MODELING FERTILITY RATE OF INDONESIA IN THE PRESENCE OF INTERFERENCE: THE 2004 TSUNAMI.

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ABSTRACT

A lot of studies have been done on fertility for many years. But, scarce literature is found on modeling of fertility in the presence of interference, yet interference to fertility is a common phenomenon. This study focused on modeling of fertility rate in the presence of interference. We have fitted Probability distributions to interference free data set of Indonesia 2002 and also to the Indonesia 2007 fertility data set which had interference in it, so as to determine the effect of interference on the shape of the fertility data. The parameter of the distributions were estimated and then fitted by maximum likelihood estimation available in the `fitdistr' package, in the R statistical software. The model life table approach was also used to determine the net fertility value F_0 which was modeled from the net reproduction value R_0. A relationship between fertility rate in the presence of interference and population growth was then established. A major finding of this study is that interference free fertility data fit a gamma distribution, data containing interference fit a modified gamma distribution with a mounded but skewed shape. The results also showed that in the presence of interference $F_0 > 2$, hence population increases. Results of this study would help demographers and businessmen to deal with random factors that affect all areas of demography and businesses striving to succeed in today's highly competitive environment. Probability distribution is a scientific tool that would help demographers and business persons to deal with uncertainty and hence make informed decisions. The modeling results would protect demographers from potential time and money loss which might arise due to invalid model selection thereby, helping the Government in planning for social amenities for its citizens.

Key Words: Fertility rate, Interference and Fecundity

Introduction

Interference continues to affect fertility globally. The world war I and II which took place in the years 1914-1918 and 1939-1945 respectively, the 1994 Genocide of Rwanda, the 2002 Gulf war of Iraqi, the 2004 Indian Ocean Tsunami, 2008 Kenya Post election Violence, the Haiti earthquake and the recent 2011 floods in Japan, among others are some of the interferences that leave thousands of people dead and millions displaced in various countries. Considering the Indonesia Demographic and Health survey data, the analysis of the mean number of children born in the years 1997, 2002, 2007 and 2012, (IDHS ,1997),(IDHS,2002), (IDHS,2007),(IDHS ,2014) gave the following figures: 2.995, 2.665, 3.930 and 3.618 respectively. We hypothesize that the Tsunami interference which took place in Indonesia in the year 2004 may have been responsible for the high mean number of children born in the year 2007. The term Interference, in this context interference refers to a situation of large scale strike of unanticipated natural phenomenon such as high magnitude earthquake, major floods, Wars and Genocides, which leave many people dead and thousands displaced. Fertility is believed to be affected if a sudden interference occurs in a population. Following the experience of interference, households may have the incentive to increase the number of children ever born thereby leading to a positive fertility response in excess of replacement effects (Guarcello,2002). Much has been done on modeling of fertility curves by researchers for many years and many mathematical models have been proposed in order to describe the age specific fertility pattern. Many of these models have been shown to provide excellent fits to one-year age-specific fertility distributions of human populations (Hoem, et al ,19812). Palloni and Rafalimanana (Palloni and Rafalimanana, 199) in their study, documented that the strike of an interference ,may change a household's preference for children through a changed perception of community spirit, or the return of the traditional family values, all which encourage replacement effects. Finlay (Finley, 2009) , used cross sectional surveys and compared fertility of residents of areas affected by earthquake, before and after the earthquake. He documented that fertility rose after the disaster. A similar approach of study was also carried out by Hosseini and Abbasi (Hosseini and Abbasi,2013) who investigated the impact of the Bam earthquake in Iran and observed that Iran's fertility had declined in the year 2004 and then rose in 2005-2007 , which was far much later after the Bam earthquake which took place in 2004. Stiegler (Stiegler,2006), studied the impact of Genocide by doing the analysis of the fertility before, during and after the 1994 genocide in Rwanda. She documented a decreasing trend of population and TFR (Total fertility rate) before the Genocide, a sharp rise after the interference and later a rebound afterwards. A study carried out by Jenna, Frankenberg and Duncan in 2015 (Jenna, Elizabeth and Duncan,2015), on the effects of Mortality on Fertility as a result of the Indian Ocean Tsunami, documented a sustained fertility increase at the aggregate level following the Tsunami. It is worth mentioning that although there has been notable contribution in pursuit of research in this line of study, the existing literature on modeling of fertility in the presence of interference is relatively scarce, hence the major motivation for this work. In this paper, we hypothesize that interference may increase fertility rate hence cause a change in the fertility pattern. The R statistical software has been used to model fertility data of Indonesia 2002 and Indonesia 2007 so as to investigate the effect that the 2004 Tsunami interference had on the Indonesia fertility distribution. It is our assumption that interference changes fertility rate hence fertility pattern. We first fit probability distribution to interference free data set of Indonesia 2002 (DHS), then, fit probability distribution to data set of Indonesia 2007 (DHS) that was affected by interference. Modeling of fertility rate in relation to population growth in the presence of interference is then done.

