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A STOCHASTIC MODEL OF HUMAN FERTILITY IN BANGLADESH

by

S.M. SHAFIQUL ISLAM

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled A STOCHASTIC MODEL OF HUMAN FERTILITY IN BANGLADESH submitted by S.M. SHAFIQUL ISLAM in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in DEMOGRAPHY.

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TO MY PARENTS

ABSTRACT

A stochastic model of human fertility has been developed in this thesis under certain assumptions regarding socio-biological factors which influence human reproduction. The model is applied to study fertility patterns and differentials for two first marriage cohorts (first married during 1965-69 and 1970-74) of fecund Bangladeshi women in terms of time spent in nonpregnant state before a direct transition to pregnant state, conception and live birth intervals, and annual probability of the occurrence of a live birth.

A woman belonging to the 1965-69 cohort is found to remain in nonpregnant state for 6.7 months, on average, before a direct transition to pregnant state while the corresponding average time spent by a woman in the 1970-74 cohort is 7.2 months. Mean conception intervals are estimated at 32.0 and 32.7 months for women in the 1965-69 and 1970-74 first marriage cohorts respectively. While the estimate of mean live birth interval is found to be 33.6 months for women in the 1965-69 cohort, the corresponding estimate for those in the 1970-74 cohort is found to be 36.0 months. One of the plausible reasons for this apparent small difference between the estimates of mean conception and mean live birth intervals, particularly for women in the 1965-69 cohort may be under-reporting of conceptions terminating in non-live births. The estimates of average time spent in

nonpregnant state before a direct transition to pregnant state, mean conception and mean live birth intervals for women in both the cohorts are found to be higher among urban than rural women, among women with at least some schooling than those with no schooling, and among Muslims than non-Muslims.

Annual fertility rates per woman are estimated at 0.375 and 0.334 for the 1965-69 and 1970-74 first marriage cohorts respectively. As documented in most of the studies on fertility differentials, the model estimates of fertility for both the cohorts have exhibited negative relationships with urbanization and education, and fertility for non-Muslims is found to be lower than that for Muslims.

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It is with much pleasure, I wish to express my profound indebtness to my supervisor, Dr. P. Krishnan for his invaluable advice, guidance and encouragement without which this research would not have been possible. Dr. Krishnan has stimulated my interests in the application of mathematics and statistics in sociology, and contributed substantially to formulating the initial direction of this research. I am particularly grateful to Professor Krishnan for his permission to use the computer tape of the Bangladesh Fertility Survey, 1975-76 from the WFS Comparative Studies Project funded by the University of Alberta.

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Finally, my wife, Shakila and our children, Shami and Samina merit special recognition for bearing with my inconsiderateness during the period of this research endeavour.

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1.1 Background and Objectives

Concern about the rapid population growth in most of the developing countries has led population scientists to formulate stochastic models as a tool in understanding the dynamics of population change and in explaining the components of such change. According to Mode (1975: 247), "....stochastic models provide not only a means for a more realistic description of the variation in the biological and social phenomena underlying population growth, but also a natural milieu for drawing statistical inferences from data, a subject that is inextricably intertwined with notions of probability". In the past few decades, there has been considerable interest among many mathematical demographers in the development and construction of probability models in fertility with a view to study the reproductive pattern, particularly the pattern of occurrence of live births to women as they progress through their reproductive span. Significant contributions toward the formulation of probability models for the study of human fertility have been made, among others,. by Henry (1953, 1957, 1961), Dandekar (1955), Brass (1958), Potter (1960, 1961), Singh (1963, 1964a, 1964b), Sheps and Perrin (1963, 1966), Perrin and Sheps (1964), Sheps (1964, 1967), Sheps et al. (1969), Chiang (1971), Krishnan (1971), Mode (1972, 1975), Sheps and

(1974, 1975).

A developing country like Bangladesh lacks suitable data covering all aspects of fertility on a national level. But if, for instance, data on the distribution of women according to the number of live births are available through census or national sample surveys, it is possible, by fitting a suitable stochastic model to these data, to approximate the distribution of time intervals between successive births, and the distribution of live births per woman in a specified period of years for a given cohort of women. In addition, stochastic models of fertility may contribute to investigating the effectiveness of various contraceptive methods and their effects on birth rate (see, for example, Tietze, 1959; Sheps and Perrin, 1963; Sheps, 1966, 1967; and Singh et al. 1974). Such models may also be applied as an aid both in the formulation of national population policy and in the evaluation of family planning programs launched in many developing countries, including Bangladesh, aimed at reducing birth rates.

The purpose of this thesis is to develop a stochastic model to study the fertility patterns of various marriage cohorts of women and to investigate differential fertility behaviour by rural-urban, educational, and religious backgrounds of Bangladeshi women. Attempts will also be made to derive policy implications for fertility regulation in the context of Bangladesh.

1.2 The Study Area and the People

Bangladesh lies approximately between 20°30' and 26°45' north latitudes and 88°00' and 92°56' east longitudes. Except for a short border with Burma in the southeast, the country is bounded by a long ~~land~~-border with India on the west, north and east and by the Bay of Bengal on the south. The low-lying riverine country has a total area of 55,598 square miles including river surface. More than 85 per cent of the total land is flat alluvial plain transversed by three major rivers, the Ganges-Padma, the Brahmaputra-Jamuna and the Megna, and their innumerable tributaries. Bangladesh has a humid sub-tropical climate with three seasons: a hot summer with high humidity from March to June, a moderate hot and humid monsoon from June to early October, and a cool dry winter from mid October to early March. Average annual temperatures vary between 57°F and 80°F. January is the coolest month while the hottest months are April and May. Mean annual rainfall varies from 50 inches in the west to 100 inches or more elsewhere. The heavy rainfall spreads over the whole monsoon season and causes frequent floods. Tropical cyclones often accompanied by tidal bores from the Bay of Bengal and floods have, on many occasions, brought about havoc in the country resulting in considerable loss of human lives and properties (Nyrop et al., 1975; Bangladesh, 1978).

The area now encompassed by Bangladesh has been known by a number of names. Before August 14, 1947, it was known as East Bengal, a part of the British Indian state of Bengal. Between 1947 and 1971, it was the eastern province of Pakistan called East Pakistan. During the 24 years of union, the two wings of Pakistan (east and west) separated by 1500 miles of foreign territory had an uneasy partnership with occasional regional, economic, political, cultural conflicts (Curlin et al., 1976). A political debacle escalated into a civil war in March 1971 which culminated in an all-out war of liberation against West Pakistan. After a tremendous sacrifice of life and property, Bangladesh emerged as a sovereign and independent nation on December 16, 1971.

Bangladesh is the eighth most populous country in the world. According to the 1981 census, its population was 89.9 million. Density of population is one of highest in world with an average of 1,617 persons per square mile. With an estimated growth rate of 2.32 per cent per annum, its population may double in about 30 years. The population was fairly stable at about 17 million during the eighteenth century (Mosley and Hossain, 1973). Since then it began to grow slowly reaching 29 million in 1901 and approximately 55 million in in 1961. The rate of growth has increased considerably since the decade of sixties (Bangladesh Bureau of Statistics, 1984). The population of Bangladesh is characterized by a youthful age structure with 46.4 per cent below age 15, and only 3.8 per cent aged 65 and over (Bangladesh Bureau of Statistics, 1984).

Bangladesh is predominantly a rural country with about 85 per cent of the population living in rural areas (Bangladesh Bureau of Statistics, 1984). With the exception of some tribal population in the hilly regions, the population is ethnically homogeneous. The major religious community in the country is formed by the Muslims. About 87 per cent of the population are Muslims who have largely contributed to the overall growth of the population. Among other religious communities, Hindus comprise about 12 per cent and Christians and Buddists constitute only about 1 per cent of the total population (Bangladesh Bureau of Statistics, 1984).

Marriage patterns in Bangladesh are characterized by near universality and early age at marriage for women. According to the 1981 census, only 1.2 per cent of males and 0.3 per cent of females aged 45-49 reported to have never married. Singulate mean age at marriage based on the 1981 census data were estimated at 16.8 years for females and 23.9 years for males. The value of the singulate mean age at marriage has increased by about 1.5 years for males and 2.4 years for females since 1951 (Bangladesh Bureau of Statistics, 1984). The practice of near universality of marriage and low age at marriage are associated with the prevailing socio-religious customs in Bangladesh (Duza and

Baldwin, 1977; Chaudhury, 1984).

The literacy rate in Bangladesh is very low. It is lower among females than males. Only 25.8 per cent of males and 13.2 per cent of females were able to read and write in any language according to the 1981 census. Slightly less than one-fourth of the population aged 5 years and over were literate. The rural-urban and religious differentials in literacy rate are substantial. Among urban population the literacy rate for both sexes was 34.8 as against 17.0 for their rural counterparts while the literacy rate among Muslims was 18.8 as against 26.3 for Hindus (Bangladesh Bureau of Statistics, 1984).

The economy of Bangladesh is chiefly dominated by agriculture which contributes about two-thirds of the gross national product (Chen and Chaudhury, 1975). Agricultural land in Bangladesh has been fertile and about 80 per cent of the total cultivable land provides for food production. Despite the predominance of agriculture, food supply has been inadequate for the needs of the population even in the periods of good harvest (Rosenberg, 1973). According to Khan (1972 : 25-27) "... nearly half the population are on a starvation diet, nearly 90 per cent have some kind of deficiency in food, and that a vast majority are ill-clad and nearly shelterless". Further, the agricultural production deteriorated in recent years due to cyclone, war and monsoon floods resulting in a decline in the per capita availability of food for consumption (Chen and Chaudhury, 1975). By 1975, the population was economically worse off than it had been before independence. "Average per capita income was the equivalent of US$70 a year; the poor majority of the population had substantially less on which to live" (Nyrop et al., 1975 : 209). Per capita GNP in Bangladesh during 1983 was equivalent to US$ 180 which is one of the lowest in the world (Population Reference Bureau, 1985).

Crude activity rate in Bangladesh is low. The percentage of the total population economically active has declined from 28.7 in 1974 to 27.1 in 1981 (Bangladesh Bureau of Statistics, 1984). About 61 per cent of the economically active population 10 years and over were engaged in agricultue, and only 4.2 per cent of the females aged 10 and over were economically active according to the 1981 Bangladesh population census. The low activity rate among females may be attributed to the prevailing social customs that discourage participation by women in outside work for wages with their male counterparts. Bangladesh has a high dependency ratio of 109 persons which is mainly due to an exceptionally high proportion of young persons in its age structure (Bangladesh Bureau of Statistics, 1984).

1.3 Stochastic Models of Fertility: a Review

The formulation of mathematical models for human populations, though deterministic, may be traced back to Euler in 1796 and pioneering works by Lotka (1907), and Sharpe and Lotka (1911). However, the early major research in the development of stochastic model in the domain of human fertility has been due to an Italian statistician and demographer, Gini (1924, 1926). He has introduced the concept of fecundability, i.e., the probability that a fecund woman susceptible to conception will conceive during a menstrual cycle (usually taken as a month). He has proposed a method of estimating fecundability by assuming that it is not affected by duration of exposure to risk of pregnancy. Further assuming constant fecundability of a married woman (except for the first month of marriage) before conception, he has estimated the mean fecundability of women conceiving for the first time in months x to x+y of marriage. He has found that the number of women conceiving for the first time in a given month is proportional to the number of first live births nine months later. This finding has been based on the assumption that the duration of gestation and the frequency of fetal deaths remain constant in the months x to x+y of marriage.

Henry (1953) has formulated stochastic models incorporating Gini's notion of fecundability. On the assumption of constant fecundability per woman, he has suggested that the values of the mean fecundability of a population and its coefficient of variation can be estimated from data on the proportions of women conceiving during the first and second months of exposure to risk of conception. He has studied both discrete as well as continuous-time reproductive models postulating both homogeneous and heterogeneous populations. Later in a series of papers, Henry (1957, 1961a, 1961b) has derived limiting results for birth rates and studied the relationships between underlying biological factors, such as fecundability, durations of pregnancy, and postpartum sterility. He has explored the possible causes of variation in birth rates by duration of marriage, and problems in analyzing intervals between successive births. He suggests that the differentials and trends in birth rates or conception rates should not be regarded as a direct reflection of the corresponding differentials and trends in fecundability and fetal death.

On the assumption of constant effective fecundability (monthly probability of a conception resulting in a live birth) and constant total infecundable period (gestation period plus postpartum amenorrhea period) following a conception, Dandekar (1955) has constructed several models of reproduction. Based on these assumptions, he has obtained expressions for the probability of at least x births in y years of marriage. He has derived two different expressions for the probability of m conceptions in a fixed period of time t depending on whether time is treated as a discrete or continuous variable or whether the waiting time follows a geometric or an exponential distribution. The expression for continuous-time model derived by him is similar to that obtained by Neyman (1949) with regard to the problem of estimating the number of schools of fish. Dandekar has also obtained the expression for the asymptotic pregnancy rate. The same expression for this rate has been derived by Henry (1953) and Basu (1955).

Vincent (1956) has investigated the possible influences of factors, such as timing of marriage, variations in fecundability, variations in the duration of menstrual cycle, and the variations in the duration of pregnancy on the distributions of conceptions and births. He suggests that the mean fecundability of newly married women may be estimated from the distribution of intervals between marriage and first birth. From the model for estimating the fecundability using the data on first births, he also suggests that the difference between the proportion of a group of women conceiving in the first month of marriage and the estimated harmonic mean may be taken as a measure of heterogeneity of the group.

Brass (1958) has developed a continuous-time model assuming constant fecundability of a given woman. This constant varies from woman to woman and he uses a gamma mixing distribution to allow for this variation. He has also assumed that the total infecundable period following a conception is constant and that a pregnancy will terminate only as a live birth. Corresponding to this model, he has derived an expression for the probability of m conceptions in time t. He has introduced some modifications into Dandekar's model and derived descriptive parameters based on the number of births borne at specified ages of women.

Adding a provision for fetal wastage to Dandekar's discrete model, Potter (1960, 1961) has obtained the probability distribution of the number of births in a given time period assuming the use of relatively effective birth control methods. Singh (1963, 1964a) has also modified Dandekar's discrete-time model making the assumptions of a fixed fecundability for each woman and a beta mixing distribution to adjust for the fecundabilities of all women and derived an expression for the probability of m conceptions in time t. Taking the mean duration of gestation and postpartum amenorrhea at 12 months and estimating the proportion fecund and fecundability using Dandekar's data, he has found a better fit than Dandekar has done. Later, Singh (1964b) has derived an expression for the distribution of waiting time in the continuous case confining the model to that part of the reproductive period where a woman is susceptible and waits for a conception, assuming that each woman has constant fecundability and that the fecundabilities of all women follow a gamma distribution.

Using a special case of Henry's discrete-time model, namely, constant non-susceptible period associated with live births and stillbirths, Sheps and Perrin (1963) have examined the effectiveness of contraceptive practices on fertility rates and found that more effective methods used by a smaller proportion of a population will result in the greater decline in fertility rates than will less effective methods practised by a larger proportion of the population. In a later paper, Sheps and Perrin (1966) have again used the same special case of Henry's discrete-time model to obtain the distribution of time required for the occurrence of a fixed number of conceptions terminating in live births. In their model, they have taken into account more than one type of pregnancy, i.e., any pregnancy that terminates either in fetal wastage, stillbirth or live birth with a given probability. The model also allows for variable periods of gestation and of nonsusceptibility to conception.

Perrin and Sheps (1964) have formulated a stochastic model to approximate the human reproductive behaviour which is viewed as a Markov renewal process with a finite number of states. In this model, they have assumed that at any time after marriage (before the occurrence of secondary sterility or menopause), a woman is in any one and only one of the following five states: (1) nonpregnant fecundable, (2) pregnant, (3) postpartum amenorrhea period associated with abortion or fetal wastage, (4) postpartum amenorrhea period associated with stillbirth, and (5) postpartum amenorrhea period associated with live birth. They have also assumed that the length of stay in each state is a random variable and that each pregnancy terminates in one of the following outcomes: fetal death, stillbirth or live birth with fixed probabilities. In their model, they have further assumed constant fecundability for a woman in the nonpregnant fecundable state, and the waiting time for a conception follows a geometric distribution. Expressions have been derived by them for the mean and variance of different time intervals (e.g., the interval between successive live births), and for the monthly probability of a live birth. They have also obtained expressions for the mean and variance of live births, stillbirths, and miscarriages in a given period after marriage, and the probabilities of the different states at a given point in time.

For a heterogeneous population of couples with unequal monthly probability of conception, Sheps (1964) has derived the distribution of time needed for conception and the distribution of conception delays. In a later paper, Sheps (1967) has formulated a class of stochastic models for a homogeneous cohort of women in terms of a Markov renewal process on the assumption that the process is independent of age and parity. She has explored the effects of various levels of contraceptive effectiveness and abortion rates on birth rates, and the use of these models in evaluating population policies. She has also derived the moments of the distribution of conception delays in a group where the woman but varies between women in an unspecified manner. Sheps and Menken (1973) have presented a unified approach to the derivation of the existing models of human reproduction. While introducing the various models, they have included a comprehensive review of the techniques and methods used in their construction.

In addition to developing a stochastic model of conjugal history in terms of Markov renewal process, Krishnan (1971) has introduced a special type of Markov renewal process to set up a model of human fertility taking into consideration only social institutional factors. He has also suggested alternative models of conjugal history and fertility incorporating mortality factor explicitly into the models.

Considering two transient states (nonpregnant fecundable, and pregnant infecundable state) and an absorbing state (death state), Chiang (1971) has developed a stochastic model of human fertility. The model is non-homogeneous with respect to time as he has treated the transition from fecundable state to pregnant or infecundable state and the corresponding probability as a function of woman's age and the transition from infecundable to fecundable state a function of the length of time she has been pregnant and her age. Expressions have been derived for the multiple transition probabilities between the three a female to have certain number of pregnancies. As he has put together both gestation and postpartum amenorrhea into a single state, namely infecundable state, there are some limitations in his model. The probability that a woman aged x who has been in the pregnant or infecundable state for a length of time t will have a transition to the fecundable state in the age interval (x, x+dx) will not only be influenced by x and t, but also on the division of t into its two parts, namely gestation period and postpartum amenorrhea period.

Mode (1972) has studied the Malthusian parameter (intrinsic rate of geometric growth of a population) in terms of a modification of the Markov renewal model of human reproduction formulated by Perrin and Sheps (1964). In his stochastic model, Mode has taken into account the biological factors that the reproductive period of every woman terminates eventually and that every woman runs the risk of death throughout her life span. He has derived an expression for evaluating what influences a population policy consisting, for example, of contraceptive practices and laws of abortion, may have on population growth. In a subsequent paper, Mode (1975) has attempted a modification of the classical renewal theory to construct a model of a terminating reproductive process in which waiting time among live births are age and parity dependent. He has obtained the distributions of waiting times among live births by restructuring the Perrin-Sheps model as a non-homogeneous absorbing semi-Markov process. He has given numerical examples illustrating how the models of human reproduction may be linked to generalized age dependent branching processes in the evaluation of family planning programs.

Das Gupta (1973a, 1973b) has constructed a stochastic model of human reproduction along the lines suggested by Perrin and Sheps (1964). This model is more general than that of Perrin and Sheps, and takes into account the likely dependence of postpartum amenorrhea on the previous gestation period, and for live births, on the breast-feeding status of the women. He has formulated two models, almost identical in concepts, treating time in one case as continuous and in the other case as discrete variables. He has derived exact probability distributions of various characteristics of fertility in terms of Laplace transforms (or probability generating functions in the case of discrete-time), their moments as well as the asymptotic behaviour of the exact results.

Assuming fecundability to be parity dependent, no fetal wastage, and a constant period of non-susceptibility associated with each conception, Singh et al. (1974) have developed a stochastic model for the number of births to a woman during a given time interval since marriage. They have applied the model to find the probabilities of the number of births for women of a marriage cohort using contraceptive methods of varying effectiveness depending on parity during a given period of time. Singh et al. (1975) in a later paper have derived a probability model of the number of births to a female during a specified period of t years assuming that females have the same conception rate. They have discussed the application of the model and, as an illustration, it has been fitted to the observed data collected in the Demographic Survey of Varanashi (Rural), India, 1969-70. They have suggested that the model may be used to assess the effectiveness of a family planning program in the case where couples want to limit their family size after a certain number of births.

