Estimate model of total fertility rate based on effectiveness of contraception

G Gunawan*, E Kurniati, I Sukarsih and D Suhaedi

Mathematics Department of Universitas Islam Bandung, Jalan Ranggamalela No. 1, Bandung 40154, Indonesia

*ggani9905@gmail.com

Abstract. In this paper we will show an indirect way of calculating fertility. Where this can determine the prevalent birth rate as an indicator of successful control of population through family planning program (KB). So The results of the research show that the higher the effectiveness of the use of contraceptives, the higher the number of preventable births resulting in the least possible birth rate, and this calculation can be determined total fertility rate based on the effectiveness of the use of contraceptives.

1. Introduction
One of the factors affecting population growth is the rate of birth or fertility in addition to mortality and migration factors. Fertility factors are generally positively correlated with population growth rates. Therefore, the control of population-related fertility factor can be done through family planning program (KB). In general, within a certain period of time the fertility rate of an area tends to be fluktuatif. This suggests that many factors affect birth control or fertility control through Family Planning (KB) [1].

In this paper will be shown a way to determine the birth rate in a region indirectly through a mathematical model. Estimated birth rates in this way are relatively simple, and in calculations can be done manually. In general, it can be said that through this model, formulated a mathematical method to be able to show a negative relationship between the achievement of KB participants with Crude Birth Rate (CBR) and Total Fertility Rate (TFR). TFR calculation is always based on the population so it cannot see the effectiveness of the use of contraceptives in controlling the population through the family planning program. Through this calculation will be able to calculate the estimated projected TFR and contraceptive effectiveness, so the calculations obtained for TFR not only based on population but also based on the effectiveness of contraceptive use. In addition, for the purposes of calculation in this paper, the assumption of growth rate of Age Fertile Couples (AFC) which always assumed to be exponential. Whereas according to Azizah [1] growth rate AFC can be logistic [2].

2. Literature study
Demographic estimates consist of measuring the baseline values of demographic parameters such as birth rates and mortality rates in less than perfect data. This basic parameter indicates how a population will evolve over time in terms of both quantity and age structure. Basically fertility estimation can be done using two types of data that is directly related to birth events (direct way, direct method) and indirectly related to birth incident but with certain technique can be converted to the size of fertility [3]. Fertility is an actual reproductive performance of a woman or group of individuals, which is generally
imposed on a woman or a group of women [4]. Meanwhile, according to Lucas [5] fertility is the result of a real reproduction of an or a group of women based on the number of babies born alive. In the demographic sciences there are several measures of fertility, including the Crude Birth Rate (CBR) or the crude birth rate, is a commonly used birth measure. In this case the crude birth rate is the number of births in a given year divided by the number of people in the same mid-year [6]. Mathematically can be formulated by

\[ CBR = \frac{B(t)}{P(t)} \]

Where \( B(t) \) represents the number of live births at time \( t \) and \( P(t) \) represents the number of population at time \( t \).

In this CBR the number of births is not directly related to the female population, but is associated with the total population [7,8]. Another measure of fertility for indirect calculation purposes is the child-woman ratio (Child Woman Ratio, CWR) is a measure of fertility obtained from population census, this CWR is expressed by the ratio of the number of children age \([c, d]\) old to women of reproductive age \([h, k]\) old expressed in the formula

\[ CWR = \frac{P_{[c,d]}}{P_{[h,k]}} \]

This \( P_{[c,d]} \) is the number of population \([c, d]\) old and \( P_{[h,k]} \) is the number of female population of reproductive age \([h, k]\) old.

The next fertility size is the Age Specific Fertility Rate (ASFR) which is a measure of fertility in women of a certain age, and the fact that the number of births over a given period varies according to the mother’s age. Mathematically formulated by

\[ ASFR_x = \frac{B_x(t)}{P_{x,w}^t(t)} \]

in which \( B_x(t) \) the number of live births of women of age \( x \) at time \( t \) and \( P_{x,w}^t \) is the female population of age \( x \) at time \( t \), or may also be written

\[ f_x^t = \frac{B_x(t)}{P_{x,w}^t(t)} \]

With \( f_x^t \) is the fertility rate of women of age \( x \) at time \( t \). The total of the ASFR fertility size can be expressed as the total fertility rate (TFR), ie

\[ TFR = \sum_{x=h}^{k} f_x^t \]

where \( h \) and \( k \) represent the lower and upper limits of the reproductive age of women.

