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SIMULATION OF THE FAMILY LIFE CYCLE

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Abstract

The study of the determinants of the changing composition of the family over its life cycle is a principal focus of research in the newly emerging field of family demography. Most existing work on the subject is descriptive in nature, but increasing attention is being given to the construction of quantitative models which allow a more detailed causal analysis of the effects of the timing and frequency of various demographic events on family structure. After a brief review of existing family models, this paper presents a new macro simulation model that generates distributions of numbers of sons and daughters ever born and currently living, and distributions of family size by age of the wife in a population with given levels of fertility, mortality, nuptiality, and migration. These results can be produced separately for husband-wife and female-headed nuclear families. The validity of the model is successfully tested by comparing a number of simulated distributions with observed distributions based on WFS data from Pakistan 1975. Future more complex versions of this model will allow detailed analyses of the determinants of family composition in a variety of demographic settings.

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Although the family has been the subject of intense study by social scientists for a long time, it has received relatively little attention from demographers. The field of family demography is still in the early phases of development despite a growing literature on households and families.[1] Ryder[2] defines family demography as the study of the determinants of the number, size, and composition of families. More specifically, the following topics can be identified as falling within the domain of household and family demography:[3]

1) the variation in the size and structure of families and households, both among populations or subpopulations and over time;

2) the family life cycle, including the size and composition at different points in the cycle and the timing and quantity of events, such as births, deaths, and marriages, that change the family structure;

3) the family and household formation process;

4) the determinants of the size and structure of families and households. A distinction should be made between the direct demographic determinants, such as fertility, mortality, nuptiality, and migration rates, and the indirect social, economic, and cultural determinants;

5) the consequences of the size and structure of famlies and households, both demographic (e.g., the fertility, mortality, and marriage rates of the family members) and socioeconomic (e.g., child care, economic security, labor force participation, and dependency among the elderly).

Much of the existing work in household and family demograpny is descriptive in nature, relying heavily on census data, but increasing attention is being given to modeling the demographic dynamics of the family. The objective of this paper is, first, to discuss briefly the different types of family and

household models, and then to present a macrosimulation model that describes various demographic characteristics of nuclear families at different points in the life cycle.

Models of Family and Household Demography

Existing demographic family and household models focus on the relationship between selected family and household characteristics and their demographic determinants. To classify these models, it is convenient to adopt the following typology, which has been used elsewhere to categorize reproductive models:[4]

1) Analytic models consist of equations in which family and household characteristics are the independent variables and levels of fertility, mortality, and nuptiality are the dependent variables. To keep these equations from becoming excessively complex, analytic models must often rely on simplifying assumptions. Studies by Coale,[5] Burch,[6] and Goodman et al.[7] provide examples of this type of model.

2) Macrosimulation models have a mathematical basis consisting of equations that are difficult or impossible to solve analytically. But by programming the equations on a computer (or by using a desk calculator) numerical solutions can be calculated. Macrosimulation models, sometimes called projection models, are deterministic because the rate at which demographic events and changes in family status occur is exactly determined by specified input variables. Because more complex assumptions can be incorporated, macrosimulation models are usually more realistic than analytic models. Examples of this type of model are found in the work of Oechsli[8] and Ryder.[9]

3) Microsimulation or Monte Carlo models simulate demographic histories for each individual separately. A large number of individual records (e.g., a few hundred or more) are combined to obtain average characteristics for the population as a whole. The crucial difference between the deterministic macro- and the stochastic microsimulation models is the role of chance. The occurrence and timing of demographic events in the microsimulations, although governed by overall rates, are determined by chance at the individual level. Microsimulations can be made complex and quite realistic, but suffer from one weakness: any aggregate results from the simulation are subject to a sampling error. This error can be made smaller by increasing the number of individuals in the simulated population, but this would add to the computer cost of the simulation. Perhaps the best known example of a microsimulation model is SOCSIM, developed by Hammel et al.[10] This model will now be discussed in more detail.

SOCSIM is a demographic-sociological microsimulation program that traces the consequences for family and household structure of assumptions about individual behavior. At the start of a simulation the computer generates an initial population of several hundred people. Each individual in this population and new additions to the population through birth are then subjected to specified risks of fertility, mortality, and marriage and to complex rules of residence. While the overall levels of demographic rates are given as inputs to the model, events for each individual occur randomly. At the time of births, deaths, and marriages, persons move in and out of households, new households are formed, or headships of households change. The computer keeps track of all these changes in households and produces as one of its main outputs the distribution of different types of households (e.g., nuclear,

multiple or extended lineal, multiple or extended lateral, etc.) at the end of the simulation period.

