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The Demographic Modeling Of Household Cycles: Analytical And Microsimulation Approaches

Ashok Kumar Madan

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THE DEMOGRAPHIC MODELING OF HOUSEHOLD CYCLES: ANALYTICAL AND MICROSIMULATION APPROACHES

by

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Submitted in partial fulfillment
of the requirement for the degree of
Doctor of Philosophy

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ABSTRACT

This dissertation first identifies the household cycle as the core concept in formal household demography, and presents a simple model of the determinants of the size distribution and the average size of the household. In this model, the proximate processes which govern the end points of the household cycle are the fission, fusion, and fission-fusion of households and the joint mortality of household members. The growth of the household during its cycle is, on the other hand, influenced by events occurring to individual household members given that the household is viable. Analytical models can then be developed for the study of the household using the concept of the household cycle as the unit of analysis.

From the perspective of the household cycle, then, Ryder's model of the average size of the nuclear family household cycle is first formalized, and then extended to two cases: the extended family household with and without a foster mother. Expressions of average household size are determined in terms of various demographic parameters such as the gross level of fertility, parental survival, and the net reproduction rate. Illustrative results are provided for three hypothetical societies described in the classical theory of demographic transition.

In addition, a microsimulation model of Canadian household cycles is developed in order to examine the sensitivity of average household size to different demographic parameters associated with the formation, growth, and extinction of households. An interesting and counterintuitive finding of this research is that mortality has a dual effect on average household size. On the other hand, household extinction, per se, is likely to result in an increase in average household size because smaller households have a higher probability

of extinction than larger households, holding other factors constant. On the other hand, the mortality of the individual, independent of household extinction, leads to a decrease in the average size of the household. The overall influence of mortality would thus depend on the net outcome of these two contradictory effects at the two levels of analysis - the household and the individual. It is quite possible, therefore, that mortality could even increase the average size of the household depending on the relative influence of mortality at the two levels of analysis. This finding is in contradiction to the popular hypothesis in social demographic literature that mortality decline (necessarily) leads to a decline in average household size. Such a finding assumes critical importance in formal household demography because it suggests not only that fertility but mortality as well can increase the average size of the household. There is no question that fertility necessarily leads to an increase in the average size of the household, keeping other factors constant. Nuclear family household formation, the last component in the simulation model, on the other hand, checks the growth of households and lowers the average size of the household.

It is finally suggested that more varieties of household organization could be modeled using the analytical approaches developed in this dissertation. One could also use the microsimulation model to study the demographic component of the size distribution of households.

ACKNOWLEDGEMENTS

I would like to thank Dr. Thomas K. Burch for all the discussions that we have had relating to this dissertation and for keeping the pressure on me to finish it. Discussions with Dr. John Carroll of the Computer Science department about the simulation work in this dissertation were very helpful. Dr. T. R. Balakrishnan, Dr. R. P. Beaujot, and Dr. P. Krishnan provided critical comments on all the chapters. Thanks to all of them. I would also like to thank Dr. Samuel Clark, Dr. Edward Ebanks, Dr. Richard Henshel, Dr. Susan McDaniel, Dr. Kevin McQuillan, Dr. Leroy Stone, and Dr. Frank Trovato for providing useful comments on various parts of this dissertation. I would also like to thank Dr. Frans Willekens of NIDI (The Hague) and Dr. Jan Bartlema of the University of Tilburg (The Netherlands) for some interesting academic correspondence which proved valuable to my work.

I presented some of my basic ideas related to the use of the household cycle in formal demographic research at a colloquium held in November, 1985, at the Centre for Canadian Population Studies, University of Western Ontario, on the invitation of Dr. Kevin McQuillan. Discussions at this meeting were intellectually stimulating and I extend my thanks to all who participated in it.

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CHAPTER 1

THE DYNAMICS OF HOUSEHOLD ORGANIZATION AND THE STATEMENT OF THE PROBLEM

1. 1. Introduction

The importance of the "household" as a unit of analysis in the study of various social structures has been well accepted in social scientific research, especially since the Second World War. In precapitalist peasant societies, the household constitutes the fundamental unit of social life (see, e. g., Chayanov, 1925; Friedman, 1982, 1984; Shanin, 1971), and is therefore an important social and economic unit in these societies. At the turn of this century, for example, the Russian peasant household was "the basic unit of production, consumption, property holding, socialization, sociability, moral support and mutual economic help" (Shanin, 1971, p. 31). Shanin continues further that "both the social prestige and the self-esteem of a peasant were defined by the household he belonged to and his position in it, as were his loyalties and self-identification" (p. 31). With reference to the importance of the compositional characteristics of the household, note, for example, that at the heart of Chayanov's (1925) theory of peasant economy lies the proposition that the ratio of labourers and consumers within the household determines the level and nature of activity on a peasant farm.

In modern economies, too, the household serves as a valuable unit of research, with important implications for economic-demographic modeling and theory building. The most notable contribution in this area is that of Kuznets

(1974, 1976, 1981, 1982a, 1982b), who has tried to relate income distribution across households to both the observed distribution of households by size and to the demographic component of the household size distribution. In one of his papers (Kuznets, 1982a), for example, he has argued that the size-distribution of households may influence significantly the total distribution of income in the population. Wachtel's (1984) assertion that the demographic structure of the household sector is an important determinant of aggregate consumption and saving further stresses the importance of the demographic component of households in economic-demographic theorizing.

Recently, demographers have also renewed their interest in the study of the household, particularly because the size and composition of households in both developed and developing countries have experienced considerable change over the last thirty years or so. The formal aspects of household demography, however, still remain in their initial stages (Bongaarts, 1984; Ryder, 1985), and will form a major focus of study in this dissertation. First, however, an overview of the literature on the factors responsible for changes in household characteristics will be made.

1. 2. The Dynamics of Household Organization

Household organization refers to the system of households observed in a given society at a given time. The study of the dynamics of this organization involves the examination of changes in one or more of its parameters, such as the size-distribution of households, the average size of the household, or some compositional measure of households as, for example, the proportion of households with at least one child. In an endeavour to study the dynamics of household organization, several questions, all equally interesting and challenging, may be raised about the determinants of these and other parameters. For example, one could ask: What is the appropriate unit of analysis in modeling household organization? How do changes in the parameters of a given household organization relate to changes in, say, demographic factors or class structure in a given society? How significant are the combined and independent influences of different causal factors on the parameters of a given household organization? What are the social, economic, and political consequences, if any, of changes in the size and composition of households? Addressing all these questions and several others that may arise in the study of household organization is beyond the scope of this dissertation. The research here will, therefore, limit its interest to the demographic component of household organization - the component driven by three demographic factors, namely, mortality, fertility, and nuptiality.

At a general level, changes that occur in the parameters of household organizations could be explained by adopting major sociological perspectives on social change such as those of Durkheim, Weber or Wallerstein[1]. Caldwell (1982) has criticized major theories of social change, and has argued that they are inadequate because they focus only on explaining behavioural changes, and overlook the question of why behaviours persist. His theory focuses mainly on

[1]Some of the references related to these perspectives are Durkheim (1964), Weber (1958), Lesthaeghe (1982), Smith, Wallerstein, & Evers (1982), and Wallerstein (1974, 1978).

values and attitudes and considers the direction of the flow of wealth[2] across successive generations. It would follow from this theory that the family or the household[3] would reduce in size if the net direction of wealth is to the advantage of children rather than to the advantage of their parents. Closely related to this theory is the work of Stone (1977) who has linked changes in sentiments to changes in the size and composition of families and households[4].

From our perspective. Shanin (1982) has provided the best critique of the differentiation model of the peasantry. In doing so, he illustrates how concepts related to the household may contribute to the development of sociological theory. While Shanin does not dispute the proposition that the differentiation of the rural peasantry into the class structure typical of capitalist societies does occur, he argues that other processes act to contain this differentiation and reinforce stability. About these processes, Harris (1982) has summarized the following: "the partitioning, merger, and extinction of households, as well as changes relating to the biological life-cycle of the family, had a levelling tendency which blunted the trend of differentiation" (p. 210).

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[2]The flow of wealth in Caldwell's (1982) theory refers to "the money provided by children to parents as well as such duties as caring for parents in their old age, ensuring the survival of the lineage or family name, undertaking the necessary religious services for the ancestors, helping in need and scarcity or devastation, relieving their middle-aged fathers of labour, etc." (p. 138)

[3]The terms *family* and the *household* are frequently used interchangeably. In most cases, the use of the term family actually refers to a family-household whose members are related either by blood or marriage or both. In the general case, however, not all members of a family belong to the household and vice versa. Bender (1969) makes a strong case for treating the two concepts - the family and the household - as analytically distinct.

[4]Thadani (1978) provides an excellent review explicating the similarities and differences between Caldwell's and Stone's perspectives.

Whatever the sociological perspective adopted for explaining changes in the parameters of a household organization, at a more specific level, these changes are induced by a wide range of variables, classifiable into three sets of factors - demographic, economic, and stratification (Yanagisako, 1979). Demographic factors such as the age at marriage, life expectancy, migration, and the level of fertility, may be regarded as setting constraints or limits within which these parameters operate (Bongaarts, 1983). Economic and stratification factors (Cherlin, 1983), such as the demand for labour for household production, the transmission of property across generations, and social class impinge upon the constraints set by the demographic variables, yielding, eventually, the observed parameters of the household organization.

Besides the demographic factors - also called the proximate determinants of the size and composition of households (Bongaarts, 1983) - the rules of household formation, residence, and extinction also govern the size and composition of households. These rules may be either tied to or independent of the demographic factors. Thus, strictly speaking, it is not only the demographic factors but also the rules of household formation, residence, and extinction that should be referred to as the proximate determinants of the size and composition of households.

It is generally argued that changes in household organization in Western societies have occurred primarily as a result of changes in the demographic factors prior to the middle of this century, and not due to changes in the patterns of household formation or extinction. However, since the 1950s, the pattern of household formation has changed dramatically, especially in the developed countries, although the pace at which it has occurred has differed across societies (Glick, 1984; Kobrin, 1976; Nilsson, 1985; Roussel, 1983; Wargon, 1978).

Research with a view to studying the demographic components of household organization points to the need for developing formal methods of analysis. The field of household demography, however, still lacks conceptual and analytical maturity and has yet to develop a systematic and well-defined framework for research. One example of these inadequacies is the debate in formal demographic literature, as to the appropriate unit of analysis for addressing questions about household organization. Some demographers (e. g., Muhsam, 1984) advocate the use of the household as the unit of analysis, whereas others (Espenshade and Braun, 1982) argue that this is not a feasible approach and the individual is more appropriately used as the unit of analysis in the modeling of households. Although the concept of the family life cycle has been popular as an analytical concept in family demography (see, e. g., Colluver, 1963; Glick, 1947, 1955, 1977; Glick and Parke, 1965; Harold and Feldman, 1975; Kono, 1977; Norton, 1974; Peron and Lapierre-Adamcyk, 1984; and Uhlenberg, 1974), a similar concept has not yet emerged with a comparable enthusiasm in formal household demography. Interestingly, the household cycle has been well appreciated as a unit of analysis in other fields of scientific enquiry such as anthropology (Goody, 1958), and history (Berkner, 1972), and to some extent in household demography as well (see, for example, Hanada, 1984; Hohn, 1984; and Wachter, 1985). In social demographic research, Cain (1978), for example, examined the impact of variations in the household-life cycle in Bangladesh on the economic mobility of individuals within and between generations.

As a first step in our understanding of the dynamics of household organization, the basic concepts of the formal demography of the household will be laid out and explicated, and an effort made to resolve the debate about the unit of analysis that would be most appropriate for use in formal household demography. Based on this stronger and well-defined conceptual foundation, a clear exposition of the nature and scope of the formal demography of the household can be made. Different approaches to modeling, such as analytical and simulation, may then be developed for analyzing the influence of various demographic factors on household organization.

The proposed research will, therefore, be organized along the following themes.

1. 3. The Aim of this Dissertation

The various parts of this dissertation will be bound together by the central purpose of modeling household cycles from a demographic perspective in order to compute the average size of the household.

Chapter 2

This chapter will elaborate on the nature and the scope of the formal demography of the household, including features that distinguish it from individual demography. Only those basic concepts of household demography that are relevant to the present research will be defined. Also, the question of what constitutes the appropriate unit of analysis for studying household organization will be addressed. This chapter will argue for the use of the household cycle as the basic framework for the development of formal models of household organization.

Chapters 3 & 4

Having defined the nature of formal household demography, measures of the average size of the household that have been used in the literature will be critically appraised. A distinction will be made between cross-sectional type measures (Chapter 3) and cohort type measures of household cycles (Chapter 4). These discussions will be restricted within the stationary and stable population models. As some earlier attempts at computing average household size (Burch, 1965; Coale, 1970) do not provide complete analytical expressions for the average size of the household, these formulations will also be expressed formally. Also, some assumptions that have been overlooked by these studies in their formulations of measures of average household size will also be identified in Chapter 3.

Chapter 4 will be devoted fully to Ryder's (1975) approach to estimating the average size of the household. His model, which is not formally developed in his paper, will first be expressed for the nuclear family household cycle, and then extended to two cases: the extended family household cycle with a foster mother and the extended family household cycle without a foster mother. The expressions for the average size of the household will be developed in terms of the mortality and fertility parameters of that part of the individual life cycle that is bounded by the household cycle of affiliation. Illustrative applications of these developments will be provided for the three types of hypothetical societies defined by Ryder (1975) - high equilibrium, disequilibrium, and low equilibrium, which correspond to the three stages of the classical demographic transition theory (Notestein, 1945).

Chapter 5

The two above chapters will deal with Lotka's stationary or stable population models. These models, however, are limited in their ability to mimic reality (Keyfitz, 1973). In order, therefore, to place demographic modeling within a more realistic framework, a microsimulation model of the Canadian household organization will be developed, for the purpose of studying the sensitivity of the measure of average household size to different parameters of the household cycle: household extinction, household growth (including individual mortality and fertility), and household formation. Various scenarios of each of these parameters will be used in the analysis in order to examine Kobrin's (1976) hypotheses with respect to the levels of mortality and fertility in a given society, on the one hand, and the average size of households in the society, on the other.

CHAPTER 2

FORMAL DEMOGRAPHY OF THE HOUSEHOLD:

BASIC CONCEPTS, UNIT OF ANALYSIS, AND ITS DISTINCTIVE NATURE

2. 1. Introduction

Formal demography of the household, which is still in its infancy, opens new frontiers of research for demographers (Brass, 1984; Hajnal, 1982; Lee, 1981). It has frequently been pointed out that the major concepts in the field lack conceptual clarity (Bongaarts, 1983; Brass, 1984; Burch, 1979). Recent attempts to redefine them (McMillen & Herriot, 1984; Muhsam, 1984) have not been entirely successful. In addition, a question of some debate has been the choice of the appropriate unit of analysis for the study of the household, that is, whether this unit should be the individual (Espenshade & Braun, 1982), or the household (Muhsam, 1982, 1984, 1985). This chapter will first discuss some major concepts in household demography (i. e., those that are relevant to the present work) and will provide analytical definitions for them. Second, it will attempt to resolve the debate concerning the appropriate unit of analysis in the study of the household. Finally, the distinctive nature of household demography, as compared to conventional individual demography, will be explicated.

2. 2. The Definition of the Household

The household may be defined as a socioeconomic unit, consisting of one or more individuals living together. According to the United Nations (1973a) definition,

"The concept of 'household' is based on the arrangements made by persons, individually or in groups, for providing themselves with food or other essentials for living. A household may be either: (a) a one-person household that is, a person who makes provision for his own food or other essentials for living without combining with any other person to form part of a multiperson household, or (b) a multiperson household, that is, a group of two or more persons who make common provision for food or other essentials for living. The persons in the group may pool their incomes and have a common budget to a greater or lesser extent; they may be related or unrelated persons or a combination of both" (p 336).

By this definition, a given population may be partitioned into subgroups termed "households" on the basis of the criterion that the members of each subgroup have "a common provision of food or other essentials of living." As such, a delineation of households is impractical to operationalize, at least in large scale social and demographic surveys. Censuses have adopted a more manageable, but not necessarily more acceptable definition of these subgroups of the population in terms of the dwelling unit[1] labelling them households. Obviously, the way households are delineated in a population will influence the results of a study. Different boundaries set for households following different definitions, may result in greatly varying statistics about, for example, the frequency of different types of households in a population (Hammel, 1984).

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[1] In the 1971 Canadian census, a dwelling unit was defined as "a structurally separate set of living quarters with a private entrance from outside or from a common hallway or stairway inside the building; i. e., the entrance must not be through someone else's living quarters" (Statistics Canada, 1973).