Edmonston (1983) has outlined a microanalytic simulation model of human reproduction for Bangladesh. The model assumes that the biological factors (fecundability, live births, stillbirths, fetal deaths, and sterility) vary with a woman's age. He has incorporated two key features, breastfeeding and early childhood mortality in the model. This simulation model incorporates a Weibull survival function for early childhood mortality and a model schedule of postpartum amenorrhea, developed by Lesthaege and Page (1980), which depends on the duration of breastfeeding. Employing the Monte Carlo simulation model in which age at marriage is allowed to vary, Edmonston (1983) has found that the mean family size reported in the Bangladesh Fertility Survey, 1975-76 agrees, in general, with the non-contracepting simulation model. He has also derived age specific marital fertility rates for women marrying at age 15, 17.5, and 20 from the simulation runs and observed that the Coale-Trussell (1974) model fertility schedule was slightly higher for women aged 15-35 years and lower for older women when compared to the simulation fertility schedule for women marrying at age 20.

1.4 Organization of the Thesis

The thesis is organized into six chapters. Following this introductory chapter, description of data employed in this study and characteristics of the respondents are presented in chapter 2. This chapter also contains a discussion of the levels and trends of period and cohort fertility in Bangladesh obtained through the analysis of birth history data. In chapter 3, a stochastic model of human fertility is developed from the standpoint of socio-biological considerations. Reproductive data for two recent five-year marriage cohorts of Bangladeshi women are fitted to the model in chapter 4. Patterns of fertility for these cohorts are studied by the application of the model in chapter 5. In this chapter, the model is also applied to examine the differential fertility patterns by rural-urban, educational, and religious backgrounds of women. Finally, chapter 6 summarizes the results, looks at policy implications for fertility regulation in the light of the findings obtained in chapter 5, and suggests future lines for modelling fertility studies.

2. DESCRIPTION OF DATA AND CHARACTERISTICS OF RESPONDENTS

2.1 Data Source

Data for this study were derived from the Bangladesh Fertility Survey (BFS) which was conducted during 1975-76 under the auspices of the World Fertility Survey (WFS). A detailed description of the methodology of data collection including the sample design for the survey can be found in Bangladesh (1978). However, it seems pertinent to discuss here briefly the sample design and the critera for selection of the respondents for the survey.

The survey was based on a three-stage sample design of non-institutional households for both the rural and urban strata. A sample was drawn independently in all the three stages. In the first stage, 160 rural and 80 urban primary sampling units (PSU) were selected with probability proportional to size. Each PSU consisted of a few contiguous villages in the rural stratum and a few census blocks in the urban stratum. From each selected PSU, one village in the rural areas and one census block in the urban areas were selected again with probability proportional to size. These were the secondary or intermediate sampling units (ISU) and each consisted of approximately 50 households. Complete listing of households in each selected ISU was made. The households (ultimate sampling units) were then selected from each ISU with probability inversely proportional to the measure of size used in the selection of the respective PSU and ISU. Thus the sample was theoretically self-weighting within each stratum, rural and urban. In order to obtain national estimates, weighting was necessary. The number of selected households varied between 15 and 45 in a rural ISU and 5 and 29 in an urban ISU.

The total number of households selected in the sample was 6,145 of which 4,626 were rural and 1,519 were urban. However, only 4,437 households were successfully contacted in the rural areas and 1,418 in the urban areas. The non-contact rates were 4.1 per cent in rural areas and 6.6 per cent in urban areas. 'Dwelling vacant' was the main reason for non-contact in both rural and urban areas (Bangladesh, 1978). Details of residence, marital status, age, sex, and educational attainment of all members in the selected households were recorded on the household schedule of the BFS. After the household interview, all ever married women below 50 years of age who slept in the household the night preceding the interview were selected as eligible respondents for the individual interview. The individual questionnaire was thus administered on a de-facto basis and contained 11 sections in the following order: respondent's background, marriage history, total pregnancy history, knowledge and use of contraceptives, fertility regulation, work history, current (last) husband's background, children's education and work, assets and expenditures, abortion, and height and weight. Out of 6,648 eligible respondents identified in the household interview, 6,513 were interviewed in the individual interview with a non-response rate of 2.0 per cent.

Among the interviewed females, 5,024 were from rural areas and 1,497 from urban areas. However, later in the process of cleaning the data, 4 respondents in rural areas and 5 respondents in urban areas were excluded which resulted in the sample size as being equal to 6,504. An oversampling in the urban areas was purposely done to obtain a reasonably large sample required for carrying out a separate study for urban women. Sample weights were assigned with a view to allow for this oversampling. Details of the calculations of weighting factors can be found in Bangladesh (1978). Weights assigned to the rural and urban samples were 1.194 and 0.347 respectively.

2.2 Description of Data

Information obtained from the pregnancy history section of the individual questionnaire of the BFS was the main source of data for this study. The pregnancy history questionnaire was designed to obtain information as reliably and completely as possible. Some filter type questions were asked at the beginning of the pregnancy history section in order to introduce the topic and determine the eligibility of the respondents for this section. Details of all pregnancies experienced by the selected women were recorded in a chronological order. The pregnancy history table consisted of two parts: a recording of all pregnancies that resulted in live births followed by a recording of all pregnancies terminating in non-live births. A single integrated history of all pregnancies was obtained probing for pregnancies not resulting in live births in each interval bounded, as appropriate, by marriage and first live birth, first live birth and second live birth, and so on until the open interval. This segmental approach was designed to help the respondents minimize memory lapse and misplacement in the location of events of their reproductive life. The pregnancy history provides informations, among others, the dates of birth of live born children in calendar months and years, dates of termination of pregnancies in non-live births and their durations. In cases where the respondents were unable to report the dates of events in calendar months and years, they were asked 'How many years ago did the event occur?' A copy of the English version of the pregnancy history questionnaire has been reproduced in Appendix Table A.

The standard recode file BD. SR03 created in the standard WFS format at the WFS Headquarters from the individual recode file BD. IN01 of the BFS was used for obtaining the data for this study. Some inconsistencies detected in the original Bangladesh recode file were corrected in the standard recode file. This might slightly affect comparison of the findings with those previously published. The standard recode file comprised of a single record for each respondent. Dates of various demographic events were recorded in the standard recode file in the century month code, that is, January 1900 was coded as 1, February 1900 as 2, and so on. Dates of these events were imputed in the cases where these were not avialable in calendar months and years. The imputation procedure assumed that the years of events were known in some form (calendar year stated and month not stated, years ago or the estimated year of event by examining relevant information in the questionnaire where it was not stated). This procedure of imputation of dates in the century month form is described in Bangladesh (1978).

As the standard recode file BD. SR03 does not contain the dates of termination of pregnancy in non-live births (stillbirths, spontaneous and induced abortions), a separate file was created incorporating these dates from the individual Bangladesh recode file BD. IN01 into the standard recode file BD. SR03. This was done by matching the two files (BD. SR03 and BD. IN01) with respect to two identifications (line number and household number) of the respondents. The dates of termination of pregnancy in non-live births were transformed into century month form by using the imputation procedure outlined in Bangladesh (1978). Then all pregnancies (terminating in live and non-live births) were arranged in a chronological order of occurrence for each respondent.

The accuracy of estimates of fertility based on pregnancy history data depends on whether dates of various events were correctly reported. Available evidence suggests that retrospective data of WFS type are subject to errors of various kinds. "The high standard set by WFS for data collection operation are expected to result in better quality data than typically obtained in the past but this expectation in no way obviates the need for detailed assesment of the quality of data" (O'Muircheartaigh and Marckwardt, 1980 : 1).

In a traditional society like Bangladesh, where a vast majority of the respondents are illiterate and are not calendar-conscious, it is very difficult to obtain correct reporting of dates of demographic events. Although intensive training was given to the interviewers in the use of probes, local calendars, and historical events with a view to obtain the data as accurately as possible, unfortunately, a great majority of the respondents were unable to provide the dates of events in calendar months and years. Table 2.1 shows, for example, that about 99 and 88 per cent of the respondents could not report their own dates of birth and dates of birth of their children. However, the dates stated in terms of 'years only' and 'years ago' were imputed into calendar months and years using the WFS imputation program. The imputation of dates affects the quality of data in situations where the proportion of dates to be imputed is high and rises sharply from the recent to the more distant

Table 2.1

Percentage Distribution of Reporting of Dates of Some Events in the BFS, 1975-76

	Calendar Month and Year	Calendar Year Only	Years Ago	Total
Respondents Date of Birth†	1.4	1.4	97.0	99.8
Date of Last Live Birth‡	33.0	4.0	63.0	100.0
Date of All Live Birth‡	12.0	3.0	85.0	100.0

†WFS/Tech. 1065 (1979 : 3)
‡Chidambaram et al. (1980 : 30)

past (Chidambaram et al., 1980).

A re-interview survey was conducted in May 1976 after the completion of the main field work. The sample was designed to over represent the urban areas. A shortened version of the original individual questionnaire of the BFS (Section 1 through 4) was used in the re-interview survey. Out of 430 respondents selected for re-interview, 322 were successfully re-interviewed. The response rate was much lower than that for the main survey. The unedited re-interview raw data file was matched with the partially edited main survey raw data file. The results were reported in a draft document by Ahmad (cited in O'Muircheartaigh and Marckwardt, 1980). Based on the data from the draft document, O' Muircheartaigh and Marckwardt (1980) computed the means and levels of discrepancies for selected variables. They found, for instance, that the mean current age of the respondents was 28.7 years in both the main survey and the re-interview survey, while about 80 per cent of the respondents stated their ages differently in the two surveys. It was, however, found by them that 40 per cent of respondents stated their ages differently with respect to five-year age groups. Also in the dating of first births discrepancies of two or more years were found to have occurred among approximately one-third of the respondents. O'Muircheartaigh and Marckwardt (1980) noted that the reporting of age at marriage was substantially more reliable than that of current age of the respondents.

2.3 Some Characteristics of the Respondents

2.3.1 Age Distribution

A comparison of the five-year age distribution of the respondents of BFS with those of the ever married female population according to the 1974 and 1981 Bangladesh population censuses is made in Table 2.2. The reported age distribution of the BFS respondents up to age group 20-24 both in rural and urban Bangladesh are relatively older as compared to those of the census ever married females. Nevertheless, the age structures of the survey and census ever married females do not show much difference as revealed by the index of dissimilarity (see Table 2.2). However, it is expected that the age reporting in the BFS was relatively more accurate because an indirect procedure (establishing age with reference to historical or local important events) was followed by the well-trained interviewers to determine the ages of the respondents who were unable to report their exact ages.

2.3.2 Proportion Married Among Females

Table 2.3 shows that, in general, there has been a gradual change in the proportion of ever married females, particularly below age 20 during the period 1974-81. It is revealing that most marriages in Bangladesh take place at an early age. About 99 per cent of females below age 30 were ever married and the short span of time during which most

Place of Residence: Bangladesh

Source	Age Group								
	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	Total†
BFS, 1975-76									
Rural	4.1	18.5	20.3	17.2	12.0	10.5	9.7	7.7	100.0
Urban	2.9	17.3	22.8	18.3	13.2	9.9	8.9	6.7	100.0
Total‡	4.0	18.4	20.5	17.3	12.1	10.4	9.7	7.6	100.0
1974 Population Census¶									
Rural	3.0	15.2	17.3	18.0	14.6	12.9	11.0	8.0	100.0
Urban	1.8	14.7	19.7	19.1	14.8	12.4	10.3	7.0	99.8
Total	2.9	15.2	17.5	18.1	14.6	12.1	10.9	7.9	100.0
1981 Population Census§									
Rural	2.3	16.3	19.2	18.0	14.2	12.2	10.3	7.5	100.0
Urban	1.6	14.7	21.6	19.8	14.6	11.4	9.6	6.6	99.9
Total	2.2	16.1	19.5	18.3	14.2	12.1	10.2	7.4	100.0

†Percentages do not add up to 100.0 because of rounding
‡Weighted
¶Computed from Bangladesh Bureau of Statistics
(1977 : 583-86)
§Computed from Bangladesh Bureau of Statistics
(1984 : 192-93)

Note:

Index of Dissimilarity Between Age Distributions

	BFS and 1974 Census	BFS and 1981 Census
Rural	7.4	5.3
Urban	6.7	5.2
Total	6.9	5.3

Proportion of Women who are Ever-Married by 5 Year
Age Group and Place of Residence: Bangladesh

	Age Group							
Source	10-14	15-19	20-24	25-29	30-34	35-39	40-44	45-49
BFS, 1975-76†								
Rural	.102	.721	.966	.992	.998	.996	.999	.997
Urban	.062	.561	.888	.966	.990	.994	1.000	1.000
Total	.088	.702	.959	.990	.998	.996	.998	1.000
1974 Population Census‡								
Rural	.100	.778	.975	.992	.995	.996	.996	.997
Urban	.048	.554	.899	.979	.991	.994	.994	.995
Total	.095	.755	.968	.991	.994	.996	.996	.997
1981 Population Census¶								
Rural	.075	.713	.960	.989	.991	.996	.994	.997
Urban	.045	.549	.891	.974	.983	.993	.985	.993
Total	.070	.687	.949	.987	.990	.966	.993	.997

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†BFS, Household population
‡Computed from Bangladesh Bureau of Statistics (1977 : 93-94)
¶Computed from Bangladesh Bureau of Statistics (1984 : 62-63)

proportions of ever married females in various age groups were consistently higher in rural areas than in urban areas. It should be pointed out that the incidence of premarital conception has been rare in Bangladesh and most females remain in married state during the reproductive period. About 87 and 82 per cent of women aged 10-49 were currently married according to the 1974 Bangladesh population census and the BFS household population (Shahidullah, 1979).

2.3.3 Age at First Marriage

Age at first marriage and age at consummation of marriage are not always the same in Bangladesh. "The interval between marriage and consummation depends on the onset of menarche, gaurdian's monetary savings, completion of education of spouses and other family circumstances" (Bangladesh, 1978 : 50). Unfortunately, the age at consummation of marriage was available only for those who were currently married. The reported mean interval between age at first marriage and consummation for currently married women (including women whose current marriage was not their first marriage) was only 0.4 years (Bangladesh, 1978). The reliability of this estimate may be disputed because of mis-statement of age at marriage and memory lapse.

The mean age at marriage for selected five-year first marriage cohorts by place of residence is presented in Table 2.4. Although mean age at first marriage ,in general, shows

Mean Age at First Marriage by Selected First Marriage Cohort and Place of Residence: Bangladesh

First Marriage Cohort	Rural	Urban	Total†
1951-55	11.8 (593)	12.3 (143)	11.8 (758)
1956-60	11.6 (659)	12.7 (218)	11.7 (862)
1961-65	12.0 (893)	13.1 (249)	12.1 (1153)
1966-70	12.9 (833)	14.0 (281)	13.0 (1092)
1971-75	14.0 (880)	15.3 (295)	14.1 (1153)

Source: Computed from the BFS, 1975-76

†Weighted

Note: Figures in parantheses refer to number of first married females.

national estimate of the mean age at first marriage rose consistently from 11.7 years for those married for the first time in 1956-60 to 14.1 years for those first married during 1970-75. Table 2.3 shows that there is a marked rural-urban differential in the mean age at first marriage. Relatively higher mean age at first marriage for urban women may partly be attributed to the higher proportion of educated urban women as compared to their rural counterparts (see Bangladesh, 1978).

2.3.4 Use of Contraception

The use of contraception among couples is very low in Bangladesh. According to the BFS, only 14 per cent of ever married females reported to have ever used any methods of contraception and 10 per cent had ever used any efficient method' while 9.6 per cent of all 'exposed' women reported to be using any contraceptive methods at the time of survey (Bangladesh, 1978). Sirageldin et al. (1975) found from the data collected by the National Impact Survey, 1968-69 that only 6.4 per cent of the married couples had ever used any contraceptive methods. Although the findings of the two nationally representative surveys were not totally comparable because of the differences in methodology and quality, it appears that the use of contraception has

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'The method defined as efficient were: pill, interuterine device (IUD), condom, sterlization, and use of foam tablets, jelly and cream.

of the National Family Planning Program by the Government in 1965 with a marked rural focus, this increase in the use of contraception is not quite encouraging.

Both the ever use and the current use of contraception by first marriage cohorts as shown in Table 2.5 reveal an interesting pattern. The older the first marriage cohort at the time of survey, the higher the ever use of contraception. About 18 per cent of all women who married for the first time during 1951-55 had ever used contraception while only 7.5 per cent of all women first married in the period 1971-75 reported to have ever used any contraceptive methods. It is interesting to note that the ever use of contraception among the Bangladeshi women in each first marriage cohort was about two-fold the current use of contraception. The proportions of both the ever users and current users of contraceptive methods were much lower among women first married during 1971-75 as compared to those first married during 1966-70. There exists a pronounced rural-urban differential in both ever use and current use of contraception as can be seen from Table 2.5. Relatively higher proportions of ever users and current users of contraceptive methods among urban women in each first marriage cohorts may to some extent be attributed to the concentration of more educated couples in urban areas.

Percentage of Respondents by Use of Contraception, Place of Residence and Selected First Marriage Cohorts: Bangladesh

First Marriage Cohort	Use of Contraception					
	Ever User			Current User		
	Rural	Urban	Total†	Rural	Urban	Total†
1951-55	16.7	34.3	17.8	8.3	23.1	9.2
1956-60	14.9	34.9	16.6	7.4	17.9	8.4
1961-65	14.8	30.9	16.0	7.4	20.5	8.4
1966-70	11.3	27.0	12.7	5.0	16.4	6.0
1971-75	5.9	23.4	7.5	3.3	10.2	3.9

Source: Computed from the BFS, 1975-76
†Weighted

2.4 Fertility Levels and Trends

Fertility in Bangladesh is high even by the standards of developing nations. Various nationally representative estimates of summary measures of fertility from different sources (Table 2.6) indicate that there has been no marked change in fertility during the period 1901-76. These estimates, though not strictly comparable because of different methods of data collection and different techniques of estimation, show that fertility in Bangladesh has been considerably high. The estimated crude birth rate remained at a level of around 50 live births per thousand population during the period 1901-61 (Table 2.6). Since 1961, whether there was a long term fertility decline remains somewhat controversial. "Most retrospective fertility surveys document a decline, but methodological constraints preclude firm conclusions" (Chen et al., 1979 : 104). The Chandrasekar-Deming estimates of crude birth rate and total fertility rate were probably high (Ahmed, 1970), while those based on birth history data from the National Impact Survey were low, which might possibly be attributed mainly to the under-reporting of births (Sirageldin et al., 1975).

A decline in fertility has been documented in the first-half of the 1970s from the vital registration data collected by the former Cholera Research Laboratory in

Table 2.6

Summary Measures of Fertility for Bangladesh, 1901-76

Period	Crude Birth Rate ('000)	Total Fertility Rate
1901-11‡	53.8	-
1911-21‡	52.9	-
1921-31‡	50.4	-
1931-41‡	52.7	-
1941-51‡	49.4	-
1951-61‡	51.3	-
1962-65‡	50.0	-
1962-65†	53.0	7.4
1962-65¶	43.0	6.3
1966-68§	42.0	6.0
1974*	48.3	7.1
1974**	47.4	6.6
1974-76#	43.0	6.1

‡Khan (1973 : 179). Rates for the decades 1901-11 through 1951-61 were obtained from the adjusted census age data and the adjusted intercensal growth rates. Rate for the period 1962-65 was derived from the Population Growth Estimation (PGE) Experiment, 1962-65.

†Farooqui et al. (1971 : 91-93). Chandrasekar-Deming estimate from PGE, 1962-65. TFR refers to the period 1963-65.

¶Farooqui et al. (1971 : 91-93). Longitudinal registration estimate from PGE, 1962-65. TFR refers to the period 1963-65.

§Sirageldin et al. (1975 : 209). Derived from the National Impact Survey (NIS), 1968-69.

*Census Commission (1977 : 76). Derived from the Bangladesh Retrospective Survey of Fertility and Mortality (BRSFM), 1974.

**Rabbani et al. (1979 : 27). Derived from the 1974 Bangladesh Population Census.

#Hanenberg (1980 : 15). Derived from the BFS, 1975-76.

Matlab Thana,[2] though not fully representative of Bangladesh. A modest decline in crude birth rate was observed in 1971-72, one year following the 1971 war of liberation and the birth rate fell again in 1974-75 beginning the year of the 1974 famine (Curlin et al., 1976; Chen and Chowdhury, 1977; Chowdhury and Curlin, 1979; and Chen et al., 1979). A dip in fertility in the period 1973-76 has also been found by Hanenberg (1980) using the BFS data.