In a recent application of SOCSIM by Wachter et al.,[11] the household structure in historical Europe is studied in an attempt to resolve the current controversy over the kin composition of these households. Historical records show that coresident kin other than members of the nuclear families were rare, particularly in sixteenth and seventeenth century England. Two explanations have been offered for this finding: either individuals or couples decided voluntarily not to live together, or demographic constraints, such as high mortality and late marriage, were operating to limit the proportion of complex households independent of any residence rules or desires. On the basis of a large set of SOCSIM simulations with varying demographic inputs and residence and inheritance rules, it is concluded that demographic variables imposed only loose constraints on household structures in historical European populations and that individual residence decisions had more effect on the prevalence of different household types.

SOCSIM is the only complete demographic household microsimulation model in existence. In comparison, the development of macrosimulation models is still in its early stages. The remainder of this paper presents a macrosimulation model that in its current basic version deals only with the nuclear family.

A Macrosimulation Model for Projecting Size and Structure of the Nuclear Family Over the Life Cycle

The simulation of the life cycle of nuclear families consists of tracing their size and composition over time with an accounting framework in which demographic events such as births, deaths, marriages, and divorces alter the family's composition. The duration of marriage (i.e., the time since the "birth" of the nuclear family) is theoretically the most appropriate variable to measure time in the projection of families, but this option is not attractive for several practical reasons, including the lack of family statistics by duration of marriage. Instead, the age of the head of the family (husband or wife) is the standard measure for timing the occurrence of family life cycle events, a convention that is adopted here. Since the projection of one family is rather uninteresting, the focus will be on the projection of a group of families. More specifically, the characteristics of a set of nuclear families generated over the life of a cohort of women will be studied.

In the most basic version of the simulation model, to be described next, it is assumed that:

- only currently married fecund women bear offspring;
- the fertility of fecund couples and the instantaneous risks of marriage, death, sterility, marital disruption, and remarriage are functions of age only;
- if a remarriage takes place, the time lost between the remarriage and the preceding marital disruption is negligible (as a consequence the model needs to take account only of permanent marital disruptions[12]);

- children stay with their mother after a marital disruption even if she does not remarry; if the mother dies, the children are taken care of by the husband if he remarries, or by relatives or institutions. (The model ignores the very small proportion of nuclear families consisting of a widower who does not remarry and his children, so that there are only two types of nuclear families, one in which husband and wife are both present and one in which the woman is alone after a permanent marital disruption.);
- there are no multiple births.

It should be emphasized that these assumptions are provisional ones made primarily to simplify the presentation of the technical aspects of the model. The restrictions imposed by the assumptions can be removed in later versions of the model. It would, for example, be simple to introduce extramarital fertility and parity-specific fertility and divorce rates, or to allow time between marital disruptions and subsequent remarriages, but these refinements would require detailed input data that are not available in many populations.

Based on these assumptions, a set of models will now be developed to describe the following family characteristics by age of the woman:

- distribution of the number of children ever born, by sex
- distribution of the number of currently living children, by sex
- distribution of the sizes of nuclear families

These distributions will be generated separately for all families, husband-wife families, and female-headed families. In each case only the woman's own children are included.

a. Distribution of number of children ever born

A model that projects parity distributions by age of the woman is used to calculate the distribution of children ever born in nuclear families at different points in their life cycle. The model follows women as they progress over time through various demographic states. A distribution of women among these states is calculated successively for each age of the cohort.

Six exposure states are recognized: 1) fecund single; 2) sterile single; 3) fecund, currently married; 4) sterile, currently married; 5) fecund, previously married; and 6) sterile, previously married. Within each of these exposure states a distinction is made between parity levels. State transitions take place at the time of a marriage (e.g., from state 1 to 3), birth (to the next parity level), permanent marital disruption (e.g., from state 3 to 5), or onset of sterility (e.g., from state 3 to 4). Women are distributed among states on the basis of their current marital status, parity, and fecundity status.