The concept of the dwelling unit which is generally used in delineating households is subject to various limitations. A dwelling unit may contain more than one household but may still be classified as one. On the other hand, two or more dwelling units may, in fact, constitute one household (Carter, 1984). Also, in any given case, the members of a household may be related by blood or marriage, or may be unrelated, or may even consist of a single person. In any case, once a group of persons constituting a household has been identified, this identity, and not that of the dwelling unit, is of interest for the demographic modeling of the size and composition of the household.

2. 3. A Critique of the United Nations' Definition of the Household

The United Nations definition of the household captures neatly the meaning of *the formation of the household.* Households are formed at the time *arrangements* are made *by persons, individually or in groups, for providing themselves with food or other essentials of living.* However, this definition does not address the question of what happens to the household once it is formed. It makes no explicit reference to the viability of the household.

Once the notion of household viability, or of household extinction, is introduced into the definition, the concept of the household cycle becomes pertinent. Interestingly enough, in anthropological and historical research, the household cycle has achieved considerable recognition as a core concept in the study of household organization (Berkner, 1974; Chaudacoff, 1978; Fortes, 1949; Goody, 1958; Hammel, 1961, 1972; Harevan, 1974; Shanin, 1982). Hammel (1984) has observed that the concept of the household cycle has permitted a greater understanding of the reasons for the changes that occur in domestic structures. Formal demography of the household has yet to incorporate this concept into mainstream research. Some authors, however, have used this concept in their work. In family research, for example, "the first model of the nuclear family was the family life cycle, a sequence of dates of critical changes in family structure" (Ryder, 1985, p. 216). In 1982 Muhsam observed that there have been "no attempts to my knowledge where a demographer has tried to explain changes in numbers of families or households from one census to the next, by drawing the basic demographic balance of 'births' and 'deaths' of families in the intercensal period" (p. 25). Because analytical approaches to studying household organization have generally neglected to consider explicitly the cyclical nature of the household, they have limited themselves to considerations of either the formation or the extinction of the household rather than covering the whole range of events that define the household cycle, namely, formation, growth, and extinction. One notable exception to this criticism is the study by Ryder (1975) whose analytic work lies in the forefront of the formal demography of the household.

2. 4. The Household Cycle: The Core Analytical Concept in Formal Household Demography

In a review article published in 1977 Sweet, following Glick (1955), made a strong case for the use of the cycle approach in family (and household) demography. However, as in other demographic studies, he focused on the changes that occur during the family life cycle assuming that the household was already formed and remained static. This section, however, looks at the entire span of the household cycle and examines not only the growth of the household but also the processes of formation and extinction.

The demographic literature on the average size of the household (Burch, 1970; Coale, 1965; Goodman, Keyfitz, and Pullum, 1974) shows a distinct bias towards either the concept of household formation or the concept of household extinction, neglecting to include both concepts in the sociological definition of the household. When both household formation and extinction are given explicit consideration, this approach to the study of the household would fully incorporate the entire span (or duration) of the household cycle. By focusing on household cycles rather than on either the formation or the extinction of households, a perspective of demographic modeling of household size would necessarily incorporate the formation, growth, and extinction of households.

In addition, the household cycle approach has the advantage of being dynamic, in the sense that it encompasses all the stages through which households pass during their respective cycles. If, on the other hand, a cross-sectional approach to estimating average household size were adopted, it would be considerably more difficult to link the different stages of a given household cycle in order to compute certain measures of household size and composition.

2. 5. The Formation and Extinction of the Household

Various terms have been used in the literature to define the events of household formation and extinction. These terms include the birth or beginning of a (new) household to denote formation, and household dissolution or death to denote extinction. These two events can best be defined in terms of three sociodemographic processes, namely, *fission*, *fusion*, and *fission-fusion*, and one demographic process, namely, the joint mortality of all household members[2]. If the population is open to migration, the immigration and emigration of households will also lead to their respective formation and extinction in the population.

The analytical definitions of the first three processes may be formulated on the basis of the biological definitions of fission and fusion (Carnap, 1956). Consider the case of the fission of a (parent) household. Assume that this household divides itself into 'n' (offspring) households at a given time. Then, if the members of the 'n' households at the time of their formation belonged to the parent household at the start of its division, the parent household is said to have undergone fission. The fission of a parent household leads to the formation or the birth of (n-1) households, if at least one person is still a member of the parent household at the completion of the fission.

In the general case, if the parent household is not affiliated by any of its members at the end of its fission, the birth of 'n' households takes place, accompanied by the extinction of the parent household, but if the parent household is still affiliated by even one of its members at the end of its fission,

---

[2]Or the joint mortality of one or more members of a household which makes the household non-viable. In the subsequent discussion, joint mortality of the household members will be considered equivalent to the extinction of the household either due to its non-viability or due to the death of all its members.

the birth of (n-1) households occurs, without the extinction of any household[3] Thus, the fission of a parent household into 'n' households would result in the birth of either 'n' or (n-1) offspring households. Theoretically, all households in a population can be expected to experience fission. Consequently, the upper limit of the total number of households in the population would depend upon smallest feasible social unit that constitutes a household. For a diagrammatic illustration of the concept of fission, see Figure 2.1

Like the fission of households, the fusion of households can also be conceptualized on the basis of the biological definition of fusion given by Carnap (1956). Consider 'n' (> or = 2) households, all of which fuse at a given time. Then, all individuals who are affiliated with the 'n' households at the beginning of the fusion should belong to, and only to, the fused household at the time of its formation. For example, a widow's household would be extinct if she were to move with her children into another existing household, say, upon her remarriage (Ryder, 1975).

The formation of a new household could also occur from the fusion of 'n' households and would be accompanied by the extinction of 'n' households. If, however, the fused household is still one of the 'n' households involved in the

---

[3]Whether or not the parent household, after fission, is still affiliated with one of its members would depend upon the definition of the household. If the dwelling unit is taken as the criterion for delineating households, one could argue that the parent household is still viable at the end of its fission if at least one of its members continues to occupy the unit. However, if the household is defined as viable if the members maintain their previous arrangements for providing themselves with food or other essentials of living, the parent household may be considered extinct at the time of its fission only if these arrangements are defined afresh for all the households formed at the end of its fission.

Figure 2.1 A Diagrammatic Representation of the Fission of Households

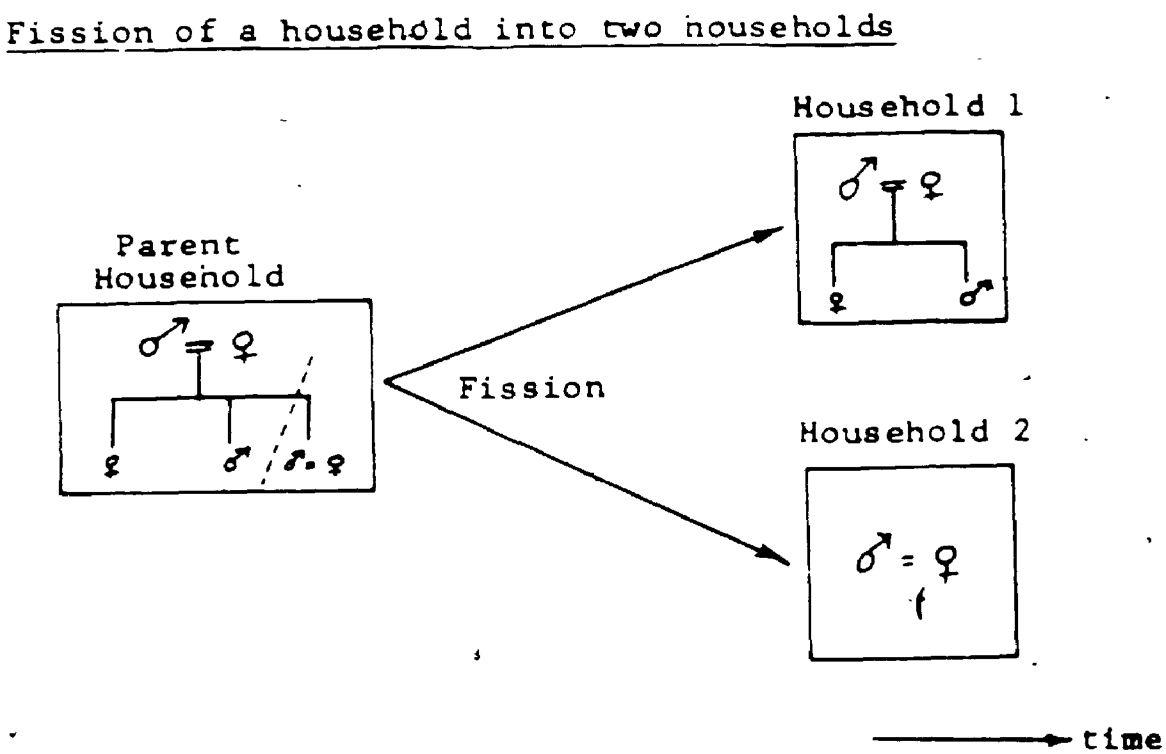
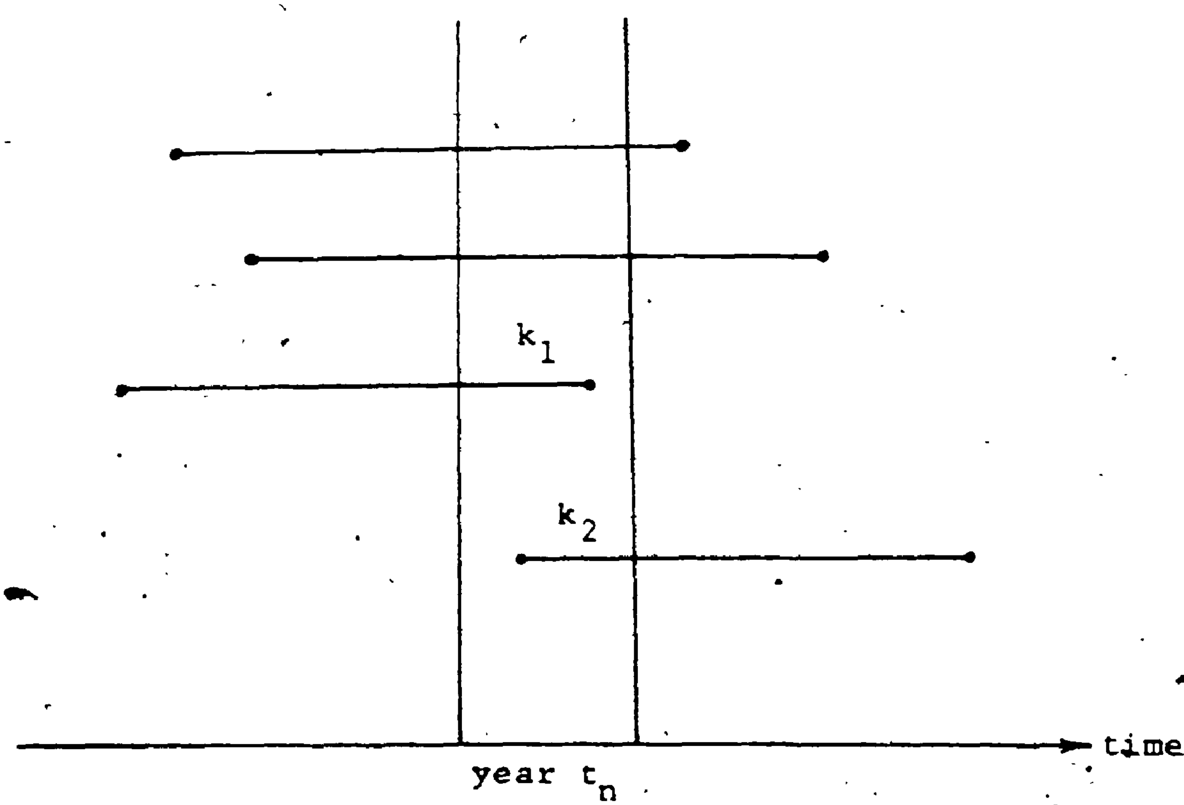


Figure 2.4. An Illustration of the Concept of the Size of a Household in a Given Year t_n



The horizontal lines represent the life lines of the members of a given household. These lines are shown above only to the extent that they overlap with the given household cycle. The size of the given household in the year t_n will equal $(2+k_1+k_2)$ "person years", where k_1 and k_2 refer, respectively, to the fraction of the year t_n lived in the given household by two of its members. If the events are assumed to be uniformly distributed within the year t_n, the size of the household in the year t_n would equal 3.0 persons, or more accurately, 3.0 person years.

Figure 2.2. A Diagrammatic Representation of the Fusion of Households

Fusion of three households: ego's, ego's parents' and ego's spouse's parents'

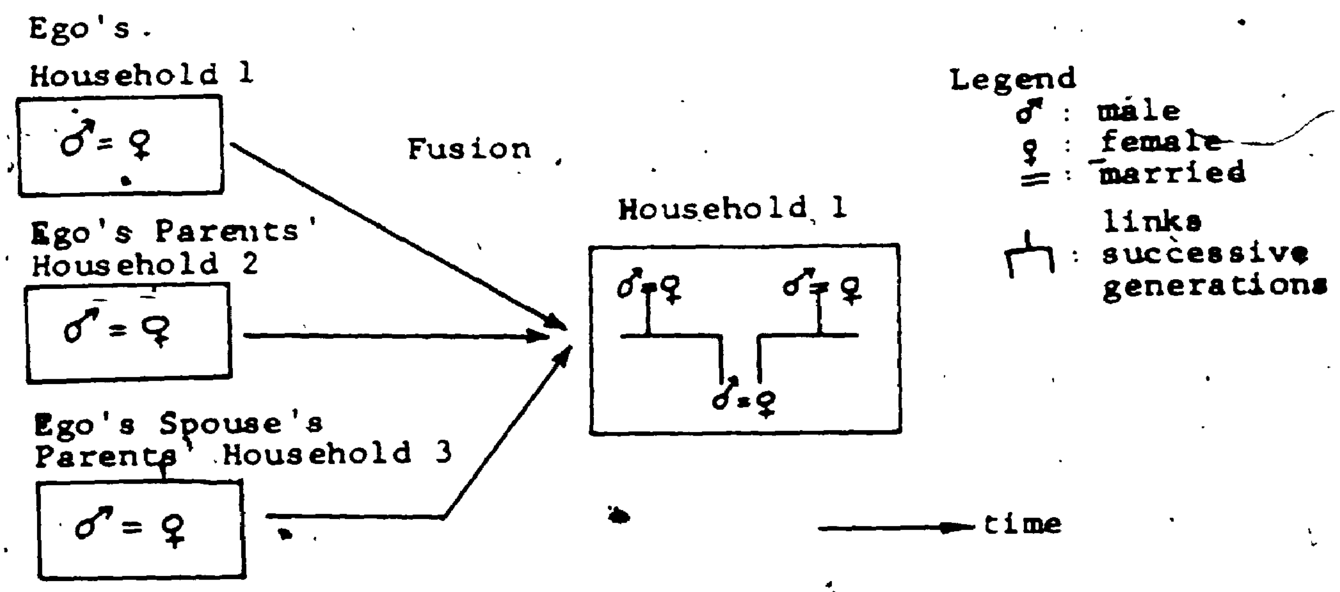
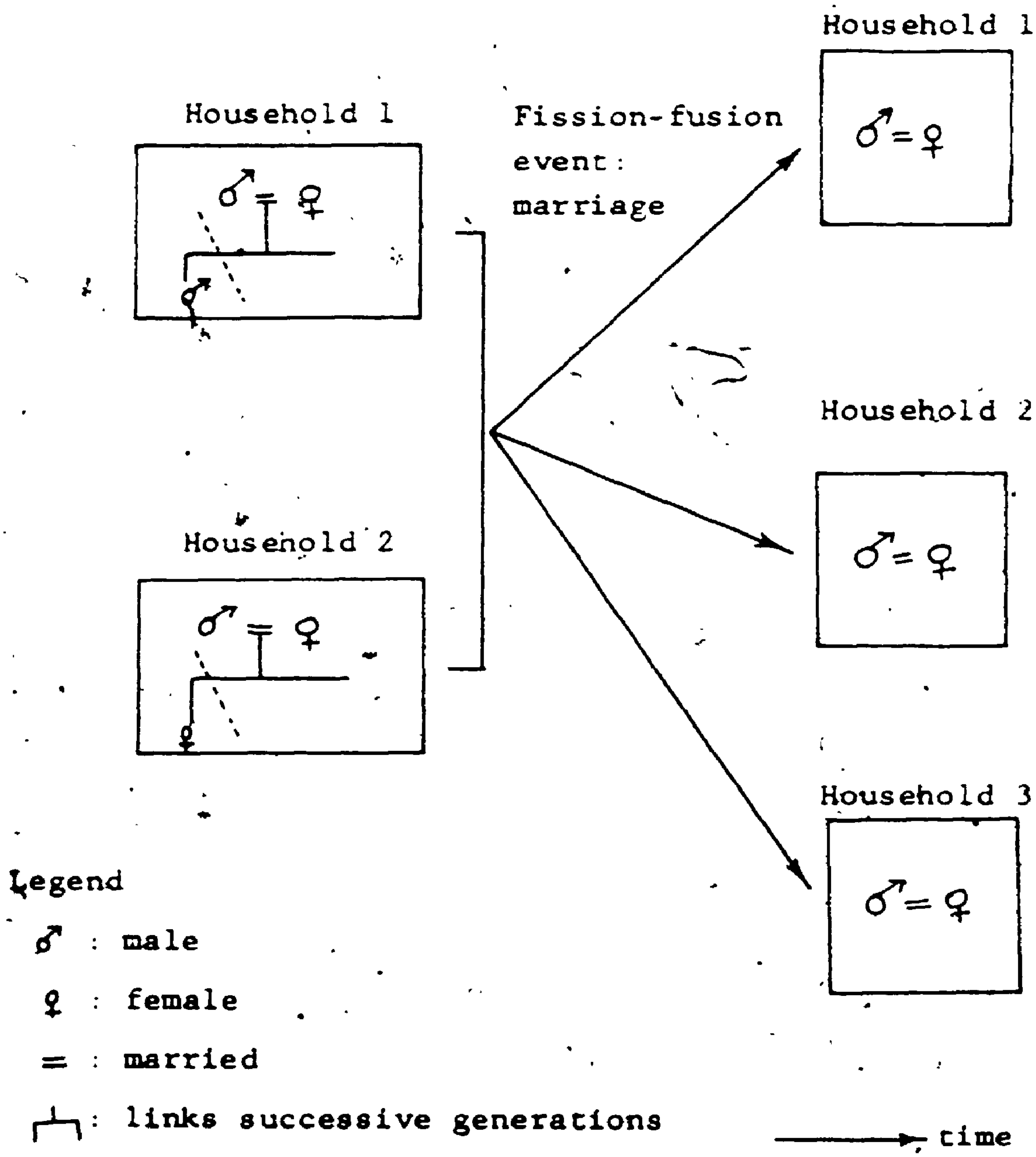


Figure 2.3. A Diagrammatic Representation of the Fission-Fusion of Households



taking the simplest case of fission-fusion, namely, the case of nuptiality[4], which is essential to the formation of the nuclear family household. Modeling the process of nuptiality involves an explicit consideration of both sexes. The development of two-sex models of nuptiality is in itself a difficult task (see, e. g., Keyfitz, 1985), and incorporating it into household modeling presents a complex problem, especially because in the general case of household formation, the event of marriage does not necessarily coincide with the event of household formation.