In this section, we shall be concerned with studying the levels and trends in fertility using the birth history data collected in the BFS. Informations obtained from the birth history data can be cross-tabulated according to (1) all births by age (or age group) of women and period (number of years) prior to the date of interview (or calendar year of occurrence of birth), and (2) all births by duration since first marriage of women and period prior to the date of interview (or calendar year of occurrence of births). The women in the same age group and those in the same duration group since first marriage are referred to as age-cohort and duration-cohort respectively. In order to make full use of the most recent data collected in birth histories, cohorts are defined in the present analysis in terms of age or marital duration of women before the date of interview

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[2] The system of vital registration has been carried out since 1966 by the International Centre for Diarrhoeal Disease Research (former Cholera Research Laboratory) in Matlab Thana of Comilla District, a rural area 40 miles south of Dhaka, covering 233 villages with a population of about 221,000.

rather than women born during the same calendar year. Thus, births are allocated to different time periods prior to the date of interview rather than calendar year of occurrence of births. With a view to minimize the effects of sampling errors and age mis-statement, the analysis is based on five year age and duration cohorts, and periods of five years preceding the date of interview.

Cohort-period specific fertility rates rather than the conventional age-specific fertility rates have been recommended by several demographers when informations are obtained from retrospective fertility surveys (see, for example, Brass, 1979; Verma, 1980; Ryder, 1980; Goldman and Hobcraft, 1982). Although the conventional age-specific fertility rates are more appropriate when the data source is a census or a vital registration system, these rates calculated from birth history data are disadvantageous because of the bias that creeps in when allocating fractions of person-years of exposure of different age groups to different time periods (see Goldman and Hobcraft, 1982). Thus cohort-period specific fertility rates are employed to study the levels and trends in fertility for Bangladesh.

2.4.1 Cohort-Period Fertility Rates

Cohort-period specific fertility rates are obtained by dividing the number of births born to a given cohort (age cohort or marriage duration cohort) of women in different periods prior to the date of interview by the number of women in that cohort. In order to obtain the rates on a per annum basis, fertility rates derived above should be divided by the average number of years of exposure to risk by the relevant cohort, which is five years for all age cohorts or marriage duration cohorts except for those in the age group 10-14 and marriage duration group 0-4 corresponding to 0-4 years preceding the date of interview for which the exposure is approximately 2.5 years. It should be noted that each fertility rate for ever married women should be multiplied by the proportion of women ever married for the appropriate cohort in the case of age cohort-period fertility rates. Cohort-period fertility rates by duration since first marriage are restricted to ever married women. Details of the computation of cohort-period specific fertilty rates can be found in Verma (1980), Ryder (1980), and Goldman and Hobcraft (1982).

Table 2.7 shows the cohort-period fertility rates by age for rural, urban, and total Bangladesh. Rates for a given period preceding the date of survey can be obtained from a column, rates for a given cohort along an upward diagonal, and rates at equivalent age groups for different

Table 2.7
Cohort-Period Fertility Rates by Age and Place of Residence: Bangladesh

Age Group of Cohort at End of Period	No. of Women in Cohort	Years Prior to Survey							
		0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
				Rural					
10-14	208	.004	.008	.012	.009	.015	.011	.011	.014
15-19	929	.112	.177	.187	.179	.167	.151	.135	
20-24	1020	.274	.368	.348	.300	.296	.263		
25-29	863	.281	.355	.346	.310	.279			
30-34	600	.236	.337	.305	.254				
35-39	526	.178	.239	.224					
40-44	489	.107	.146						
45-49	385	.037							
TFR		6.13†	8.33‡	8.02‡					
				Urban					
10-14	43	.003	.010	.010	.011	.017	.019	.015	.004
15-19	257	.101	.137	.168	.156	.181	.162	.110	
20-24	338	.266	.319	.355	.284	.286	.252		
25-29	271	.280	.322	.360	.282	.332			
30-34	196	.224	.341	.286	.292				
35-39	147	.158	.211	.242					
40-44	132	.088	.120						
45-49	100	.040							
TFR		5.79†	7.50‡	7.90‡					
				Total (Weighted)					
10-14	264	.003	.008	.012	.010	.015	.011	.012	.013
15-19	1198	.110	.174	.185	.177	.168	.152	.134	
20-24	1335	.274	.364	.349	.299	.295	.263		
25-29	1124	.281	.352	.347	.307	.284			
30-34	785	.234	.337	.304	.257				
35-39	679	.177	.237	.226					
40-44	630	.106	.145						
45-49	494	.037							
TFR		6.10†	8.27‡	8.02‡					

Source: Computed from the BFS, 1975-76

†TFR is calculated in the usual manner except that ASFR for age group 10-14 is multiplied by 2.5

‡TFR has been calculated on the assumption that the missing rates are the same as the corresponding rates for the most recent period.

cohorts across a row of the Table 2.7.

An examination of the rates in all the panels of Table 2.7 reveals that fertility in Bangladesh has declined dramatically for all age groups (age at the end of period) in the period 0-4 years preceding the date of the survey. Although truncation does not allow for the reconstruction of fertility rates for the older women except for the most recent period, total fertility rate (TFR), calculated by assuming that the missing rate was the same as the corresponding rate for more recent period, has declined by about 26 per cent in Bangladesh from a level of 8.3 in the period 5-9 years before the date of the survey to the level of 6.1 in the period 0-4 years prior to the date of the survey. An almost similar decline in TFR was also found in rural areas while the corresponding decline in urban areas was about 23 per cent.

Whether this marked decline in fertility in the 0-4 years before the date of survey is genuine or an artifact of data quality caused by systematic misplacement of dates of birth into the past and age mis-statement of women is a difficult question which cannot be resolved conclusively. However, the social disruptions caused by the war of liberation in 1971 and the widespread famine in 1974 might have contributed to a fertility decline in Bangladesh during the five-year period immediately preceding the date of the survey.

variables, such as proportion married among females, voluntary or involuntary abstinence, frequency of coitus (see Davis and Blake, 1956) which in turn affected the reproductive performance of couples. During the period of social disruption, the number of persons entering reproductive life might have reduced because of the temporary postponement of marriages. A large exodus of about 16 per cent of the population (Curlin et al., 1976) to neighbouring India as refugees might have contributed to the reduction in conception either by voluntary or involuntary separation of spouses. Due to psychological stress or the desire to postpone pregnancy, coital frequency might have been reduced.

Again the acute food shortage associated with the 1974 famine in Bangladesh resulting from the severe monsoon flooding (which caused almost total crop failure of the major annual rice harvest) might probably have decreased the nutritional status of a vast majority of women. Maternal malnutrition has resulted in the reduction in fecundity and lengthening of the period of temporary infertility, and the conception rate among exposed women might have reduced. Also fetal wastage might have increased, and among menstruating women, there might have been an increased number of anovulatory cycles.

1974 famine from the reasonably complete vital registration data in Matlab Thana (Curlin et al., 1976; Chen and Chowdhury, 1977; Chowdhury and Sheikh, 1980). Although this finding was limited to a relatively small area and might not be representative of all Bangladesh, it might be taken to support the evidence of the pronounced decline in fertility in Bangladesh during the first half of the 1970s corresponding to the period 0-4 years before the date of the BFS. However, the magnitude of this fertility decline may not probably be attributed to the social disruptions alone.

First, event misplacement in the form of pushing earlier births forward and recent births backward over time affects the fertility rates derived from birth histories. It has been observed that the dating of live births in birth histories are distorted in systematic ways and a common form of such distortions appears to be pushing back recent births into the past, contributing to a deficit in the number of births in the recent years and an excess of births in the period 5 to 14 years prior to the date of survey (see, for example, Potter, 1977; Cain et al., 1979; Brass and Rashad, 1980). If such misplacement of live births should occur in the BFS, the fertility rate in the most recent period (0-4 years before the survey) would be understated and the rate corresponding to the period 5 to 14 years before the survey would be inflated. A decline in period fertility in the 0-4 survey indicate the existence of event misplacement errors. However, a rising age at first marriage, particularly in recent years (see Table 2.4) might also contribute to a slight reduction in period fertility in 0-4 years prior to the date of the survey.

The second problem concerns with the reporting of dates of birth in the BFS. Dates were supposed to be reported in terms of 'years ago'- i.e., the completed number of years prior to the date of survey, if the respondents could not report the dates in calendar months and years. Ahmad (1980) suggests that year ago might have been rounded to the nearest year rather than reporting in terms of completed years. In the BFS, of all births reported to have occurred during the period 1971-75, dates were reported for 2,239 children and years ago were reported for 3,670 children. While examining the fertility rates derived from the BFS, Committee on Population and Demography (1981 : 45) observes that

> "If it is assumed that the recording was in the form of completed years, the fertility rates for the years before the survey show a very rapid decline taking place, the birth rate declining from around 53 per thousand 5 to 9 years before the survey to around 38 per thousand 0 to 4 years before the survey. If, on the other hand, it is assumed that

> were recorded as having occurred zero years before the survey - the birth rate falls less drastically, from 54 per thousand 5 to 9 years before the survey to 46 per thousand 0 to 4 years before the survey".

Brass and Rashad (1980) have applied the P/F ratio method and the Gompertz relational model with a view to detect errors and to adjust the fertility rates derived by using the birth history data from the BFS. They have also found that the fertility rates for Bangladesh were affected by a substantial amount of various reporting errors. Applying the P/F ratio method and Gompertz relational model, Brass and Rashad (1980) found the adjusted total fertility rates for Bangladesh for the period 1971-75 to be 7.5 and 7.4 respectively. Again, Brass (1981) applying the Gompertz relational model to the same set of data with a slightly modified fitting procedure adjusted the total fertility rates for Bangladesh for the periods 1961-65, 1966-70, and 1971-75 to be 7.4, 7.3, and 6.8 respectively. However, he has observed from the fitted model that the births in the period 5-14 years prior to the survey were over-reported and those in the past five years were modestly under-reported. He has also noted that the fertility decline in the period 0-4 years preceding the date of survey has occurred among young women, possibly as a result of a rising age at marriage and the decline might have been temporary because

Although it is difficult to detect the effects of various response errors on fertility estimates by internal consistency checks, because birth history data are edited for internal consistency, an alternative way to look for internal consistency is to compare the estimates of fertility obtained from the BFS with those available from other sources. A comparison of the available national estimates of TFRs from various sources (see Table 2.6), which are themselves found to be inconsistent for reasons indicated earlier, with those obtained from the BFS provides no indication whatever of the very high levels of fertility estimated from the BFS in the period 5-14 years before the survey or of the sharp decline in the period 0-4 years prior to the survey.

Table 2.7 shows that fertility rates at equivalent ages for various age groups (age at end of period) at different periods before the survey follow an irregular pattern. Except for the women aged 10-14 and the period 0-4 years prior to the survey, fertility rates for different periods beyond the 15 years preceding the survey were generally lower, particularly in rural areas. As there has been no evidence of lower fertility beyond the 15 years prior to the survey, this contradictory situation strongly suggests that some births in the relatively distant past were omitted, probably in addition to errors in dating of births.

children who have died or moved away from home, infants, females and illegitimate children are more likely to be omitted than others from birth histories. Omission of births is directly related to the time elapsed since the birth of child (Brass, 1979; Potter, 1975). This may be due to memory lapse associated with a larger number of births, longer intervals, and absence of children through death or migration. This is probably the reason why birth history analysts very often study fertility trends in the 10 or 15 years prior to the survey.

The national estimates of cumulative fertility rates (from Table 2.7) were 7.13 and 6.79 for cohorts aged 40-44 and 45-49 years at interview respectively. Although cumulative fertility for both the cohorts compares well with the mean parities 7.10 and 6.73 reported by the women aged 40-44 and 45-49 years respectively, the cumulative fertility rate for the oldest cohort as compared to that for the cohort aged 40-44 at interview seems to be an under-estimate of the actual fertility situation. Relatively lower cumulative fertility reported by the women belonging to the oldest cohort might be attributed to the following : (i) the women in this cohort might have failed to report some of their children due to memory lapse; (ii) this cohort might have experienced a lower fertility; (iii) there might have been age misreporting among the older cohorts; and (iv) there might have been selective survival of women in this cumulative fertility rates 6.67 and 6.96 for the cohorts aged 40-44 and 45-49 years respectively in urban areas, however, give no indication of such under-reporting of fertility by the oldest urban cohort.

Table 2.8 presents cohort-period fertility rates for marriage cohorts defined by duration of marriage at end of period. Since the upper age limit of the respondents has been 49 years, women at longer durations were necessarily married at young ages. Thus the rates for the longer duration cohorts (35-39, 30-34, and to a lesser extent 25-29) are affected by truncation bias and must be interpreted with caution. Moreover, the rates for the longer duration cohorts in the distant periods (when they were at early durations 0-4 or 5-9) might often be low due to teenage subfecundity.

Except for urban women at duration 0-4, the duration specific marital fertility rates in all the panels of Table 2.8 show a decline in the period 0-4 years prior to the survey which is consistent with the earlier finding. The rates for all the marriage duration cohorts, in general, seem to have been exaggerated in the period 5-14 years before the date of the survey. An examination of the changes in marital fertility rates at equivalent marriage duration groups for different periods before the survey also reveals a misleading picture (i.e., generally lower marital

Cohort-Period Fertility Rates by Duration of Marriage and Place of Residence: Bangladesh

Marriage Duration Group of Cohort at End of Period	No. of Women in Cohort	Years Prior to Survey							
		0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
				Rural					
0-4	896	.187	.201	.166	.131	.123	.120	.088	.036
5-9	830	.275	.323	.294	.254	.254	.214	.152	
10-14	905	.289	.365	.341	.309	.301	.253		
15-19	654	.272	.348	.347	.296	.260			
20-24	594	.211	.294	.271	.232				
25-29	471	.139	.211	.205					
30-34	434	.083	.141						
35-39	200	.024							
				Urban					
0-4	298	.278	.259	.231	.186	.207	.138	.136	.011
5-9	284	.323	.325	.347	.264	.259	.270	.142	
10-14	248	.281	.367	.352	.287	.336	.247		
15-19	222	.269	.299	.309	.305	.263			
20-24	141	.174	.258	.254	.237				
25-29	145	.124	.161	.226					
30-34	103	.047	.121						
35-39	38	.032							
			Total (Weighted)						
0-4	1173	.195	.206	.170	.136	.128	.121	.092	.035
5-9	1090	.279	.323	.299	.255	.254	.218	.152	
10-14	1167	.288	.365	.342	.307	.304	.252		
15-19	858	.271	.345	.344	.294	.260			
20-24	758	.209	.291	.270	.233				
25-29	613	.138	.208	.206					
30-34	554	.081	.140						
35-39	252	.025							

Source: Computed from the BFS, 1975-76

fertility for all duration groups beyond the period 0-14 years prior to the survey) which indicates that the rates were affected by a substantial amount of truncation bias and mis-dating of events. The apparent lower fertility rates for the longer duration cohorts in the earlier periods reflect teenage subfecundity and also the rates seem to have been affected by truncation bias combined with event misreporting.

To summerize, a substantial fertility decline in Bangladesh is found to have occurred during the period 0-4 years preceding the date of the survey. This decline might probably be associated with the social disruptions caused by the 1971 war of liberation and the 1974 widespread famine. Observed fertility rates beyond 15 years prior to the survey was found to be considerably affected by response errors, particularly the misplacement and ommission of events.

3. STOCHASTIC MODEL OF HUMAN FERTILITY

3.1 Socio-Biological Factors and Assumptions Regarding them in the Construction of the Model

Human fertility is a complex phenomenon influenced mostly by biological and sociological factors. However, some of the biological factors influencing fertility are socially determined. In other words, the social determinants of fertility act through some biological factors. For example, the reproductive span, demarcated biologically by menarche and menopause, may be shortened by postponement of marriage, by widowhood, divorce or separation, and by voluntary sterilization. Fertilization of ova may be prevented by using various contraceptive methods. Resumption of cohabitation following the termination of pregnancy is dependent on social customs and taboos. The onset of ovulation following a live birth may be suppressed by the practice of lactation which is culturally determined (Pool, 1970); and the effects of such suppression may be augmented by taboos on cohabitation during the period of lactation.

One of the most articulate categorizations of social-structural factors that affect fertility, whatever be the society under consideration, has been provided by Davis and Blake (1956). These 'intermediate variables' are grouped under three main headings: (1) factors affecting exposure to intercourse - the 'intercourse variables', (2) factors affecting exposure to conception - the 'conception variables', and (3) factors affecting exposure to gestation and parturition - the 'gestation variables'. Often it is possible to find social-structural factors corresponding to many of the biological factors influencing fertility.

Stochastic models of fertility which have been constructed so far are mainly based on biological factors and differ widely with respect to their underlying assumptions. Consequently, the expressions derived for various fertility characteristics differ from one model to another depending on their underlying assumptions. The present model is based on socio-biological factors and the following are the socio-biological factors and assumptions regarding them in the construction of the present model of human fertility.

1. A woman starts her reproductive span in a nonpregnant, fecundable stage following her entry into sexual union presumably after marriage. This assumption is based on the fact that in most of the developing countries marriage or some form of it is nearly universal. To illustrate: only 0.3 and 1.2 per cent of Bangladeshi women and men respectively aged 45-49 years were reported to have never married according to the 1981 Bangladesh population census (Bangladesh Bureau of Statistics, 1984).

2. For a married woman, the probability that an ovum becomes fertilized and implanted during any menstrual cycle is dependent on the interplay of many factors, such as

occurrence of ovulation during that menstrual cycle, the frequency and timing of coitus as related to ovulation, the practice of contraception, characteristics of the semen, and the age and health status of the woman and her spouse (Hartman, 1962). Thus, conception may be treated as a chance event, and the waiting time for a conception is a random variable.

3. Each conception terminates eventually either as a live birth or a fetal loss. A fetal loss is defined as any termination of pregnancy other than a live birth, so that it includes induced or spontaneous abortion, and stillbirth. The probability that the outcome of any conception will be a live birth or a fetal loss may depend on maternal age and health, rank order of the pregnancy, length of time from the termination of previous pregnancy to that conception (Nesbitt, 1957). The probability of a fetal loss will also be influenced by individual genetic or other characteristics of women (James, 1961). If pregnancy occurs, there are numerical probabilities associated with the termination of pregnancy in a live birth or a fetal loss.

4. After a conception, there is a period during which a woman is not susceptible to another conception. This period consists of the duration of pregnancy (gestation) and the interval after the termination of pregnancy until the resumption of ovulation (postpartum amenorrhea period) or cohabitation, whichever comes later. The durations of both

the pregnancy and the postpartum nonsusceptibility are related to the outcome of pregnancy, the mean duration being longer in the case of a live birth than a fetal loss. The gestation period for a live birth is a random variable and hence has a probability distribution. Similarly, the gestation period for a fetal loss is also a random variable and the probability distribution associated with it is generally different from that for a live birth. The postpartum amenorrhea period following a live birth is a random variable with a distribution function which may be influenced not only by the gestation period for the live birth, but also on the survival status of the child and on the breast-feeding practice of the mother, if the child survives. Similarly, the amenorrhea period for a fetal loss is a random variable, the distribution function of which depends on the gestation period of the fetal loss.

5. A woman runs the risk of death at any stage of her reproductive span. In most of the developing countries, where modern medical care is out of reach of a vast majority of population, death rates for females in the childbearing ages are usually higher than those of their male counterparts. For example, in Bangladesh mortality rates for males and females in the age span 15-44 years during the period 1962-65 were 4 and 8 per thousand population respectively estimated (Chandrasekar-Deming estimate) from the Population Growth Estimation (PGE) Experiment (Committee on Population and Demography, 1981). However, in the

developed countries, mortality at childbirth has been so greatly reduced by antisepsis and obstetrical skills that even in the childbearing ages females have lower death rates than males (Wrong, 1977).

6. The resumption of ovulation following the termination of pregnancy may be delayed for some time. The rank order of pregnancy, maternal age, outcome of pregnancy, social customs, and psychological factors may influence this delay (Henry, 1961c). Ovulation may be irregular when it is first resumed and the level of fecundability may be lower than the prepregnancy level. Subsequently, fecundability may increase to attain its previous level or some new level (Perrin and Sheps, 1964). The reproductive process starts anew after the resumption of ovulation and the above socio-biological considerations and assumptions will apply. However, as the biological factors depend on the age, parity, and other characteristics of women, the present model will allow for the variations in these characteristics to some extent by suitably grouping the women on the basis of these characteristics and assuming the female population in each group is homogeneous with respect to the characteristics under consideration.