The projection is started at the beginning of the reproductive years when all women are assumed to be single and fecund[13] (state 1, parity 0). As time progresses, women are at risk of moving to other states. The rates at which the four types of transition--marriage, birth, permanent marital disruption, and onset of permanent sterility--take place are determined by the following age-specific risk variables:

m(a) = probability of marriage between exact ages a and a+1 among single women;

$f(a)$ = probability of giving birth between exact ages $\underline{a}$ and $a+1$ among fecund married women;

$d(a)$ = probability of a permanent marital disruption between exact ages $\underline{a}$ and $a+1$ among currently married women;

$s(a)$ = probability of becoming sterile between exact ages $\underline{a}$ and $a+1$ among fecund women;

a = age in single years.

The distribution of women among all demographic states at each exact age is represented by the variable $\overset{a}{P}(m,n)$, where

n = number of children ever born (parity);

m = exposure state: $m = 1, \ldots 6$.

Since the $n \times m$ available states are mutually exclusive, it follows that

$$\sum_m \sum_n \overset{a}{P}(m,n) = 1 \text{ for all ages.}$$

The following set of equations projects the parity distribution $\overset{a}{P}(m,n)$ for successive single years:

$$\overset{a+1}{P}(1,0) = \overset{a}{P}(1,0) - s(a)\ \overset{a}{P}(1,0) - m(a)\ [1-s(a)]\ \overset{a}{P}(1,0) \tag{1}$$

$$\overset{a+1}{P}(2,0) = \overset{a}{P}(2,0) + s(a)\ \overset{a}{P}(1,0) - m(a)\ [\overset{a}{P}(2,0) + s(a)\ \overset{a}{P}(1,0)] \tag{2}$$

$$\begin{aligned}\overset{a+1}{P}(3,0) = \overset{a}{P}(3,0) &- s(a)\ \overset{a}{P}(3,0) - d(a)\ [1-s(a)]\ \overset{a}{P}(3,0) \\ &+ m(a)\ [1-s(a)]\ \overset{a}{P}(1,0)\ [1-f(a)] \\ &- f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,0)\end{aligned} \tag{3}$$

$$\overset{a+1}{P}(3,1) = \overset{a}{P}(3,1) - s(a)\ \overset{a}{P}(3,1) - d(a)\ [1-s(a)]\ \overset{a}{P}(3,1)$$

$$- f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,1)$$

$$+ f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,0) \tag{4}$$

$$+ f(a)\ m(a)\ [1-s(a)]\ \overset{a}{P}(1,0)$$

$$\overset{a+1}{P}(3,n) = \overset{a}{P}(3,n) - s(a)\ \overset{a}{P}(3,n) - d(a)\ [1-s(a)]\ \overset{a}{P}(3,n)$$

$$- f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,n) \tag{5}$$

$$+ f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,n-1)$$

$$\text{for } n \geqslant 1$$

$$\overset{a+1}{P}(4,0) = \overset{a}{P}(4,0) + s(a)\ \overset{a}{P}(3,0)$$

$$- d(a)\ [\overset{a}{P}(4,0) + s(a)\ \overset{a}{P}(3,0)] \tag{6}$$

$$+ m(a)\ [\overset{a}{P}(2,0) + s(a)\ \overset{a}{P}(1,0)]$$

$$\overset{a+1}{P}(4,n) = \overset{a}{P}(4,n) + s(a)\ \overset{a}{P}(3,n) - d(a)\ [\overset{a}{P}(4,n) + s(a)\ \overset{a}{P}(3,n)] \tag{7}$$

$$\text{for } n \geqslant 1$$

$$\overset{a+1}{P}(5,n) = \overset{a}{P}(5,n) - s(a)\ \overset{a}{P}(5,n) + d(a)\ [1-s(a)]\ \overset{a}{P}(3,n) \tag{8}$$

$$\text{for } n \geqslant 0$$

$$\overset{a+1}{P}(6,n) = \overset{a}{P}(6,n) + s(a)\ \overset{a}{P}(5,n) + d(a)\ [\overset{a}{P}(4,n) + s(a)\ \overset{a}{P}(3,n)] \tag{9}$$

$$\text{for } n \geqslant 0$$

These equations are obtained by quantifying the flow of women between states. In each equation the proportion of women in a given state at exact age a+1 equals the proportion in that state at exact age a, minus the women who leave