2. 6. Growth of the Household

During the life span of a household cycle, the household may undergo changes in size[5]. The size of a household during a given period may be measured either by the number of persons living in the household at the mid-point of the period, or by the number of person years lived in the household during the period by all its members (see Figure 2.4). If the time reference for estimating the size of the household refers to a point in time, both definitions would yield the same result. Such an equality would also hold when the time reference is a period under the assumption that the events of birth and death experienced by individual household members are distributed uniformly within the specified time interval. The individual life histories of household members become important in the study of the growth of a household, and some of the mechanisms by which the two are linked are described below.

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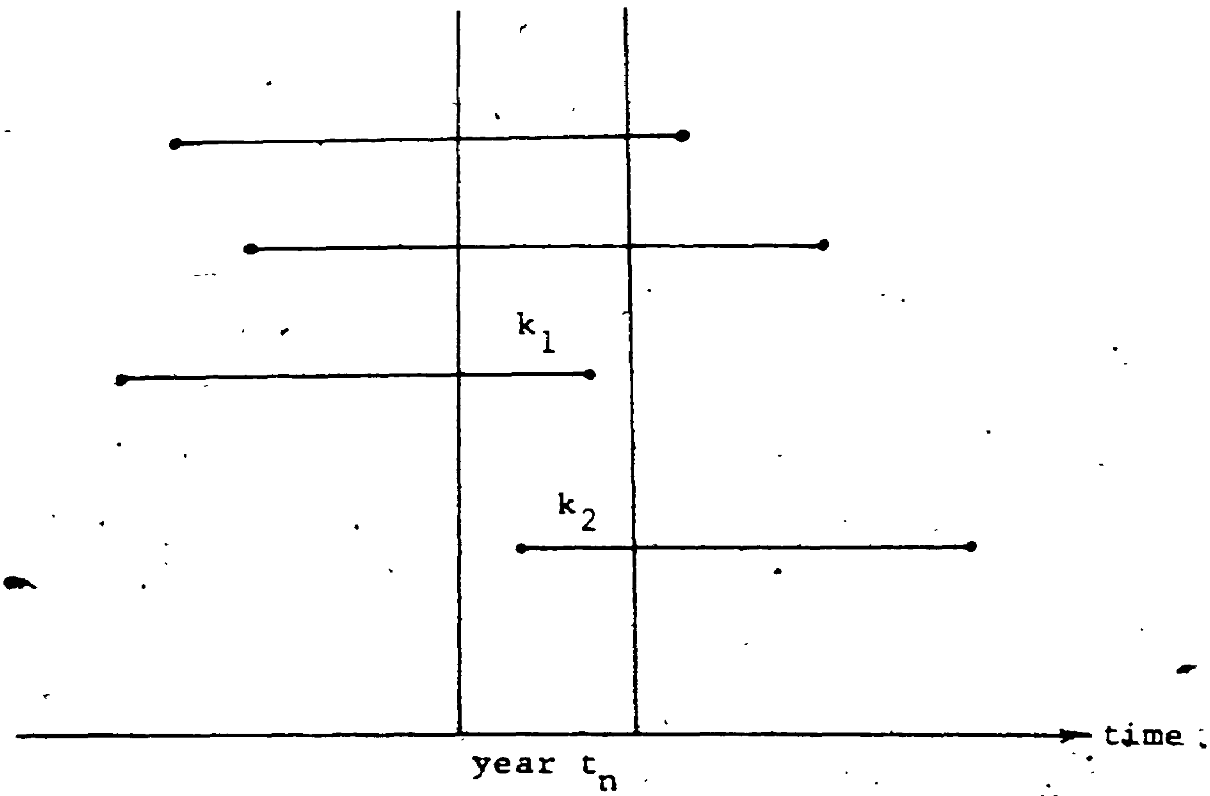
[4]Except in the case of households such as those of size one in which nuptiality would lead to the merging or fusion of households of the bride and the bridegroom.

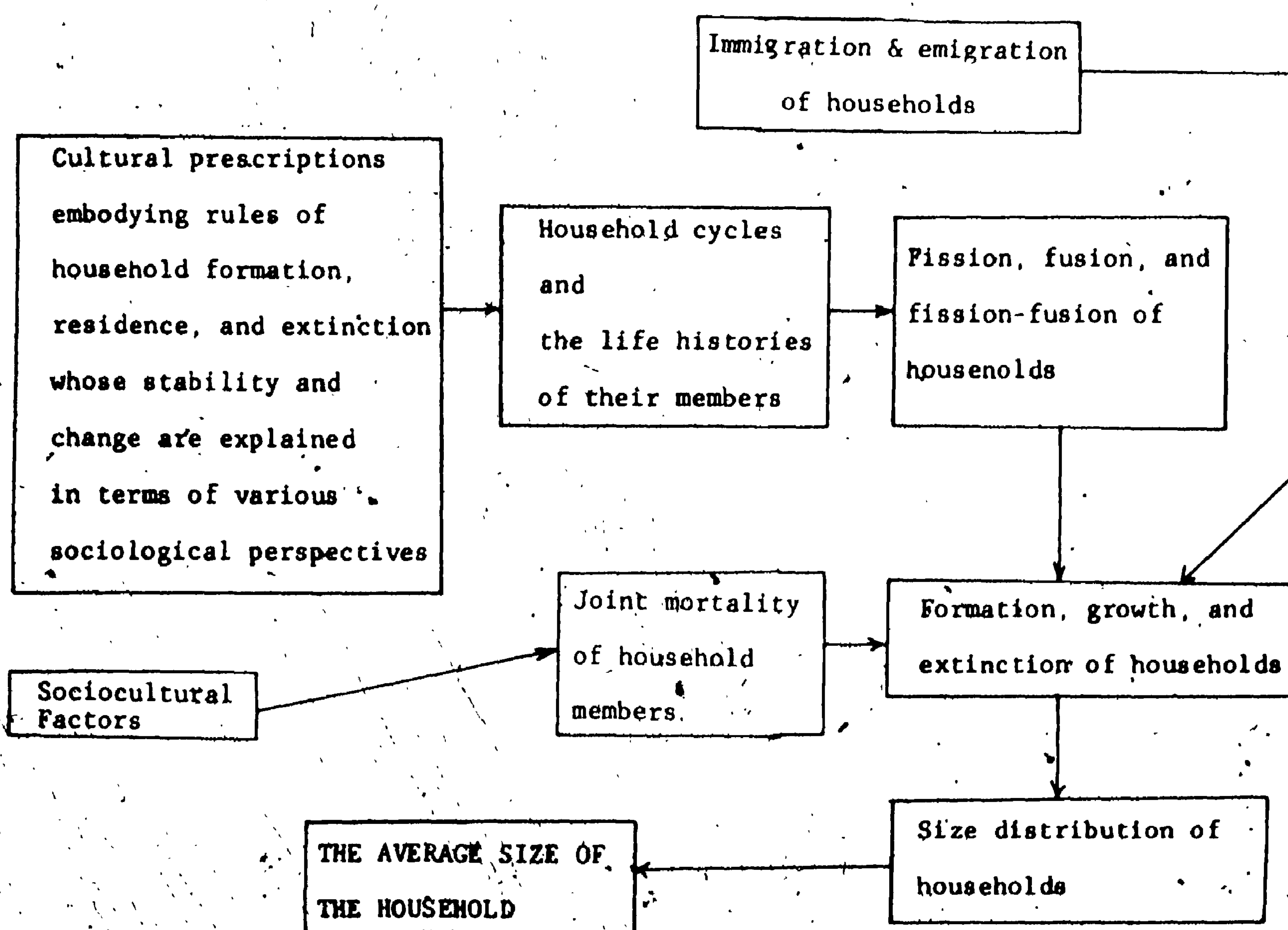
[5]Many features of the household such as its consumer-earner ratio also change during the course of the household cycle but these features would more appropriately be discussed under a separate subsection on changes in the composition of households.

Figure 2.4. An Illustration of the Concept of the Size of a Household in a Given Year t_n



The horizontal lines represent the life lines of the members of a given household. These lines are shown above only to the extent that they overlap with the given household cycle. The size of the given household in the year t_n will equal $(2+k_1+k_2)$ "person years", where k_1 and k_2 refer, respectively, to the fraction of the year t_n lived in the given household by two of its members. If the events are assumed to be uniformly distributed within the year t_n, the size of the household in the year t_n would equal 3.0 persons, or more accurately, 3.0 person years.

Figure 2.5. A Simplified Model of the Determinants of Average Household Size



Household Cycles and Individual Life Histories

The household-level processes of fission, fusion, fission-fusion, and the joint mortality of all the household members in a given unit of time, mark the extreme points of household cycles, and thus determine the size and other characteristics of households at the beginning and at the end of their respective cycles.

Three mechanisms through which the life histories of individual household members may be involved in the four above household-level processes are identified below.

I) Exit of one or more individuals from the household during the year t, from among the household members present in the household at the end of the year (t-1).

The processes leading to the exit of individual household members from the household of their affiliation are:

a) mortality of one or more household member in the year t.

b) outward movement from the household of residence: such a movement would depend upon the rules of household formation and residence being followed by the household. For example, in the case of the nuclear family household, such a movement would result from marriage. Other demographic events that would be important here include the splitting of the household due to divorce, separation, formation of a cohabitation union, and children leaving their parents' household.

II) Entrance of one or more persons into the household during the period t

The processes underlying the entrance of individuals into the household are:

a) fertility

b) inward movement into the household: as in the outward movement of household members, such a movement inward would depend upon the rules of household formation and residence that are followed by the given household. Some of the demographic events that may be relevant here include the formation of a marital union or of a cohabitation union, and the adoption of children.

iii) Household members continuing to live in the same household during the given period t, from among the members present in the household at the end of the year (t-1). This factor would also depend upon the rules of household formation and residence followed by the given household.

Determination of the Average Size of the Household

As households in a population undergo changes in size the average size of the household changes as well. A simplified model of the determinants of average household size is illustrated in Figure 2.5. The changes in household size are initiated by several processes: fission, fusion, fission-fusion, the immigration and emigration of households, and by the joint mortality of the household members. The fission of households would necessarily lead to an increase in the number of households of smaller size and a corresponding decrease in the number of large-sized households, thus leading to a decrease in average household size. The composition of the households would, of course, change accordingly. The fusion of households on the other hand, would have exactly the opposite effect. The third process described, that of fission-fusion, may lead to a simultaneous increase in the number of households of large size and of small size as compared to the sizes of the households initially involved in the process, thus causing one of three effects: no change in average household size, a decline in average household size resulting from a net increase in the proportion of smaller households at the end of the process, or an increase in average household size as a result of a net increase in the proportion of smaller households[6]. In a homogeneous set of households which vary only in their size, the rate of extinction of a household because of the joint mortality of all its members will correlate negatively with the size of the household. Thus, smaller households will have a higher probability of household extinction than larger households under the impact of the joint probability of death of all the members of a household. As a result, the proportion of larger households will increase in the population and, in turn, so will the average size of the household. Average household size in the total population will therefore be the net effect of all these processes. Finally, for modeling the size-distribution of households it is sufficient to know the rates of fission, fusion, and fission-fusion of households and the probability of household extinction because of the joint mortality of all the household members. The modeling of household composition, on the other hand, would require the disaggregation of rates by the demographic characteristics of the individual household members.

2. 7. The Unit of Analysis in Household Demography

Finally, it becomes imperative to arrive at a decision about what the

[6] These three processes will undoubtedly have a more complex effect on household composition than on the size of the household.

appropriate unit of analysis in household demography should be. Muhsam (1982, 1984, 1985) has repeatedly emphasized that the household should be the unit of analysis, since the legitimate domain of household demography is the study of households. Espenshade and Braun (1982) and Pullum (1984), on the other hand, argue that the relative instability of the household as a unit, compared to the individual, precludes its use as the unit of analysis in household demography. They point out that the relative ease with which a household can recombine or reunite with similar units or individuals, or decompose into two or more units, or even disappear, puts it at a disadvantage when a decision about the unit of analysis has to be made. There is, in other words, always the risk that households might undergo fission, fusion, or fission-fusion, and therefore, might even become extinct. Even though these observations made by Espenshade and Braun (1982) and Pullum (1984) are accurate, they do not constitute valid grounds for selecting the individual as the unit of analysis in household demography. It may be pointed out that conventional individual demography is not immune to the above problems; the event of marriage, and the event of birth as well, in which two or more individuals must "fuse" and cease to be independent, are cases in point. Demographers have circumvented this problem, at the cost, unfortunately, of obtaining inconsistent results, by resorting to one-sex population models (Keyfitz, 1985). Similarly, the "two-sex" problem that pervades household demography, especially through the process of fission-fusion has been overcome by the use of one-sex population models.

Although the household appears to be the more appropriate choice for the unit of analysis in household demography, direct data even on the three proximate determinants of household size, namely, fission, fusion, and fission-fusion, are rarely available. Indirect approaches may, however, be used for constructing demographic models of households. Two such approaches are to be found in the literature: an individual-oriented approach that may be called *tagging*, wherein each individual in the population is tagged with the household of his or her affiliation, and a household-oriented approach that may be called the *marker* approach in which each household is represented by an appropriately chosen marker.

The individual oriented or tagging approach, suggested in the work of Elder (1981), Espenshade and Braun (1982), Hanada (1981), and Pullum (1984), uses the individual along with an identification mark of his or her affiliation to a particular household, as the unit of analysis. The question as to who is affiliated with an entirely new household is determined by the cultural prescriptions which embody the rules of household formation. Changing membership to a different but an already existing household is determined by a different set of cultural prescriptions, that which embodies the rules of residence prevailing in the society at the time.