Data and methodology

The following data sets were used in our study:

The Indonesia 1997 Demographic and Health survey data, The Indonesia 2002 Demographic and Health survey data, The Indonesia 2007 Demographic and Health survey data and The Indonesia 2012 Demographic and Health survey data.

Modeling of fertility rate in the presence of interference

This chapter uses life table approach to determine net fertility rate (NFR) and links it to population growth. For comparison purposes, the chapter fits probability distribution to both interference free data and also to the data containing interference. Life table is a simple way of laying out the reproductive and mortality schedule of a population to aid in the measuring of population parameters. The two basic parameters are; age specific survival (mortality) rate and the age specific fertility rate, and from the two parameters, rate of population growth can be determined. A life table is a table of data on survivorship and fecundity of individuals within a population. Our study applies the cohort type of life table whose construction bases on to collection of data on a cohort or group of individuals all born in the same time period. The cohort life tables can then be used to determine the age specific fecundity and mortality rates, survivorship and basic reproduction rates.

The assumptions made in the Modeling

The population is closed (the net migration is Zero).

The population is stationary.

Deaths and births are evenly spread through time

There is stable age distribution - the proportion of individuals in each class is constant through time.

Demography of a population (Variables of a life table)

variable	Definition
x	Life stage or age group
a_x	Total number of individuals observed at each life stage or age group
l_o	The radix of the life table. It is a cohort of some arbitrary number of births on which a life table is based
l_x	Proportion of original number of individuals surviving to the next stage or age group (survivorship)
d_x	Proportion of original number of individuals dyeing during each stage or age group (mortality)
q_x	Mortality rate for each stage or group
m_x	Individual fecundity or mean reproductive output, for each stage or age group
$l_x m_x$	Number of offspring produced per original individual during each stage or group. (product of survival and fecundity)
R_0	Basic reproduction number
S_x	The likelihood of living (surviving) from birth to a given age, $Sx=l_x / l_0$

Relating fertility rate to population growth

Population variables depend on properties of the individuals that compose the population. The two basic parameters of a population are the individuals likelihood of surviving and the individuals likelihood to produce offspring. The parameters both depend on the individual's age.

Basic reproduction number, Also called, Net reproduction rate $R_{o}

In epidemiology, the transmissibility of an infection can be quantified by its basic reproductive number R_0, which is defined as the mean number of secondary infections produced by a single infection into a completely susceptible host population.

For many simple epidemic processes, this parameter determines a threshold:

whenever $R_0 > 1$, typical infective gives rise, on average, to more than one secondary infection, leading to an epidemic.

In contrast, when $R_0 < 1$, infectious individual typically give rise, on average, to less than one secondary infection, and the prevalence of infection cannot increase (Fraser, 2009).

In the demography context, Basic reproduction number may represent the Net reproduction number or Net reproductive rate, R_0 .

Net reproductive rate R_0 is the average number of offspring produced by an individual in its lifetime, taking normal mortality into account.

The word 'an individual' in this context means 'one female' and 'offspring' represent the 'female child'. This is because it is only females who carry the process of reproduction forwards in a population. It was an assumption in this study that only women who were between 15 years old and 49 years old were reproducing.