plus the women who enter between ages a and a+1. For example, in equation (5) the proportion of all women that is married and fecund and has exact parity n at exact age a+1, $\overset{a+1}{P}(3,n)$, is equal to the proportion at parity n at exact age a, $\overset{a}{P}(3,n)$, minus the proportion that becomes sterile between ages a and a+1, $s(a)\ \overset{a}{P}(3,n)$, minus the proportion that has a permanent marital disruption, $d(a)\ [1-s(a)]\ \overset{a}{P}(3,n)$, minus the proportion that has a birth of order n+1 and hence progresses to the next parity level, $f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,n)$, plus the proportion that has a birth of order n $f(a)\ [1-s(a)]\ [1-d(a)]\ \overset{a}{P}(3,n-1)$. (To simplify the equations, marriages, marital disruptions, and onsets of sterility are assumed to take place at the beginning of each year.) The approach used here to estimate the parity distribution by age is similar to the one proposed by Keyfitz[14] for the calculation of multiple decrement life tables by parity. The crucial difference between the two methods is the separation of women into the various fecundity and marital status groups. Without this distinction unrealistic parity distributions are obtained. The idea of controlling fecundity status, as well as marital status, was first introduced by Whelpton[15] in his pioneering study of U.S. cohort fertility, but it has not seen much further development.

Equations (1)-(9) are easily programmed on a computer, which calculates the distributions $\overset{a}{P}(m,n)$ iteratively--one year at a time--from age 10 to age 50. The only required input data, the variables m(a), f(a), d(a), and s(a), can be derived from available statistics on proportions of women currently and ever married by age, age-specific marital fertility rates, and proportions currently sterile by age.

Finally, the distributions of children ever born in different types of nuclear families are calculated from $\overset{a}{P}(m,n)$. Let $\overset{a}{P}(n)$, $'\overset{a}{P}(n)$, and $''\overset{a}{P}(n)$ represent the number of children ever born among, respectively, all nuclear families, husband-wife families, and female-headed families with the woman at exact age a; then:

$$\overset{a}{P}(n) = \sum_{m=3}^{6} \overset{a}{P}(m,n)/N(a) \tag{10}$$

$$'\overset{a}{P}(n) = \sum_{m=3}^{4} \overset{a}{P}(m,n)/M(a) \tag{11}$$

$$''\overset{a}{P}(n) = \sum_{m=5}^{6} \overset{a}{P}(m,n)/[N(a)-M(a)] \tag{12}$$

where M(a) equals the proportion currently married among all women at exact age a and N(a) equals the proportion ever married among all women at exact age a.

The above procedure for calculating children ever born can also be applied to project the distributions of sons or daughters ever born. The only modification required in equations (1)-(9) is the multiplication of f(a) by the proportion of births that is male to find the distribution of sons ever born and by the proportion of births that is female find the distribution of daughters ever born.

b. Distribution of number of living children

In order to obtain the distributions of number of living children, it is necessary to first calculate the distributions $\overset{a,b}{V}(m,i)$, where a is the exact age of women, b is a given future age of women, m denotes the exposure state as defined previously, and i equals the number of currently living

children that will survive to exact age b of the woman (i.e., of all children alive age a of the woman, only i will live until she reaches age b, b a).

The projection technique described earlier can, after a small modification, be applied to calculate $\overset{a,b}{V}(m,i)$. For each age b a separate projection is made from a=10 to a=b. A wife progresses from level i to i+1 at age a if a child is born that will survive x years from a to b, (x=b-a). If l(x) denotes the probability of surviving x years among newborns, then among all births at age a of the woman a proportion l(b-a-0.5) will survive until the woman reaches exact age b. The distributions $\overset{a,b}{V}(m,i)$ are obtained from modified versions of equations (1)-(9) (not presented here). The only essential modification is the substitution of l(b-a-0.5) f(a) for f(a) in these equations.