The reproductive pattern of a married woman may be considered as consisting of passages through one or more mutually exclusive states as depicted in Figure 1. It should be remembered that some females suffer from primary sterility; they are never able to reproduce. Since they are assumed to form a very small proportion of female population in any society, the present model is concerned with the married, fecund women only. Again the married, non-sterile women may be classified into three groups according to their use of contraception. These groups may be formed as follows: (1) those who use efficient contraceptive methods (e.g., oral pill, condom, IUD, injectibles, sterilization) though the methods vary in efficiency, (2) those who use any other methods of contraception not included in (1), and (3) those who never use any contraceptive methods. Nevertheless, the schematic representation of the states of the model (Figure 1) will be the same for each group of women.

At the start of the sexual union, a woman is assumed to be in the nonpregnant, fecundable state S_0. After a random length of time, she may be in the pregnant state S_1 if she is being impregnated. From this state she may enter into the states S_2, S_3, S_4 or S_5 depending upon whether the pregnancy is terminated as a fetal loss by spontaneous abortion, fetal loss by induced abortion, stillbirth or a live birth. After remaining nonsusceptible to pregnancy for a random period of

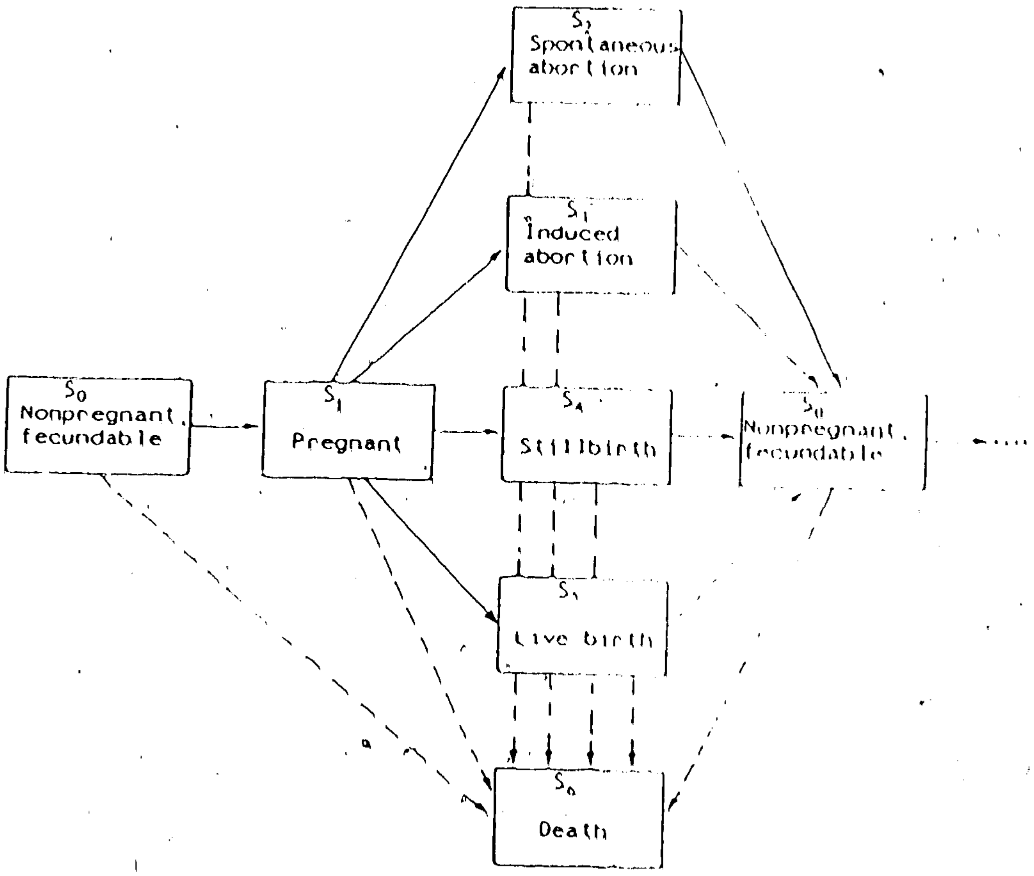

FIGURE 1. A Schematic Representation of the States in the Fertility Model

time, she eventually make a passage to the state S_0 to start the process anew. However, a woman may die at any state of the process and enter the absorbing state S_6 from any of the states S_0, S_1, S_2, S_3, S_4 or S_5. Thus the reproductive history of a woman is fully characterized by the sequence in which she visits various states and the length of stay in each state at each visit (Perrin and Sheps, 1964). For instance, the number of transitions from state S_1 to state S_5 in any specified period of time yields the number of live births borne by a particular woman in that period. Although the present model follows the framework suggested by Perrin and Sheps (1964), it incorporates the death state S_6 as an absorbing state. Hence it is more realistic than that of Perrin and Sheps, particularly in the cases of developing countries.

Under the assumptions regarding socio-biological factors (as described earlier), except for the death state, the length of stay in any state of the model can be viewed as a random variable with a distribution function which depends on the state being occupied and on the next state to which the passage is being made. If we further assume that the parameter of the various probability distributions and the transition matrix do not change over time, the reproductive history of a married woman can be characterized as a Markov renewal/semi-Markov process (Pyke, 1961a, 1961b). However, the above assumptions may not be exactly true because of the fact that the distribution of intervals for a first birth is expected to be different from that of intervals between subsequent births. In this case the reproductive history of a woman may be characterized as a general Markov renewal process (Kshirsagar and Gupta, 1969). Since a general Markov renewal process is the same as a Markov renewal process except for the first state and transition, it is possible to derive explicit mathematical results combining the two processes. However, various results for the present model will be derived from fundamental probability considerations along the lines suggested by Perrin and Sheps (1964) and by Krishnan (1971, 1977, 1979) without recourse to renewal theory.

3.3 Derivation of Results for the Model

In this section, we shall be concerned with the derivation of the results on the three characteristics which are important in the study of the patterns of human fertility. These characteristics are : (1) distribution of intervals between successive outcomes of pregnancy terminating in spontaneous abortions, induced abortions, stillbirths or live births, (2) expected number of live births, stillbirths, spontaneous abortions, and induced abortions per woman occurring in a specified period of time, and (3) annual probability of the occurrence of a live birth (fertility rate).

The following are the standard notations to be used in developing various results:

$P = (P_{ij})$ $(i,j = 0,1,2,\cdots,6)$

is the transition probability matrix

P_{ij} = probability of transition from state S_i to state S_j

T_{ij} = first passage time from state S_i to state S_j, i.e., the time taken by the process to go from state S_i to S_j for the first time, ignoring death state

T_{ii} = recurrence time for state S_i, i.e., starting from state S_i, the time taken by the process for the first return to state S_i, ignoring death state

T^*_{ij} = waiting time in state S_i before a direct transition to state S_j, ignoring death state

$G_{ij}(t)$ = distribution function of the first passage time from state S_i to state S_j, ignoring death state

$F_{ij}(t)$ = distribution function of the waiting time T^*_{ij}

$r^{(n)}_{ij}$ = nth moment of $G_{ij}(t)$

$\mu^{*(n)}_{ij}$ = nth moment of $F_{ij}(t)$

$\mu_{ij} = P_{ij}\mu^*_{ij}$

$\mu_i = \sum_j P_{ij}\mu^*_{ij}$

In accordance with the permissible paths as shown in Figure 1, the transition probability matrix P should have the following form:

$$\begin{array}{c|ccccccc|}
 & \text{Non-pregnant} & \text{Pregnant} & \text{Spon. abortion} & \text{Induced abortion} & \text{Still birth} & \text{Live birth} & \text{Death} \\
 & S_0 & S_1 & S_2 & S_3 & S_4 & S_5 & S_6 \\
S_0 & P_{00} & P_{01} & 0 & 0 & 0 & 0 & P_{06} \\
S_1 & 0 & 0 & P_{12} & P_{13} & P_{14} & P_{15} & P_{16} \\
S_2 & P_{20} & 0 & 0 & 0 & 0 & 0 & P_{26} \\
S_3 & P_{30} & 0 & 0 & 0 & 0 & 0 & P_{36} \\
S_4 & P_{40} & 0 & 0 & 0 & 0 & 0 & P_{46} \\
S_5 & P_{50} & 0 & 0 & 0 & 0 & 0 & P_{56} \\
S_6 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}$$

3.3.1 First Passage and Recurrence Times

Since the death state S_6 is an absorbing state, a female ,on entering it, cannot leave. A female may make a passage to the death state without reaching some of the other states in the state space. Hence the mean first passage time r_{ij} $(i,j = 0,1,2,\cdots,5)$ will be all infinite. However, the mean first passage time from all states to the death state $(r_{06}, r_{16}, r_{26}, \cdots, r_{56})$ can be obtained from the following theorem due to Barlow and Proschan (1967:135)

Theorem (Barlow-Proschan)

Let $[P, F(t)]$ be an absorbing semi-Markov Process with $k(0,1,2,\cdots,k-1)$ absorbing state where P has the normalized form

$$P = \left[\begin{array}{c|c} I & 0 \\ \hline R & Q \end{array}\right].$$

Then the mean time to absorption, starting from state i $(i > k)$ is

$$\sum_j r_{ij}\mu_j \qquad \text{where } (r_{ij}) = (I - Q)^{-1}$$

In the present case, the normalized form of P is given by

$$\begin{array}{c|ccccccc|} & S_6 & S_0 & S_1 & S_2 & S_3 & S_4 & S_5 \\ \hline S_6 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ S_0 & P_{06} & P_{00} & P_{01} & 0 & 0 & 0 & 0 \\ S_1 & P_{16} & 0 & 0 & P_{12} & P_{13} & P_{14} & P_{15} \\ S_2 & P_{26} & P_{20} & 0 & 0 & 0 & 0 & 0 \\ S_3 & P_{36} & P_{30} & 0 & 0 & 0 & 0 & 0 \\ S_4 & P_{46} & P_{40} & 0 & 0 & 0 & 0 & 0 \\ S_5 & P_{56} & P_{50} & 0 & 0 & 0 & 0 & 0 \end{array}$$

Here,

$$Q = \begin{bmatrix} P_{00} & P_{01} & 0 & 0 & 0 & 0 \\ 0 & 0 & P_{12} & P_{13} & P_{14} & P_{15} \\ P_{20} & 0 & 0 & 0 & 0 & 0 \\ P_{30} & 0 & 0 & 0 & 0 & 0 \\ P_{40} & 0 & 0 & 0 & 0 & 0 \\ P_{50} & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

Therefore

$$(I-Q) = \begin{bmatrix} 1-P_{00} & -P_{01} & 0 & 0 & 0 & 0 \\ 0 & 1 & -P_{12} & -P_{13} & -P_{14} & -P_{15} \\ -P_{20} & 0 & 1 & 0 & 0 & 0 \\ -P_{30} & 0 & 0 & 1 & 0 & 0 \\ -P_{40} & 0 & 0 & 0 & 1 & 0 \\ -P_{50} & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Next we compute $(r_{ij}) = (I - Q)^{-1}$ and the estimates of mean first passage time from various states to the death state are obtained by

$$r_{i6} = \sum_{j=0}^{5} r_{ij}\mu_j \qquad i = 0,1,2,\cdots,5$$

These results yielding mortality rates specific for the various pregnancy outcomes are, however, not of much interest to us.

It is to be noted that the states S_0, S_1, S_2, S_3, S_4, and S_5 are transient; there is, strictly speaking, no recurrence of these states since S_6 is an absorbing state. But we can think of recurrence of these states on the assumption of the survival of the female during the period under consideration. Now we shall develop some meaningful results from the model.

Let Y_{ij} $(i,j = 0,1,2,\cdots,5)$ denote the random length of time spent in state S_j before death given that the female started from state S_i. Let $E(Y_{ij})=m_{ij}$. The following are the mutually exclusive possibilities for a female in making a passage from state S_i to state S_j:

(i) the female may move directly from S_i $(i \neq 6)$ to the death state;

(ii) the female may move directly from S_i to S_j and then from S_j to the death state;

(iii) the female may move from S_i to S_k $(k \neq j,i)$ first and then from there move to S_j from where she moves to the death state.

Now the random length of time in nonpregnant fecundable state before death given that the female started from nonpregnant fecundable state (i.e., the recurrence time for nonpregnant fecundable state) is given by

$$Y_{00} = \begin{cases} T^{*}_{00} & \text{with probability } P_{00} \\ T^{*}_{01} + \underline{Y_{10}} & \text{with probability } P_{01} \\ T^{*}_{06} & \text{with probability } P_{06} \end{cases}$$

since a female who enters death state S_6 cannot return to any other state, $Y_{6j} = 0$ ($j = 0,1,2, \cdots,5$) with probability unity.

The expected recurrence time for the nonpregnant fecundable state is

$$\begin{aligned} E(Y_{00}) = m_{00} &= P_{00}E(T^{*}_{00})+P_{01}E(T^{*}_{01}+Y_{10})+P_{06}E(T^{*}_{06}) \\ &= P_{00}\mu^{*}_{00}+P_{01}\mu^{*}_{01}+P_{06}\mu^{*}_{06}+P_{01}m_{10} \\ &= \mu_{0}+P_{01}m_{10} \end{aligned} \quad (1)$$

To evaluate m_{10} we proceed as follows:

We have

$$Y_{10} = \begin{cases} T^{*}_{12}+Y_{20} & \text{with probability } P_{12} \\ T^{*}_{13}+Y_{30} & \text{with probability } P_{13} \\ T^{*}_{14}+Y_{40} & \text{with probability } P_{14} \\ T^{*}_{15}+Y_{50} & \text{with probability } P_{15} \\ T^{*}_{16} & \text{with probability } P_{16} \end{cases}$$

Then

$$m_{10} = E(Y_{10}) = \mu_{1}+ \sum_{i=2}^{5} P_{1i}m_{i0} \quad (2)$$

We have to evaluate m_{20}, m_{30}, m_{40}, and m_{50}. It is easy to see that

$$Y_{20} = \begin{cases} Y_{00} & \text{with probability } P_{20} \\ 0 & \text{with probability } (1-P_{20}) \end{cases}$$

because the female has to move to nonpregnant fecundable state S_0 with probability P_{20}.

Thus

$$m_{20} = E(Y_{20}) = P_{20}m_{00} \qquad (3)$$

Similarly

$$\begin{aligned} m_{30} &= P_{30}m_{00} \\ m_{40} &= P_{40}m_{00} \qquad (4) \\ m_{50} &= P_{50}m_{00} \end{aligned}$$

Using (2), (3), and (4) in (1), we have

$$m_{00} = \mu_0+P_{01}\mu_1+P_{01}(P_{12}P_{20}+P_{13}P_{30}+P_{14}P_{40}+P_{15}P_{50})m_{00}$$

$$\text{i.e.,} \quad m_{00} = \frac{\mu_0+P_{01}\mu_1}{1-P_{01}\sum_{i=2}^{5} P_{1i}P_{i0}} \qquad (5)$$

Now let us derive expressions for the random length of time a female in pregnant state before death given that she started from pregnant state (i.e., the recurrence time for pregnant state). We have,

$$Y_{11} = \begin{cases} T^{*}_{12}+Y_{21} & \text{with probability } P_{12} \\ T^{*}_{13}+Y_{31} & \text{with probability } P_{13} \\ T^{*}_{14}+Y_{41} & \text{with probability } P_{14} \\ T^{*}_{15}+Y_{51} & \text{with probability } P_{15} \\ T^{*}_{16} & \text{with probability } P_{16} \end{cases}$$

Then the expected recurrence time in months for the pregnant state is given by

$$m_{11} = E(Y_{11}) = \mu_{1} + \sum_{i=2}^{5} P_{1i}m_{i1} \qquad (6)$$

Now we have to evaluate m_{21}, m_{31}, m_{41}, and m_{51}. We can see that

$$Y_{21} = \begin{cases} Y_{20}+Y_{01} & \text{with probability } P_{20} \\ 0 & \text{with probability } (1-P_{20}) \end{cases}$$

because the female has to move to nonpregnant fecundable state S_0 with probability P_{20}. Then

$$m_{21} = E(Y_{21}) = P_{20}m_{20}+P_{20}m_{0} \qquad (7)$$

It is clear that

$$Y_{01} = \begin{cases} Y_{11} & \text{with probability } P_{01} \\ 0 & \text{with probability } (1-P_{01}) \end{cases}$$

Thus $m_{01} = E(Y_{01}) = P_{01}m_{11}$ (8)

From (3), (7) and (8), we get

$$m_{21} = P_{20}{}^2m_{00}+P_{20}P_{01}m_{11} \tag{9}$$

Similarly

$$\begin{aligned} m_{31} &= P_{30}{}^2m_{00}+ P_{30}P_{01}m_{11} \\ m_{41} &= P_{40}{}^2m_{00}+ P_{40}P_{01}m_{11} \\ m_{51} &= P_{50}{}^2m_{00}+ P_{50}P_{01}m_{11} \end{aligned} \tag{10}$$

Substituting the values of m_{21}, m_{31}, m_{41}, and m_{51} from (9) and (10) in (6), we obtain

$$\begin{aligned} m_{11} = \mu_1&+m_{00}(P_{12}P_{20}{}^2+P_{13}P_{30}{}^2+P_{14}P_{40}{}^2+P_{15}P_{50}{}^2) \\ &+P_{01}m_{11}(P_{12}P_{20}+P_{13}P_{30}+P_{14}P_{40}+P_{15}P_{50}) \end{aligned}$$

$$\text{i.e., } m_{11} = \frac{\mu_1+m_{00}\sum_{i=2}^{5} P_{1i}P_{i0}{}^2}{1-P_{01}\sum_{i=2}^{5} P_{1i}P_{i0}} \tag{11}$$

We shall be interested in finding the recurrence time for live births T_{55}. If mortality is ignored, we can follow the Perrin-Sheps (1964) procedure for computing various moments of T_{55}. According to our notation, $E(T_{55}) = r_{55}$. Ignoring mortality as in the Perrin-Sheps procedure is equivalent to experiencing very small probabilities of death P_{j6} $(j = 0,1,2,\cdots,5)$. In view of this, we see that m_{ij} and r_{ij} are almost equivalent. T_{55} can be obtained as follows:

$$T_{55} = T_{50}+T_{01}+\overset{(1)}{T}_{11\cdot\bar{5}}+\overset{(2)}{T}_{11\cdot\bar{5}}+ \cdots\cdot+\overset{(N)}{T}_{11\cdot\bar{5}}+\overset{*}{T}_{15} \tag{12}$$

where $T_{11\cdot\bar{5}}^{(k)}$ denotes the time spent in the kth consecutive recurrence of state S_1 without passage to state S_5. The total number of times, N, the female cycles between pregnant state S_1 without making a passage to state S_5 is equivalent to the "failures" (not having a live birth) before the first "success" (having a live birth). The probability distribution of the number of failures can be found to follow a geometric distribution with probability of success P_{15}. Thus

$$E(N) = (P_{12}+P_{13}+P_{14})/P_{15} \qquad (13)$$

$$\text{and } Var(N) = (P_{12}+P_{13}+P_{14})/P_{15}^2 \qquad (14)$$

From the Blackwell and Girshick theorem (1954) on the expectation of random sequences of random variables, we have from (12)

$$E(T_{55}) = m_{50}+m_{01}+E(N)E(T_{11\cdot\bar{5}})+\mu^*_{15}$$

$$= m_{50}+m_{01}+\mu^*_{15}+E(T_{11\cdot\bar{5}})[P_{12}+P_{13}+P_{14}]/P_{15} \qquad (15)$$

Now

$$T_{11\cdot\bar{5}} = \begin{cases} T^*_{12}+T_{20}+T_{01} & \text{with prob. } P_{12}/(P_{12}+P_{13}+P_{14}) \\ T^*_{13}+T_{30}+T_{01} & \text{with prob. } P_{13}/(P_{12}+P_{13}+P_{14}) \\ T^*_{14}+T_{40}+T_{01} & \text{with prob. } P_{14}/(P_{12}+P_{13}+P_{14}) \end{cases}$$

We have

$$E(T_{11\cdot\bar{5}}) = (P_{12}\mu^*_{12}+P_{12}m_{20}+P_{12}m_{01}+P_{13}\mu^*_{13}+P_{13}m_{30}$$

$$+P_{13}m_{01}+P_{14}\mu^*_{14}+P_{14}m_{40}+P_{14}m_{01})/(P_{12}+P_{13}+P_{14}) \qquad (16)$$

$$+P_{12}m_{20}+P_{13}m_{30}+P_{14}m_{40}+(P_{12}+P_{13}+P_{14})m_{01}]/P_{15}$$

$$\text{i.e., } P_{15}m_{55} \simeq P_{15}m_{50}+P_{15}m_{01}+(P_{12}\mu^*_{12}+P_{13}\mu^*_{13}+P_{14}\mu^*_{14}$$

$$+P_{15}\mu^*_{15})+P_{12}m_{20}+P_{13}m_{30}+P_{14}m_{40}$$

$$+(P_{12}+P_{13}+P_{14})m_{01}$$

$$= P_{15}m_{50}+m_{01}+\mu_1+P_{12}m_{20}+P_{13}m_{30}+P_{14}m_{40}$$

Thus

$$m_{55} \simeq [\mu_1+m_{01}+\sum_{i=2}^{5} P_{1i}m_{i0}]/P_{15}, \qquad (17)$$

which is the average waiting time between live births for a female.

