysian age-specific fertility rates (ASFR) for Malay (a), Chinese (b) and Indian (c) from 1958-2015.

Moreover, we examine the Malaysian TFR patterns across ethnicity. Each ethnic group in Malaysia practices their own cultural values and religion belief which lead to diversification of childbearing behaviour. Based on the Fig 3, Indian women recorded the highest TFR with 7.3 number of babies per woman in 1958 followed by the Chinese and Malay with 6.3 and 5.7 babies respectively. After 1958, the TFR rates were decreased continuously over the years. It should be noted that the TFR of the Malay crossed and become higher than the TFR of Chinese and Indian in 1966 and 1970 respectively. These show that the rates of change in fertility were varied between ethnic groups in which the Indian and Chinese fertility rates had decreased at faster rate compared to the Malay.

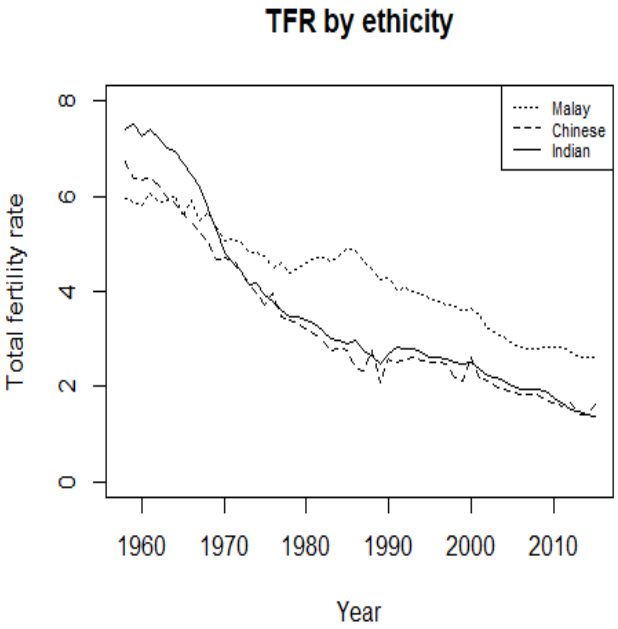
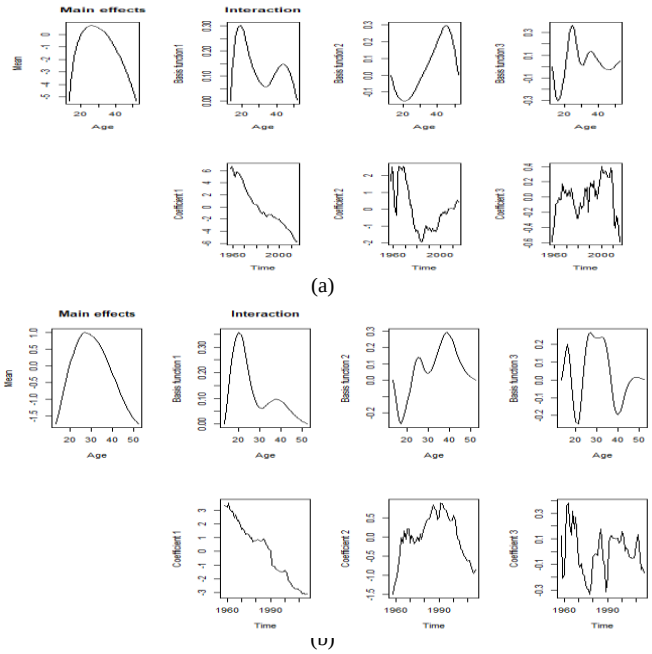


Fig. 3: Total fertility rates (TFRs) of Malay, Chinese and Indian from 1958-2015.

As the Malay fertility declined slower than the two ethnic groups, their TFR remained high and above the replacement ratio of 2.6 by 2015 whereas the TFR of Indian and Chinese fell below the replacement ratio of 1.38 and 1.37 in the same year. According to [21], the TFR below 1.3 is generally described by demographers as the lowest-low fertility. A continuous decline in fertility together with mortality will result in ageing society of the Malaysian population [22].The higher fertility rates among the Malay women may be attributed to several reasons including earlier average age at first marriage, the higher number of women ultimately married and the lower level of birth control practice [1].