The distribution of the number of living children among women of exact age a in exposure state m, $\overset{a}{L}(m,i)$, is now obtained directly from $\overset{a,b}{V}(m,i)$, since $\overset{a}{L}(m,i) = \overset{a,b}{V}(m,i)$ when b=a. From $\overset{a}{L}(m,i)$ the distribution of number of living children in different types of nuclear families can be calculated as follows. Let $\overset{a}{L}(i)$, $'\overset{a}{L}(i)$, and $''\overset{a}{L}(i)$ represent the number of living children among, respectively, all nuclear families, husband-wife families, and female-headed families with the woman at exact age a; then:

$$\overset{a}{L}(i) = \sum_{i=3}^{6} \overset{a}{L}(M,i)/N(a)$$

$$'\overset{a}{L}(i) = \sum_{i=3}^{4} \overset{a}{L}(m,i)/M(a)$$

$$''\overset{a}{L}(i) = \sum_{i=5}^{6} \overset{a}{L}(m,i)/[N(a)-M(a)]$$

As was the case for the parity distributions, the above projection procedure for distributions of living children is easily modified to yield distributions of living sons or daughters. This is done by making the survival probabilities $l(x)$ sex specific and by multiplying the variable $f(a)$ by the proportion of all births that is male (for sons) or female (for daughters).

In the discussion up to this point, the place of residence of children has not been considered, that is, in the distributions $\overset{a}{L}(i)$, $'\overset{a}{L}(i)$, and $''\overset{a}{L}(i)$ refer to all living children including those who do not live with their parents. Let $\overset{a}{T}(i)$, $'\overset{a}{T}(i)$, and $''\overset{a}{T}(i)$ denote the distributions of the number of children living at home in, respectively, all nuclear families, husband-wife families, and female-headed families. These distributions can be estimated with the same procedure used to obtain the distributions of all living children except that the variable $l(x)$ is replaced by $r(x)$ where $r(x)$ is the probability that a newborn is alive and living with its parents $\underline{x}$ years after birth.

c. Distribution of the size of nuclear families

Let $\overset{a}{S}(i)$, $'\overset{a}{S}(i)$, and $''\overset{a}{S}(i)$ represent the size distributions among, respectively, all nuclear families, husband-wife families, and female-headed families. Once the distributions $\overset{a}{T}(i)$, $'\overset{a}{T}(i)$, and $''\overset{a}{T}(i)$ are known, it is a simple matter to calculate the distributions of family size, because in addition to the children living at home, there are two adults in husband-wife families and one adult in female-headed families. Consequently: $'\overset{a}{S}(i+2) = '\overset{a}{T}(i)$ and $''\overset{a}{S}(i+1) = ''\overset{a}{T}(i)$. $\overset{a}{S}(i)$ is calculated as the weighted average of $'\overset{a}{S}(i)$ and $''\overset{a}{S}(i)$.

Validation of the Simulation Model

A test of the validity of the model is provided by comparing the family characteristics estimated by the model with those observed in a population for which the required model input data are available. Such comparisons should ideally be carried out in a large number of populations in a variety of demographic settings in order to assess the accuracy of the model with confidence. A comprehensive testing of the model is beyond the scope of this brief paper, and in any case more complex versions of the model would be required to simulate populations in which the basic assumptions made here are not reasonable approximations of reality.

As a first step toward testing the model, a projection was made of the distribution of number of children ever born by age of the woman for Pakistan 1975. Pakistan was chosen because fairly reliable data on children ever born are available from the 1975 WFS Survey, and fertility has been quite stable in recent decades so that period and cohort data are virtually the same. The fertility, sterility, and nuptiality patterns on which the simulations are based are presented in Table 1. [The variable N(a) and the distribution of age at first marriage are estimated with the Coale marriage model.] From these data the input variables m(a), f(a), s(a), and d(a) are computed.[16] With these variables as inputs, the model projects the distributions of children ever born among all families by age of the woman. The results of the simulations are plotted in Figure 1, along with the observed distributions. The close agreement between the observed and simulated distributions suggest that the basic model adequately represents the family building process in this population.

Table 1: Selected demographic variables used to calculate input functions for a model simulation based on data from the 1975 Pakistan Fertility Survey

Age	Marital fertility rate[a]	Proportion permanently sterile at beginning of interval[c]	Proportion currently married among ever married[a]	Distribution of age at first marriage[a]
10-14	100[b]	1.00[b]	1.00	
15-19	264	0.98[b]	1.00	Coale marriage model parameters:[d]
20-24	355	0.97	0.97	- mean age = 16.9
25-29	362	0.95	0.95	- proportion ever marrying = 0.99
30-34	286	0.90	0.95	- initial age at marriage = 12[b]
35-39	221	0.85	0.94	
40-44	104	0.68	0.90	
45-49	9	0.31[b]	0.85	

a. Population Planning Council of Pakistan, Pakistan Fertility Survey, First Report, October 1976.

b. Estimated or assumed.

c. L. Henry, "French statistical research in natural fertility," in Public Health and Population Change, ed. M.C. Sheps and J.C. Ridley (Pittsburgh: University of Pittsburg Press, 1965).

d. A.J. Coale and D.R. McNeil, "The distribution by age of the frequency of first marriage in a female cohort," Journal of the American Statistical Association 67, no. 340 (1972):743-749.