With respect to the marker or household oriented approach, Brass (1984) has recommended the use of a marker as a proxy for the household. Thus, there is a one-to-one correspondence between household markers and their respective households. A preferred marker, according to Brass (1984), is an adult member in the household to whose life-cycle events are linked as they occur over the household cycle. A similar approach has been used extensively in projecting the number of households, using headship rates (United Nations, 1973b). Each head[7] by definition, is associated with a household and, therefore, represents a marker, serving as a proxy for the household. The number of new markers observed would then automatically provide the number of new households formed. An important feature of this approach lies in its ability to estimate in one step, the number of households formed without explicitly using the household as the unit of analysis. In the absence of direct data on households, the use of markers to represent them is an attractive way of studying some aspects of household demography, and may be viewed as an indirect method of estimating various parameters relating to households. The marker approach has, however, certain disadvantages. A given household may not necessarily have a specified (standard) marker for various reasons, such as the individual's death, mobility, or simply never being part of a household in the study population (Muhsam, 1984). Furthermore, the marker

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[7] Here, the use of the head of the household as a marker is merely as a replacement for the household, in order to simplify analytic modeling. Sociologically, however, the notion of the head carries considerable significance. Before his or her death, the head may decide when new households will be formed by the members of his or her household, how the property of his or her household should be divided among the heirs before or after his or her death, and even the timing of the distribution of this property. From a sociological perspective, the utility of assuming that households always have a single head is questionable, especially in North American society. Thus, if a sociologically meaningful definition of the head is used in the demographic modeling of households in the North American context, "the assumption that there is a demographically meaningful single-person household formation process needs to be challenged for many households, [and] the routine computation of headship rates which assume the single-person-headed household in all cases also needs to be challenged" (Dr. Leroy O. Stone, personal communication, August 15, 1985). A similar point, though far less emphatic, is made by Astra-Meesook (1982). Of course, single person households in which there is necessarily a single-person-household-formation process are exempt from such a challenge. Other problems also arise when dealing with the sociological concept of the head. For example, different meanings may be attached to the word "head" in different contexts. In the absence of a single definition of the head of the household over time and space, the appropriateness of the use of the age of the head of the household as a proxy for household duration remains in question (Astra-Meesook, 1982).

approach necessitates a consideration of the characteristics of the selected marker. Often, all the events that occur in the household may not occur to the marker; for example, the death of the head's spouse, home leaving of the children, etc., Under such circumstances, a marker who cannot represent all the events occurring in the household would have to be replaced by a more suitable one. Such a replacement would only introduce greater complexity into the formulation of demographic models of households.

From the above discussion, it is clear that at the heart of the debate about the unit of analysis in household demography lies the fundamental question of the link between individual and household cycles. The nature of this link in the case of both the formation and the extinction of the household is discussed below.

Consider, first, the case of household extinction. The probability of household extinction may be estimated by following a set of households formed at a given time (that is, a household formation cohort), and observing their extinction over time. Although the extinction of these households depends upon the life histories of their respective household members, all individuals, along with their households of affiliation, must be followed over time for studying the process of household extinction. The identity of the individual life histories, which are affiliated to a given household selected from a given cohort of households, must therefore be retained.[7] Further, since the individuals from a household formation cohort may belong to different birth cohorts of individuals, the latter cohorts cannot, as a rule, replace the household formation cohort. If the possibility of observing household extinction in a birth cohort of households does not exist, indirect methods are available for deducing probabilities of household extinction from the durations of their life cycles. One such method is the household marker approach, in which the part of the marker's life history that coincides with the life history of the household serves as a proxy for household duration. The salient point of the study of the pattern of household extinction is that the household, or its marker who spans the household cycle, must, of necessity, be taken as the unit of analysis. The possibility of a cohort of individuals substituting a cohort of households does not exist in general, within the context of the demographic modeling of households.

The study of household formation, on the other hand, poses a greater problem with respect to the choice of the individual[8] or the household as the basic unit of analysis. Unlike the study of household extinction, which must use the household as the basic unit of analysis, the pattern of household formation, from a theoretical standpoint, may be studied either by following a birth cohort of individuals or by following a household formation cohort. Hence, in the light of the choice available in selecting a unit of analysis, the debate assumes greater importance in the study of household formation compared to that of household extinction.

The interpretation of results obtained from studying household formation in a birth cohort of individuals would differ from those made of the results obtained using a cohort of households formed at a given time. Consider, for example, using a cohort of births to study the incidence of household formation by the

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[8] Here, the individual is not the same as the household marker

members of the cohort as they complete their life cycles. The process of headship, that is, the transition from nonhead to head, may then be used to operationalize the process of household formation by the individual cohort members. Valid probabilities of household formation by the individual can then be computed from data on the transition from the state of nonhead to the state of head of the household. This approach to estimating the probability of household formation by the individual takes a different perspective from that of the study of the risk of household extinction, which necessarily traces a cohort of households[9] as they complete their cycles. The inconsistency in the use of different cohorts, individual and household, when dealing with two events, household formation and extinction, suggests that the household should be taken as the unit of analysis in studying household formation. What is, therefore, required for consistency in studying household formation and extinction, is first, a cohort of households formed at a given time, just as in the case of studying household extinction. The cohort should then be followed over time, to study the pattern of household formation associated with the given cohort of households. The number of households thus formed over the course of a birth cohort of households would then give the total number of births of households. Thus, a parent household unit, on the average, would give birth to, say, 'n' offspring household units during its cycle.

As one household unit could give birth to more than one household, the probabilities of household formation would not be defined when a birth cohort of

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[9]Except in the special case where each household is of size 1.

households is followed, that is, when the household is taken as the unit of analysis. However, it would be possible to compute other measures of household formation. Two examples of such measures are the number of offspring household units per parent household and a net household replacement index similar to the net reproduction rate in fertility. However, probability type measures may also be estimated if individual life histories belonging to the given cohort of households are followed in order to monitor their household formation. For example, one may compute the probability of household formation by an individual belonging to a cohort of households. Of importance in distinguishing between the household and the individual as units of analysis, is the fact that individual household members belonging to a given birth cohort of households may not necessarily belong to the same birth cohort. For example, according to the rules of formation and residence of the extended family household the parent household dissolves at the time of the death of its head. Concurrently, an offspring household unit is formed by all the surviving household members who may not necessarily be of the same age. Hence, the replaceability of a birth cohort of household cycles by a birth cohort of individuals does not exist. Thus, it may be argued that the household in the entirety of its cycle constitutes the basic unit of analysis for the study of households. This choice, however, does not preclude the use of individuals, who are involved in the formation of households. A study of households would thus involve a consideration of both household cycles, and those parts of individual life histories that are bounded by the household cycles of their affiliation.

Because of the lack of conceptual clarity in the definitions of important concepts relevant to household demography and in the light of the debate about the appropriate unit of analysis, it has been difficult to describe the nature of the formal demography of the household. Now that these problems have been addressed, it is possible to clarify the distinctive nature of this field of study.

2. 8. The Distinctive Nature of the Formal Demography of the Household:

The formal demography of the household is not only distinct from, but also more complex than, the formal demography of the individual. Even though the problems of the demography of households and families may be regarded as "very natural extensions of traditional 'atomic' demography of individuals" (Lee, 1981, p. 508), these extensions are not necessarily straightforward, as the previous sections of this chapter have demonstrated. Just as individual demography constitutes the study of the demographic events that occur during the life cycle of the individual, the study of demographic events of individual household units forms the distinguishing feature of the formal demography of the household. The study of household cycles does not, however, preclude a consideration of individual life histories. The life histories of individual household members combine to form the household cycle, and are relevant to formal household demography to the extent that they are bounded by the household cycle. Thus, maintaining the consistency between individual life histories and household cycles while developing models of households becomes a critical methodological issue in formal household demography. In addition, the similarity between individuals and households in terms of the concepts of birth or formation, death or extinction, and the life cycle or life history is not coincidental. The analytical models developed for the individual may therefore be adapted to the study of households as well. The following section highlights the similarities between the two types of models.

2. 9. Formal Models of Household Demography: Concluding Comments

Following closely the methods of conventional demography of the individual, two types of models, namely, decrement and increment-decrement, have been constructed for families or households. In decrement models applicable to household demography, it is assumed that there is only a one-way transition from the state of being nonhead to the state of being head and vice versa. The use of decrement models in family demography, especially in the study of nuptiality, is quite well known (see, e. g., Mertens, 1965; and Wunsch and Termote, 1978). Two types of nuptiality tables, net and gross (Merten, 1965), with direct implications for use in household demography, may be identified in the literature. The net nuptiality table takes into account two factors of decrement - first marriage and mortality. Thus, a typical survival column of a net nuptiality table refers to the proportion of women alive *and* single at various ~~exact~~ ages. The nuptiality rate in a net nuptiality table, also referred to as the dependent rate by Mertens (1965), is defined as the ratio between the number of first marriages to persons between exact ages x and (x+1) and the number of unmarried persons at exact age x. An analogous table in household demography, with the same computations, would be called the *net headship table*, whose typical survival column would give the proportion of women alive and in the state of being nonhead at various exact ages. This approach underlies the computation of the average size of the household made by Burch (1970), Coale (1965), and Goodman et al. (1974). Under certain assumptions, the use of the net table approach in computing the average size of the household is valid. However, if the purpose of the study is to compare or contrast the effects of, say, different risks of household formation and fertility on the average size of the household, the gross table approach, which is described below, would be more appropriate.

The gross nuptiality table takes into account first marriage as the only factor of decrement, operating on nonhead individuals in a given population. The nuptiality rate (n_x) in this kind of table, also called the independent rate by Mertens (1965), is defined as the ratio between the number of first marriages N_x between exact ages x and (x+1) and the number of person years lived (L_x) in the never married state between exact ages x and (x+1). The nuptiality rates n_x's are also referred to as occurrence-exposure rates (Hoem, 1976). The analogous table in household demography would be referred to as the *gross headship table*. An example of the use of this approach is to be found in Ryder (1975).

The construction of decrement life table models has been quite popular among demographers working with family processes, notably nuptiality. However, if there exist reentries of persons between the states of being nonhead and being head, or, in general, among other states, which have an influence on the parameters of a given household organization, decrement models will not be applicable. Prior to 1970, methods dealing with these types of reentries into a given state space had not yet made their impact upon demographers studying processes of family formation and dissolution. Consequently, they treated the 'ever married' category as an undifferentiated group of people. This group was subsequently decomposed into the categories of divorced, widowed, and presently married, when increment-decrement life table methodology became available. Although the possibility of reentry into certain states was not unknown to demographers, there seem to have been three factors which probably account for the delay in the use of increment-decrement methodology:

i) the lack of the availability of life history data

ii) the time lag between the methodological developments and their applications, and

iii) very low probabilities of reentry among a given set of states

The period 1970 to 1980 witnessed not only the development of increment-decrement models but also their application to the study of family formation and dissolution (Krishnamoorty, 1979; Rogers and Ledent, 1976; Schoen, 1975, 1976, 1979; Schoen and Land, 1979; Schoen and Nelson, 1974; and Willekens et al. 1980). The development of increment-decrement modeling in demography first involved the use of the demographic accounting framework. Using this framework, Schoen and Nelson (1974) estimated the probabilities of transition among a given set of states in their increment-decrement stationary life table model. Later Schoen and Land (1979) formalized the structure of the Schoen and Nelson (1979) model in terms of the Kolmogorov-Forward Differential Equation for estimating the same transition probabilities among a given set of states. These developments have so far been found to be very useful in family or household models.

2. 10. Summary

This chapter has developed some of the basic ideas about formal household demography, along with a critique of the United Nations' definition of the household. Then, the core analytical concept of household demography, namely, the household cycle, is identified and discussed in detail. The use of this concept in household modeling necessarily involves a consideration of both the formation and extinction of the household, which occur as a result of the processes of the fission and fusion of households. Once the two extremes of the household cycle - formation and extinction - are defined, the growth of a given household in terms of its size can be studied.

The choice of the unit of analysis in formal household demography is also discussed. Two approaches to the study of the household, namely, the household marker approach and the tagging approach are identified and discussed in detail. It has been argued that the household cycle constitutes the basic unit of analysis. However, individual life cycles are also important to the extent that they are bounded by the household cycle. Finally, life table models that are used in individual demography and have potential applications in household demography, along with their relative advantages and limitations; are also summarized.

CHAPTER 3

DEMOGRAPHIC MEASURES OF AVERAGE HOUSEHOLD SIZE:

A CRITICAL APPRAISAL

3. 1. Introduction

Several demographic measures of average household size for stationary and stable populations have been computed in the literature (Burch, 1970; Coale, 1965; Goodman et al., 1974; Ryder, 1975; Willekens, 1985). These computations have been developed for various types of household systems including the nuclear and extended family households.

The definitions describing three types of households (summarized below) were given by Coale (1965), and subsequently adopted by Burch (1970), and two of them adopted by Goodman et al. (1974). In the case of the nuclear family household, each woman is assumed to form her own household at the time of marriage. On the other hand, in the extended family household type I, it is assumed that a woman's natural mother is replaced by a foster mother of the same age as the natural mother, should the natural mother die before the woman's marriage. At the time of her marriage, the woman forms her own household if her natural mother is dead; otherwise, she forms her own household upon the death of her natural mother. The rules of the extended family household type II are the same as those of the extended family household type I, except that a woman, after marriage, continues to live with her natural or foster mother as the case may be, and forms her own household at the time of the death of her (natural or foster) mother[1].

The demographic measures of average household size for the the three above household systems have been based on Lotka's one-sex stationary and stable population models. For each of the three types of households. Coale (1965) pioneered the use of the stationary population model to estimate average household size. Burch (1970) extended Coale's computations to the stable population case by replacing the stationary by the stable population distribution from Coale-Demeny's tables. Subsequently, Goodman et al. (1974) presented analytical expressions for making similar estimates not only under different patterns of fertility and mortality but also under different patterns of nuptiality.

3. 2. Measures of the Average Size of the Nuclear Family Household

Three demographic measures of the average size of the nuclear family household reported in the literature on the demographic modeling of households are reviewed below. Willekens' (1984) measure of the nuclear family household cycle, based on multistate demographic analysis, is not reviewed here because the analysis in this chapter is restricted to decrement life table type of models.

Coale's and Burch's Measures

Coale (1965) formulated a measure of the average size of the nuclear family household within the context of the female one-sex stationary population model, and Burch (1970) extended it to the one-sex stable population case. Under the

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[1]One may also use the labels extended family households with and without a foster mother for extended family households type I and type II, respectively. The latter terminology is used here because a foster mother is involved in both cases when the woman is in the unmarried state.

rules of household formation that have been incorporated in formulating the two measures, every female forms her own household at the time of marriage. Both measures are based on the assumptions that:

i) only the female population is considered, and total household size is computed by doubling female household size under the assumption that the sex ratio is unity

ii) all females marry

iii) all marriages take place at the average age of marriage ($\bar{n}$)

iv) each female forms her own household at the time of marriage

v) there is only a one-way transition from the status of being nonhead to the status of being head of the household

vi) Coale's measure is based on the stationary population model whereas Burch's measure is based on the stable population model

Let Coale's measure be denoted by ${}_{n}\overline{H}_{c}$, and Burch's measure by ${}_{n}\overline{H}_{b}$. The subscripts n, c, and b identify the nuclear family household system, Coale's formulation, and Burch's formulation, respectively.

The formulas for the two measures are given by:

$${}_{n}\overline{H}_{c} = 2\, T_{o} / T_{\bar{n}}$$

and

$${}_{n}\overline{H}_{b} = 2\ (\text{Total Population/Population aged } \bar{n} \text{ and above})$$

governs the size distribution of households and thus of average household size at a given time.

In each type of household system discussed in this chapter, the female one-sex stationary or the female one-sex stable population model underlies the development of the measures of average household size. The male, for all practical purposes, is treated external to the pool of females under consideration. Whenever a male has to be linked to a female's household, as for instance, in the case of marriage leading to the formation of a household, the male is assumed to exist in a hypothetical pool of males and can be *imported* into the household. In other words, the model underlying the development of the three measures may be termed *open* so far as the question of the two sexes is concerned. If, on the other hand, males have to be selected from a given population, appropriate males for linking to female households may not necessarily be found. The underlying model in such a case is termed *closed* and this restriction raises considerable difficulties, as has been observed in the development of two-sex models. One advantage of an open model is that it eliminates the need for explicitly modeling the movement of males into female households, thereby eliminating the need for modeling fusion and fission-fusion, both of which may occur as a result of males moving into female households. The formulation of the measures of average household size is, therefore, simplified considerably as a result of treating the male population external to, and independent of, the female population. Female households may, however, still change in size and their average value would be an outcome of the net effect of their fission, fusion, and fission-fusion and the joint mortality of the where l_x is the standard life table survivor function giving the number of persons surviving at exact age 'x', and 'r' is the intrinsic rate of growth of the given stable population.

Note that if

$$m(a)=\begin{cases} 1 & \forall a \geq n \\ 0 & Otherwise \end{cases}$$

then, Goodman et al.'s measure of the average size of the nuclear family household reduces to

$$\frac{2}{\int_{n}^{w} c(x,t)dx}$$

which is clearly equal to $2T_0/T_n$ in the stationary population case (Coale's measure) and to 2(Total population /Population aged n and above) in the stable population case. Thus, under the above restrictions on m(x), Goodman et al.'s measure reduces to Coale's measure, $({}_n\overline{H}_c)$, in the stationary population case, and to Burch's measure, $({}_n\overline{H}_b)$, in the stable population case.