In a similar way, the average waiting times between spontaneous abortions, induced abortions, or stillbirths for a female can be found to be, respectively:

$$m_{22} \simeq [\mu_1+m_{01}+\sum_{i=2}^{5} P_{1i}m_{i0}]/P_{12}, \qquad (18)$$

$$m_{33} \simeq [\mu_1+m_{01}+\sum_{i=2}^{5} P_{1i}m_{i0}]/P_{13}, \qquad (19)$$

and

$$m_{44} \simeq [\mu_1+m_{01}+\sum_{i=2}^{5} P_{1i}m_{i0}]/P_{14} \qquad (20)$$

state of live birth. This can be obtained as follows:

$$m_{05} \simeq E(T_{05}) = E(T_{55}-T_{50}) \qquad (21)$$

since $T_{55} = T_{50}+T_{05}$.

Using (17), we have

$$\begin{aligned} m_{05} &\simeq m_{55}-m_{50} \\ &\simeq [\mu_1+m_{01}+\sum_{i=2}^{5} P_{1i}m_{i0}]/P_{15}-m_{50} \\ &= [\mu_1+m_{01}+\sum_{i=2}^{4} P_{1i}m_{i0}]/P_{15} \qquad (22) \end{aligned}$$

Similarly, the expected length of the waiting time between the nonpregnant state and the state of spontaneous abortion, induced abortion, or stillbirth, respectively, can be easily found as:

$$m_{02} \simeq [\mu_1+m_{01}+\sum_{i=3}^{5} P_{1i}m_{i0}]/P_{12}, \qquad (23)$$

$$m_{03} \simeq [\mu_1+m_{01}+\sum_{i=4}^{5} P_{1i}m_{i0}+P_{12}m_{20}]/P_{13}, \qquad (24)$$

and

$$m_{04} \simeq [\mu_1+m_{01}+\sum_{i=2}^{3} P_{1i}m_{i0}+P_{15}m_{50}]/P_{14} \qquad (25)$$

It is of particular interest to determine the number of various pregnancy outcomes that can be expected to occur in a specified interval of time. Let $N_i(t)$ be the random number of times a woman enters S_i $(i = 0,1,2,\cdots,5)$ in time $(0,t]$. Then, for example, $N_5(t)$ is the number of live births borne by a woman in time t. We shall be particularly interested in computing the conditional means and variances of $N_i(t)$ given that the female starts from S_0, the nonpregnant fecundable state following her entry into sexual union.

According to Smith (1958), the sequence of recurrence times of S_i (i.e., $T^{(1)}_{ii},T^{(2)}_{ii},\cdots$) constitutes a renewal process. If this sequence is augmented with the first passage time from S_j to S_i (i.e., $T_{ji},T^{(1)}_{ii},T^{(2)}_{ii},\cdots$), we have a modified or general renewal process (Murthy, 1961). It follows from results on the general renewal process (Murthy, 1961) that the asymptotic mean and variance of $N_i(t)$ are given by the following approximate expressions:

$$E[N_i(t)/J_0=j] \simeq t/m_{ii}+m^{(2)}_{ii}/2m^{2}_{ii}-m_{ji}/m_{ii} \qquad (26)$$

and

$$Var[N_i(t)/J_0=j] \simeq t\sigma^{2}_{ii}/m^{2}_{ii}+5(m^{(2)}_{ii})^{2}/4m^{4}_{ii}-2m^{(3)}_{ii}/3m^{3}_{ii}$$
$$-m^{(2)}_{ii}/2m^{2}_{ii}-m_{ji}m^{(2)}_{ii}/m^{3}_{ii}+\sigma^{2}_{ji}/m^{2}_{ii}+m_{ji}/m_{ii} \qquad (27)$$

variance of T_{j1}.

From (26), we have the following:

(a) expected number of total pregnancies for a woman in (0,t] is

$$\simeq t/m_{11}+m^{(2)}_{11}/2m^{2}_{11}-m_{01}/m_{11} \qquad (28)$$

(b) expected number of spontaneous abortions for a woman in (0,t] is

$$\simeq t/m_{22}+m^{(2)}_{22}/2m^{2}_{22}-m_{02}/m_{22} \qquad (29)$$

(c) expected number of induced abortions for a woman in (0,t] is

$$\simeq t/m_{33}+m^{(2)}_{33}/2m^{2}_{33}-m_{03}/m_{33} \qquad (30)$$

(d) expected number of stillbirths for a woman in (0,t] is

$$\simeq t/m_{44}+m^{(2)}_{44}/2m^{2}_{44}-m_{04}/m_{44} \qquad (31)$$

and

(e) expected number of live births for a woman in (0,t] is

$$\simeq t/m_{55}+m^{(2)}_{55}/2m^{2}_{55}-m_{05}/m_{55} \qquad (32)$$

be obtained from (27).

To derive expressions for $m_{11}^{(2)}$, we proceed as follows:

We have,

$$m_{11}^{(2)} \simeq E(T_{11}^{2}) \simeq P_{12}E(T_{12}^{*}+T_{21})^{2}+P_{13}E(T_{13}^{*}+T_{31})^{2}$$

$$+P_{14}E(T_{14}^{*}+T_{41})^{2}$$

$$+P_{15}E(T_{15}^{*}+T_{51})^{2}+P_{16}E(T_{16}^{*})^{2}$$

$$= \mu_{1}^{(2)} + \sum_{i=2}^{5} P_{1i}m_{i1}^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i1} \qquad (33)$$

since $\mu_{ij}=P_{ij}\mu_{ij}^{*}$

Now $m_{21}^{(2)} \simeq E(T_{21}^{2}) \simeq P_{20}E(T_{20}+T_{01})^{2}$

$$\simeq P_{20}(m_{20}^{(2)}+m_{01}^{(2)}+2m_{20}m_{01}) \qquad (34)$$

From (3) and (4) we have,

$$m_{i0}^{(2)} \simeq E(T_{i0}^{2}) \simeq P_{i0}m_{00}^{(2)} \qquad i=2,3,4,5 \qquad (35)$$

Again

$$m_{00}^{(2)} \simeq E(T_{00}^{2}) \simeq P_{00}\mu_{00}^{*(2)}+P_{01}\mu_{01}^{*(2)}+P_{01}m_{10}^{(2)}$$

$$+2P_{01}\mu_{01}^{*}m_{10}$$

$$\simeq \mu_{0}^{(2)}+P_{01}m_{10}^{(2)}+2P_{01}\mu_{01}^{*}m_{10} \qquad (36)$$

$$m_{10}^{(2)} \simeq E(T_{10}^{2}) \simeq \mu_1^{(2)} + P_{12}m_{20}^{(2)} + P_{13}m_{30}^{(2)} + P_{14}m_{40}^{(2)} + P_{15}m_{50}^{(2)}$$

$$+2(\mu_{12}m_{20} + \mu_{13}m_{30} + \mu_{14}m_{40} + \mu_{15}m_{50})$$

$$= \mu_1^{(2)} + \sum_{i=2}^{5} P_{1i}m_{i0}^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i0} \qquad (37)$$

From (35), (36), and (37) we get,

$$m_{00}^{(2)} \simeq \mu_0^{(2)} + P_{01}[\mu_1^{(2)} + \sum_{i=2}^{5} P_{1i}P_{i0}m_{00}^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i0} + 2\mu_{01}^{*}m_{10}]$$

$$\text{ie, } m_{00}^{(2)} \simeq [\mu_0^{(2)} + P_{01}\{\mu_1^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i0} + 2\mu_{01}m_{10}\}]/$$

$$[1 - P_{01}\sum_{i=2}^{5} P_{1i}P_{i0}] \qquad (38)$$

From (35) and (38) we obtain,

$$m_{20}^{(2)} \simeq P_{20}[\mu_0^{(2)} + P_{01}\{\mu_1^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i0} + 2\mu_{01}^{*}m_{10}\}]/$$

$$[1 - P_{01}\sum_{i=2}^{5} P_{1i}P_{i0}] \qquad (39)$$

$$\text{Now, } m_{01}^{(2)} \simeq E(T_{01}^{2}) \simeq P_{01}E(T_{11}^{2}) \simeq P_{01}m_{11}^{(2)}. \qquad (40)$$

Using (39) and (40) in (34) we have,

$$m_{21}^{(2)} \simeq P_{20}^{2}[\mu_0^{(2)} + P_{01}\{\mu_1^{(2)} + 2\sum_{i=2}^{5} \mu_{1i}m_{i0} + 2\mu_{01}^{*}m_{10}\}]/$$

$$[1 - P_{01}\sum_{i=2}^{5} P_{1i}P_{i0}] + P_{20}P_{01}m_{11}^{(2)} + 2P_{20}m_{20}m_{01} \qquad (41)$$

$$m_{k1}^{(2)} \simeq P_{ko}^{2}[\mu_o^{(2)}+P_{o1}\{\mu_1^{(2)}+2\sum_{i=2}^{5}\mu_{1i}m_{io}+2\mu^{*}_{o1}m_{1o}\}]/$$

$$[1-P_{o1}\sum_{i=2}^{5}P_{1i}P_{io}]+P_{ko}P_{o1}m_{11}^{(2)}+2P_{ko}m_{ko}m_{o1} \qquad k=3,4,5 \tag{42}$$

Using (41) and (42) in (33) we get,

$$m_{11}^{(2)} \simeq \mu_1^{(2)}+\sum_{i=2}^{5}P_{1i}P_{io}^{2}[\mu_o^{(2)}+P_{o1}\{\mu_1^{(2)}+2\sum_{i=2}^{5}\mu_{1i}m_{io}+2\mu^{*}_{o1}m_{1o}\}/$$

$$[1-P_{o1}\sum_{i=2}^{5}P_{1i}P_{io}]+P_{o1}\sum_{i=2}^{5}P_{1i}P_{io}]m_{11}$$

$$+2m_{o1}\sum_{i=2}^{5}P_{1i}P_{io}m_{io}+2\sum_{i=2}^{5}\mu_{1i}m_{i1}$$

$$\text{ie, } m_{11}^{(2)} \simeq \{\mu_1^{(2)}+\sum_{i=2}^{5}P_{1i}P_{io}^{2}[\mu_o^{(2)}+P_{o1}(\mu_1^{(2)}+2\sum_{i=2}^{5}\mu_{1i}m_{io}+2\mu^{*}_{o1}m_{1o})]/$$

$$[1-P_{o1}\sum_{i=2}^{5}P_{1i}P_{io}]+2(m_{o1}\sum_{i=2}^{5}P_{1i}P_{io}m_{io}+\sum_{i=2}^{5}\mu_{1i}m_{i1}\}/$$

$$[1-P_{o1}\sum_{i=2}^{5}P_{1i}P_{io}] \tag{43}$$

If the second raw moments of the direct passage time from nonpregnant state as well as from pregnant state to various possible states of the model are known, $m^{(2)}_{11}$ can be easily evaluated from (43).

A quantity of special interest is $m^{(2)}_{55}$, the second raw moment of inter-live birth interval. Before deriving the expression for $m^{(2)}_{55}$, we find out the variance of T_{55}.

Subtracting (13) from (12) we get,

$$T_{55}-E(T_{55}) \simeq (T_{50}-m_{50})+(T_{01}-m_{0,1})+(T^*_{15}-\mu^*_{15})$$

$$+[T^{(1)}_{11.\hat{s}}-E(T_{11.\hat{s}})]+\cdots+[T^{(N)}_{11.\hat{s}}-E(T_{11.\hat{s}})]$$

$$+[N.E(T_{11.\hat{s}})-E(N)E(T_{11.\hat{s}})] \qquad (44)$$

Squaring both sides of (44) and taking expectation, we get (cf. Blackwell and Girshick, 1954) the following:

$$E[T_{55}-E(T_{55})]^2 \simeq E[T_{50}-E(T_{50})]^2+E[T_{01}-E(T_{01})]^2$$

$$+E[T^*_{15}-E(T^*_{15})]^2+E(N).E[T_{11.\hat{s}}-E(T_{11.\hat{s}})]^2$$

$$+[E(T_{11.\hat{s}})]^2E[N-E(N)]^2$$

i.e., $\text{Var}(T_{55}) \simeq \text{Var}(T_{50})+\text{Var}(T_{01})+\text{Var}(T^*_{15})$

$$+E(N)\text{Var}(T_{11.\hat{s}})+[E(T_{11.\hat{s}})]^2\text{Var}(N) \qquad (45)$$

Since $\text{Var}(T_{55}) = E(T_{55}^2)-[E(T_{55})]^2 \simeq m^{(2)}_{55}-(m_{55})^2$, we have from (45),

$$m^{(2)}_{55} \simeq \text{Var}(T_{50})+\text{Var}(T_{01})+\text{Var}(T^*_{15})$$

$$+E(N)\text{Var}(T_{11.\hat{s}})+[E(T_{11.\hat{s}})]^2\text{Var}(N)+(m_{55})^2 \qquad (46)$$

Now, $\text{Var}(T_{50}) = E(T_{50}^2)+[E(T_{50})]^2 \simeq P_{50}E(T_{00}^2)-P_{50}^2m_{00}^2$

$$\simeq P_{50}m^{(2)}_{00}-P_{50}^2m_{00}^2 = P_{50}(m^{(2)}_{00}-P_{50}m_{00}^2) \qquad (47)$$

$$\text{Var}(T_{01}) = E(T_{01}^2)-[E(T_{01})]^2 \simeq P_{01}E(T_{11}^2)-P_{01}^2m_{11}^2$$

$$\simeq P_{01}(m^{(2)}_{11}-P_{01}m_{11}^2) \qquad (48)$$

and

$$
\begin{aligned}
\mathrm{Var}(T_{11\cdot\bar{5}}) &= E(T_{11\cdot\bar{5}}^{2})-[E(T_{11\cdot\bar{5}})]^{2} \\
&= [P_{12}E(T_{12}^{*}+T_{20}+T_{01})^{2}+P_{13}E(T_{13}^{*}+T_{30}+T_{01})^{2} \\
&\quad +P_{14}E(T_{14}^{*}+T_{40}+T_{01})^{2}]/(1-P_{15}) \\
&\quad -[E(T_{11\cdot\bar{5}})]^{2} \\
&\simeq [(P_{12}\mu_{12}^{*(2)}+P_{13}\mu_{13}^{*(2)}+P_{14}\mu_{14}^{*(2)}) \\
&\quad +(P_{12}m_{20}^{(2)}+P_{13}m_{30}^{(2)}+P_{14}m_{40}^{(2)})+m_{01}^{(2)}(P_{12}+P_{13}+P_{14}) \\
&\quad +2P_{12}(\mu_{12}^{*}m_{20}+m_{20}m_{01}+\mu_{12}^{*}m_{01}) \\
&\quad +2P_{13}(\mu_{13}^{*}m_{30}+m_{30}m_{01}+\mu_{13}^{*}m_{01}) \\
&\quad +2P_{14}(\mu_{14}^{*}m_{40}+m_{40}m_{01}+\mu_{14}^{*}m_{01})]/(1-P_{15}) \\
&\quad -[E(T_{11\cdot\bar{5}})]^{2} \\
&\simeq [\mu_{1}^{(2)}-P_{15}\mu_{15}^{*(2)}+\sum_{i=2}^{4}P_{1i}m_{i0}^{(2)}+m_{01}^{(2)}(P_{12}+P_{13}+P_{14}) \\
&\quad +2\sum_{i=2}^{4}\mu_{1i}m_{i0}+2m_{01}\sum_{i=2}^{4}P_{1i}m_{i0} \\
&\quad +2m_{01}\sum_{i=2}^{4}P_{1i}\mu_{1i}]/(1-P_{15})-[E(T_{11\cdot\bar{5}})]^{2} \qquad (49)
\end{aligned}
$$

If the second raw moments of the direct passage time from pregnant state to the various states of the model are known, $m^{(2)}_{55}$ can be easily obtained from (46) using (13),(14),(17),(47),(48) and (49).

On similar lines, $m_{22}^{(2)}$, $m_{33}^{(2)}$, and $m_{44}^{(2)}$ can be evaluated.

3.3.3 Annual Fertility Rate

The annual probability of live birth for a homogeneous cohort of women is dependent on the length of exposure of the women in the cohort since entry into sexual union. Usually a woman tends to have a greater probability of conceiving during the early months of marriage (Sheps and Perrin, 1964; Leridon, 1977). It is very difficult to derive an explicit mathematical result for the probability of live birth as a function of the duration of marriage. However, considering the entry into the state S_5 (live birth) as the act of renewal and viewing the model to follow the renewal process, the probability of the occurrence of a live birth at time t can be obtained by subtracting the expected number of live births in time (0,(t-1)] from the number expected in time (0,t] (Perrin and Sheps, 1964). That is,

$$\text{Prob[Passage into } S_5 \text{ at time t]} \doteq E[N_5(t)]-E[N_5(t-1)] \qquad (50)$$

Applying Blackwell's theorem (Smith, 1958) in (32), it follows that the asymptotic annual fertility rate for a homogeneous cohort of women, which is observed for a reasonable length of time, is approximately equal to $1/m_{55}$ i.e., the reciprocal of the mean recurrence time for live births.

4. APPLICATION OF THE MODEL TO BANGLADESH

4.1 Reproductive Data for Marriage Cohorts

Data to be fitted to the stochastic model developed in chapter 3 should ideally be generated by a group of women exposed to the risk of conception. The group of women are all observed for the occurrence of conceptions from a specified date, such as the date of marriage, the date of first visit to a birth control clinic, the date of discontinuation of a contraceptive method, or a fixed calendar date. In this study, two recent five-year first marriage cohorts of women (first married during 1965-69 and 1970-74) were considered. These two cohorts were selected because the reporting of various demographic events are expected to be relatively more reliable among the members of these cohorts. Moreover, if a group of women is followed for more than 10- or 15- year period, the model becomes less adequate because of the assumption of constant fecundability (Perrin and Sheps, 1965).

The dates of conception were not available in the BFS. However, as stated earlier, the dates of different order pregnancies terminating in live births or non-live births were available in century month code. The dates of conceptions were calculated by subtracting 9, 8, 3, and 3 months from the dates of termination of pregnancies as live births, stillbirths, spontaneous abortions, and induced abortions respectively.[1] The women who reported themselves to be infecund at the time of survey were excluded from the analysis. The 1965-69 first marriage cohort consisted of 1,114 women of whom 29 were infecund while 1,120 women formed the 1970-74 marriage cohort in which there were 26 infecund women. Both the spontaneous and induced abortions were combined together because there were very few cases of these.

4.4.1 Distribution of Conceptions

Distribution of first order conceptions by months since first marriage occurred to women in each of the five-year marriage cohorts was obtained as discussed earlier. To allow for the conceptions occurring to women who entered the five-year marriage cohorts in the fifth year, all pregnancies terminated in live births or non-live births in the following year were taken into consideration. For example, live births or non-live births occurred to women in the year 1975 who were first married during the year 1974 were ta[illegible] into account in the distribution of conceptions for the 1970-74 marriage cohort. For simplicity, the distribution of first order conceptions was restricted to first 12 months since marriage. It is to be noted that 19 and 2 months were taken as the average postpartum non-susceptible period associated with a live birth and a

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[1] The average durations of pregnancies were taken as 9 months for live births, 8 months for stillbirths, 3 months for spontaneous abortions, and 3 months for induced abortions (see, for example, Huffman et al. 1980).

non-live birth respectively (see, for instance, Bongaarts and Potter, 1983; Huffman et al., 1980; Chen et al., 1974). Relatively longer period of postpartum amenorrhea following a live birth may be attributed to the prolonged period of lactation, the mean duration of which was found to be 24.4 and 20.9 months for rural and urban women respectively in Bangladesh (Nag, 1983). For rural Matlab Thana in Bangladesh, Chen et al. (1974) also found that the median duration of breastfeeding exceeded 24 months.