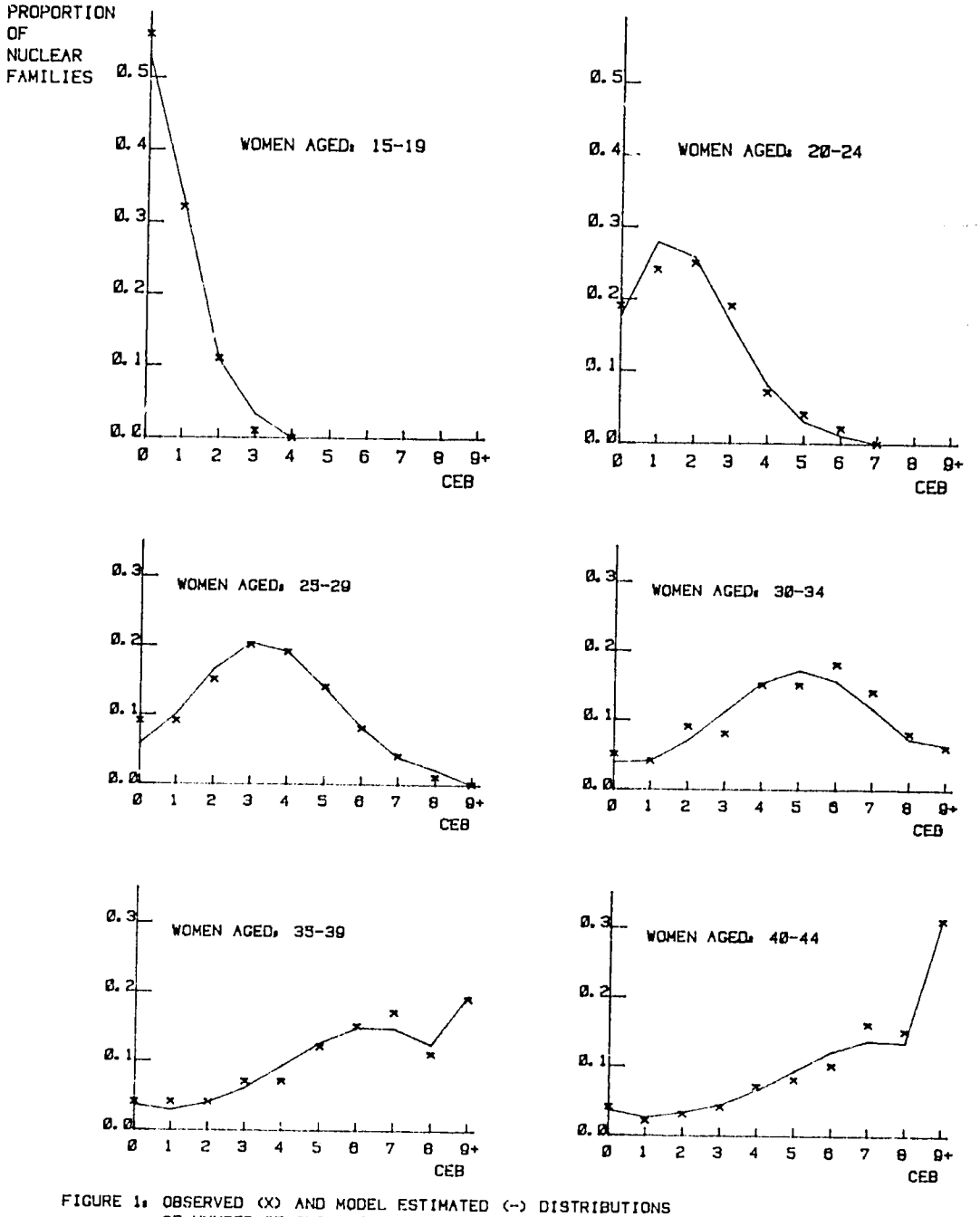

FIGURE 1: OBSERVED (X) AND MODEL ESTIMATED (-) DISTRIBUTIONS OF NUMBER OF CHILDREN EVER BORN (CEB) AMONG ALL NUCLEAR FAMILIES BY AGE OF THE WOMAN FOR PAKISTAN 1975.