3. 3. Measures of the Average Size of the Extended Family Household Type I

Three studies, those of Coale (1965), Burch (1970), and Goodman et al. (1974), which have computed the average size of the extended family household type I are described below.

Coale's and Burch's Studies

Coale (1965) computed the average size of the household type I for the stationary population case by using Coale-Demeny's model stationary populations, and Burch (1970) computed the same average size by using Coale-Demeny's model stable populations.

The probability that a female ego who marries at age $\hat{n}$ does not form her own household by age $(\hat{n}+x)$ is equal to the probability that her mother is alive when ego is aged $(\hat{n}+x)$. Thus, the probability that ego forms her own household by age $(\hat{n}+x)$ is $(1-l_{a-\hat{n}-x}/l_a)$, where l_x is the standard life table survivor function.

As both Coale and Burch used stationary and stable population distributions given in Coale and Demeny (1966) model populations, the analytical formula - *not* provided by Coale (1965) or Burch (1970) - for the average size of the extended family household type I may be written as follows:

$$_1\overline{H}=2/\int_0^w (1-l_{a-\hat{n}-x}/l_a)c(\hat{n}+x)dx$$

where, the subscript '1' identifies the extended family household type I, and $c(y)dy$ is the Coale-Demeny proportional age distribution of females in a stationary population in the case of Coale's study, and in a stable population in the case of Burch's study.

Goodman, Keyfitz, and Pullum's Measure

Goodman et al.'s measure, which is based on the following assumptions, refers to the extended family household type I:

(a) each married female forms a household if her mother is dead.

(b) each married female is a member of her mother's household if her mother is alive.

(c) each unmarried female is a member of the household of some married female (her mother or foster mother), and

(d) each male is a member of the household of some married female (his mother, foster mother, or wife).

According to Goodman et al. (1974), the probability that a female ego's mother, who was aged x[2] at the time of ego's birth, is alive when ego is aged a at time t is given by

$$M_1(a)=\int_0^w (l_{a+x}/l_x)W(x;t-a)dx$$

where, W(x;t-a) is the proportional age distribution at time (t-a), of women who gave birth to daughters at that time, assuming that the probability of ego's mother survival after giving birth and the probability of giving birth are mutually independent.

Thus, the probability that ego's mother is not alive at time t when ego is aged 'a' will be $\{1-M_1(a)\}$, and the probability that ego will form her own household by age a will therefore be $\{1-M_1(a)\}m(a)$, where n(a) is the proportion of egos who are married by age a. The formula for the average size of the extended family household type I, denoted by $_1\overline{H}$, may now be written as follows:

$$_1\overline{H}=2/\int_0^w \{1-M_1(a)\}m(a)c(a)da$$

where c(a) is the proportion of women who are aged a in a given

[2] We have retained the same symbols as used by the various authors. Even though it makes the discussion somewhat inconsistent with respect to the symbols used in this chapter, it has the advantage of retaining the fine details of the various formulations.

population. The term $W(x;t-a)$ which enters the above equation through $M_1(a)$ may be estimated by any one of the three formulas given below (Goodman et al., 1974).

I) For the stable population case

$W(x;t-a) = W(x)$

$= l_x m_x e^{-rx}$

and

II) If $B(t)$ denotes the number of females born at time t, then

$$W(x;t-a)=B(t-a-x)/\int_0^w B(t-a-x)l_x m_x dx.$$

III) For non-stable population case, $W(x;t-a)$ may be estimated from the observed age distribution of women who gave birth to daughters at time (t-a).

3. 4. Measures of the Average Size of the Extended Family Household Type II

Three studies, those of Coale (1965), Burch (1970), and Goodman et al. (1974), which discuss the average size of the extended family household type II, are described below.

Coale's and Burch's Studies

Coale (1965) computed the average size of the extended family household type II for the stationary population case by using Coale-Demeny's model stationary population distributions, and Burch (1970) extended Coale's computations by using Coale-Demeny's model stable population distributions.

The probability that a female ego who marries at age n does not form her own household by age (n+x) is equal to the probability that her mother or foster mother is alive when ego is aged (n+x). Thus, the probability that ego forms her own household by age (n+x) is $(1 - l_{a+n+x}/l_{a+n})$.

Both Coale and Burch use stationary and stable populations given in Coale and Demeny (1966). Thus, their analytical formula - *not* provided by Coale (1965) or Burch (1970) - for the average size of the extended family household type II may now be written as follows:

$$_{c}\overline{H}=2/\int_{0}^{w}(1-l_{a+n+x}/l_{a+n})\, c(n+x)dx$$

where c(y)dy refers to the stationary population in the case of Coale's study, and the stable population in the case of Burch's study.

Formulation of a New Measure of the Extended Family Household Type II

The measure of the average size of the household formulated in this section is an extension of the Goodman et al. measure of the extended family household type I.

Consider a randomly chosen female ego, denoted by (a,t), who is aged 'a' at time 't.' Let us suppose that her mother is aged (a+x) at time t, where x is the age of the mother at ego's birth. The probability that a female ego's natural mother or foster mother is alive at the time of ego's marriage is unity. Thus, the probability that ego's natural or foster mother is alive when ego is aged a will be

$$M_2(a)=\begin{cases}\int_0^{w}(l_{x+a}/l_{x+n})W(x/t-a)dx & \forall a \geq n \\ 1 & \text{if } a \leq n\end{cases}$$

where the term W(x/t-a) has already been defined. The term W(x/t-a) may be estimated by any of the three formulas given below (Goodman et al., 1974).

The formula for the average size of the extended family household type II may now be written as follows:

$$_2\overline{H}=2/\int_n^{w}\{1-\int_0^{w}(l_{x+a}/l_{x+n})W(x/t-a)dx\}m(a)c(a)da$$

where m(a) is the proportion of females married by age a and c(a)da is the proportion of females between the ages (a, a+da).

3. 6. The Analytical Measures of Average Household Size and the Processes Underlying them

Let us examine how the three sociodemographic processes, namely, the fission, fusion, and fission-fusion of households are incorporated in the above measures of the average size of the household. According to the simplified model of average household size given in the previous chapter, the fission, fusion, and fission-fusion of households assume importance, because they avoid the simple computation of a static measure of average household size at different points in time and instead incorporate the processes that lead to changes in household organization. It is the net effect of these three processes and the process of household extinction because of the joint mortality of all its members that governs the size distribution of households and thus of average household size at a given time.

In each type of household system discussed in this chapter, the female one-sex stationary or the female one-sex stable population model underlies the development of the measures of average household size. The male, for all practical purposes, is treated external to the pool of females under consideration. Whenever a male has to be linked to a female's household, as for instance, in the case of marriage leading to the formation of a household, the male is assumed to exist in a hypothetical pool of males and can be *imported* into the household. In other words, the model underlying the development of the three measures may be termed *open* so far as the question of the two sexes is concerned. If, on the other hand, males have to be selected from a given population, appropriate males for linking to female households may not necessarily be found. The underlying model in such a case is termed *closed* and this restriction raises considerable difficulties, as has been observed in the development of two-sex models. One advantage of an open model is that it eliminates the need for explicitly modelling the movement of males into female households, thereby eliminating the need for modeling fusion and fission-fusion, both of which may occur as a result of males moving into female households. The formulation of the measures of average household size is, therefore, simplified considerably as a result of treating the male population external to, and independent of, the female population. Female households may, however, still change in size and their average value would be an outcome of the net effect of their fission, fusion, and fission-fusion and the joint mortality of the members of the household. It may be pointed out that the simplification achieved in the demographic modeling of households by reducing the process of fission-fusion to fission with the help of one-sex models does not change the operation of the three processes influencing average household size at a given time. It may further be seen in the studies reviewed above that further simplification is introduced through various assumptions in order to avoid modeling the processes of fusion and fission-fusion of female households. For example, in the case of the extended family household type I, the foster mother is assumed to exist within a given pool of households from which she is always available for replacing ego's natural mother should the latter die prior to ego's marriage. Ideally, one would consider the reallocation of a female from one household to another, should the need for a foster mother arise. Such a consideration would necessarily demand a treatment of fusion and fission-fusion of ego's parent household and her to-be foster mother's household. However, the case of the extended family household type II assumes that the foster mother is always available from "outside" the population in case ego's natural mother dies prior to ego's marriage thus eliminating the need for modeling the fission-fusion of ego's and ego's to-be-foster mother's household.

CHAPTER 4

RYDER'S DEMOGRAPHIC MODEL OF THE HOUSEHOLD CYCLE: A FORMALIZATION AND EXTENSION

4. 1. Introduction

It follows from Chapter 2 that the household cycle forms the core concept in the formal demography of the household. Using this concept, Ryder (1975) developed a model of the nuclear family household in order to examine the effect of mortality on fertility, and the effect of both mortality and fertility on the duration of life spent by different family members within a typical nuclear family household cycle. A by-product of this research was the estimation of the average size of the nuclear family household over its cycle. Although Ryder's (1975) emphasis was substantive rather than formal, his work has great potential for formal household demography. The aim of this chapter, therefore, is first to formalize Ryder's model of the nuclear family household cycle, and then to extend it to two cases: the extended family household cycle with a foster mother and the extended family household cycle without a foster mother. These developments will provide expressions for the average size of the household for the three types of household cycles, in terms of the parameters of fertility, mortality, and nuptiality. In order to be consistent with formal household demography in which the household cycle forms the basic unit of analysis, the probabilities of various demographic occurrences will be expressed not only in terms of the ages or marital durations of individual household members but also in terms of household durations. Using the expressions thus developed, the sensitivity of the average size of the household to the gross level of fertility and to the combined effect of mortality and fertility will also be examined.

.4. 2. Ryder's Model

Ryder has formulated a unique measure of the average size of the nuclear family household over its cycle. This measure is computed as a ratio of the total number of person years lived by the members of a nuclear family over its life cycle and the length of the cycle. The measure is based on a two-component demographic model. First, the number of births that occur during the course of a typical parent nuclear family cycle are estimated. Second, the time spent by the family members of both generations while they were affiliated with the parent family over its cycle are estimated, given that the number and timing of births is known.

The number of births per couple is estimated on the basis of the following assumptions:

i) all births occur within marriage

ii) marriage is monogamous

iii) all females marry

iv) all females marry at 20 years of age

Ryder's (1975) contribution to the existing literature on formal household demography lies in his decomposition of the net reproduction rate, a conventional measure of the replacement of a population in successive generations. Two sequential components are involved: one, the estimation of the number of female egos, who, when exposed to the risk of marriage or family formation, will produce a prespecified number (R_0) of offspring nuclear families, and two, the estimation of the number of births that a parental family would have borne had ego's mother not been exposed to the risk of mortality.

With reference to the first component, suppose that R_0 is a given value of the net reproduction rate. Here, the fertility of ego's mother is measured in terms of the duration of marriage, and ego's survival is measured from her birth to her age at marriage. Also, assume that G is the actual average number of births that a woman should have borne in order that the given value of R_0 is achieved. In other words, G takes into account the extent to which parental non-survival reduces fertility per couple. Assuming that the sex-ratio at birth is unity, R_0 and G may then simply be related as follows:

$G = R_0/S$ .... (4.1) where S is the probability of survival of a child from birth to the average age of marriage at which all females are assumed to marry.

With respect to the second component, however, the probability of ego's mother's survival from the time of her marriage to the time of ego's birth is taken into account in the estimation of the average number of births per married female that would have prevailed had the parents not been exposed to the risk of mortality from the time of marriage to the end of the reproductive period. Ryder expresses his rationale for the choice of marital duration rather than age as the basis for fertility measurement in the following words: "to distribute fertility over the course of the family life cycle, it has been decided to work with successive marital durations, rather than ages, since the former seems a more appropriate temporal variable for family analysis" (p. 278).

If F denotes the gross level of ego's mother's fertility and L the probability of couple survival from marriage to the time of giving birth, then clearly,

$$G = F \cdot L \qquad (4.2)$$

provides a link between the gross and net levels of fertility. Note that the parameter L in Eq. (4.2) is a function of both nuptiality and mortality.

Once the number of births that occur in a typical nuclear family are known, and the life table for the study population becomes available, the numerator of Ryder's measure of the average size of the nuclear family cycle can easily be computed. It is given by the total number of person years lived in a family over the course of its cycle. The denominator of the measure, on the other hand, is obtained by computing the number of person years lived by a nuclear family marker from the time of nuclear family formation to the time of its extinction (Ryder, 1975).

In summary, then, Ryder's model estimates the average number of births that a married female should bear in the absence of (i) exposure to mortality from the time of marriage to the end of her reproductive period and (ii) the exposure of her children to mortality from the time of their birth to the time of their marriage - for a given value of the net reproduction rate.

The formulas developed in the subsequent sections are illustrated with data from three types of hypothetical societies described below.

4. 3. The Three Scenarios

Type I: The High Equilibrium Society (HES)

This society is characterized by high mortality (Model West Life Table Level 3) with female expectation of life of 25 years, and a high fertility level - with a birth rate of about 42 births per 1,000 population per annum, which is sufficiently high to ensure replacement of generations. This type of society corresponds to the first stage of the classical demographic transition theory.

Type II: The Disequilibrium Society (DES)

This society is characterized by a moderately low level of mortality (Model West Life Table Level 17), with female expectation of life of 60 years but with the same level of fertility as in HES, i. e., a birth rate of about 42 births per 1,000 population per annum. The net reproduction rate in this society is 2.5079. This type of society corresponds to the second stage of the classical demographic transition theory.

Type III: The Low Equilibrium Society (LES)

In this society, both mortality and fertility are at low levels. The mortality condition for the society is represented by the Model West Life Table Level 23. The level of fertility, on the other hand, is just sufficient to ensure replacement in terms of its survival functions. Both birth rate and death rate are a little less than 14 per 1,000 population per annum. This type of society corresponds to the third stage of the classical demographic transition theory.

Each of the three types of household cycles - nuclear family, extended family with a foster mother, and extended family without a foster mother, - will be subjected to each of the three scenarios. The following are notations used subsequently in the developments in this chapter. They are specific for ages of individual household members and household durations at which events occur.

4. 4. Notations

$l_{d_o(x)}$ = the number of females, among a given cohort of households, of exact age x at exact household duration 'o'

$l_{d_i(y)}$ = the number of females of exact age y at exact household duration d_i, when the ith demographic event occurs to a female of a typical household cycle. Note that $y=x+d_i$ for a female (ego's mother) belonging to a parent household, and y=o at household duration d_i when ego is born.

$T_{d_o(x)}$ = the total number of person years expected to be lived by $l_{d_o(x)}$ females, from the time of the formation of their households, to the time of the extinction of their households.

$T_{d_i(y)}$ = the total number of person years expected to be lived by $l_{d_i(y)}$ females, subsequent to the occurrence of the ith demographic event in their households of affiliation. Note that $y=x+d_i$ for a female (ego's mother) belonging to a parent household, and y=0 at household duration d_i when ego is born.

${}_{d_j(z)}S_{d_i(y)}$ = the probability of survival of a female from exact age y at exact household duration d_i to exact age z at exact household duration d_j, where z and j are greater than or equal to y and i, respectively.

$e_{d_o(x)}$ = the average number of years that a female who is of exact age x at exact household duration o will be expected to live in her own household since the time of its formation. This parameter can be computed by the ratio

$$\frac{T_{d_o(x)}}{l_{d_o(x)}}$$

$e_{d_i(y)}$ = the expected number of years that a female is expected to live in her own household from the time of the occurrence of the ith event in the household. This parameter can be computed by the ratio

$$\frac{T_{d_i(y)}}{l_{d_i(y)}}$$

The above notations will be identified for two successive generations of females: the parameters for females of the parent generation will be written in bold letters whereas those of the offspring generation of the initial cohort will be written in standard text.

