A Simulation Approach for Human Fertility Measurement

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Abstract

Fertility, in any society, is affected with demographic, economic, social and health characteristics of this society. Simulation of human fertility represents a promising way to improve the understanding of fertility measurements. Measuring human fertility is a complex task so the simulation is used to handle this problem. The main objective of this paper is to provide decision support tools for measuring, prediction and validation of fertility rate. A model that include all variables affecting the fertility rate is built and the simulation approach is used depend on the historical data for fertility in Egypt. The result concluded that the simulation is a powerful approach to measure and forecast the fertility because it takes into account all the variables that affect the fertility.

Key Words: Fertility, Simulation, Measurement, Prediction, Regression, Human development.

1. Introduction

Fertility, in any society, is affected with demographic, economic, social and health characteristics of this society. A large number of researchers attempted to identify the relationship between fertility and these characteristics and also the strength effect of each other. So, the focus was on the characteristics that related to women in particular and the family in general. The demographic characteristics of women are the age of first marriage and use of family planning methods; the social factors include the educational level of wife while economic factors are women's work outside the home and the level of family income. Furthermore, the health status illustrates the availability of health services at the family level.

Multiple surveys and studies indicate that there are differences between fertility in different geographic regions (Health Demographic Survey of Egypt, 2000). Hence, an important question arises about what are the factors that make fertility in a given area are higher than in other regions. So, it is attempted to identify the demographic, economic, social, health variables which is representing a group of characteristics that are exposed populations such as employment, standard of living, education, health standards and other. All or some of these variables affect one way or another on fertility in the community.

In this research, a model that include all the variables affecting the fertility rate is built and the simulation approach is used to simulate the study problem to determine the most effective factors that affect the fertility and to forecast the fertility rate in the future. The paper is organized as follows. Section 2 is assigned to the study problem and the literature review while the methodology used is presented in section 3. The implementation and the validation are discussed in section 4. Finally, conclusions and points for further research are drawn.

2. The Study Problem and the Literature Review

Egypt classified from countries with medium human development and ranks (113) from (177) country in the world in terms of the level of human development (Human Development Report, 2011). And facing challenges in many aspects of development.

High population growth is one of the most important challenges facing development efforts to improve the standard of living and quality of life of the population. There is no doubt that high fertility rates have to do a set of demographic, economic, social and health variables. This study detect and investigate the relationship between demographic, economic, social and health variables that affect the population and fertility behavior in Egypt which expressed as the total fertility rate that refers to the number of children supposed to be born to each woman if destined to live until the end of the fertility age.

2.1. Aim of the study

To provide decision support tools for prediction and validation of fertility rate using simulation approach.

2.2. Literature Review

This problem is studied all over the world and in this section, we review some important papers. Bongaarts (1978) studied A frame work for analyzing the proximate determinants of fertility indicated that the intermediate variables that have a direct impact on fertility is represented in marriage and breastfeeding, the use of family planning and abortion. Khan (1997) studied multiple modeling approaches to the determinants of urban and rural fertility in Bangladesh showed that among the social and cultural factors, the age of marriage for women is one of the most important variables which have a direct adverse correlation with fertility. Neupert (1992) studied the demographic trends in Mongolia; found the affecting factors on reducing fertility in Mongolia are the high rate of literacy, lower infant mortality, urbanization, industrialization and women's participation in economic activity. In a study of the determinants of fertility in Abu Dhabi by Al Jabri (2002) found that, the demographic, economic and social variables interpret 61% of the changes in fertility in Abu Dhabi and only three variables (woman's age, age of marriage first for women and educational level of women) from these variables have a significant correlation with fertility, where the variables age of first marriage and the educational level of women have shown inverse correlation with fertility while a woman's age showed a positive correlation, i.e., the greater the woman's age the greater the desire to have children and higher fertility.