Projections were also made for the distributions of number of living children and living sons, and the distributions of family sizes in husband-wife and female-headed families with the woman aged 45-49. For these projections the variables $l(x)$ and $r(x)$ were needed. Since mortality in Pakistan has changed in the past decades, different $l(x)$ and $r(x)$ functions were estimated for each birth cohort of children during the period 1945-1975. Life expectancy at birth of the children was assumed to increase based on mortality trends estimated by the U.N.,[17] and Coale-Demeny model life tables were used to obtain approximate values of $l(x)$ for the different cohorts. The function $r(x)$ was obtained by assuming the proportion of all living children that actually live at home to equal $1-N(x)$ so that $r(x) = [1-N(x)]\ l(x)$. The results of the projections are presented in Figure 2. Unfortunately, observed values for only two distributions in Figure 2 were available. For these two distributions--the number of living children and living sons among currently married women--the agreement between observed and estimated values is quite good. The other estimated distributions in Figure 2 are therefore probably also fairly realistic.

Conclusion

The basic version of the macrosimulation model described in the preceding section allows the projection of a number of characteristics of nuclear families over the life cycle of a cohort of women. A comparison of model estimates with observed distributions of the number of children ever born and the number of living children and living sons, by age of the woman, for Pakistan 1975 demonstrated that, at least in this population, the model