4. 5. The Nuclear Family Household Cycle: Formalization of Ryder's Measure

Following Ryder's definition, the formula for the average size of the nuclear family household cycle may be expressed as the ratio of the number of person years lived by all individuals affiliated with a given cohort of households as they are observed over their cycles to the total number of "person" years of all the household cycles in the cohort. Thus, we may write the formula for the average size of the nuclear family household over its cycle as follows:

$$_n\overline{H} = 2(\mathbf{T}_{d_o(n)} + \mathrm{T}_{d_i(o)} - \mathrm{T}_{d_2(n)})/\mathbf{T}_{d_o(x)}$$

The subscript i in $d_i(o)$ is defined as follows:

$l=o$: the event of parent household formation

$l=1$: the event of ego's birth

$l=2$: the event of ego's marriage

Since, by definition, $T_x = l_x e_x$ and ${}_yS_x = l_y/l_x$, the above equation may be written as:

$$_n\overline{H} = 2(l_{d_o(n)} e_{d_o(n)} + l_{d_1(o)} e_{d_1(o)} - {}_{d_2(n)}S_{d_1(o)} l_{d_1(o)} e_{d_2(n)}) / l_{d_o(n)} e_{d_o(n)}$$

Dividing both the numerator and the denominator of the above equation by $l_{d_o(n)}$, we get:

$$_n\overline{H} = 2\{1 + \{(l_{d_1(o)}/l_{d_o(n)}) e_{d_1(o)} - {}_{d_2(n)}S_{d_1(o)} (l_{d_1(o)}/l_{d_o(n)}) e_{d_2(n)}\} / e_{d_o(n)} \quad \text{.................(4.3)}$$

If a married female is expected to give (G) female births on average, then

$$l_{d_1(o)}/l_{d_o(n)} = G. \quad \text{.....................(4.4)}$$

Substituting (4.4) in (4.3), we get:

$$_n\overline{H} = 2\{1 + (G\, e_{d_1(o)} - {}_{d_2(n)}S_{d_1(o)}\, G\, e_{d_2(n)})/e_{d_o(n)}\} \quad \text{............(4.5)}$$

It is likely however, that the mortality parameters are functions of age, marital duration, household duration, etc., of the individual household member who is exposed to the risk of mortality. The same likelihood holds for both fertility and nuptiality. For simplicity, therefore, it will be assumed that the various demographic variables are functions of the age of the individual. If females who form households at a given time belong to different age cohorts, household duration may be replaced by a weighted average of the ages of all females present in the cohort of households at a given duration, for the purpose of computing various demographic rates. The weights would be given by the proportion of persons at each age who are observed at a specified duration of the life of the household. But, according to the rules of nuclear family household formation, all females form their own respective households at the same age, and give birth at the same age, so that females who belong to a given generation and are members of a cohort of households will have the same age throughout the household cycle.

As data on different demographic parameters are available only for the characteristics of the individual, the dependence of demographic parameters on household duration will not be considered further. Thus, by translating the durations of the household cycles to ages of the (female) household members, Eq. (4.5) may be reexpressed as follows:

$$_n\overline{H} = 2\{1 + (G\ e_o - {_n}S_o\ G\ e_n)\} \quad\ldots\ldots\ldots\ldots\ldots\ldots (4.6)$$

The formula in Eq. (4.6) may be expressed in two ways. As $G = R_o/{_n}S_o$, which is given in Eq. (4.1), we have:

$$_n\overline{H} = 2[1 + \{(R_o/{_n}S_o)e_o - R_o\ e_n\}/e_n]$$

$$= 2(1 - R_o) + 2(R_o/{_n}S_o)(e_o/e_n) \quad\ldots\ldots\ldots\ldots\ldots\ldots (4.7)$$

Alternatively, by substituting $G = F\ .\ L$ from (4.2) in (4.6), we get:

$$_n\overline{H} = 2\{1 + (F\ L\ e_o - {_n}S_o\ F\ L\ e_n)/e_n\} \quad\ldots\ldots\ldots\ldots\ldots\ldots (4.8)$$

For sensitivity analysis, the use of the formulas in Eqs. (4.7) and (4.8) would depend on the purpose of the study. For example, if the aim of the study is to examine the variation in ${}_n\overline{H}$ with respect to F, the formula in Eq. (4.8) may be used. On the other hand, the formula in Eq. (4.7) may be used if the aim of the study is to examine the sensitivity of average household size with respect to changes in R_o. Partial differentiation of Eqs. (4.8) and (4.7) with respect to F and R_o, respectively, yields expressions which may be used to examine the sensitivity of the average size of the nuclear family household with respect to changes in the values of F and R_o.

$$\frac{\partial\, {}_n\overline{H}}{\partial F} = 2L\{(e_o/e_n) - {}_nS_o\} \qquad (4.9)$$

and

$$\frac{\partial\, {}_n\overline{H}}{\partial R_o} = -2 + (2/{}_nS_o)(e_o/e_n) \qquad (4.10)$$

It is clear from Eq. (4.9) that changes in average household size with respect to the gross level of fertility depend upon the mortality factor as well as upon age at marriage. The mortality factor is, in fact, influenced by three variables: the probability of the survival of ego's mother from her marriage to the end of her reproductive period, the expectation of life at age at marriage, and age at marriage.

Some illustrative results from the application of formulas in Eqs. (4.7), (4.9), and (4.10), are given in Table 4. 1. They indicate the differences among the three (hypothetical) societies - HES, DES, and LES - in which the rules of nuclear family household formation, residence, and extinction prevail. It is seen, from Table 4. 1., that the average size of the nuclear family household (over its cycle) is higher in the disequilibrium situation (3.49 persons per household) than in either the high equilibrium or the low equilibrium situations (3.49 and 2.71 persons per household, respectively). The result that the average size of the household is higher in the disequilibrium situation than in the high equilibrium situation is consistent with the observation that the average size of the household in many countries increased during the early stages of demographic transition.

Levels of the average size of the household in the three types of societies, however, respond differently to changes in the gross level of fertility and to changes in the replacement parameter, R_o. Values of the partial derivatives of $_n\overline{H}$ with respect to F and R_o are given in Table 4.1. These results suggest that the average size of the household in the high equilibrium situation is least sensitive to the changes in the gross level of fertility. The differences in such sensitivity among the three societies are, however, minimal. The change in average household size corresponding to a unit change in the gross level of fertility is 0.59 in the high equilibrium society, 0.67 in the disequilibrium society, and 0.68 in the low equilibrium society. In each case, it is, of course, assumed that the level of mortality is held constant when change is introduced in the gross level of fertility. When the mortality of individual household members is also taken into account, the changes in average household size become more striking. The average size of the nuclear family household is then found to be most sensitive to changes in R_o in the case of the high equilibrium society. A unit

Table 4.1.

Some characteristics of the nuclear family household cycle in three hypothetical societies

Type of society	Average age at household formation (in completed years)	Average household size ($_n\overline{H}$) (persons per household)	$\frac{\partial\, _n\overline{H}}{\partial F}$	$\frac{\partial\, _n\overline{H}}{\partial R_o}$
HES	20	3.49	0.59	1.86
DES	20	4.11	0.67	0.84
LES	20	2.71	0.68	0.71

change in R_o is expected to lead to a change in average household size by about 1.9 (Table 4.1). The effect of changes in R_o on the average size of the household decreases substantially as one moves from one type of society to the next along the demographic transition path; i. e., from 1.9 in the high equilibrium situation to 0.84 in the disequilibrium situation, and 0.71 in the low equilibrium situation. Overall, the average size of the household is less sensitive to changes in the gross level of fertility than to the changes in R_o. The difference in the effect of F and R_o on ${}_n\overline{H}$ decreases as one moves to the low equilibrium situation.

4. 6. The Extended Family Household Cycle With a Foster Mother: Extension I of Ryder's Measure

In the extended family household cycle with a foster mother, it is assumed that a woman's natural mother is replaced by a foster mother of the same age as the natural mother, should the natural mother die before the woman's marriage. The woman, after marriage, continues to live with her natural foster mother as the case may be and forms her own household at the time of the death of her (natural or foster) mother.

Ryder's model of the nuclear family household cycle can be extended in a straightforward manner to the case of the extended family household cycle with a foster mother. It is assumed here that females give birth in their own households. Just as in the case of the nuclear family household cycle, the numerator in the extended family household case will consist of the total number of person years lived by all individuals who are affiliated with a given cohort of extended family households. The denominator, on the other hand, will consist of the total number of person years of the household cycle, which would be equivalent to the total number of person years lived by the (female) head of the household at the time of household formation. Under the rules of household formation, residence, and extinction of the extended family household with a foster mother, the average size of the household can be written as follows:

$$_{ef}\overline{H} = 2\{T_{d_o(n+y)} - T_{d_1(n+y+d_1)} + (d_2-d_1)l_{d_1(n+y+d_1)} + T_{d_2(n+y+d_2)} + T_{d_1(o)} - T_{d_3(n+y)}\} / T_{d_o(n+y)}$$

where $(n+y)$ is the female's age at the time of her household formation, and the subscript i in $d_i(o)$ is defined as follows:

i=o : the event of parent household formation

i=1 : the event of ego's birth

i=2 : the event of ego's marriage

i=3 : the event of ego's mother's death

As, by definition, $T_x = l_x e_x$, the above equation may be reexpressed as:

$$_{ef}\overline{H} = 2\{l_{d_o(n+y)} \cdot e_{d_o(n+y)} - l_{d_1(n+y+d_1)} e_{d_1(n+y+d_1)} + (d_2-d_1) l_{d_1(n+y+d_1)} + l_{d_2(n+y+d_2)} e_{d_2(n+y+d_2)} + l_{d_1(o)} e_{d_1(o)} - l_{d_3(n+y)} e_{d_3(n+y)}\} / l_{d_o(n+y)} e_{d_o(n+y)}$$

Dividing both the numerator and the denominator of the above equation by $l_{d_o(n+y)}$, and using the relationship: $l_{d_1(o)}/l_{d_o(n+y)} = G$, we get:

$$_{ef}\overline{H} = 2[1 + \{_{d_1(n+y+d_1)}S_{d_o(n+y)} (-e_{d_1(n+y+d_1)} + d_2 - d_1) + {}_{d_2(n+y+d_2)}S_{d_o(n+y)} e_{d_2(n+y+d_2)} + G\, e_{d_1(o)} - {}_{d_3(n+y)}S_{d_1(o)}\, G\, e_{d_3(n+y)}\} / e_{d_o(n+y)}]$$

If $\bar{a}$ is the average age at childbearing, then $\tilde{n}+\varsigma+d_1=a$, $\tilde{n}+\varsigma+d_2=a+\tilde{n}$, and $(d_2-d_1)=\tilde{n}$. Using these relationships, and assuming, as in the case of the nuclear family household cycle, that both fertility and mortality are functions of the age of the woman, then, the above equation may be written as follows:

$$ {}_{ef}\overline{H} = 2[1 + \{(G\ e_o - {}_{\tilde{n}+\varsigma}S_o\ G\ e_{\tilde{n}+\varsigma}) / e_{\tilde{n}+\varsigma}\} + \{{}_{a}S_{\tilde{n}+\varsigma}\ (\tilde{n}-e_a) / e_{\tilde{n}+\varsigma}\} + {}_{a+\tilde{n}}S_{\tilde{n}+\varsigma}\ e_{a+\tilde{n}}/e_{\tilde{n}+\varsigma}] $$

As the probability of ego's mother's survival from the time of ego's birth to the time of ego's marriage is unity in the foster mother case, that is, as ${}_{a+\tilde{n}}S_{\tilde{n}+\varsigma}$ equals ${}_{a}S_{\tilde{n}+\varsigma}$, the last two terms in the above equation may be combined. Then, using the two relationships in Eqs. (4.1) and (4.2), the above formula can be reexpressed in the two following formulations:

$$ {}_{ef}\overline{H} = 2(1 - R_o) + 2(R_o/{}_{\tilde{n}+\varsigma}S_o)\,(e_o/e_{\tilde{n}+\varsigma}) + 2\ {}_{a}S_{\tilde{n}+\varsigma}\ (\tilde{n}+e_{\tilde{n}+a}-e_a) / e_{\tilde{n}+\varsigma} \qquad \text{.................(4.11)} $$

$$ = 2[1 + \{(F\ L\ e_o - {}_{\tilde{n}+\varsigma}S_o\ F\ L\ e_{\tilde{n}+\varsigma})/e_{\tilde{n}+\varsigma}\} + \{{}_{a}S_{\tilde{n}+\varsigma}\ (\tilde{n}+e_{a+\tilde{n}}-e_a)/ e_{\tilde{n}+\varsigma}\}] \qquad \text{......................(4.12)} $$

Partial differentiation of Eq. (4.12) with respect to F and of Eq. (4.11) with respect to R_o yields the two following equations:

$$ \frac{\partial_{ef}\overline{H}}{\partial F} = 2L\{(e_o/e_{\tilde{n}+\varsigma}) - {}_{\tilde{n}+\varsigma}S_o\} \qquad \text{..............(4.13)} $$

and

$$ \frac{\partial_{ef}\overline{H}}{\partial R_o} = -2+(2/{}_{\tilde{n}+\varsigma}S_o)(e_o/e_{\tilde{n}+\varsigma}) \qquad \text{...........(4.14)} $$

which can be used to examine the sensitivity of the average size of the extended family household with a foster mother with respect to the gross level of fertility and to the degree of replacement, respectively.

Table 4.2 provides some illustrative results from the application of Eqs. (4.11), (4.13), and (4.14) for the three types of societies.

They indicate that the average size of the extended family household with a foster mother differs across the three societies. It is the highest in the disequilibrium situation (6.12 persons per household) followed by the high (5.68 persons per household) and the low (3.34 persons per household) equilibrium situations, respectively. The sensitivity of the average size of the household to both the gross level of fertility and the net reproduction rate also varies across the three societies. However, among the three societies, average household size in the low equilibrium society is most sensitive to changes in the gross level of fertility compared to the high equilibrium and disequilibrium societies. A unit change in the gross level of fertility induces a change of 1.24 units in the average size of the household in the low equilibrium society, whereas it induces a change of 1.20 and 0.79 units, respectively, in the disequilibrium and high equilibrium societies (Table 4.2). Furthermore, the average size of the household is more sensitive to changes in R_0 than to changes in the gross level of fertility, in all the three societies. The average size of the household is most sensitive to changes in R_0 in the high equilibrium society than the low and the disequilibrium societies. The change in the average size of the household induced by a small change in R_0 in the high equilibrium, disequilibrium, and the low equilibrium societies is 2.95,

Table 4.2.

Some characteristics of the extended family household cycle with a foster mother in three hypothetical societies

Type of society	Average age at household formation (in completed years)	Average household size (${}_{ef}\overline{H}$) (persons per household)	$\frac{\partial\, {}_{ef}\overline{H}}{\partial F}$	$\frac{\partial\, {}_{ef}\overline{H}}{\partial R_o}$
HES	30	5.68	0.79	2.95
DES	30	6.12	1.20	1.57
LES	30	3.34	1.24	1.29

1.57, and 1.29 respectively.

4.7. The Extended Family Household Cycle Without a Foster Mother: Extension II of Ryder's Measure

In the extended family household cycle without a foster mother, it is assumed that a woman's natural mother is replaced by a foster mother of the same age as the natural mother, should the natural mother die before the woman's marriage. At the time of her marriage, the woman forms her own household if her natural mother is dead; otherwise, she forms her own household at the time of the death of natural mother.

As in the case of the nuclear family household cycle and the extended family household cycle, Ryder's model will again form the basis for the development of measures for the average size of the extended family household cycle without a foster mother. Again, it is assumed that married females give birth in their own households. Based on the rules of household formation, residence, and extinction of the extended family household without a foster mother, the total number of person years lived in a given cohort of the extended family household cycle would be given by the sum of the number of person years lived by ego and by her mother in the latter's household. The denominator, on the other hand, will be estimated by the life span of the household marker, the female head. The average size of the extended family household over its cycle may now be written as follows:

$$_{e}\overline{H} = 2(T_{d_0(x)} + T_{d_1(o)} - T_{d_2(x)})/T_{d_0(x)}$$

The subscript i in $d_i(x)$ is defined as follows:

i=o : the event of parent household formation

i=1 : the event of ego's birth

i=2 : the event of ego's mother's death

For simplicity, x is assumed to remain constant at its mean value $\bar{x}$, across individuals in the household population.

As in the two earlier types of households, on reexpressing the above Eq. in terms of the expectations of life and the survivorship probabilities, and then dividing both the numerator and the denominator by $l_{d_o(\bar{x})}$, we obtain the following equation:

$$_e\bar{H} = 2[1 + \{(l_{d_1(o)}/l_{d_o(\bar{x})})e_{d_1(o)} - {}_{d_2(\bar{x})}S_{d_1(o)}\,(l_{d_1(o)}/l_{d_o(\bar{x})})\,e_{d_2(\bar{x})}\}]$$

On substituting $(l_{d_1(o)}/l_{d_o(\bar{x})})=G$ in the above equation, we get:

$$_e\bar{H} = 2\{1 + (G\,e_{d_1(o)} - {}_{d_2(\bar{x})}S_{d_1(o)}\,G\,e_{d_2(\bar{x})})\} / e_{d_o(\bar{x})} \quad \text{...............(4.15)}$$

As in the case of the nuclear family household and the extended family household with a foster mother, we will make the simplifying assumption that the fertility and mortality parameters are functions of the age of the female involved. Then, the formula in Eq. (4.15) may be reexpressed as follows:

$$_e\bar{H} = 2\,\{1 + (G\,e_o - {}_{\bar{x}}S_o\,G\,e_{\bar{x}})/e_{\bar{x}}\} \quad \text{.....................(4.16)}$$

Using Eqs. (4.1) and (4.2), we may reexpress the formula in Eq. (4.16) in the two following alternative expressions:

$$_e\bar{H} = 2(1 - R_o) + 2(R_o/{}_{\bar{x}}S_o)(e_o/e_{\bar{x}}) \quad \text{..........(4.17)}$$

$$= 2\{1 + (F L e_o - {}_xS_o F L e_x)\} \qquad (4.18)$$

Partial differentiation of Eq. (4.18) with respect to F and of Eq. (4.17) with respect to R_o, yields the two following equations.

$$\frac{\partial\, {}_e\overline{H}}{\partial F} = 2L\{(e_o/e_x) - {}_xS_o\} \qquad (4.19)$$

and

$$\frac{\partial\, {}_e\overline{H}}{\partial R_o} = -2 + (2/{}_xS_o)(e_o/e_x) \qquad (4.20)$$

Some illustrative results of the above formulas are given in Table 4.3. Average age at household formation is varied across the three types of societies for illustrative purposes. The average size of the household shows some variability: 4.13 persons per household cycle in the high equilibrium situation, 5.94 in the disequilibrium situation, and 4.82 in the low equilibrium situation. The high equilibrium situation is the least sensitive to changes in the gross level of fertility, whereas the low equilibrium situation is the most sensitive to these changes. Note that changes in average household size with respect to a unit change in the gross level of fertility are 0.62, 1.20, and 2.66 respectively, in the high equilibrium, disequilibrium, and low equilibrium situations. However, the sensitivity of average household size to R_o is different from its sensitivity to F. It is most sensitive to R_o in the case of the low equilibrium society, followed in turn by the high equilibrium and the disequilibrium societies, with the corresponding values of the partial derivative of ${}_e\overline{H}$ with respect to R_o being 6.82, 2.13, and

Table 4.3.