Al-Miqdad (2007) studied demographic growth and its impact on the population in Oman, pointed out that the high birth rate in Oman is due to demographic factors represent in high proportion of young people and then the high fertility rate. In addition, the low participation of women outside the home and the high illiteracy rate, as there are social factors because the rural community encourages greater proportion of reproduction. Al-Ghamdi (1996) studied women's work and its impact on some of its family functions in Saudi Arabia, revealed a tendency of employed women in the study population to having a small number of children In order to give them more care under distribute of their efforts between multiple responsibilities towards work, home and children. He emphasized that the introduction of the idea of family planning and the demand for family planning methods are the most important implications of women going out to work. Bin Azzun and Al-Saqqaf (2006) studied social and cultural determinants of early marriage in Yemen by using logistic regression analysis method, pointed that women's education variable is important in delaying the occurrence of early childbearing. This means that educated women do not think much about early marriage and thus delayed the marriage and to have fewer children compared with illiteracy women or the woman with little education. Shteiwi (2006) studied the determinants of fertility in Tunisia, pointed that the illiterate women and women with primary education have an average 1.22, 1.14 additional children Compared with women with secondary or higher education. Furthermore, the more educated women, the lower fertility.

Al-shayab and Ababneh (2001) studied family planning programs and theirs affecting factors in the governorate of Irbid, Jordan by using a sample of married women. They showed that there is an inverse relationship between the level of education (for the wife and husband) and the number of unwanted children. They found that the higher the educational level of the husband and wife, the fewer unwanted children, as well as increasing knowledge about family planning which makes the decision to have children standing on the base of a scientific background. Schoemaker (2005) showed in his study that there are fundamental differences in the use of modern family planning among poor women and richer women in Indonesia. This mean that Poor women have a tendency to large families and less widely used family planning methods compared to richer women with high economic and social level. Al-Zoubi (2006) studied the population, development, reproductive health and its relationship to the living conditions in Yemen by using Yemeni Family Health Survey data of 2003.

He pointed that the enrollments of women education have a strong impact on the use of family planning methods, as one of the moderate indicators that affecting fertility. While the spread of education in general among family members, would have no impact. Therefore the impact of education is personal and not for the general. Makhlouf (2006) pointed in his study on the demographic situation in Egypt, that the decline in the total fertility rate in Egypt from 5.3 children in 1980 to 3.5 children in 2000 and then to 3.1 in 2005 due largely to the intense efforts that have been made in the areas of education, as well as efforts in the field of family planning, where the proportion of married women of childbearing age who use family planning methods from 24.2% in 1980 to 56.1% in 2000 and then to 59.2% in 2005. Hassan (2006) studied differences factors of fertility between Arab countries by using multiple regression method, showed that the income variable does not directly affect in reducing fertility, but through a strong positive relationship with education, health and urbanization.

Al-Saqqaf (2007) studied fertility and its relationship with some demographic, economic and social variables in Yemen based on Yemeni Family Health survey data for 2003 by using the method of multiple regression analysis, indicated that the age variables at first marriage for women, the urban population, households with electricity, households with access to piped water, literate females and females enrolled in primary and secondary education Construed together 90% of the change in fertility, among these variables. He found that age at first marriage for females, female enrollment in primary and secondary education and households with electricity are the most important variables that have a statistically significant correlation with fertility in Yemen. In the study of (Khater and Mustafa, 2007) of factors affecting fertility levels and trends in Egypt depending on the Egyptian Health Demographic Survey data for 2000 using factor analysis, the results indicated that the demographic factors are the most affecting factors in fertility followed by the economic factor and finally the social factor. Also, when studying the variations of the effect of the above factors on fertility by using pathway analysis model, showed that the demographic factor is most affecting factor followed by a health factor then the social factor and finally the economic factor. The age effect on fertility is certainly clinically relevant.

To evaluate and quantify the exclusive effects of women and men's ages on fecundity, Hassan and Killick (2003) found an evidence for and quantification of the decline in men's fertility with increasing age. Kidd et al. (2001) claimed that there has been no comprehensive review of the effects of male aging on semen quality and fertility in humans. They have conducted a review of the scientific literature of the past 20 years to evaluate the weight of the evidence for reproductive aging among men.

3. The Methodology

Simulation optimization has gained wide acceptance among researchers and many approaches have been developed. Simulation modeling has the capability of representing complex real world systems and the constraints in detail. Huseby et al. (2013) presented a simulation approach for establishing environmental contour lines for use in structural analysis of marine structures. Villada and Olaya (2013) used simulation approach to evaluate alternative policies for increasing the security of natural gas supply in Colombia. Korytkowski et al. (2013) developed evolutionary simulation-based heuristics to construct near-optimal solutions for dispatching rule allocation. The following figure 1 shows the simulation steps from Law and Kelton (2000).