$l_{x=}$ the proportion of original number of individuals surviving to the next stage or class (survivorship)

By definition,

$m_{x=}$ average number of offspring produced or mean reproductive output, for each stage or age group

then ,

$l_x m_x$= the number of offspring produced per original individual of age group x or (product of survival and fecundity).

And, summing across all ages, this gives the average lifetime reproduction.

Thus,

$$R_o = \sum l_x m_x$$

If, $R_0 < 1$, individuals not fully replacing themselves, hence the population is shrinking

If, $R_0 = 1$, individual exactly replacing themselves, and the population size is stable

If, $R_0 > 1$, individuals more than replacing themselves, and the population is growing

R_0 is also called the replacement rate:

Basic fertility number F_0, (Also called Net fertility rate)

Fecundity Schedule

m_x = half the number of offspring born to parent of age x.

For each offspring produced, male and female parent each credited with 1/2 of an offspring produced. This is because , in sexual organism, each individual must produce two offspring for exact replacement.

In practice, m_x is measured as female offspring per female of age x (m for maternity). This is simply because paternity is usually unknown, so numbers of offspring per male cannot be measured.

It is therefore clear that ,

$$R_0 = \frac{1}{2} F_0$$

If, $R_0 > 1$, implies that $\frac{1}{2} F_0 > 1$

Thus, $F_0 > 2$, implies that population is increasing

If, $R_0 = 1$, implies that $\frac{1}{2} F_0 = 1$

Thus, $F_0 = 2$, implies that population is stable

If, $R_0 < 1$, implies that $\frac{1}{2} F_0 < 1$

Thus, $F_0 < 2$, implies that population is shrinking

It was an assumption in this study that presence of interference increases fertility rate of a population.

Letting ρ be interference presence such that $\rho \geq 1$ and $F_0 > 2$

then,

$\rho F_0 > 2$ and population increases.

Determination of Generation time (T)

Generation time (T) is the time it takes for a new born baby to produce a baby. This time is referred to as the lasting interval of time.

(Regarding calculation of generation time of cohort. It takes the average length of time between the birth of an individual and the birth of one of its own offspring.

Like any average it is the sum of all those lengths of time from all offspring, divided by the total number of offspring.)

Let R_0 be = the average number of offspring born to a female at age x

then,

$R_0 = l_x m_x$

On weighing each offspring by the age of the mother, x, and then summing across all ages ,

we obtain the mother's age when each offspring was born, summed across all offspring born in her life.

On dividing the value with R_0 , we obtain weighted average (Generation time).

$$T = \frac{\sum X l_x m_x}{\sum l_x m_x}$$

$$T = \frac{\sum X l_x m_x}{\frac{1}{2} F_0}$$

The denominator is $\frac{1}{2} F_0$, thus,

In a stable population, $F_0 = 2$, so the denominator has no effect on generation time.

In a growing population $F_0 > 2$and T is decreased, because it takes less time for a cohort to • replace • itself.

In a shrinking population F_0 =<2 and T is increased, because it takes longer for a cohort to • replace • itself.

R_o measures reproduction on the basis of individual lifetimes (offspring produced per individual per lifetime), and most models of population growth measure growth on the basis of births - deaths per unit time, where time does not have to be a generation (often years are the units).

The most common measure of population growth is the intrinsic rate of increase, r.

$$r = \frac{\ln \frac{1}{2} F_0}{T}$$

when:

$F_o = 2$, r = 0, stable population

$F_0 < 2$, $r > 0$, shrinking

$F_0 > 2$, $r > 0$, growing

$r = b - d$ where b = births/unit time and d = deaths/unit time.

So units of r are individuals produced per unit time.

Fitting probability distribution to data

Fitting Distribution is the procedure of selecting a statistical distribution that best fits to a data set generated by some random process. It is the task of finding a mathematical function which represents in a good way a statistical variable. It involves the choosing of a probability distribution modeling the random variable. Statistical data modeling is a field of statistical reasoning that seeks to fit models to data without knowing what the true model is or might be . One therefore needs to learn the model by a process called statistical model identification which requires judgment and expertise and generally needs an iterative process of distribution choice, parameter estimation and quality of fit assessment.