For five-year marriage cohorts, one should ideally consider up to third order conceptions. However, as there were only 46 and 55 cases of reported second order conceptions, and 11 and 7 third order conceptions to the 1965-69 and 1970-74 first marriage cohorts respectively during the first 12 months since the end of first and second order postpartum amenorrhea, the present study is restricted to only first order conceptions. Since the distribution of first order conceptions is expected to be different from that of second or higher order conceptions, the results derived in this study may approximate the reproductive behaviour of a group of women during the early years of marriage. Among 1085 and 1094 fecund women belonging to the 1965-69 and 1970-74 first marriage cohorts respectively, 25 and 22 women reported first order conception before the date of marriage. These cases of reported conceptions before the date of marriage were excluded from the analysis.

Table A.1 shows the distribution of first order conceptions in the first 12 months since first marriage for the 1965-69 and 1970-74 first marriage cohorts. It should be pointed out that among 1,060 fecund women (excluding those who reported conception before the date of marriage) who were married for the first time during 1965-69, only 223 (21.0 per cent) were found to have conceived in the first 12 months of marriage. Also among 1,072 fecund women (omitting those who reported conception before the date of marriage) belonging to the 1970-74 cohort, 22.0 per cent had a first order conception during the first year of marriage.

There are several possible explanations for the unusually lower proportion of women conceiving in the first year of marriage. The mean age at first marriage among females in Bangladesh has been very low; it is, for example, 13.0 years for the 1966-70 first marriage cohort and 14.1 years for the 1971-75 cohort (see chapter 2), and the mean age at menarche is 15.7 years (Bongaarts and Potter, 1983). Lower age at first marriage and higher age at menarche combined with the sub-fecundity among adolescent females in the Indian sub-continent (Chandrasekaran, 1961) contribute to the delayed conception. Moreover, the prevalent social custom, particularly in rural areas, of frequent and long visits by the newly married females to their parental homes lead to infrequent cohabitation with their husbands and for most of these women "... first births are characteristically delayed until two or three years after marriage" (Chen et

It is worthwhile to note from Table A.1 that the proportions of conception ending in live births, stillbirths, and abortions were 0.96, 0.03, and 0.01 respectively for the 1965-69 first marriage cohort and the corresponding proportions for the 1970-74 cohort were 0.92, 0.03, and 0.05. Perrin and Sheps (1965) have suggested that the proportion of pregnancies which terminate in live births is approximately 0.80, in stillbirths approximately 0.02, and in abortions approximately 0.18. From the reasonably complete vital registration data in Matlab Thana, Bangladesh, Chen et al. (1974) have estimated the probability of a live birth, a stillbirth, and an abortion per conception at 0.85, 0.02, and 0.13 respectively. The apparent lower proportion of abortions in the BFS, which in turn inflated the proportion of conceptions resulting in live births, may be attributed to the under-reporting of the occurrence of abortions, particularly of spontaneous abortions since women are frequently not aware of early spontaneous abortions (see, for example, Leridon, 1977; Bongaarts, 1975; Bongaarts and Potter, 1983).

.2 Transition Probability Matrix

The elements of the transition probability matrix were obtained as follows:

The estimate of P_{00} was obtained for a marriage cohort as the proportion of women who did not conceive during the first 12 months since first marriage while the proportion of women who had conceived in the first year of marriage was taken as an estimate of P_{01}. The estimate of $P_{1(2-3)}$, the annual probability that a pregnancy will end in an abortion (spontaneous and induced) was obtained as the proportion of pregnant women whose pregnancy terminated in an abortion. Similarly, P_{14} and P_{15} were estimated for a marriage cohort as the proportions of pregnant women whose pregnancies ended in stillbirths and live births respectively.

Transition probabilities from various states to the death state, $P_{06}, P_{16}, \cdots, P_{56}$ could not be estimated directly because of the lack of data. However, using the model life table constructed for Bangladesh (Census Commission, 1977), indirect estimates of the probability of death were obtained by subtracting the survival ratios corresponding to mean ages of the cohorts (see Table A.9) from unity. The elements of the transition probability matrix were finally adjusted in order to make the row totals equal unity. The transition probability matrices for both the 1965-69 and 1970-74 cohorts are shown in Table A.10 and those for selected social backgrounds of women in these cohorts are presented in Tables A.11, A.12, ····, A.16.

4.3 Mean Waiting Time in Various States Before a Direct Transition to Another State

The waiting time for conception is a function of fecundability. The higher the fecundability, the shorter the conception wait. For a homogeneous group of women with same levels of fecundability, there is an exact inverse relationship between conception wait and fecundability (Henry, 1953; Sheps and Menken, 1973). Thus mean waiting time in nonpregnant fecundable state before a direct transition to pregnant state (μ^*_{01}) for a marriage cohort is estimated as the reciprocal of fecundability. Fecundability (p), in turn, was estimated by assuming that the waiting time for conception in months (T) since first marriage follows a geometric distribution (see, for instance, Sheps and Perrin, 1964; and Leridon, 1977) with parameter p. Then the probability that the first conception occurs at month T is given by

$$\text{Prob}(T = x) = (1 - p)^x p \qquad x = 0,1,2,\cdots$$

We have,

$$E(T) = (1 - p)/p$$

$$\text{and } Var(T) = (1 - p)/p^2$$

p was estimated from the monthly distribution of conceptions by equating the sample mean to (1 - p)/p, the population mean and solving for p, assuming that all first married women constitute a homogeneous group.

According to our model $\mu^*_{00} = \mu^*_{01}$. Since detailed data are not available, the values of $\mu^*_{1(2-3)}$, μ^*_{14}, μ^*_{15}, $\mu^*_{(2-3)0}$, μ^*_{40}, μ^*_{50} for both the 1965-69 and 1970-74 cohorts as well as for various background characteristics of women are assumed to be 0.25, 0.66667, 0.75, 0.16667, 0.16667 and 1.58333 years respectively (as discussed earlier). Mean waiting time from various states to the death state for the cohorts and for selected social backgrounds of women in the cohorts are assumed to be equal to the expectation of life corresponding to their mean age (see Table A.9).

5. FERTILITY PATTERNS AND DIFFERENTIALS: RESULTS FROM STOCHASTIC REPRESENTATION

5.1 Introduction

A sound knowledge of the patterns of occurrence of conceptions and births to women as they progress through their childbearing period is essential for understanding the dynamics of human fertility in any society. Most of the studies so far carried out have been concerned with the analysis of the patterns of pregnancies in cohorts of married women with a particular emphasis on the patterns of live births as they occur in time. This is because the data regarding live births are more readily available and more complete than those for conceptions. Most studies are restricted to cohorts of married women since the cohorts are formed of a relatively homogeneous group of women for whom it is possible to study the patterns of fertility in details when the pregnancy history of each woman in the cohort is known.

Fertility pattern is a function of two classes of determinants: (1) socio-economic and environmental 'background' variables, and (2) proximate variables. The former consist of social, economic, institutional, cultural, psychological, health and environmental variables while the proximate determinants include biological and behavioural factors through which the background variables must operate to influence fertility (Davis and Blake, 1956; Bongaarts and

Potter, 1983; Bongaarts et al., 1984). The proximate determinants include the following variables: proportion of women married or in sexual unions, frequency of intercourse, postpartum abstinence, lactational amenorrhea, contraception, induced abortion, spontaneous intrauterine mortality, natural and pathological sterility (Bongaarts et al., 1984). Socioeconomic and environmental variables influence fertility only indirectly by modifying the proximate determinants, where as the main characteristic of a proximate determinant is its direct effect on fertility.

The inclusion of proximate determinants in the study of fertility patterns provides an improved understanding of the influences of the socioeconomic determinants. For example, education as a socioeconomic variable could generally have a negative effect on fertility through the use of contraception and a positive effect through the influence of education on the length of breastfeeding. Thus depending on the relative contributions of the positive and negative effects of the proximate determinants on fertility, the net effect of a socioeconomic variable could be negative, positive, or insignificant.

In this Chapter, fertility patterns and differentials in Bangladesh are studied by the application of the stochastic model developed in Chapter 3 for two selected first marriage cohorts of women (first married during 1965-69 and 1970-74) in terms of conception intervals, interlive birth intervals, and annual probability of a live birth. Differential fertility patterns are studied by rural-urban, educational, and religious backgrounds of Bangladeshi women. As the numbers of reported cases of stillbirth and abortion were very small for both the cohorts (see appendix Tables A.1 to A.7) and the data on these are not reliable (as pointed out earlier), the present study of fertility patterns and differentials is restricted to live births only: Although it is difficult to incorporate the proximate determinants directly into the model, the relative contributions of most of them in determining fertility patterns are discussed, wherever appropriate.

5.2 Conception Wait and Fecundability

A susceptible woman (who ovulates and engages in regular intercourse) takes, on the average, several months to conceive. The most reliable estimate of waiting time to conception can be obtained from the interval between the date of marriage and the date of first conception (Bongaarts, 1983). Mean conception waits estimated from the interval between the dates of first marriage and first conception for two selected first marriage cohorts as well as for selected social characteristics of women are presented in Table 5.1. Average conception waits for the 1965-69 and 1970-74 first marriage cohorts are estimated at 6.9 and 6.6 months respectively. These estimates fall in the range of 5 to 8 months, with typical values close to 7

Table 5.1

Estimates of Mean Waiting Time in Years in Non-pregnant State Before a Direct Transition to Pregnant State by First Marriage Cohorts of Women and Selected Social Characteristics: Bangladesh

Characteristics	First Marriage Cohort	
	1965-69	1970-74
A All	.57847 (.144)	.54995 (.152)
B Place of Residence†		
Rural	.59032 (.141)	.55227 (.152)
Urban	.50225 (.166)	.54487 (.153)
C Level of Schooling		
No Schooling	.60517 (.138)	.57264 (.152)
Others	.52885 (.158)	.51684 (.161)
D Religion		
Muslim	.57971 (.144)	.55807 (.149)
Non-Muslim	.57265 (.146)	.51871 (.161)

Source: Estimated from the BFS, 1975-76.

Note: Figures in parantheses refer to the estimates of fecundability.

†Unweighted.

months, estimated from the first pregnancy interval of non-contracepting women in some historical populations and in some developing countries (see, for example, Bongaarts, 1983; Wilson, 1980; Balakrishnan, 1979; Leridon, 1977; Majumdar and Sheps, 1970; Jain, 1969; Potter and Parker, 1964). Mean conception wait for women in the 1965-69 cohort is found to be slightly longer than that for women in the 1970-74 cohort. This may be explained in part by relatively lower mean age at marriage for the 1965-69 cohort (see Table A.8), although the fertility performance of a proportion of women belonging to the 1970-74 cohort was presumably affected by the social disruptions caused by the 1971 war of liberation and the 1974 famine. Since the incidence of anovulatory cycles are usually higher for younger women in the years immediately following menarche, conception waits tend to be longer for these women (Balakrishnan, 1979; Jain, 1969).

It is to be noted that the mean conception wait for rural women in Matlab Thana during 1975-76 was estimated at 10.9 months (Chowdhury, 1978). This estimate, though not strictly comparable, is much higher than the corresponding estimate in the present study. Moreover, this estimate was based on pregnancies of all orders. Since coital frequency tends to fall with the rise in age and/or duration of marriage, mean conception wait is expected to be longer for older women although, Bongaarts (1983) suggests that the difference in mean conception waits for successive birth intervals may be quite small, at least for women aged up to the late thirties. Chowdhury's estimate might also be affected by some upward bias as the waiting time for conception of a proportion of women overlapped with the 1974-75 famine.

Differentials in mean conception wait among women broadly classified by place of residence, level of schooling, and religiosity can also be seen in Table 5.1. Mean conception waits for both the cohorts under study are found to be longer for women living in rural than urban areas, for women with no schooling than those with at least some schooling, and for Muslims than non-Muslims. Differentials in mean age at first marriage (see Table A.8) may partly be accounted for these differentials in mean conception waits. However, the differences in mean waiting time for conception among women with different background characteristics range from 0.01 month to 1.0 month.

Table 5.1 also presents estimates of fecundability levels following first marriage. About 14 per cent of all women married for the first time in the period 1965-69 may be expected to conceive during a month, while about 15 per cent of the corresponding women in the 1970-74 cohort may be expected to conceive during a month. In a two-year prospective study of 200 women in rural Bangladesh (Matlab Area) during 1968-89, Chen et al. (1974) estimated the mean fecundability for a woman to be 0.10. This estimate was found to be affected by the seasonal occupational absences of husbands from home for rice harvests in other areas and fishing in the major rivers as the study was conducted in a rural agricultural and fishing society. Correcting for the factor of seasonal migration of husbands, the mean fecundability was adjusted to be 0.13 (Chen et al., 1974). The estimated mean fecundability for the rural 1965-69 first marriage cohort of women in the present study closely agrees with the adjusted mean fecundability for Matlab women, although these two estimates are not strictly comparable.

When the women are classified according to the selected social characteristics, the estimates of mean fecundability are found to be higher for the 1970-74 cohort as compared to the 1965-69 cohort with the exception of urban women. Since, there is an exact reciprocal relationship between fecundability and conception wait for a homogeneous cohort of women (as pointed out earlier), differentials in mean fecundability are thus found to be exactly opposite to those in mean waiting time for conception.

In general, differences in the estimates of fecundability are observed between cohorts and between socioeconomic groups. Even though adhoc explanations can be provided to explain these differences, a more detailed socio-demographic theoretical examination is called for.

5.3 Mean First Passage Time

Tables 5.2 and 5.3 present estimates of mean first passage time from one selected state to another selected state of the model for 1965-69 and 1970-74 first marriage cohorts of women respectively. These tables also show the estimates of mean first passage time for selected social characteristics of women. The estimate of m_{01}, mean first passage time from state S_0 to state S_1 (average time spent by a woman in the nonpregnant fecundable state until first or next pregnancy), is found to be about 6.7 months for the 1965-69 cohort and 7.2 months for the 1970-74 cohort. Mean first passage time from nonpregnant to pregnant state is assumed to be inversely related to fertility. The higher mean first passage time for women in the 1970-74 cohort as compared to that in the 1965-69 cohort is consistent with the lower fertility of the 1970-74 cohort mainly attributed to the social disruptions during the first half of the 1970s.

It may be pointed out that the estimates of mean first passage time from nonpregnant to pregnant state should be consistent with the estimates of mean waiting time in nonpregnant state before a direct transition to pregnant state as found in the preceding Section. The estimate of m_{01} for the 1965-69 cohort is found to be lower while the mean conception wait higher than those for the 1970-74 cohort. One of the plausible reasons for this inconsistency may be

Table 5.2

Estimates of Mean First Passage Time ($\hat{m}_{ij}$) in Years from State S_i to State S_j of the Model for 1965-69 First Marriage Cohort of Women by Selected Social Characteristics: Bangladesh .

Characteristics	Selected $\hat{m}_{ij}$		
	$\hat{m}_{01}$	$\hat{m}_{10}$	$\hat{m}_{50}$
A All	0.55902	2.11822	1.19913
B Place of Residence†			
Rural	0.54567	2.11474	1.20153
Urban	0.86337	2.27360	1.31636
C Level of Schooling			
No Schooling	0.48762	2.08765	1.17738
Others	0.80543	2.26526	1.33407
D Religion			
Muslim	0.56136	2.12537	1.20844
Non-Muslim	0.57887	2.14896	1.22015

Source: Estimated from the BFS, 1975-76.
†Unweighted.

A	All	0.59915	2.13437	1.21646
B	Place of Residence†			
	Rural	0.54104	2.08996	1.17723
	Urban	1.60974	2.74330	1.78995
C	Level of Schooling			
	No Schooling	0.52348	2.09238	1.18261
	Others	0.76788	2.23130	1.30013
D	Religion			
	Muslim	0.54570	2.10307	1.18647
	Non-Muslim	0.94901	2.33775	1.41077

Source: Estimated from the BFS, 1975-76.
†Unweighted.

of marriage spends on the average slightly more than 25 months until she is fecundable again (Tables 5.2 and 5.3). Relatively longer mean first passage time from pregnant to nonpregnant fecundable state has ensued from unusually prolonged duration of postpartum amenorrhea associated with a live birth, the average duration of which was assumed to be 19 months (see Chapter 3). However, the mean duration of postpartum amenorrhea following a live birth estimated from the model are found to be about 14.4 and 14.6 months for the 1965-59 and 1970-74 cohorts respectively. It is worthwhile to note that these estimates do not differ much from the mean duration of lactational amenorrhea of 16.4 months among rural Matlab women aged below 30 years with surviving infants (Chen et al., 1974).

An examination of Tables 5.2 and 5.3 reveals that the estimates of m_{01}, m_{10}, and m_{50} for both the 1965-69 and 1970-74 first marriage cohorts are higher for urban than rural women, for women with at least some schooling than those with no schooling, and for non-Muslims than Muslims. The differentials in mean first passage time from

Bangladesh, 1978). Rural-urban differential in the mean first passage time from susceptible state to pregnant state is found to be more pronounced among women in the 1970-74 cohort (the mean first passage time is almost three-fold for urban women compared to their rural counterparts). This has probably ensued from the fact that about 6 per cent of rural women as against 23.4 per cent of urban women in the 1971-75 first marriage cohort were reported to have ever used any contraceptive method (see Table 2.5).

It is to be noted that both the estimates of m_{10}, and m_{80} are highly influenced by the duration of postpartun amenorrhea which in turn is largely affected by the duration of breastfeeding (Bongaarts, 1983; Billewicz, 1979; Van Ginnenken, 1977; Buchanan, 1975). This is because suckling of infant stimulates secretion of prolactin from the pituitary gland which not only plays an important role in milk production but also have a direct inhibitory effect on the release of gonadotrophins which initiate resumption of menstruation (McNeilly, 1979; Buchanan, 1975). Available evidence suggests that, for developing countries, the mean duration of lactation is generally higher for rural than that they would be higher for non-Muslims than Muslims. The estimates of m_{10} and m_{50} for both the cohorts of women classified according to various social backgrounds are found to support the above hypothesis.

Pronounced rural-urban differentials in both m_{10} and m_{50} are observed for women belonging to the 1970-74 cohort. Unusually high values of both m_{10} and m_{50} for urban women in the 1970-74 cohort compared to their rural counterparts may be attributed, among others, to the following factor: The mean duration of postpartum amenorrhea following a live birth, which has been assumed to be 19 months irrespective of social backgrounds of women in the estimation of both m_{10} and m_{50}, is expected to be lower than 19 months for urban women because of the relatively lower duration of breastfeeding among urban mothers who generally have higher educational and employment opportunities outside home, and have greater use of breast milk substitutes.

of women in these cohorts. Mean recurrence time for pregnant state (m_{11}), i.e., mean conception interval, is estimated at 32.0 months for the 1965-69 cohort and 32.7 months for the 1970-74 cohort. On the other hand, the estimates of mean live birth interval (m_{55}) are found to be 33.6 and 36.0 months for the 1965-69 and 1970-74 cohorts respectively. Since all conceptions do not generally lead to live births, mean conception interval is expected to be lower than mean live birth interval. This is because of the fact that the duration of postpartum amenorrhea following a non-live birth is smaller than that following a live birth. Although the estimates of mean conception interval for both the cohorts are found to be lower than the corresponding mean live birth interval, the difference between m_{55} and m_{11} in the case of 1965-69 cohort is unexpectedly small. One of the plausible reasons for this may be the relative under-reporting of non-live births among women in the 1965-69 cohort (see Table A.1).

Using the stochastic model developed by Perrin and Sheps (1964), Chen et al. (1974) have estimated the mean conception interval at 28.7 months and mean live birth

Characteristics	Selected $\hat{m}_{ii}$			Asymptotic Fertility Rate per Woman
	$\hat{m}_{00}$	$\hat{m}_{11}$	$\hat{m}_{55}$	
A All	1.20396	2.66798	2.79870	0.35731
B Place of Residence†				
Rural	1.20633	2.65725	2.79188	0.35818
Urban	1.32212	3.08191	3.32991	0.30031
C Level of Schooling				
No Schooling	1.18206	2.57607	2.66647	0.37503
Others	1.34045	3.07122	3.30818	0.30228
D Religion				
Muslim	1.21346	2.68671	2.81226	0.35559
Non-Muslim	1.22544	2.71310	2.88035	0.34718

Source: Estimated from the BFS, 1975-76.
†Unweighted.