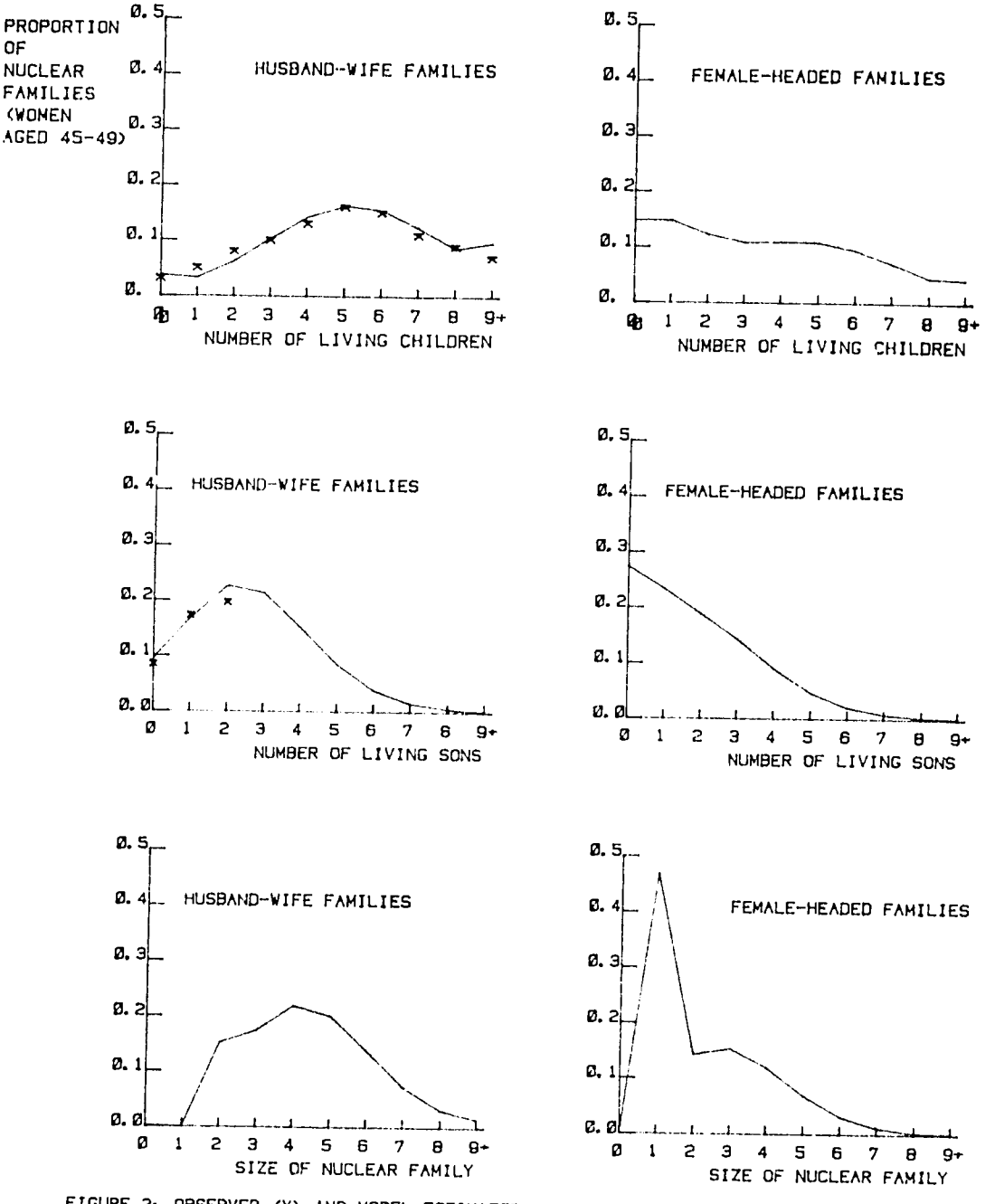

FIGURE 2: OBSERVED (X) AND MODEL ESTIMATED (-) DISTRIBUTIONS OF NUMBER OF LIVING CHILDREN AND LIVING SONS, AND OF SIZES OF NUCLEAR FAMILIES, FOR HUSBAND-WIFE FAMILIES AND FEMALE-HEADED FAMILIES WITH A WOMAN AGED 45-49 FOR PAKISTAN 1975.

and the hypotheses about the family building process incorporated in it are reasonably accurate representations of reality. If further testing shows that this model with additional refinements can simulate the life cycle of nuclear families in a variety of demographic settings, then the model could become a useful tool for making detailed analyses of the effects of fertility, mortality, nuptiality, divorce, and migration rates on the size and composition of different types of nuclear families.

As was mentioned earlier, microsimulation models are at present more advanced than macro models. Assuming that the macrosimulation models can be developed further, which of the two types of models is likely to see wider application? The answer to this question depends on the type of application. Microsimulations are best in situations where complex rules of behavior have to be incorporated in the model. The very detailed rules of residence and inheritance used in SOCSIM would be very difficult, if not impossible, to simulate with a macro model. On the other hand, macro models are likely to be preferred in cases where accurate projections are required of relatively rare events or of family characteristics that occur infrequently. For example, to study the effects of mortality (or other demographic determinants) on the probability that a woman, on reaching age 60, is a widow without surviving sons, one needs a breakdown of the population by age, sex, and marital status of adults, and by sex, survival status, and number of children. In a micro model such as SOCSIM, which typically contains a population of a few hundred individuals, there may only be a few widows in any given age group, and an estimate of the proportion without a living son would be subject to a very large sampling error. Increasing the size of the simulated population would reduce but not eliminate this error. In this case a macrosimulation model

would be preferable because there are no sampling errors even when very small subpopulations are projected. It is therefore likely that the use of both micro- and macrosimulation models will increase in the future, although in different types of applications.

Notes

1. For a detailed review see T.K. Burch, "Household and family demography: A bibliographic essay," Population Index 45, no. 2 (1979):173-195.

2. N.B. Ryder, "Models of family demography," Population Bulletin of the United Nations 9, (1977):43-46.

3. Based on Burch (note 1) and Ryder (note 2).

4. M.C. Sheps, "A review of models for population change," Review of the International Statistical Institute 39, no. 2 (1971):183-194; J. Menken, "Biometric models of fertility," Social Forces, 54, no. 1 (1975):52-65.

5. A.J. Coale, "Appendix: Estimates of average size of households," in Aspects of the Analysis of Family Structure, ed. A. Coale et al., (Princeton: Princeton University Press, 1965), pp. 64-69.

6. T.K. Burch, "Some demographic determinants of average household size: An analytic approach," Demography 7, no. 1 (1970):61-69.

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12. Women who remarry immediately following a marital disruption are assumed to remain in the married state, where they continue reproducing without interruption.

13. The fact that women are sterile before menarche may be ignored if all women are past menarche when they marry and if premarital fertility is zero.

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