The distribution fitting process was guided by the following steps:

step one : Model /function choice

step two : Estimation of parameters

step three : evaluation of quality of fit

step four : Goodness of fit statistical test

All the above steps were performed using the 'fitdistrplus' package available in the R software.

Results and Discussion

Analysis of the number children ever born in Indonesia in the years 1997,2002,2007 and 2012 using the Indonesia 1997, 2002, 2007 and 2012 DHS (IDHS 1997, IDHS 2002, IDHS 2007, IDHS 2012) (See appendix A.1)

Table 1:Indonesia number of children ever born descriptive statistics for the years 1997,2002, 2007 and 2012.

Year	*Min.*	*!st Qu.*	*Median*	*Mean*	*sd*	*3rd Qu.*	*Max*
1997	*0.000*	*1.000*	*3.000*	*2.995*	*2.211*	*4.000*	*16.000*
2002	*0.000*	*1.000*	*2.000*	*2.665*	*1.896*	*4.000*	*14.000*
2007	*1.000*	*2.000*	*3.000*	*3.930*	*2.232*	*5.000*	*14.000*
2012	*1.000*	*2.000*	*3.000*	*3.618*	*2.079*	*5.000*	*14.000*

It was observed from the table that the average number of children born in the year 1997 was 2.995. This fell to 2.665 in the year 2002, then rose to 3.93 in 2007 (the data 0f 2007 was affected by the 2004 Tsunami interference). The average number of children born later reduced to 3.618, this was after the recovery from the interference.

The Indonesia 2002 fertility data follow a Gamma distribution with the following parameters. (See the R manuscript at the appendix A.2).

Table 2: Parameter estimates for Gamma distribution fitted to Indonesia 2002 fertility data

Distribution	*Parameter*	*Estimate*	*Std error*	*AIC value*
Gamma	*shape*	*2.0218812*	*0.03031398*	*28476.32*
	rate	0.7651225	0.01301053	

The shape parameter is greater than one thus the gamma distribution assumes a mounded but skewed shape. The mean of the distribution is greater than the standard deviation, which is responsible for the shape just mentioned.

The Indonesia 2007 fertility data also follow a Gamma distribution (a modified Gamma distribution) with the following parameters.(See the R manuscript at the appendix A.2).

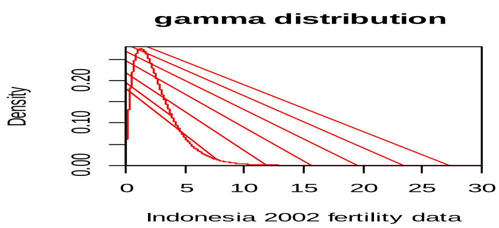
Table 3: parameter estimates for Gamma distribution fitted to Indonesia 2007 fertility data

Distribution	*Parameter*	*Estimate*	*Std error*	*AIC value*
Gamma	*shape*	3.0914084	0.014283617	356450.6
	rate	0.7888381	0.003957272	

The shape parameter is greater than one thus the gamma distribution assumes a mounded but skewed shape. The mean of the distribution is greater than the standard deviation, which is responsible for the shape just mentioned.

Comparison between gamma distributions fitted for Indonesia 2002 data and the Indonesia 2007 data.

The figure below show the summary of the gamma fitted distributions to Indonesia 2002 fertility data and also to Indonesia 2007 fertility data; (See R manuscript in appendix A.3).



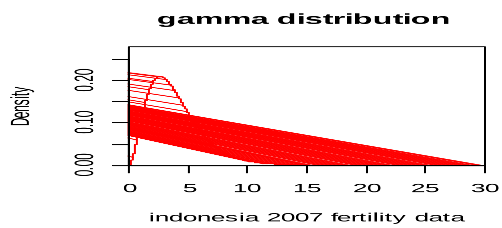


Figure 1: Gamma distribution function fitted to Indonesia 2002 fertility data and also to Indonesia 2007 fertility data.