Characteristics	Selected $\hat{m}_{ii}$			Asymptotic Fertility Rate per Woman
	$\hat{m}_{00}$	$\hat{m}_{11}$	$\hat{m}_{55}$	
A All	1.22203	2.72255	2.99616	0.33376
B Place of Residence†				
Rural	1.18252	2.62094	2.91650	0.34288
Urban	1.79963	4.32620	4.58849	0.21794
C Level of Schooling				
No Schooling	1.18779	2.60617	2.89587	0.34532
Others	1.30653	2.98532	3.24173	0.30848
D Religion				
Muslim	1.19180	2.63863	2.87211	0.34818
Non-Muslim	1.41790	3.27019	3.75879	0.26604

Source: Estimated from the BFS, 1975-76.
†Unweighted.

and m_{55} derived in the present study are not strictly comparable to those for Matlab women mainly because of the ages of women in the two studies are different, and Matlab Thana represents only a small area in rural Bangladesh. Nevertheless, the estimates of m_{11} and m_{55} for rural women in both the cohorts are higher compared to those for Matlab women, with the exception of m_{55} for the 1965-69 cohort. Apparently higher estimates of m_{11}, in particular, found in the present study may partly be attributed to the under-reporting of non-live births among women in the BFS as pointed out earlier.

Both the estimates of m_{11} and m_{55} are expected to be positively related to the practice of contraception and negatively related to the duration of lactation. As discussed in the preceding Section, the use of contraception is higher while the duration of lactation is lower among urban than rural women, among women with at least some schooling than those with no formal schooling, and among non-Muslims than Muslims. Thus it may be hypothesized that both m_{11} and m_{55} would be inversely associated with the levels of education and urbanization, and that they would be higher for non-Muslims than Muslims. The estimates of both m_{11} and m_{55} derived in the present study are consistent with

1970-74 cohort.

5.5 Annual Fertility Rate

The model estimates of annual fertility rate per woman based on the reproductive experiences of 1965-69 and 1970-74 first marriage cohorts of women are found to be 0.375 and 0.334 respectively (Tables 5.4 and 5.5). Assuming the average biological reproductive span of Bangladeshi women to be 25 years, with age at menarche at 15 years and menopause at 40 years and this span is lowered by about 4 years mainly because of widowhood, the effective reproductive period is estimated at 21 years (Chen et al., 1979). Thus based on the reproductive experiences of 1965-69 and 1970-74 first marriage cohorts, the number of live births that would be borne by an average Bangladeshi woman are estimated to be 7.5 (0.357x21)* and 7.0 (0.334x21) respectively. These estimates are equivalent to the conventional total fertility rate (TFR). Despite the various simplified assumptions, the model estimates of TFR derived in the present study for the 1965-69 and 1970-74 cohorts are in close agreement with the adjusted estimates of TFR for the periods 1966-70 and 1971-75 respectively obtained by using the Gompertz relational model (see Chapter 2). However, the above change in the levels of fertility in Bangladesh over the past remains somewhat contentious, although several nationally representative studies conducted during the 1960s and early 1970s involving different methodologies document slight but irregular fertility decline (see Table 2.6). For example, discussing the apparent declining trend in fertility evidenced by the National Impact Survey, 1968-69, Chen et al. (1979: 6) conclude that "[w]hile a decline in fertility may have occurred in the ten years preceding the Impact Survey, it seems likely that the extent of any true decline was overestimated by the survey, and it is possible that there was no decline at all". Although fertility in Bangladesh is found to have declined during the early half of the 1970s attributed mainly to the disruptions caused by the 1971 war of liberation and the 1974 widespread famine, this decline might probably be only temporary and fertility might revert to its previous roughly constant trend (Amin and Faruqee, 1980). Evidence from the vital registration data in Matlab Thana has indicated that the TFR has been rising since the year 1975 (Ruzicka and Chowdhury, 1978a, 1978b; Chowdhury and Sheikh, 1980). Thus it may be argued that fertility in Bangladesh was probably constant in the past with some fluctuations and it might probably be constant for at least some short period in the future.

fertility is generally higher than that of the followers of other major religions (see, for example, Cochrane, 1979, 1983; Rodriguez and Cleland, 1980; Chaudhury, 1984; Goldstein, 1972; Stycos, 1967; Kirk, 1966). The plausible reasons underlying the differentials in fertility for various sub-groups of population classified according to the levels of education, place of residence, and religious affiliation are suggested as follows:

Formal education tends to depress the level of fertility by raising the age at marriage, by reducing the desired family size with an increased awareness of substituting child quality for numbers, by higher aspirations of the standards of living, by providing better understanding of the process of reproduction and greater access to modern methods of contraception, and by allowing for better husband-wife communication in childbearing decision-making. Further, educated mothers are expected to take better pre-natal and post-natal care which reduce the chances of infant deaths. This in turn may result in the reduction of the desire for more children.

Urbanization also tends to affect fertility negatively attributed mainly to the availability of better contraceptive supply and services, better schooling to have better survival prospects of children to adulthood which might have depressing effects on fertility. Also relatively higher costs of food and housing in urban areas are likely to have negative influences on fertility.

The factors favouring high fertility among Muslims than non-Muslims are suggested as: Islam encourages early marriage and universality of marriage. Most followers of Islam tend to maintain that a child is born according to the wishes of God and it is the God who will take care of the well-being of the child and thus have an unfavourable attitude towards the practice of contraception. The majority of Muslim women observe the seclusion of purdah, often confined to the household and are often poorly educated.

An examination of Tables 5.4 and 5.5 reveals that the model estimates of fertility for the 1965-69 and 1970-74 first marriage cohorts of women are higher for rural than urban women, for women with no schooling than those with at least some schooling, and for Muslims than non-Muslims. Thus fertility differentials for both the cohorts of women classified according to place of residence, levels of schooling and religion are consistent with those documented in most of the other studies. It is interesting to note that the rural-urban and religious diffentials in fertility are that during the period of liberation war (which continued for about 9 months) urban areas were more affected by the social disruptions than rural areas and the followers of Hinduism, who form the vast majority of non-Muslims, were mostly affected by the disruptions and a large number of them had to take refuge in neighbouring India during the liberation period.

To sum up, the estimates of fecundability, mean duration of postpartum amenorrhea following a live birth, mean conception and live birth intervals derived in this chapter by the application of the model are not out of line with those found for Matlab Thana. The model estimates of TFR obtained in this study also agree with those found by employing the Gompertz relational model. Moreover, fertility differentials by place of residence, education, and religious affiliation are in the expected direction as documented in most of other studies. Although the goodness of fit of the model could not be tested statistically, the agreement of the results derived by the application of the model with those of other studies seems to confirm the general validity of the model.

6.1 Major Findings

This thesis has attempted to develop a stochastic model to study the fertility patterns of marriage cohorts of women in terms of conception interval, live birth interval, and annual probability of the occurrence of a live birth. Differential fertility patterns by rural-urban, educational and religious backgrounds of Bangladeshi women have been investigated by applying the model. The source of data employed in this study is the Standard Recode File BD. SR03 and the Individual Recode File BD. IN01 created from the Bangladesh Fertility Survey, 1975-76 conducted under the auspices of the World Fertility Survey.

Total fertility rates for the periods 0-4, 5-9, and 10-14 years preceding the survey are found to be 6.10, 8.27, and 8.02 respectively. Reported fertility is found to have declined substantially during the period 0-4 years before the date of the survey. Whether this decline was real or an artifact of the quality of data caused by the misplacement of dates of birth of women and their children, or/and omission of births is a difficult question which cannot be resolved conclusively. However, the 1971 war of independence and the 1974 food crisis associated with heavy monsoon flooding and crop failure, which might have reduced the proportion of women vulnerable to conception, may partly be

The observed fertility rates in the period 5-14 years preceding the survey are somewhat exaggerated, a feature mainly associated with the misplacement of earlier births forward and recent births backward in time while reporting the events. Reported fertility rates beyond 15 years preceding the survey are unreliable because the birth history data in the relatively distant past are more likely to be affected by various response errors, particularly omissions and misplacement of events.

A stochastic model of human fertility is developed under certain assumptions regarding socio-biological factors that influence reproductive behaviour. Expressions for the distribution of intervals between successive outcomes of pregnancy, expected number of various possible outcomes of pregnancy occurring to an woman during a specified period of time, and the annual probability of the occurrence of a live birth have been derived from fundamental probability consideration.

study. Although fertility patterns and differentials are studied using the data on the estimated first order conceptions occurred to these cohorts during the first 12 months since first marriage, the model takes care of subsequent conceptions after allowing for the duration of postpartum amenorrhea following the termination of each pregnancy.

Fertility patterns and differentials are studied for the 1965-69 and 1970-74 first marriage cohorts of Bangladeshi women in terms of mean waiting time to conception, mean conception interval, mean live birth interval, and annual probability of a live birth. A woman in the 1965-69 cohort waits on the average 6.9 months to conceive while the corresponding wait for a woman in the 1970-74 cohort is estimated at 6.6 months. Mean conception waits for both the cohorts, though not marked, are found to be longer among rural than urban women, among women with no schooling than those with at least some scholing, and among Muslims than non-Muslims. Lower mean ages at first marriage for rural, illiterate, and Muslim women as compared to their first passage time from nonpregnant to pregnant state for the 1970-74 cohort as compared to that for the 1965-69 cohort is consistent with the observed lower fertility of women in the 1970-74 cohort, as the mean first passage time from susceptible to pregnant state is assumed to be negatively related to fertility. Although the estimates of mean first passage time from susceptible to pregnant state should be consistent with those of the mean conception wait, the discrepancy (estimate of m_{01} for the 1965-69 cohort is lower whereas the mean conception wait higher compared to the corresponding estimate for the 1970-74 cohort) may have ensued from the different procedures of their estimation. Estimates of mean conception wait were obtained from the reported first order conceptions only during the first 12 months since first marriage while those for m_{01} were derived using the model which takes into consideration the distribution function of waits at various states of the model and is not limited to first order conception alone.

The estimates of mean conception interval (m_{11}) are found to be 32.0 and 32.7 months for the 1965-69 and 1970-74 under-reporting of conceptions terminating in non-live births. Based on the available evidence, it may be hypothesized that the mean conception wait, mean conception interval, and mean live birth interval would be higher for urban than rural women, for women with at least some schooling than those with no schooling, and for non-Muslims than Muslims. Estimates of m_{01}, m_{11}, and m_{55} for both the 1965-69 and 1970-74 first marriage cohorts of women obtained in the present study support the above hypothesis.

Based on the reproductive experiences of 1965-69 and 1970-74 first marriage cohorts of women, annual fertility rates per woman are estimated at 0.375 and 0.334 respectively. Assuming the effective biological reproductive lifespan of an average Bangladeshi woman to be 21 years, the number of live born children that would be produced by an average woman (which is equivalent to the conventional TFR) are estimated to be 7.5 for the 1965-69 cohort and 7.0 for the 1970-74 cohort. If fertility of Bangladeshi women is assumed to remain roughly constant, the model estimates of TFR for the cohorts may be considered to be equivalent to the corresponding period estimates. The model estimates of and education, and Muslims have higher fertility than non-Muslims as documented in most of the other studies on fertility differentials.

6.2 Methodological Implications

The stochastic model developed in this study may provide insights into the interactions of various socio-economic and biological factors and their influences on fertility rates. For instance, the model may help in exploring the influences of contraception, pregnancy wastage (including induced abortion), and prolonged lactation, and interactions between these factors, on the distribution of intervals between births and the expected number of births. Insights gained from the model may contribute to an improved basis for predicting changes in fertility patterns.

One of the most important implications of the model is its potential contribution to the evaluation of existing population policies. Appropriate results derived from the model may provide a useful means of examining the possible changes in fertility rates which may be expected to result from changes in the practice of contraception or changes in abortion rates. The model applied to various groups of women completely realistic, the results may provide "... an improved basis for predicting the possible effects of specified changes in reproductive behavior, whether or not these changes result from planned public policy" (Sheps et al., 1969: 178).

6.3 Policy Implications

Some findings of the present study merit consideration from the standpoint of policy implications for fertility regulation in Bangladesh which faces a serious problem of population growth vis-a-vis socioeconomic underdevelopment. The following policy recommendations may be suggested, based on the findings of this study, with a view to diffuse wider use of contraception that may lead to the reduction in fertility.

For a traditional, predominantly rural, Muslim, and premodern agrarian society where a vast majority of the population are illiterate, attention should be focused on the need of providing educational facilities to the people, particularly to the Muslim females in rural areas. The question naturally arises: what are prospects of expanding educational opportunities? Is it possible for the economy of future, the only realistic alternative seems to be the introduction of some kind of nonformal functional education. Less expensive nonformal educational programs of utilitarian nature, especially for rural Muslim women through creative use of mass media, and voluntary associations are likely to provide general enlightenment and this may lead to wider use of contraception. Such programs may also provide skills for productive work and facilitate participation in national planning and development.

Along with the efforts to improve educational status of women, there is a need for taking steps, especially through mass media to bring about changes in social attitudes towards women. In Bangladesh, women are socialized from childhood to be mainly mothers, their activities outside the home are very limited, and they are considered subservient to their male counterparts (Jahan, 1975; Chaudhury, 1984). Moreover, girls are economically less valued than boys in the family and the prevailing socio-religious customs in Bangladesh present strong constraints against later age at marriage for them. Thus efforts must be made to change socio-cultural norms and traditions which disparage the value of women. Various programs aimed at creating alternatives to childbearing (e.g., employment opportunities

The present study has been affected by a number of limitations. The stochastic model developed in this study is highly simplified and less realistic in some respects. Various results derived for the model are valid for an individual female for whom the model can be assumed to hold. Hence the results are applicable only if the female population is homogeneous with respect to all the characteristics under consideration. Although the two recent five-year first marriage cohorts considered in this study are homogeneous with respect to marital duration, there are age, socioeconomic and other background differences among the members of these cohorts. However, the cohorts classified according to place of residence, educational, and religious backgrounds of women may be considered to form relatively more homogeneous groups.

The model involves some strong assumptions. It assumes that the probabilities of conception, live births, stillbirths, abortions, and the lengths of gestation and postpartum infecundable periods are constant for an individual female regardless of age and parity. This is, in general, not true. For example, the probability of conception for a given woman, though may be taken to be constant for a relatively short period of observation, is a around 13 years, the probability of conception for newly married females depends heavily on the age at menarche. The probabilities of conception terminating in non-live births may also be functions of age and rank order of pregnancy of a woman. Moreover, the probabilities may vary among women in a given marriage cohort. Although it is very difficult to overcome the above limitations, one could minimize these limitations by applying the model to the marriage cohorts controlling for age and order of conceptions of women. This could not be done in the present study because of the smaller sizes of the marriage cohorts and fewer reported conceptions higher than the first order do not justify using the age and the order of pregnancy as control variables.

The model assumes constant durations of gestation and postpartum infecundability for each type of pregnancy outcomes. This is not always true. For instance, postpartum infecundability following a premature live birth may be shorter than that for a full term live birth because there is an increased probability of neonatal death for a premature live birth which may be expected to result in a shorter period of breastfeeding. However, this may be overcome by subdividing the live birth state into two states - premature live birth state and full term live birth state.

An important limitation of the present study is imposed by fitting the model to the data on first order conceptions occurring to the cohorts of newly married females during a short fraction of their reproductive period ignoring truncation effect. Thus results derived in this study may serve as approximations to the actual reproductive process of a group of women during their early years of marriage. Further, this study does not take into consideration such factors as age at menarche (which is important in the case of Bangladesh), and the use of contraception. Moreover, the imputation of dates of events for a vast majority of respondents who were unable to report these dates in calendar years and months might have some effects on various results derived in this study.

Due to lack of data, mean waiting time in various states of the model before a direct transition to next possible state is assumed to be the same for all women in a marriage cohort irrespective of their background characteristics. For example, mean waiting time since the termination of pregnancy in a live birth until the resumption of ovulation (which depends on the duration of lactation) is assumed to be 19 months for all women in a marriage cohort. This assumption is not tenable because differential fertility patterns by some important background characteristics of women, such as age at first marriage, labour force participation, use of contraception, etc. which have considerable policy relevance could not be studied. Thus if a study of fertility patterns using the stochastic model is to be carried out in future, there is a need for conducting an specially designed sample survey for input data. Alternatively, one may generate detailed data on human reproductive histories for a marriage or birth cohort of women through Monte Carlo simulation. A comparison of the results derived by the application of the stochastic model with those obtained through Monte carlo simulation may be useful for investigating the dynamics of conception and birth intervals.

The stochastic model developed in this study does not explicitly involve the proximate determinants through which socioeconomic, cultural, and environmental factors operate to influence fertility patterns. One problem of future research is to incorporate the proximate variables into the model. Infant mortality which influences the biological and behavioural aspects of human reproduction should also be incorporated explicitly into the model.

TABLES

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S. M. Shafiqul Islam
13 August, 1986

PREGNANCY HISTORY TABLE

308. INTERVIEWER: USE ONE ROW OF THE PREGNANCY HISTORY TABLE FOR EACH PREGNANCY, STARTING WITH THE FIRST AND PROCEEDING CHRONOLOGICALLY, (THAT IS, THE FIRST PREGNANCY IN THE FIRST LINE, THE SECOND PREGNANCY IN THE SECOND LINE........ UPTO THE LAST PREGNANCY). IF TWINS, USE ONE LINE FOR EACH AND CONNECT WITH A BRACKET AT THE LEFT.

THE FOLLOWING QUESTION SEQUENCES ARE TO BE ASKED TO RECORD PREGNANCY HISTORIES FOR THE FIRST SEGMENT, THAT IS, THE INTERVAL BETWEEN MARRIAGE AND THE FIRST LIVE BIRTH.

IF RESPONDENT HAS HAD ANY LIVE BIRTH:

309. Now I want to ask you some questions about each of your pregnancies, that is each live birth, each still birth, each miscarriage and each abortion. If you have had any of these or any children who have died or who live away from home I would like to know about them.

What is the name of your first baby born alive ________________________
(name)

310. After you (first) were married and before.........................(name) was born, did you have any other pregnancies?

YES [1]   NO [2]

YES [1]	NO [2]
NOW ASK 319-323 AND RECORD FOR THE FIRST PREGNANCY. REPEAT 319-323 FOR EACH PREGNANCY UNTIL THE FIRST LIVE BIRTH IN THIS INTERVAL. THEN REPEAT NAME OF FIRST BABY BORN ALIVE UNDER 313 IN THE NEXT ROW. ASK 315-318 AND RECORD. NOW ASK 313 AND 314 AND ACCORDINGLY PROCEED TO EITHER 315-318 OR 319-323. REPEAT SEQUENCE FOR ALL REMAINING PREGNANCIES.	ENTER THE NAME OF FIRST LIVE BIRTH UNDER 313. ASK 315-318 AND RECORD. NOW ASK 313 AND 314 AND ACCORDINGLY PROCEED IN THE NEXT ROW TO EITHER 315-318 OR 319-323. REPEAT SEQUENCE FOR ALL REMAINING PREGNANCIES.