Step 1 problem formulation is setting the objectives of the study and the specific issues to be considered. Resources available for such a study should also be considered, and expands on the importance of clarifying the issues to be considered; these include hardware design issues and operational issues. In addition, measures of performance have to be defined before starting the study. The second step in Fig. 1 is data collection. Data is collected if it exists based on the objectives of the study with the importance of data collection and stress the validation of such data which is step 3. After data is validated then step 4 is constructing a computer model, which is based on the conceptual model. After that a pilot run is done in step 5 the conceptual model is translated into a computerized model before starting step 6 and is conducts the verification and the validation steps. It must be noted that most agree on the fact that the validation and verification process should be throughout the study. Steps 7 through 10 are design of experiments for defining the different alternatives for experimentation, production runs for providing performance data on systems designs of interest, output analysis which consists of statistical techniques for analyzing output from production runs, and implementation of models findings. We apply the simulation steps for our study in the following section.

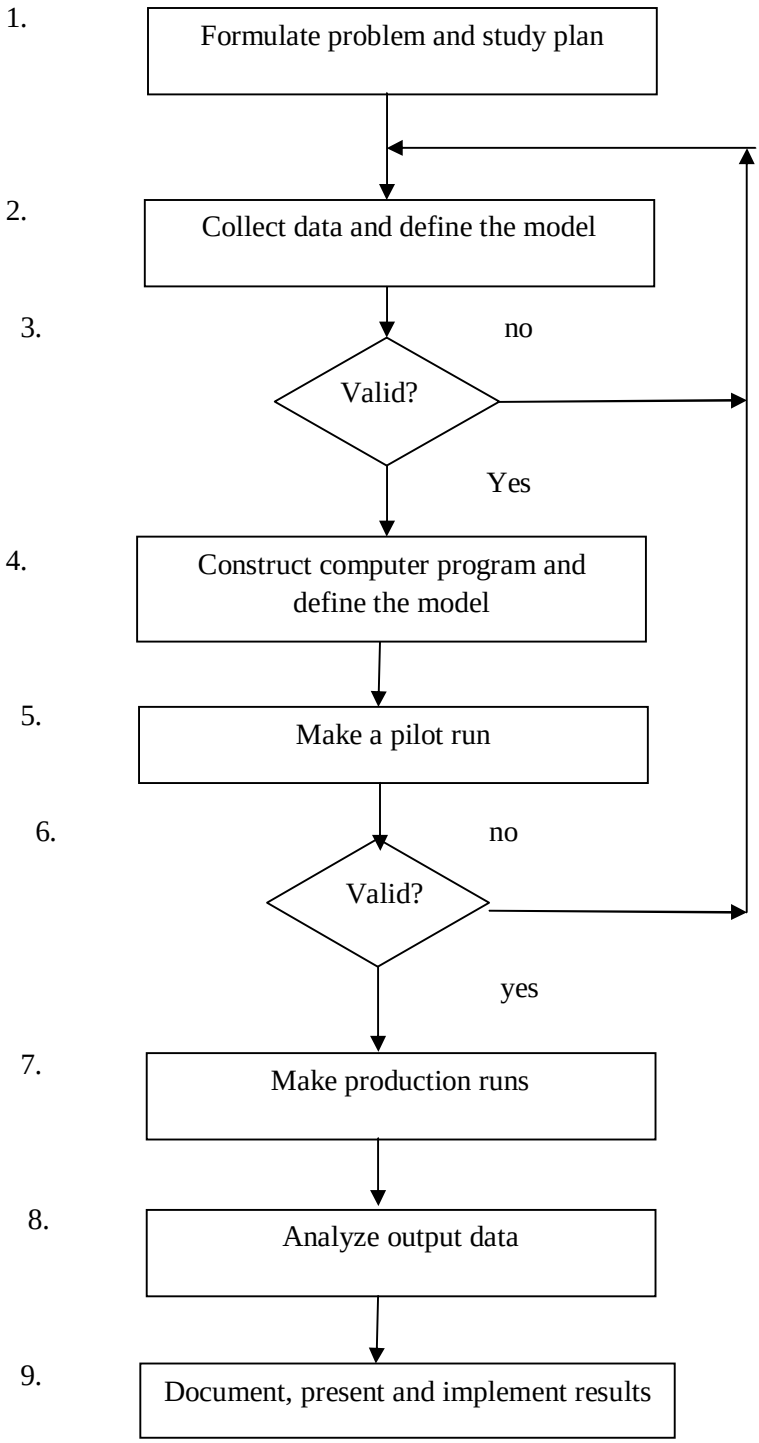

Figure 1: Simulation Steps

4. The Implementation and Validation

The ARENA simulation package from Rockwell Automation was used for modeling the fertility measurement. First, data is collected from the official sources, and Arena software is used to analyze the variables to determine their distributions. Determining variables distributions help in estimating the fertility rate more accurate. After that, the model is built and run for 5000 run to simulate the problem to know the most important affecting factors and to predict the fertility ratio for the coming years.