The summary of the results from table 2 and table 3 were as follows;

Year	*Shape Parameter*	*Rate Parameter*	*AIC value*
2002	*2.021*	*0.765*	*28476.32*
2007	*3.091*	*0.789*	*356450.6*

The shape parameter (α), increased by 52.9 percent in the year 2007 than in the year 2002.

The rate parameter ($\frac{1}{\beta}$), increased by 3.1 percent in the year 2007 than in the year 2002.

The scale parameter (β), decreased by 3.1 percent in the year 2007 than in the year 2002.

Increase in the alpha parameter lowered the skewness of the distribution.

decrease in the beta parameter stretched the range of the Gamma distribution.

On drawing the two gamma distributions on the same axes, we clearly see the effect of Interference. (See R manuscript in appendix A.3).

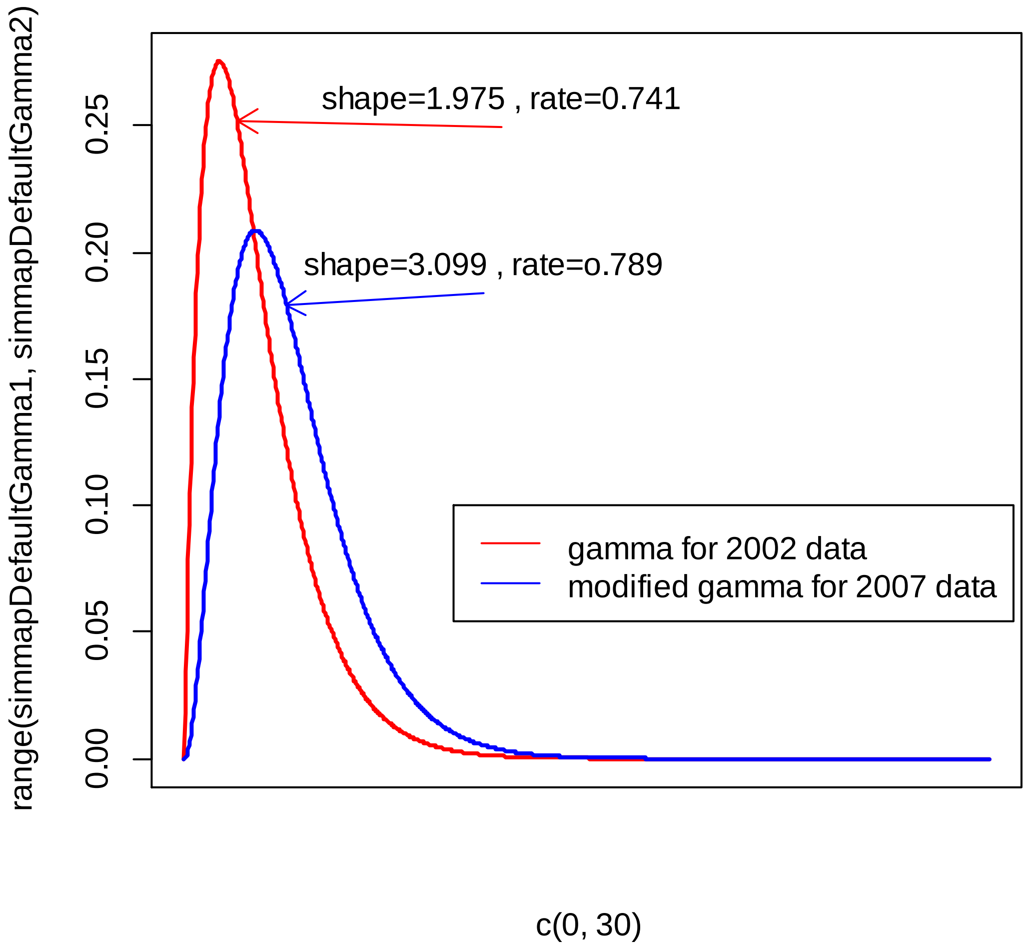


Figure 2: Gamma distribution for 2002 and 2007 fit to Indonesia data drawn on the same scale.

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