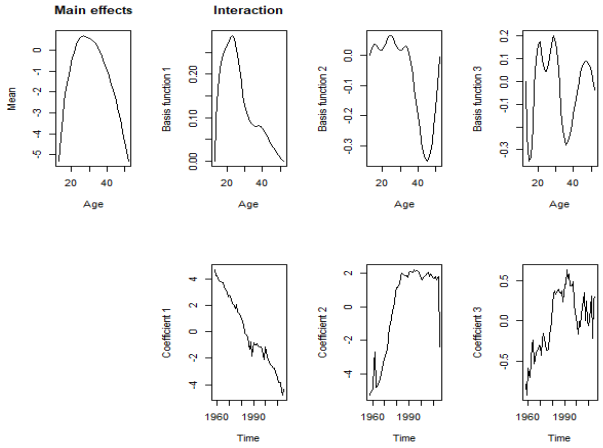
4. Projections of Malaysian Fertility by Age and Ethnicity

The smoothed fertility rates of each ethnic groups were fitted into the functional data model. Using K=3 from the equation (2), the estimated principal component functions and coefficients are obtained and shown in the Fig 4.
From the Figure 4, the coefficients show how the fertility rates change by years whereas the bases describe the associated fertility pattern in different ages. The main effects represent the $\boldsymbol{\mu_i(x)}$ which is the overall bell shape of age-specific fertility rates over years for each sub-population. The fitted models show that the first basis function explains high percentages of the data variation which are 89.9% for Malay, 91.7% for Chinese and 84.4% for Indian. The second and third bases complement the first with additional percentages of variation of 9.2%, 7.7% and 14.9% respectively. Thus, leaving the unexplained variation of only 0.9% for Malay, 0.6% for Chinese and 0.9% for Indian. The percentage of unexplained variation is small enough such that increase in the order number of K may not necessarily improve the accuracy of fertility estimates.



(a)

(b)



(c)

Fig. 4: Estimated principal component functions and coefficients of the functional data model for Malay (a), Chinese (b) and Indian (c)

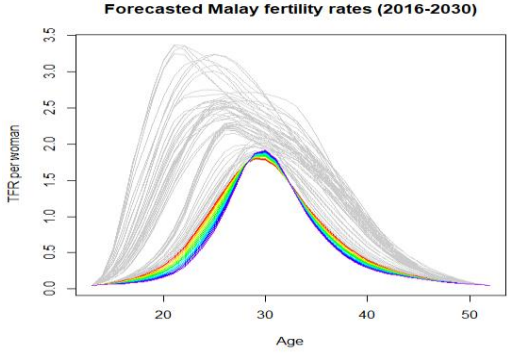
We perform 16-year forecasts of ASFR and TFR for each ethnic group, up to year 2030. The reason why we choose 2030 is because Malaysia will become an ageing nation by that year with 15% of the population represents older persons age 60 years old and above. The Fig 5 demonstrates a continuous decline in fertility from observation years (grey curves) to forecast years (rainbow curves). Clearly, a decline in the fertility rates over the years occurred in all age groups and ethnicity, except for Malay age 28 to 35 years old where the fertility rates are slightly increasing. It should be noted that the ages of the highest births are gradually changed to older age, meaning that the trend of Malaysian women delaying their first marriage, or first birth, will continue to happen in the future. Therefore, it is important for the government to provide adequate reproductive awareness among public.

Next, we calculated the total fertility rates for each ethnic group using the forecasted values of age-specific fertility rates. Refer to the Table 1 for the forecast values of TFR by ethnic groups. Results show that the Malay TFR will remain high and only will reach below replacement ratio by year 2028. The Chinese and Indian TFRs are approximately close to each other and consistently fall below the Malay's fertility, reaching towards a very low record which is below 1.0 TFR by 2027 and 2030 respectively. These results create a sense of urgency in Malaysia where the number of children will not enough to replace even single parent. The aged care provision will be affected in which informal care provided by family members will be limited and no longer appropriate in the future.