Data Sources

The study depended on a number of important sources as the Egyptian Human Development Reports during the period (1994-2010), issued by the Egyptian National Planning Institute to obtain the following variables data: (Total fertility rate - the average age at first marriage - households with electricity - households with access to piped water - households with access to sanitation - GDP per capita - woman in the labor force - females employees in government and the public sector – Growth enrollment ratio basic education – females (15+) with secondary education or higher - Doctors per 10000 people - nurses per 10000 people - female unemployment rate – Contraceptive prevalence rate - urban population (%) of total - Total beds per 10000 people - health units per 100000 population). Table 1 shows the variables with their minimum, average and maximum.

Table 1: The variables description

Symbol	Variable Name	Min.	Average	Max.
y	Total fertility rate	3	3.49	4.1
X1	Average age at first marriage	20.4	23.09667	26.1
X2	Households with electricity	87	96.83667	99.6
X3	Households with access to piped water	79.9	90.81667	98.6
X4	Households with access to sanitation	50.5	80.92333	94.7
X5	GDP per capita (L.E)	2085	5484.38	10246.1
X6	Woman in labor force	10.9	21.40167	24.3
X7	Female Employees in Government, public sector & public enterprise	7.1	34.26333	49
X8	Gross Enrollment ratio Basic education	81.9	90.22333	98.5
X9	Females (15+) with secondary education or higher	9.8	20.87	33.6
X10	Doctors Per 10000 People	6	7.136667	8.9
X11	Nurses per 10000 people	8.6	12.44667	14.7
X12	Female Unemployment rate	18.6	22.2	25.08
X13	Contraceptive prevalence rate	37.8	54.97667	60.3
X14	Urban population (%) of total	42.5	43.06667	44
X15	Total Beds per 10000 people	18.2	20.61	21.7
X16	Health units per 100000 Population	2.4	3.783333	5.9

When we tried to use regression analysis to forecast the fertility rate, the regression model took into account only nine variables (x4, x5, x6, x7, x10, x12, x14, x15 and x16) and excluded seven variables (x1, x2, x3, x8, x9, x11 and x13). These seven variables are important variables and represent 44% from the variables so the regression model cannot be used to estimate the fertility rate. So we use simulation approach to simulate the fertility rates and all the variables affect that rate. Table 2 shows the variables distributions generated from the historical data and using Arena Input Analyzer.

We used the expressions in table 2 to simulate the problem and to forecast the fertility rate and to know which factors have the strong effect on the fertility. The simulation was run for 5000 runs. Table 3 shows the minimum, maximum and the average for each variable after the simulation. Figure 1 compares the minimum, average and maximum values before and after simulation.

Table 2: Variables Distributions

variable	Expression	square error
y	TRIA(3, 3.6, 4.21)	0.125
x1	20 + 6.67 * BETA(1.21, 1.4)	0.016
x2	87 + 13 * BETA(1.2, 0.387)	0.053
x3	79 + 20 * BETA(1.38, 0.977)	0.011
x4	50 + 45 * BETA(0.688, 0.372)	0.034
x5	NORM(5.48e+003, 2.03e+003)	0.049
x6	10 + 15 * BETA(1.49, 0.47)	0.01
x7	TRIA(7, 46.8, 49)	0.001
x8	NORM(90.2, 3.53)	0.068
x9	TRIA(9, 21.5, 34)	0.132
x10	6 + WEIB(1.17, 1.1)	0.024
X11	8 + 7 * BETA(0.934, 0.536)	0.003
X12	18 + 7.73 * BETA(1.09, 0.92)	0.001
X13	37 + 24 * BETA(1.47, 0.612)	0.026
X14	42.4 + 1.65 * BETA(0.457, 0.596)	0.015
X15	18 + 4 * BETA(1.92, 1.12)	0.034
X16	2.04 + WEIB(1.97, 1.83)	0.019