According to Rusli, if the above fertility measures do not distinguish the sex of the baby then the size of the reproduction only concerns the female of baby, this is because it is seen that is directly related to the turn of the generation [4]. In this case known reproduction rate of Gross Reproduction Rate (GRR). This GRR states a gross reproductive rate that does not take into account the element of death. According to Brown it is defined that the gross reproduction rate (GRR) is the average number of female born to a woman during her reproductive years, regardless of the likelihood of the female being born dying before the end of her reproductive period, can be mathematically written [6];

\[ GRR = \sum_{x=h}^{k} f_x^{w,t} \]

Which \( f_x^{w,t} \) is the fertility rate of the female of age \( x \) to the female baby (w) at time \( t \). According to Sorvianti [9], indirect fertility measurement methods that can be used to calculate fertility rates based on the concept of a stable population are the Rele method. This method is used to predict...
GRR. In this method the GRR value is derived from the value of Child Women Ratio (CWR) and life expectancy.

3. Research method
The data required to calculate the GRR in this method is obtained using census data. The concept of fertility size calculation in West Java province is based on the concept of stable population [10,11]. However, from further search results, the calculation of fertility size estimates with this stable population concept is based only on GRR and CWR. In this case the data used to estimate the TFR rate is based solely on gender and age group by taking into account life expectancy at the time. So the projection of TFR numbers is very dependent on the estimation of the data does not pay attention to the effect of contraceptive usage and effectiveness criteria. So the measure of the success of controlling the number of people in a region can only be seen from the average of total birth rate alone.

Furthermore, according to Subrata [12], the size of fertility can be calculated by considering the effect of contraceptive usage and its effectiveness on the achievement of CBR and TFR through a mathematical model. In this case to calculate the CBR, the data used is the percentage of active KB to AFC. Growth of AFC, and the effectiveness of the weighted average contraceptive. In this model, the size of fertility is determined by estimating the effect of contraceptive use by couples of childbearing age on the birth rate. Therefore, in the calculation it is necessary to note the growth of fertile couples in this estimate using periods of time between. The size of the projected fertility in the form of crude birth rate (CBR) based on data percentage of active KB to AFC, the effectiveness of contraception weighted and EFA growth, according to Azizah [1], in this model CBR at time t can be calculated by

\[ CBR_t = CBR_0 - \frac{0.5EX_{(t-1)}}{1 + v} \]  

(1)

With \( X_{(t-1)} \) the percentage of active KB participants on AFC for year \( t-1 \), and \( CBR_0 \) is the previous CB. While contraceptive effectiveness (\( E \)) is multiplication of percentage of active KB participant from each contraceptive device based on its effectiveness criteria with contraceptive effectiveness rate, hereinafter referred to the effectiveness of contraception weighted. Then the calculated number of births and the number of births that can be prevented for a certain period of time in a region based on mathematical equations (1). Where \( v \) is the growth rate of AFC. Unlike the assumption of exponential AFC growth that has been used in the calculation of fertility rates, to calculate AFC growth (\( v \)), in logistical assumptions, the AFC growth rate will be limited. With this assumption, the population with this model will always be limited to a certain value. The logistic model is used because of the fact that the size of the population depends on its density, so the rate of birth and death rate are not constant [2,13]. The logistics growth model is as follows

\[ N(t) = \frac{a/b}{1 + \left( \frac{a}{bN_0 - 1} \right)e^{-at}} \]  

(2)

Where \( a / b \) is the maximum population size, \( N_0 \) is amount of initial year population, and \( N(t) \) is Number of population year \( t \). From equation (2) the rate of growth is as follows

\[ a = -\ln \left( \frac{N_0(N_2-N_1)}{N_2(N_1-N_0)} \right) \]  

(3)

In this case \( a = v \), with \( N_0, N_1, N_2 \) determined from data on the number of AFC for the first three or last three years or may also be determined from the first three years of intermediate time. After obtaining the approximate number of crude births (CBR), it can be calculated total birth rate (TFR) by using equation (4) as follows

\[ TFR_t = 14CBR_t \]  