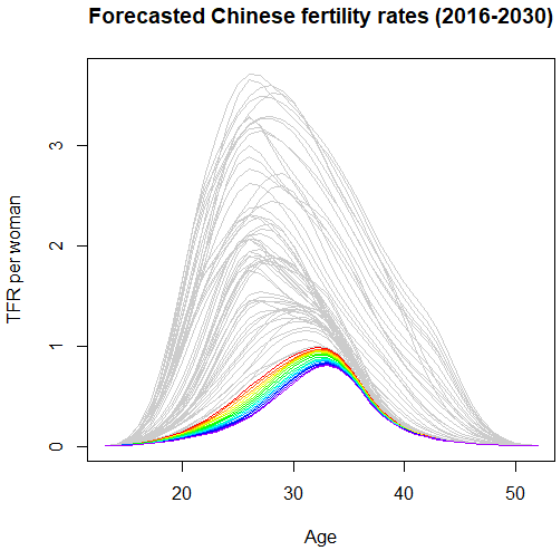
The low birth rate trend is also happening in other countries. For example, in South Korea, the average number of children a woman bears in her lifetime is expected to fall below 1.0 as soon as in year 2018 []. As a result, the South Korea government made efforts to cut medical costs for expecting mother and improve child care services. Low birth rates together with an increase in life expectancy will affect future population structure such that the percentage of older people will keep increasing leading to an aged society.

Table 1: Fifteen-year point forecasts of total fertility rates (TFRs) from 2016 to 2030 by three major ethnic groups in Malaysia

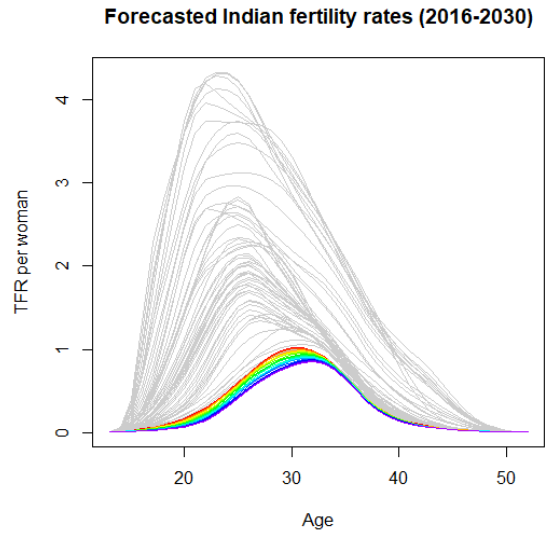
	Forecasted Total Fertility Rates		
Year	Malay	Chinese	Indian
2016	2.48	1.29	1.35
2017	2.44	1.26	1.32
2018	2.40	1.23	1.29
2019	2.36	1.20	1.26
2020	2.31	1.17	1.23
2021	2.27	1.14	1.20
2022	2.22	1.11	1.17
2023	2.18	1.08	1.15
2024	2.13	1.06	1.12
2025	2.09	1.03	1.10
2026	2.04	1.01	1.07
2027	2.00	0.98	1.05
2028	1.96	0.96	1.03
2029	1.92	0.94	1.00
2030	1.88	0.92	0.98



(a)



(b)



(c)

Fig. 5: The observed (grey) and forecasts of age-specific fertility rates (rainbow) from 2016 to 2030 for Malay (a), Chinese (b) and Indian (c).

5. Conclusions

This paper has presented comparative analyses and forecasts of age-specific fertility rates and total fertility rates for different ethnic groups in Malaysia--- Malay, Chinese and Indian. This paper is the first to adopt the functional data model to estimate Malaysian age-specific fertility rates. Using the functional data model, changes in fertility were sufficiently explained not only in terms of ages but also in terms of years. The forecasts of age-specific fertility inform the policy makers that the trends of fertility are generally declining by all women reproductive ages and years in each ethnic group. Women tend to delay in childbearing, by looking at shifts in the age of the highest births towards older age. The fertility forecasts from the functional data method shows the observed decreasing patterns of fertility will continue in the future, provided there is no change in current policy that related to women childbearing. It is an alarming fact to the government and community that the Chinese and Indian total fertility rates will reach towards the lowest low fertility, which is below 1.0 by 2027 and 2030 respectively.

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