Table 3: The min, average and Max. after simulation

Variables	Min	Average	Max
Y	3.01075	3.598981	4.20374
X1	20.4029	23.06322	26.0906
X2	87.0096	96.49679	99.6
X3	79.9117	90.75437	98.6
X4	50.5016	79.10582	94.7
X5	0	5465.05	14520
X6	10.913	21.15269	24.3
X7	7.40207	34.41228	48.8591
X8	78.1186	90.19977	103.717
X9	10.1071	21.63208	33.4957
X10	7.14003	8.262047	16.3017
X11	8.60081	12.48411	14.7
X12	18.6048	22.13341	25.0999
X13	37.9129	53.78414	60.3
X14	42.5	43.15935	44
X15	18.2618	20.38556	21.6997
X16	3.7872	5.520389	10.7068

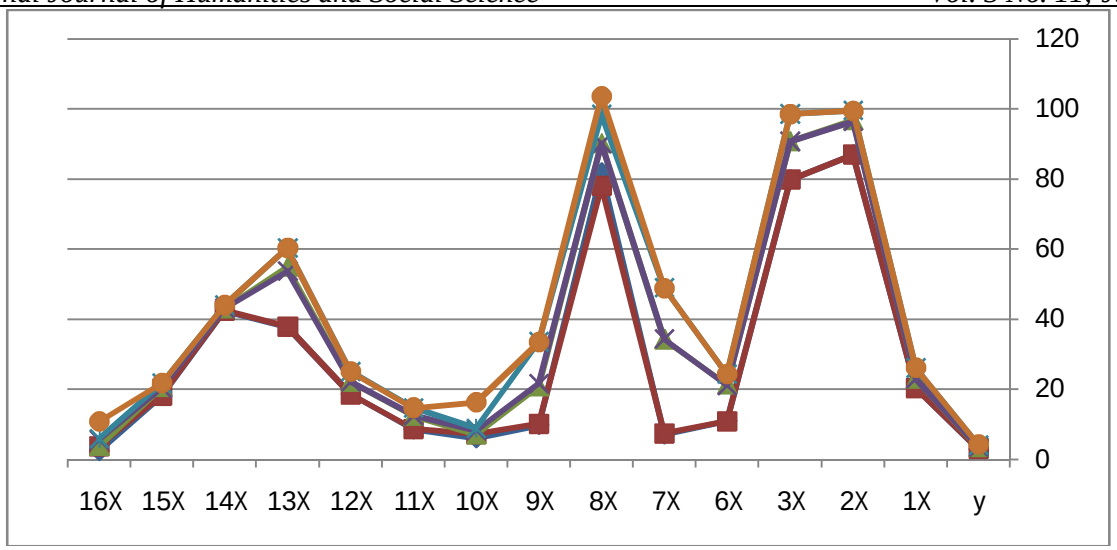

Figure 2: The minimum, average and maximum values before and after simulation (note: we excluded x4 and x5 from the graph because they have big numbers).

From figure 2 we find that the results of simulation are near to the real data. The simulation approach helps us to build a regression model that includes all the input variables as shown in table 4.

Table 4: Variables coefficients in the regression model

(Constant)	3.570084954
X1	-0.002328757
X2	-0.000268617
X3	0.000154875
X4	0.000362184
X5	-0.00000080
X6	0.00003175
X7	-0.000419843
X8	0.000643648
X9	-0.000150636
X10	-0.000726447
X11	-0.001604317
X12	-0.000201314
X13	0.001106262
X14	-0.001051866
X15	0.002006812
X16	0.00084163

From the simulation run, we found that the most effective factors for human fertility are x13, x4, x8, x15, x3, x16 and x6. From this model we can forecast the fertility ratio for the coming years

Conclusion

We developed a simulation approach for measuring fertility. From this research, we can conclude some important points that the fertility measurement is very difficult because there are many factors affect the fertility rate. Also, simulation is a powerful approach to measure and forecast the fertility because it takes into account all the variables that affect the fertility while using regression analysis exclude about %44 from the variables. This problem is still in need to further research. Other factors should be considered, when measuring the fertility, such as the place that the family live in, the food the family have and the religion issues. Also, the fuzzy approach can be used to measure the fertility because some variables are ambiguous and can't be represented as a specific number.

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