(4)

According to Subrata [12], the use of contraceptives will greatly affect the birth rate. As a result of the use of family planning, there will be an unlikely birth or a preventable birth being modeled as follows
\[ P_{BR_t} = \frac{CBR_0 - CBR_t}{1000} P_t \]  

(5)

In this case, \( P_{BR_t} \) is the final year prevented birth rate, whereas \( CBR_0 \) is the crude birth rate of the initial year, \( CBR_t \) is the crude birth rate of the final year projection, and \( P_t \) is the year \( t \) resident. Furthermore, preventable birth rates can also be used to calculate birth rates without family planning based on the number of births and population (population) in a region that is

\[ BRWC_t = CBR_t P_t \]  

(6)

Where \( BRWC_t \) is the birth rate without KB years \( t \). Then to know the birth rate that may occur in year \( t \) the following formula is used

\[ BMO_t = BRWC_t - P_{BR_t} \]  

(7)

With \( BMO_t \) is the birth rate that may occur \( t \) year.

4. Results and discussion

Fertility is a natural ability to give offspring of fertile couples (AFC). Couples of childbearing age range between the ages of 15-49 years where the couple (male and female) are mature enough in everything, especially the reproductive organs are functioning well. The data on the number of AFC West Java province period of five years from 2010 to 2015 can be seen in table 1 below.

| Year | Number of AFC |
|------|--------------|
| 2010 | 23,687,205   |
| 2011 | 24,209,863   |
| 2012 | 24,586,863   |
| 2013 | 24,846,042   |
| 2014 | 25,193,861   |
| 2015 | 25,420,808   |

Table 1. AFC of West Java Province [14].

The growth rate of AFC in West Java within five years is logistic [1], due to factors affecting the growth rate that do not continuously increase rapidly. Therefore, by using these assumptions, the growth rate of West Java province based on (4) is 36.39% per year. By knowing the growth rate of AFC, furthermore it can be determined projection of AFC of West Java province for year 2016, that is 25,274,291 people of fertile age couple. In living the family life, AFC is very easy in obtaining offspring, because the situation of both partners is normal. Therefore, AFC needs to make fertility arrangements, pregnancy care and safe delivery. One way that can regulate it is by doing contraception. Contraception is a way or method that aims to prevent conception so as not to happen pregnancy. Various kinds of contraceptives are widely used by the community today are IUD (Intra Uterine Device), Condoms, Injecting FP, birth control pills, Implant, MO (Method of Operation). The types of contraceptives used by infertile couples have an effect on the magnitude of the impact on the birth rate. This is because each type of contraceptive device has the power to protect against the possibility of pregnancy. The level of contraceptive effectiveness is determined based on the level of contraceptive ability of the concerned can protect the possibility of pregnancy based on laboratory tests and the level of discipline of the wearer. Use of contraceptives in the sense of clinical effectiveness, namely the influence of a way of contraception to prevent pregnancy [12,15]. The effectiveness of each contraceptive used is high, medium and low effectiveness, as shown in the following table 2.
Table 2. The effectiveness of each contraception device [16].

|        | High (%) | Medium (%) | Low (%) |
|--------|----------|------------|---------|
| MO     | 100      | 100        | 100     |
| IUD    | 95       | 90         | 85      |
| Implant| 95       | 95         | 85      |
| Pills  | 95       | 87         | 70      |
| Injection | 95   | 87         | 70      |
| Condom | 95       | 85         | 80      |

It can be seen from table 2 that if the use of contraceptives is correct (high), the possibility of preventing pregnancy is very high, if the use of contraception is less appropriate (medium) then the prevention of pregnancy is moderate, and if the use of contraception is not appropriate (low) then the prevention of pregnancy will low. To obtain the contraceptive effectiveness value of contraceptives can be calculated by summing up each percentage of contraceptive use with the percentage of effectiveness of each contraceptive device is as follows:

- **mix High Effectiveness**
  \[ E = (% \text{ MO} \times 1) + (% \text{ IUD} \times 0.95) + (% \text{ Implant} \times 0.95) + (% \text{ Pill} \times 0.95) + (% \text{ injection} \times 0.95) + (% \text{ Condom} \times 0.95) \]

- **mix Effectiveness Medium**
  \[ E = (% \text{ MO} \times 1) + (% \text{ IUD} \times 0.90) + (% \text{ Implants} \times 0.95) + (% \text{ Pills} \times 0.87) + (% \text{ injection} \times 0.87) + (% \text{ Condoms} \times 0.85) \]

- **mix Effectiveness Low**
  \[ E = (% \text{ MO} \times 1) + (% \text{ IUD} \times 0.85) + (% \text{ Implant} \times 0.85) + (% \text{ Pill} \times 0.70) + (% \text{ injection} \times 0.70) + (% \text{ Condom} \times 0.80) \]

The contraceptive effectiveness mix can be used to calculate the crude birth rate (CBR), in which the population growth rate of AFC must be known first. The growth rate of AFC population is the change in the number of AFC population in a particular area each year. Its usefulness is to predict the number of AFC population in a region in the future. In this case the predicted rate of EFA population of West Java province for 2016 based on equation (3) is 36.39% per year.

According to the records, the percentage of total users of contraceptives MO, IUD, implants, pills, injections and condoms in 2010 in West Java province were 1.55%; 5.22%; 1.94%; 16.55%; 37.51%; and 0.1% [14]. Thus the effectiveness mix of high, medium, and low contraceptive use are 0.598; 0.552; and 0.456. From the results it is seen that the higher the effectiveness of the use of contraceptives, the greater the success of family planning programs and the higher the prevention of pregnancy.

Based on the 2010 BPS survey it is known that CBR0 is 17.40 and TFR0 is 2.34 with the ratio of the number of active KB participants to AFC is 0.65. Based on the result of calculation of percentage of effectiveness mix above and by using growth rate of AFC 36.39% per year, hence estimation of crude birth rate (CBR) for year 2016 can be determined based on equation (2). The results obtained that CBR with high, medium, and low contraceptive effectiveness are 17,258; 17,269; and 17,292 people were born. After the results obtained, then can be calculated total birth rate (TFR) by using Soetedjo-Sahala, i.e., \[ \text{TFR} = 14 \times \text{CBR} \] Therefore, the 2016 TFR forecast with high, medium and low contraceptive effectiveness criteria is 2,416; 2,418; and 2,421. This means that women aged 15-49 on AFC have on average children not more than 2 children during their child-bearing years if affected by contraceptive use.

Furthermore, by using equation (3), the projected population of West Java province in 2016 is 46,583,074, the predicted number of preventable numbers in 2016 can be determined according to the following equation.
PBR_t = \frac{CBR_0 - CBR_t}{1000} P_t \quad (8)

with $PBR_t$ is the prevented birth rate year $t$ and $P_t$ is $t$ year population.

Thus, the projected percentage of preventable birth rate according to the criteria of high, medium and low contraceptive effectiveness are 6,603; 6,094; 5,030. Based on the number of births and population in a region, CBR can also be used to calculate birth rates without family planning. If CBR 2016 assumes logistics is 17.228 and the projected population number according to equation (3) is 46,583,074, then birth without family planning in West Java is 8,044,511. Therefore, based on the CBR according to the criteria of high, medium and low contraceptive effectiveness, the projected birth rate that may occur in 2016 is 17,348,225 respectively; 17,435,077; 17,541,513 whereas according to the results of calculations that have been done in reference BPS the results of the CBR averages of projections for 2016 is 18,000,000 [15].

5. Conclusion

Based on the calculation method as described above, the method can be used to determine TFR projections in each region in West Java province based on the effectiveness of contraceptive use in 2016. Even from the calculation using the method can be calculated the estimated number of birth rates is prevented for each region in the province of West Java, which indicates the success of family planning programs for each of these areas. From the calculation results show that the higher the effectiveness of the use of contraceptives, the higher the number of preventable births resulting in the least possible birth rate.

Acknowledgment

This article was written with the support of Directorate General of Higher Education budget year 2018 through Institute for Research and Community Service of Islamic Bandung University.

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