Some characteristics of the extended family household cycle without a foster mother in three hypothetical societies

Type of society	Average age at household formation (in completed years)	Average household size ($_e\overline{H}$) (persons per household)	$\frac{\partial_e\overline{H}}{\partial F}$	$\frac{\partial_e\overline{H}}{\partial R_o}$
HES	25	4.13	0.62	2.13
DES	30	5.94	1.20	3.57
LES	45	4.82	2.66	6.82

3.57, respectively.

4. 8. Discussion and Conclusion

In this chapter, first, a formal expression for the average size of the nuclear family household over its cycle was developed by following a cohort of nuclear family households which experienced the event-origin of household formation. Then, similar expressions were also developed for extended family households with and without a foster mother, by taking into account household duration as well as the demographic characteristics of individual household members. The use of household duration in this analytic approach is consistent with the formal demography of the household.

By partially differentiating expressions for the average size of the household with respect to the gross level of fertility and the net reproduction rate, expressions were also derived for the three types of household systems. As the data on demographic rates specific for household durations are not available, various expressions are simplified by ignoring the duration specificity of the demographic rates. That is, it was assumed that the demographic rates are independent of the characteristics of the household to the extent that the characteristics of the individual are bounded by the household cycle.

Illustrative results are shown for each household system applied to three scenarios: the high equilibrium society (HES), the disequilibrium society (DES), and the low equilibrium society (LES). These three types of societies correspond to the three stages of the classical demographic transition theory and, therefore, their introduction into this chapter introduces a sense of reality into the modeling.

Results from the developments in this chapter indicate that the average size of the household tends to be the highest in the disequilibrium society, irrespective of the type of household system prevailing in it. One should be careful in comparing average household size across types of households because ages at household formation are not constant in the computations. More illustrative results will be computed in future work related to this dissertation. The average size of the extended family household without a foster mother is very small because of a combined influence of both high fertility and mortality. A large number of children whose mothers die are allowed to form independent households which lowers the average size of the household. One should be careful in comparing average sizes across types of households because ages at household formation are not held constant in the three cases. More illustrative results will be computed in future work. The effect of changes in the gross level of fertility on the average size of the household shows only minimal variation across HES, DES, and LES in the nuclear family household case. Corresponding variation is somewhat greater in the extended family household with a foster mother and considerably more in the case of the extended family household without a foster mother. With respect to the sensitivity of the average size of the household, it is observed that it is most sensitive to changes in R_0, the net reproduction rate, in the case of the extended family household (without a foster mother) system which prevails in HES. Similar sensitivities in the cases of the average size of the nuclear family household cycle and the extended family household cycle without a foster mother are very conspicuous across the three scenarios - HES, DES, and LES.

In conclusion, it may be mentioned that Ryder's model and its extensions deal with the stationary or the stable population cases and adopt a deterministic approach to modeling. An alternative approach, the microsimulation approach to modeling, which is stochastic in nature, is more realistic for addressing similar questions and is adopted in the next chapter.

CHAPTER 5

THE DEMOGRAPHIC MODELING OF HOUSEHOLD CYCLES: A MICROSIMULATION APPROACH

5.1. Introduction

The analytical demographic measures discussed in the two previous chapters were based on Lotka's (one-sex) stationary or stable population models. Besides being deterministic, a major assumption of these models is that demographic parameters remain stationary over time. Keyfitz (1973) has succinctly summarized the limitations of Lotka's model:

> The most fully developed model of formal demography deals with one species (man) and one sex only, and is deterministic in supposing that the probability of an event occurring to an individual gives also the fraction of individuals in the population to whom events will occur. Usually ages are recognized, and at each age the fraction dying and the fraction bearing a child are obtained from data on a real population; the fractions are called age-specific rates, and they are taken as fixed and given. The stable population theory can hardly be called realistic. (p. 373).

It is clear from the above statement that the assumptions underlying the measures developed in the two previous chapters are too rigid to be realistic. In the Canadian context, for example, during the period 1971-1981, the rates of three basic demographic variables - mortality, fertility, and nuptiality - were nonstationary, thereby making the analytical measures discussed in last two chapters inapplicable to the contemporary Canadian case.

Demographic modeling using microsimulation methodology offers an alternative to analytic modeling. It enables relatively easy experimentation with data for answering questions of the nature: What would happen to a given system (of households) if one or more parameters were changed? Furthermore, microsimulation modeling is not only stochastic in nature, but is also particularly powerful when dealing with nonstationary and nonlinear phenomena, because it readily yields estimates of distribution functions even when it is impossible to derive closed form analytic expressions as is frequently the case in the development of both deterministic and stochastic models of many complex systems. Modeling through microsimulation is also dynamic because the concept of time is implicit in this approach. To make modeling comparatively realistic, then, a demographic microsimulation of Canadian household cycles will be developed in this chapter to examine the sensitivity of average household size to four demographic parameters - household extinction, individual level mortality, fertility, and household formation. The formation of the household will be contingent upon nuptiality. First, the extinction of the household will be introduced into the model, followed by the population growth components, that is, the mortality and fertility of the individual, and finally, household formation.

It may be mentioned that the use of computer simulation models has a long tradition of application in demography, especially in the study of the human reproductive process (see, e. g., Horvitz, Giesbrecht, Shah, and Lachenbruch, 1966; Hyrenius and Adolfsson, 1964; Orcutt, Greenburg, Korbel, and Rivlin, 1961; Potter and Skoda, 1966; Ridley and Sheps, 1966; Santow, 1978; Hammel, Hutchinson, Wachter, Lundy, and Deuel, 1976). However, the application of microsimulation modeling to study the demographic dynamics of households using the household cycle approach, which is compatible with formal household demography, has been attempted recently.

The main aim of this chapter will, therefore, be to examine how changes in household cycles, that is, in the formation, growth, and extinction of households, are associated with changes in three demographic parameters: mortality, fertility, and nuptiality. On the substantive side, Kobrin's (1976) hypotheses about the relationship between mortality and fertility on the one hand, and the average size of the household on the other, will be taken as the point of departure. Her hypotheses will first be extended to make them consistent with the formal demography of the household and then tested in the Canadian context using the results from the microsimulation.

5. 2. Demographic Dynamics of Household Cycles: An Extension of Kobrin's Hypotheses from the Perspective of Formal Household Demography

Of special relevance to the research in this chapter is the classic article by Kobrin, which makes an exploratory analysis of the relationships between demographic factors and the average size of the American household. She has attempted to link individual level demographic factors of mortality and fertility with the size-distribution of the American household, which, in turn, directly determines the average size of the household. The empirical work in this chapter will restrict itself to Canadian data only.

The following demographic hypotheses, implied in Kobrin's (1976) article, capture the major demographic relationships in the field of household demography.

Kobrin's Hypothesis I: the lower the level of mortality, the lower the *average size of the household, keeping other factors constant.*

According to Kobrin (1976), the effect of mortality on the average size of the household is mediated by the joint survivorship of couples. In a low mortality society, the probability of joint survivorship is higher than in a high mortality society and, therefore, the former would have a larger proportion of smaller households or, in other words, a smaller average household size. In this explanation, Kobrin takes into account, though implicitly, the survival of the household unit. Her argument has, however, not been fully developed at the household level of analysis. The following discussion elaborates on the mechanisms that govern the impact of mortality on the average size of the household.

For the analysis to be consistent with formal household demography, the effect of mortality on household cycles must be analyzed at two levels: the household and the individual. At the level of the household, only two possible outcomes for the status of the household are predicted. It either becomes extinct or it does not. How the joint mortality as well as the independent mortality of individual household members influences the average size of the household forms the focus of study in this section. Clearly, under the influence of the joint mortality of the individual household members, smaller households, on the average, have a higher probability of extinction over a given year than larger households, keeping other factors constant. Therefore, as households are exposed to the risk of extinction, the smaller households, on the average, will be disproportionately lost from the population as compared to larger households.

thereby increasing the average size of the household.

At the level of the individual, mortality may either decrease the size of the household (i. e., influence its growth) or lead to its extinction because of the implications of mortality at the individual level. These two effects of mortality at the individual and household levels, respectively, tend to have opposite implications for the average size of the household. Whereas the extinction of households, as discussed above, tends to increase the average size of the household, individual mortality tends to reduce it. In general, at the individual level, the larger the size of the household, the greater is the expected number of deaths among its members during a given year, keeping other factors constant. Thus, households of larger size are, on the average, more likely to reduce substantially in absolute size than are households of smaller size. As a result, a large household is more likely to decrease to a smaller size than is a small household, thereby favouring the development of small sized households in the distribution. It clearly follows then, that the average size of the household will, on the average, decline under the impact of the mortality of the individual, independent of household extinction.

Unlike mortality, which may have an influence on the survival, maintenance or growth of the household, fertility contributes directly only to the growth of the household over its cycle. Kobrin's work implies the following hypothesis about the effect of fertility on the average size of the household.

Kobrin's Hypothesis II: the lower the level of fertility, the lower the average size of the household, keeping other factors constant.

In addition to re-examining these two demographic hypotheses, the present paper will also incorporate household formation into the analysis, in order to cover the entire range of events that are encompassed in a household cycle. The formation of a household will be tied to the event of marriage. The effect of nuptiality, which leads to the formation of new households, is likely to counter the net-growth effect of mortality and fertility on households. It is expected that the formation of nuclear family households will lower the average size of the household.

5. 3. The Development of the Microsimulation Model

The Monte Carlo technique plays a central role in microsimulation modeling. In this technique, a random number is first generated from a uniform distribution defined over the interval 0 to 1. This number is then transformed into another random variate which follows the distribution function of the process under study (Naylor, Balintfy, Burdick, and Chu, 1966). On the basis of the random number thus generated, a decision is made about the occurrence or nonoccurrence of a given event. If the random number is less than the probability of the occurrence of the event during a given interval, the event is assumed to have occurred during the interval; otherwise, the event is assumed not to have occurred during the given interval. There are, in fact, two ways of managing successive events in a microsimulation: the critical-event (or variable time increment) approach and the time-slice (or fixed time increment) approach (Maisel and Gnugnoli, 1972; Naylor, 1966). In the critical-event approach, the model is advanced through the time between successive events, whereas in the time-slice approach, it is updated at fixed intervals of time.

The critical-event approach is advantageous if the simulation is static for long periods (Kelly and Buxton, 1962, cited in Naylor et al., 1966). However, this approach is hard to apply in the case of complex systems where events occur simultaneously (Maisel and Gnugnoli, 1972). In the present model, the time-slice approach was used and each household was updated on a yearly basis for a period of twenty years.

5. 4. The Initial Population

The initial population of households for the microsimulation is the 1-in-10,000 random sample of Canadian households enumerated in the 1971 Census. Each individual in this sample population was assigned two basic demographic variables, namely, sex and completed years of age. For individuals whose age and sex were not available in the household file, an indirect procedure was used. For example, single year completed ages were assigned to individual household members in the 18-59 year age group on the basis of the empirical 1971 Census age distribution of individuals. A similar procedure was used for the age group 70 and above. The gender of individual household members belonging to the age group 70-79 was assigned on the basis of the observed sex-ratio[1] of 0,5666 in the 1971 Census of individuals. A similar procedure was adopted for individuals belonging to the age group 80 and above, for which the observed sex-ratio is 0.6098.

[1] the sex-ratio = number of females/total population

Among the 2054 individuals in the initial population, 48.5 percent were male and 51.5 per cent female. These individuals were distributed over 601 households giving an average size of 3.42 persons per household[2].

5. 5. Demographic Components of the Microsimulation Model

The microsimulation model used in this chapter incorporated three main elements of the household cycle: its formation, growth and extinction. Although social, demographic and economic factors operate on these elements, the developments in this paper were restricted to the demographic influences of mortality, fertility, and nuptiality on average household size.

5. 6. Extinction of the Household Due to the Joint Mortality of Household Members

The extinction of a household that occurs due to the joint mortality of the household members is modeled in this section. The underlying stochastic process, estimation of the input probabilities, different scenarios used, and simulation results are discussed below.

The Underlying Stochastic Process

The stochastic process underlying the extinction of household units is termed here as the household extinction process, which is analogous to the death process when the individual is taken as the unit of analysis. The process, under the assumption that the intensity of household extinction remains constant over time, is described below (Bailey, 1965).

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[2] Households of size 10 or above constitute a single category in the Census. Excluded from the population of households are collective-type households such as institutions, hotels and large lodging houses.

If v is the force of extinction of a household in an infinitesimally small interval of time t, then the probability density of the number of households at time t is described by the probability, $P_k(t)$ - that k households survive to time t, given below:

$$P_k(t)=\binom{K}{k}P^k(t)\{1-P(t)\}^{K-k}$$

where,

$P(t) = e^{-vt}$, the probability that a household is still viable at time t.

As the estimates of P(t) are not available, the pure household extinction process may be realized on a yearly basis by approximating the probability distribution, $P_k(t)$, by a binomial one. As a first step in the realization of the microsimulation model, each household unit in the sample population was exposed to the risk of extinction in order to examine the impact of household extinction on the average size of the household. The probabilities of household extinction were computed from the probabilities of death of the individual household members by assuming that the latter probabilities are mutually independent. As, by definition, a given household was considered extinct if all its members died jointly in a given year, the probability of household extinction was computed from the (yearly) probability of death of each of its members. Such a probability, denoted by Q_i, for the ith household of 'n' members aged $x_1, x_2, \ldots, x_n$, is given by:

$$Q_i = q_{x_1} q_{x_2} \cdots q_{x_n}.$$

The Estimation of the Input Probabilities

For examining the effect of the extinction of households (due to the joint mortality of its members), on the average size of the household, the age-sex specific probabilities of death of the individual were used as input for the microsimulation model. These probabilities were computed using classical decrement life table methodology, the essence of which is to transform the occurrence/exposure rates into probabilities using the following formula:

$$q_x = 2\ m_x/(2 + m_x),$$

where, m_x is the age-specific death rate and q_x is the probability that an individual of exact age 'x' will die before reaching the exact age (x+1). This transformation holds under the assumption that the survivorship function is linear between exact ages 'x' and (x+1), and that there are no "disturbances" in the given population (Wunsch and Termote, 1978).

Estimates of q_x's for the period 1971-1981 are provided in Statistics Canada publications (Catalogue 84-532 Occasional, 1974, 1979, 1984). Using these probabilities, the microsimulation was carried forward from the 1971 base population to 1981 on a yearly basis under the observed mortality conditions.

Three Household Extinction Scenarios

The household population was projected forward even further on a yearly basis for another ten years, from 1981 to 1991, for sensitivity analysis under the three following scenarios of household extinction.