IF PREGNANCY OCCURRED TO THE RESPONDENT IN THE PAST BUT NOT RESULTED IN LIVE BIRTH:

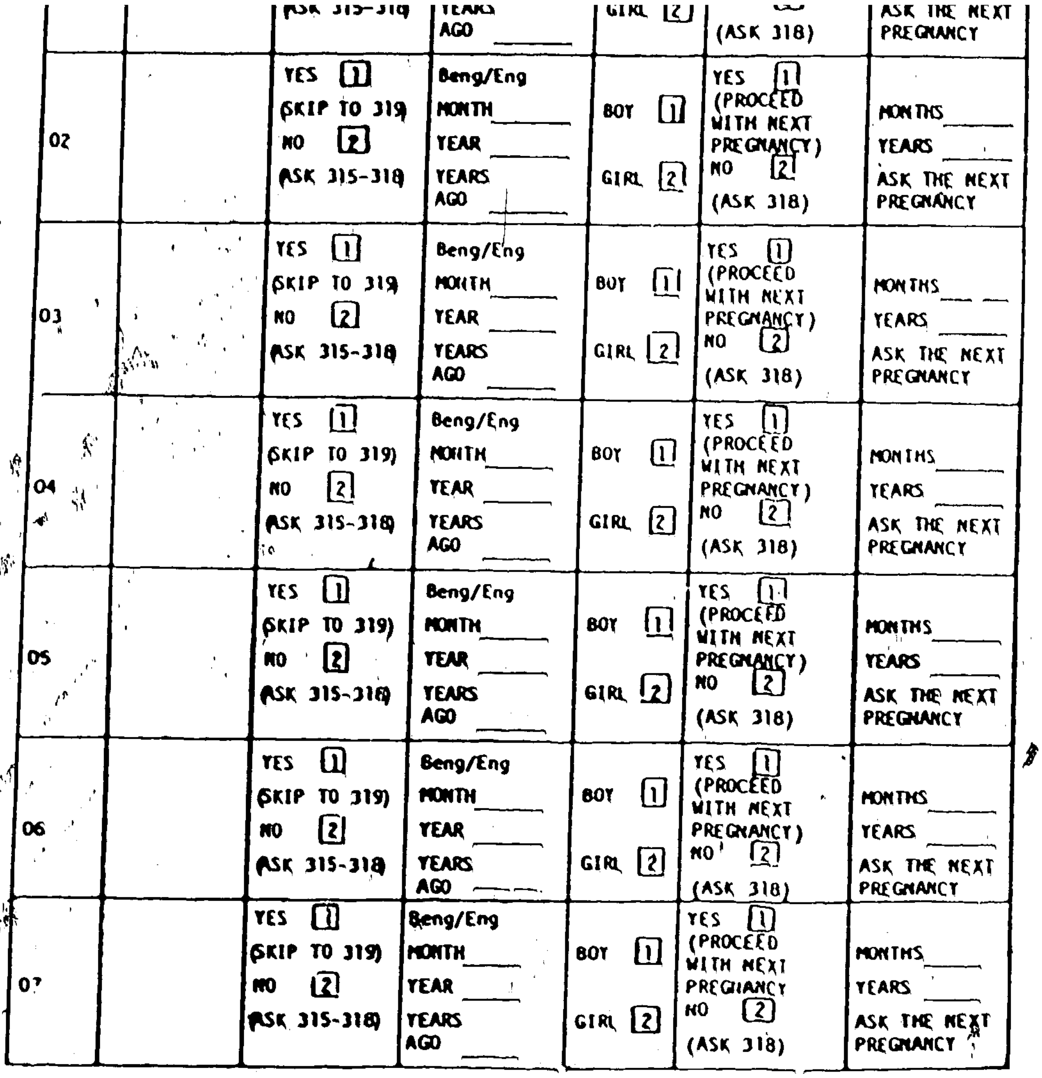
311. Think back to your first (second...............etc.) pregnancy and tell me about it.

INTERVIEWER: NOW ASK 319-323. REPEAT SEQUENCE FOR EACH PREGNANCY

IF NO PAST PREGNANCY OCCURRED TO THE RESPONDENT:

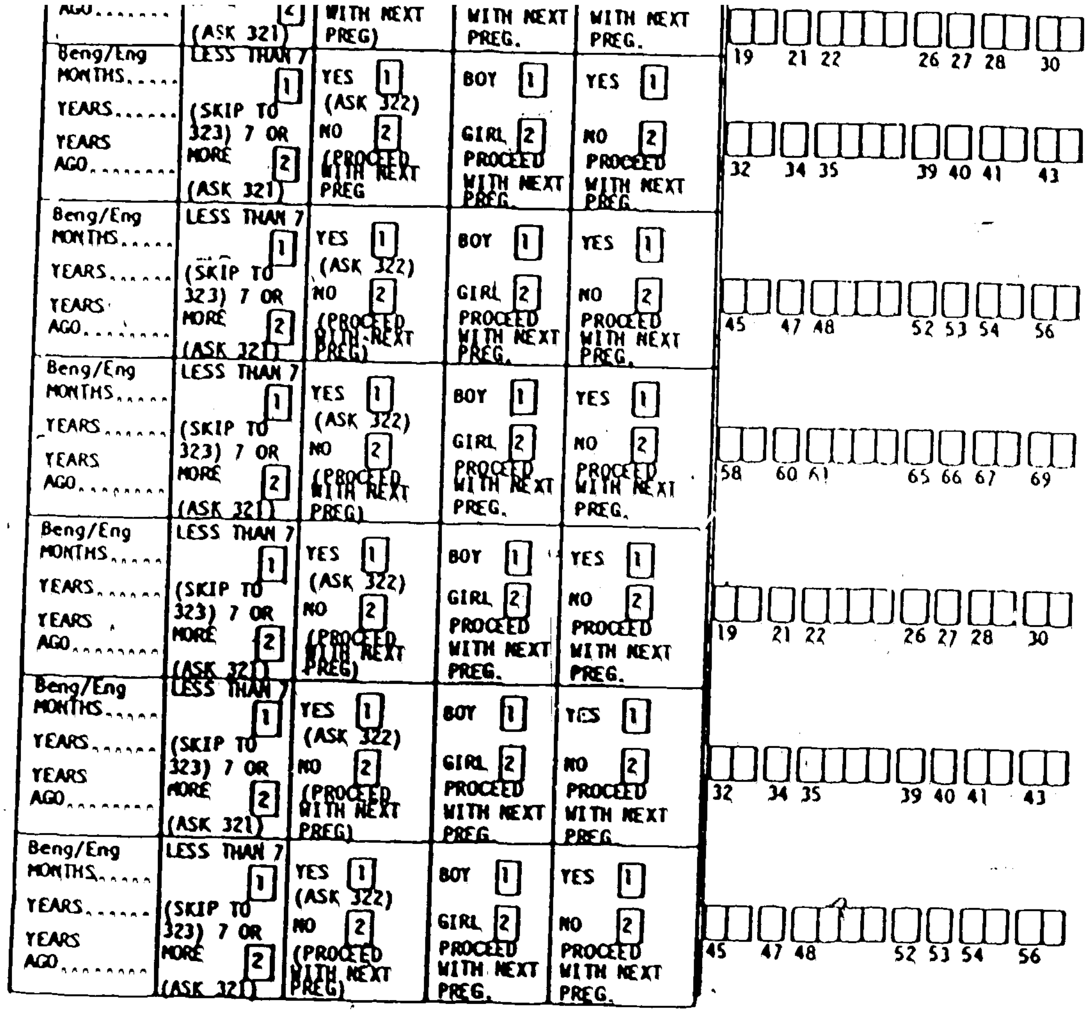
(Skip to 333)

Source: Reproduced from Bangladesh (1978 : C9)



		(ASK 315-318)	YEARS AGO ______	GIRL 2	(ASK 318)	ASK THE NEXT PREGNANCY
02		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY) NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY
03		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY) NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY
04		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY) NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY
05		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY) NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY
06		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY) NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY
07		YES 1 (SKIP TO 319) NO 2 (ASK 315-318)	Beng/Eng MONTH ______ YEAR ______ YEARS AGO ______	BOY 1 GIRL 2	YES 1 (PROCEED WITH NEXT PREGNANCY NO 2 (ASK 318)	MONTHS ______ YEARS ______ ASK THE NEXT PREGNANCY

Source: Reproduced from Bangladesh (1978 : C10)



AGO........	(ASK 321) 2	WITH NEXT PREG)	WITH NEXT PREG.	WITH NEXT PREG.	
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	19 21 22 26 27 28 30
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	32 34 35 39 40 41 43
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	45 47 48 52 53 54 56
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	58 60 61 65 66 67 69
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	19 21 22 26 27 28 30
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	32 34 35 39 40 41 43
Beng/Eng MONTHS..... YEARS...... YEARS AGO........	LESS THAN 7 1 (SKIP TO 323) 7 OR MORE 2 (ASK 321)	YES 1 (ASK 322) NO 2 (PROCEED WITH NEXT PREG)	BOY 1 GIRL 2 PROCEED WITH NEXT PREG.	YES 1 NO 2 PROCEED WITH NEXT PREG.	45 47 48 52 53 54 56

Source: Reproduced from Bangladesh (1978 : C11)

Since First Marriage	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	11	1	-	14	1	2
1	5	1	-	12	2	2
2	20	2	-	18	1	1
3	20	-	-	20	2	2
4	22	1	1	19	1	1
5	21	-	-	19	-	-
6	9	-	-	23	-	-
7	21	1	-	15	1	-
8	30	-	-	20	-	1
9	20	-	-	20	-	-
10	21	-	-	18	-	-
11	14	1	1	19	-	3
Total	214	7	2	217	8	12

Source: BFS, 1975-76

Months Since First Marriage	Pregnancy Outcome			Pregnancy Outcome		
	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	7	1	-	6	-	1
1	3	1	-	3	-	-
2	13	2	-	12	-	-
3	15	-	-	6	-	1
4	17	-	1	6	-	-
5	15	-	-	9	-	-
6	7	-	-	3	-	-
7	16	1	-	6	-	-
8	24	-	-	5	1	-
9	15	-	-	7	-	1
10	17	-	-	2	-	-
11	11	1	-	4	1	-
Total	160	6	1	69	2	3

Source: BFS, 1975-76

Months Since First Marriage	Rural			Urban		
	Pregnancy Outcome			Pregnancy Outcome		
	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	10	1	1	7	-	1
1	8	2	1	8	-	-
2	14	1	1	3	-	1
3	14	1	2	10	-	-
4	12	1	1	12	-	-
5	13	-	-	9	-	-
6	17	-	-	9	-	-
7	9	1	-	11	-	-
8	14	-	-	11	-	-
9	15	-	-	5	1	-
10	13	-	-	6	-	-
11	14	-	3	8	-	-
Total	153	7	9	99	1	4

Source: BFS, 1975-76

	No Schooling			Urban		
	Pregnancy Outcome			Pregnancy Outcome		
Months Since First Marriage	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	7	–	–	4	1	–
1	4	1	–	1	–	–
2	11	–	–	9	2	–
3	11	–	–	9	–	–
4	15	1	1	7	–	–
5	12	–	–	9	–	–
6	5	–	–	4	–	–
7	13	–	–	8	1	–
8	19	–	–	11	–	–
9	16	–	–	4	–	–
10	16	–	–	5	–	–
11	12	1	–	2	–	1
Total	141	3	1	73	4	1

Source: BFS, 1975-76

	Level of Schooling					
	No Schooling			Urban		
	Pregnancy Outcome			Pregnancy Outcome		
Months Since First Marriage	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	8	1	1	6	–	1
1	6	2	2	6	–	–
2	8	1	1	10	–	–
3	5	1	1	15	1	1
4	10	–	1	9	1	1
5	14	–	–	5	–	–
6	14	–	–	9	–	–
7	12	1	–	3	–	–
8	13	–	–	7	–	1
9	13	–	–	7	–	1
10	9	–	–	9	–	–
11	14	–	1	5	–	2
Total	126	6	7	91	2	5

Source: BFS, 1975-76

Months Since First Marriage	Religion					
	Muslim			Non-Muslim		
	Pregnancy Outcome			Pregnancy Outcome		
	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	9	1	-	2	-	-
1	4	1	-	1	-	-
2	17	2	-	3	-	-
3	16	-	-	4	-	-
4	17	-	1	5	1	-
5	18	-	-	3	-	-
6	9	-	-	-	-	-
7	16	1	-	5	-	-
8	24	-	-	6	-	-
9	16	-	-	4	-	-
10	18	-	-	3	-	-
11	13	1	-	1	-	1
Total	177	6	1	37	1	1

Source: BFS, 1975-76

Months Since First Marriage	Religion					
	Muslim			Non-Muslim		
	Pregnancy Outcome			Pregnancy Outcome		
	Live birth	Still-birth	Abortion	Live birth	Still-birth	Abortion
0	10	1	2	4	–	–
1	8	–	1	4	2	1
2	13	1	1	5	–	–
3	18	1	2	2	1	–
4	16	1	–	3	–	–
5	15	–	–	4	–	–
6	19	–	–	4	–	–
7	14	1	–	1	–	–
8	17	–	1	3	–	–
9	15	–	–	5	–	–
10	13	–	–	5	–	–
11	16	–	2	3	–	1
Total	174	5	9	43	3	3

Source: BFS, 1975-76

Characteristics	First Marriage Cohort	
	1965-69	1970-74
A All	12.73	13.90
B Place of Residence		
Rural	12.65	13.78
Urban	13.62	15.04
C Level of Schooling		
No Schooling	12.53	13.63
Others	13.28	14.38
D Religion		
Muslim	12.70	13.78
Non-Muslim	12.87	14.55

Source: Computed from the BFS, 1975-76.

	Cohort					
	1965-69			1970-74		
Characteristics	Mean Age	Survival Ratio†	Expectation of Life†	Mean Age	Survival Ratio†	Expectation of Life†
A All	15.23	.99599	45.88	16.40	.99544	44.93
B Place of Residence						
Rural	15.15	.99602	45.95	16.28	.99553	45.03
Urban	16.12	.99564	45.15	17.54	.99462	44.04
C Level of Schooling						
No Schooling	15.03	.99604	46.05	16.13	.99564	45.15
Others	15.78	.99526	45.43	16.88	.99510	44.55
D Religion						
Muslim	15.20	.99586	45.91	16.28	.99553	45.03
Non-Muslim	15.37	.99568	45.77	17.05	.99497	44.41

†Computed from model life table for Bangladesh females (Census Commission, 1977 : 91-92)

1965-69 First Marriage Cohort

$$\begin{array}{cc}
 & \begin{array}{cccccc} S_0 & S_1 & S_{2-3} & S_4 & S_5 & S_6 \end{array} \\
\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} &
\begin{bmatrix}
0.78646 & 0.20953 & 0 & 0 & 0 & 0.00401 \\
0 & 0 & 0.00893 & 0.03126 & 0.95580 & 0.00401 \\
0.99599 & 0 & 0 & 0 & 0 & 0.00401 \\
0.99599 & 0 & 0 & 0 & 0 & 0.00401 \\
0.99599 & 0 & 0 & 0 & 0 & 0.00401 \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\end{array}$$

1970-74 First Marriage Cohort

$$\begin{array}{cc}
\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} &
\begin{bmatrix}
0.77537 & 0.22007 & 0 & 0 & 0 & 0.00456 \\
0 & 0 & 0.05040 & 0.03361 & 0.91143 & 0.00456 \\
0.99544 & 0 & 0 & 0 & 0 & 0.00456 \\
0.99544 & 0 & 0 & 0 & 0 & 0.00456 \\
0.99544 & 0 & 0 & 0 & 0 & 0.00456 \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\end{array}$$

Rural

$$\begin{array}{c|cccccc}
 & S_0 & S_1 & S_{2-3} & S_4 & S_5 & S_6 \\
\hline
S_0 & 0.79067 & 0.20535 & 0 & 0 & 0 & 0.00398 \\
S_1 & 0 & 0 & 0.00597 & 0.03579 & 0.95426 & 0.00398 \\
S_{2-3} & 0.99602 & 0 & 0 & 0 & 0 & 0.00398 \\
S_4 & 0.99602 & 0 & 0 & 0 & 0 & 0.00398 \\
S_5 & 0.99602 & 0 & 0 & 0 & 0 & 0.00398 \\
S_6 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}$$

Urban

$$\begin{array}{c|cccccc}
 & S_0 & S_1 & S_{2-3} & S_4 & S_5 & S_6 \\
\hline
S_0 & 0.71550 & 0.28014 & 0 & 0 & 0 & 0.00436 \\
S_1 & 0 & 0 & 0.04036 & 0.02691 & 0.92837 & 0.00436 \\
S_{2-3} & 0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
S_4 & 0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
S_5 & 0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
S_6 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}$$

Rural

$$\begin{array}{cc}
 & \begin{array}{cccccc} S_0 & S_1 & S_{2-3} & S_4 & S_5 & S_6 \end{array} \\
\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} &
\left[\begin{array}{cccccc}
0.78910 & 0.20643 & 0 & 0 & 0 & 0.00447 \\
0 & 0 & 0.05301 & 0.04124 & 0.90128 & 0.00447 \\
0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\
0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\
0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\
0 & 0 & 0 & 0 & 0 & 1
\end{array}\right]
\end{array}$$

Urban

$$\begin{array}{cc}
\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} &
\left[\begin{array}{cccccc}
0.62253 & 0.37209 & 0 & 0 & 0 & 0.00538 \\
0 & 0 & 0.03825 & 0.00957 & 0.94680 & 0.00538 \\
0.99462 & 0 & 0 & 0 & 0 & 0.00538 \\
0.99462 & 0 & 0 & 0 & 0 & 0.00538 \\
0.99462 & 0 & 0 & 0 & 0 & 0.00538 \\
0 & 0 & 0 & 0 & 0 & 1
\end{array}\right]
\end{array}$$

$$\begin{array}{l|cccccc|}
S_1 & 0 & 0 & 0.00687 & 0.02061 & 0.96856 & 0.00396 \\
S_{2-3} & 0.99604 & 0 & 0 & 0 & 0 & 0.00396 \\
S_4 & 0.99604 & 0 & 0 & 0 & 0 & 0.00396 \\
S_5 & 0.99604 & 0 & 0 & 0 & 0 & 0.00396 \\
S_6 & 0 & 0 & 0 & 0 & 0 & 1
\end{array}$$

Others

$$\begin{array}{l}
S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6
\end{array}
\begin{bmatrix}
0.73299 & 0.26225 & 0 & 0 & 0 & 0.00476 \\
0 & 0 & 0.01276 & 0.05104 & 0.93144 & 0.00476 \\
0.99524 & 0 & 0 & 0 & 0 & 0.00476 \\
0.99524 & 0 & 0 & 0 & 0 & 0.00476 \\
0.99524 & 0 & 0 & 0 & 0 & 0.00476 \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}$$

$$\begin{array}{c} S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array}
\begin{bmatrix}
0 & 0 & 0.05014 & 0.04298 & 0.90252 & 0.00436 \\
0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
0.99564 & 0 & 0 & 0 & 0 & 0.00436 \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}$$

Others

$$\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array}
\begin{bmatrix}
0.73788 & 0.25722 & 0 & 0 & 0 & 0.00490 \\
0 & 0 & 0.05077 & 0.02031 & 0.92402 & 0.00490 \\
0.99510 & 0 & 0 & 0 & 0 & 0.00490 \\
0.99510 & 0 & 0 & 0 & 0 & 0.00490 \\
0.99510 & 0 & 0 & 0 & 0 & 0.00490 \\
0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}$$

$$\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} \left[\begin{array}{cccccc} 0.78692 & 0.20894 & 0 & 0 & 0 & 0.00414 \\ 0 & 0 & 0.00541 & 0.03248 & 0.95797 & 0.00414 \\ 0.99586 & 0 & 0 & 0 & 0 & 0.00414 \\ 0.99586 & 0 & 0 & 0 & 0 & 0.00414 \\ 0.99586 & 0 & 0 & 0 & 0 & 0.00414 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array}\right]$$

Non-Muslim

$$\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} \left[\begin{array}{cccccc} 0.78232 & 0.21336 & 0 & 0 & 0 & 0.00432 \\ 0 & 0 & 0.02553 & 0.02553 & 0.94462 & 0.00432 \\ 0.99568 & 0 & 0 & 0 & 0 & 0.00432 \\ 0.99568 & 0 & 0 & 0 & 0 & 0.00432 \\ 0.99568 & 0 & 0 & 0 & 0 & 0.00432 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array}\right]$$

$$\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} \begin{bmatrix} 0.78872 & 0.20681 & 0 & 0 & 0 & 0.00447 \\ 0 & 0 & 0.04766 & 0.02648 & 0.92139 & 0.00447 \\ 0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\ 0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\ 0.99553 & 0 & 0 & 0 & 0 & 0.00447 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

Non-Muslim

$$\begin{array}{c} S_0 \\ S_1 \\ S_{2-3} \\ S_4 \\ S_5 \\ S_6 \end{array} \begin{bmatrix} 0.70477 & 0.29020 & 0 & 0 & 0 & 0.00503 \\ 0 & 0 & 0.06091 & 0.06091 & 0.87315 & 0.00503 \\ 0.99497 & 0 & 0 & 0 & 0 & 0.00503 \\ 0.99497 & 0 & 0 & 0 & 0 & 0.00503 \\ 0.99497 & 0 & 0 & 0 & 0 & 0.00503 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

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