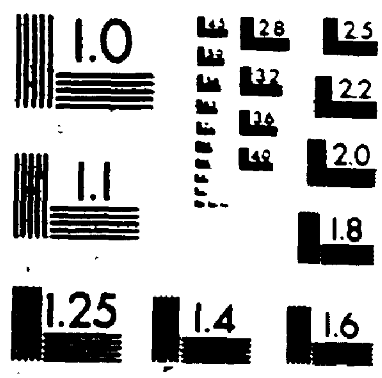
***Scenario I*: the 1980-1982 Canadian household extinction pattern remaining constant from 1981 to 1991**

Scenario II: the 1930-1932 Canadian household extinction pattern remaining constant from 1981 to 1991

Scenario III: the Indian 1971 household extinction pattern remaining constant from 1981 to 1991

These scenarios, which essentially reflect differences in individual mortality, differ considerably in their mortality patterns. For instance, with respect to the expectation of life at birth, a male, on the average, will be expected to live for 71.9, 58.0, or 48.9 years, respectively, if he is exposed to the risk of mortality in the three scenarios. Corresponding values for a female are 79.0, 61.6, and 46.8 years, respectively. The age-and-sex specific rates of mortality vary as well, across the three scenarios (Tables 5.1. and 5.2.). For example, the probability of death of a male infant in the 1930-1932 Canadian mortality scenario (Scenario II) is eight times higher than in the 1980-1982 Canadian mortality scenario (Scenario II), and the same rate in the 1971 Indian mortality scenario (Scenario III) is elevan times higher than in the 1980-1982 Canadian mortality scenario (Scenario II). Striking differences between the three scenarios are also observed for the later stages of the life span. For an individual exposed to the Indian mortality pattern, the probability of death rises most quickly at the older ages, followed successively by the 1980-1982 and the 1930-1932 Canadian patterns. These striking differences in the probability of death at the polar ends of the age span are consistent with the observation made across life tables for various societies, that the variance in the age-specific probabilities of death is the greatest for the extreme ages and the least for the middle age range.

2 OF/DE 2



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

TABLE 5.1. Age-Specific Probabilities of Death for Males, Canada, 1980-1982, 1930-1932, India 1971-1972

Exact Age (x)	Probability of Death ($_1q_x^m$) for Males		
	Canada		India
	1980-1982 Scenario I	1930-1932 Scenario II	1971-1972 Scenario III
0	0.0109	0.0870	0.1225
10	0.0002	0.0016	0.0020
20	0.0015	0.0031	0.0029
30	0.0013	0.0034	0.0040
40	0.0022	0.0049	0.0078
50	0.0063	0.0090	0.0182
60	0.0163	0.0194	0.0368
70	0.0391	0.0463	0.0703
80	0.0894	0.1153	0.1268
90	0.1898	0.2471	1.0000
100	0.7411	0.4665	1.0000

Data Source: Statistics Canada, Life Tables, Canada and Provinces, 1930-1932, and 1980-1982, Catalogue 84-532, and Daftuar and Chattopadhyay (undated).

TABLE 5.2. Age-Specific Probabilities of Death for Females, Canada, 1980-1982, 1930-1932, India 1971-1972

Exact Age(x)	Probability of Death ($_1q_x^f$) for Females		
	Canada		India
	1980-1982 Scenario I	1930-1932 Scenario II	1971-1972 Scenario III
0	0.0084	0.0693	0.1372
10	0.0002	0.0014	0.0023
20	0.0005	0.0030	0.0047
30	0.0006	0.0040	0.0056
40	0.0013	0.0051	0.0067
50	0.0034	0.0080	0.0147
60	0.0080	0.0171	0.0334
70	0.0198	0.0406	0.0648
80	0.0540	0.1077	0.1219
90	0.1435	0.2286	1.0000
100	0.7238	0.4130	1.0000

Data Source: Statistics Canada, Life Tables, Canada and Provinces, 1930-1932, and 1980-1982, Catalogue 84-532, and Daftuar and Chattopadhyay (undated).

Simulation Results

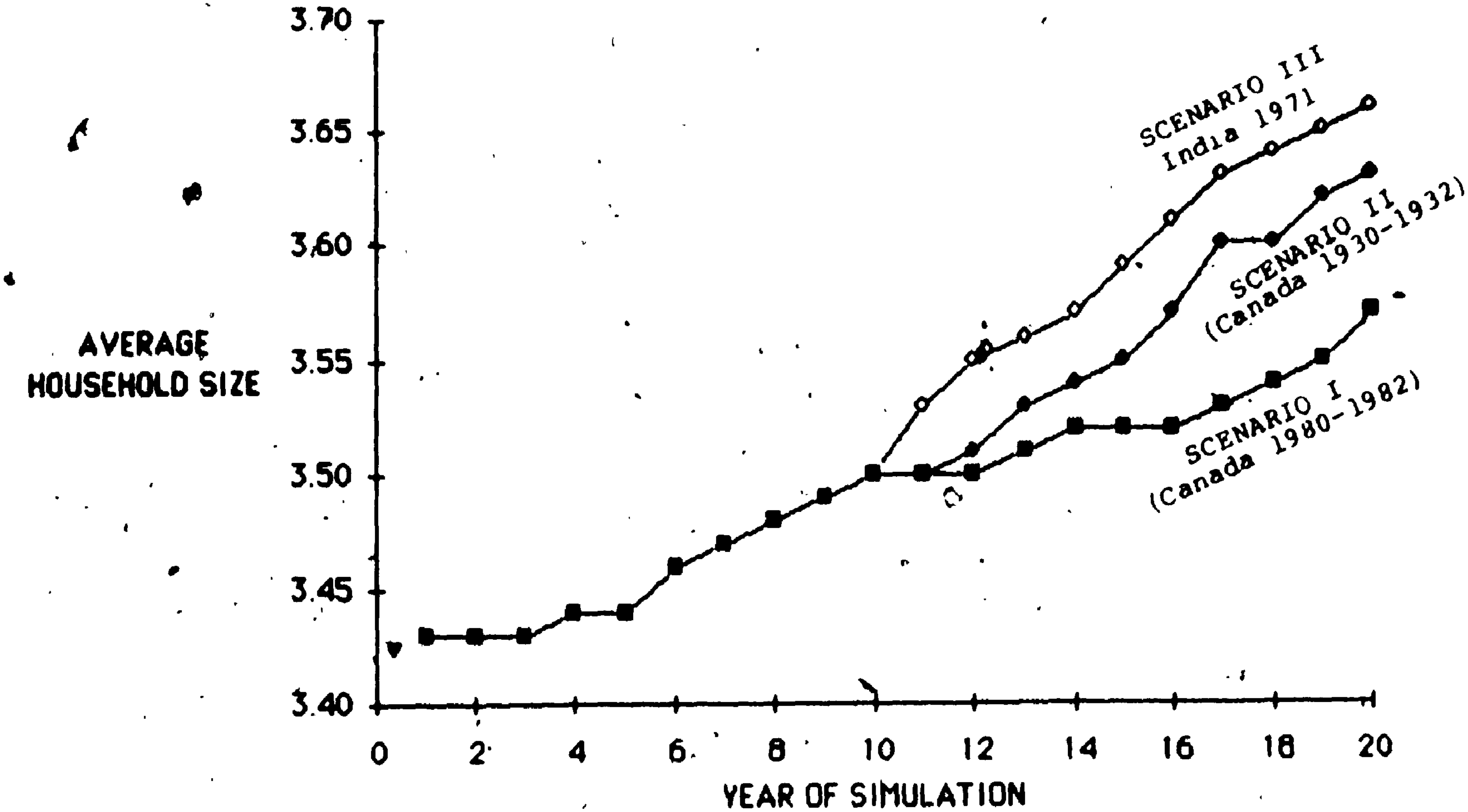
The simulation results show that the average size of the household increases from 3.42 persons per household in 1971 to 3.49 in 1981 under the impact of the observed probabilities of household extinction[3]. This increasing trend continues into 1991 under all the three scenarios described above (see Figure 5. 1). For example, under Scenario I, the average size of the household increased from 3.49 persons per household in 1981 to 3.58 in 1991. The corresponding values of average household size under Scenarios II and III increased to 3.62 and 3.66, respectively. Even though the differences in the average values are not dramatic under different mortality scenarios, they consistently retain the trend in their differences over the entire simulation period.

As smaller households have a higher probability of extinction due to mortality of their respective members, the strategy of favouring large households in traditional societies appears to be a logical choice if the survival of the household as a unit is to be maximized. Such an objective is usually achieved by concentrating individual life history events such as marriage and childbearing at the lower end of the age scale and having strong social taboos against events such as divorce that would reduce household size. A similar observation with respect to the inheritance rules among the lineages of the British aristocracy and the French nobility was made recently by Clark (1986).

[3] The values of average household size are based on one run only. Because they are based on large samples, the values of the average household size are quite stable across different simulation runs. For four runs in this case, average household size in 1991 ranged from 3.57 to 3.58 under Scenario I, from 3.62 to 3.64 under Scenario II, and from 3.66 to 3.72 under the third scenario.

FIGURE 5.1.

EFFECT OF THREE LEVELS OF HOUSEHOLD EXTINCTION ON AVERAGE HOUSEHOLD SIZE



The simulation results indicate that the extent of the increase in the average size of the household depends directly on the level of mortality. Thus, the higher the extinction probability of the household, the higher the average size of the household. Conversely, average household size in a low mortality situation is smaller than in a high mortality situation. This finding, which is at the level of the household, is consistent with Kobrin's first hypothesis. Note that her arguments in developing this hypothesis dealt with the joint survivorship of the couple, or in other words, with the nuclear family household as a unit rather than solely with the survival of the individual.

5. 7. Growth of the Household

The growth of a given household over its cycle may be affected by several factors operating on the individual household members. In the research conducted in this dissertation, the effect of mortality and fertility on the average size of the household will be investigated.

Mortality of Individual Household Members

The mortality of individual household members will have implications at both levels of analysis, the household and the individual. This case differs from the earlier case where the household was taken as the unit of analysis, in that now the size of a household is allowed to change as well. Thus, as households of larger size reduce in size over time, their probability of extinction also increases, keeping other factors constant.

The effect of individual mortality on the average size of the household is simulated by superimposing the individual level mortality effect over the set of households that has already been exposed to the risk of household extinction.

The Underlying Stochastic Process

When the possibility of death of individual household members is taken into account, the underlying stochastic process is the death process, which is essentially similar to the household extinction process described earlier in this chapter. The parameters K and k of the household extinction process may now be interpreted as the number of members of a given household at a given initial time and at time t, respectively. The probability $P_k(t)$ would now refer to the probability that of K members present in a household at the initial time, only k survive to time t.

The Estimation of the Input Probabilities

The age-sex specific probabilities of death of the individual were used as input for the microsimulation model. The estimation of these probabilities has already been described in the section on the estimation of the probabilities of joint survival of household members.

Three Mortality Scenarios

The following three scenarios of individual mortality were used for sensitivity analysis of the average size of the household.

Scenario I: the 1980-1982 Canadian mortality pattern remaining constant from 1981 to 1991

Scenario II: the 1930-1932 Canadian mortality pattern remaining constant from 1981 to 1991

Scenario III: the Indian 1971 mortality pattern remaining constant from 1981 to 1991

The probabilities of death of an individual by age and sex for the three scenarios have already been given in Tables 5.1 and 5.2, and the differences among them have been discussed.

Simulation Results

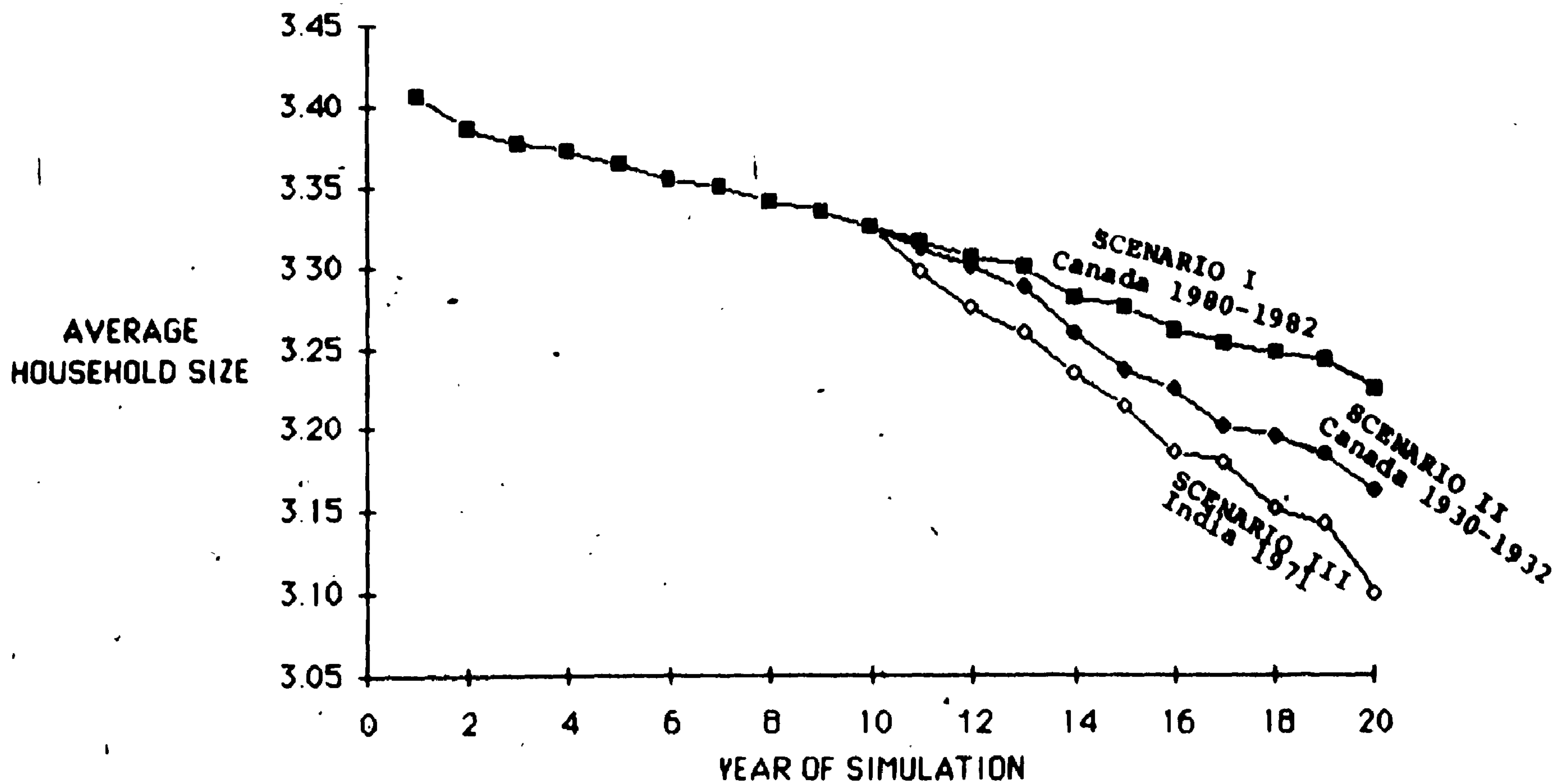
The most striking result obtained here shows that the average size of the household no longer increases with time as was the case in the household extinction process. Rather, it actually starts declining. Thus, the effect of the introduction of the mortality of the individual more than offsets the contradictory effect of the extinction of the household. Initially the average size of the household declines from 3.45 in 1971 to 3.32 in 1981 under the observed mortality conditions. Subsequent to 1981, the average size of the household is examined under the three scenarios of mortality described earlier. Not only is the declining trend in the average size of the household observed to continue under the three scenarios, but the extent of the decline also differs across them (see Figure 5. 2.).

It is clear from Figure 5. 2. that the higher the level of mortality, the lower the average size of the household. Simulation results show that when the Indian mortality (Scenario III) pattern is introduced into the model, the average size of the household decreases to 3.10[4] in 1991 compared to 3.16 in 1991 under Scenario

[4]These values are based on only one simulation run. They, however, show some variation across different simulation runs. For example, under Scenario I, they vary from 3.19 to 3.27 over three simulation runs; from 3.14 to 3.20 under Scenario II; and from 3.07 to 3.14 under Scenario III.

FIGURE 5.2.

EFFECT OF THREE LEVELS OF HOUSEHOLD EXTINCTION AND INDIVIDUAL MORTALITY ON AVERAGE HOUSEHOLD SIZE



II, and 3.22 under Scenario I. Even though the increases in absolute terms are small, the consistency of the increase is striking and does illustrate the differential impact of different mortality patterns on the average size of the household.

The Effect of Fertility

Now, fertility of individual household members is superimposed on the mortality of the individual (and the extinction of the household).

The Underlying Stochastic Process

In this section, the growth of the household as it is affected by fertility has been investigated. When both the mortality and fertility of individual household members are taken into account, the underlying stochastic process that is realized is the birth-and-death process. This process, under the assumption that the intensities of birth and death remain constant over time, is described in Bailey (1965).

Once the death process has been realized in the household system, the birth process may be superimposed on it to get the resulting birth-and-death process. Just as in the case of the death process, the binomial approximation will be used here as well, with two possible outcomes -giving birth or not giving birth- at the level of the individual. For the period 1971-1981, the observed period fertility rates specific for age and marital status of females were used in the microsimulation model.

Two Fertility Scenarios

For the next ten years over the simulation period, i. e., from 1981 to 1991, two fertility scenarios were used. They are:

Scenario I: the 1981 Canadian fertility pattern remaining constant from 1981 to 1991

Scenario II: the 1963 Chinese fertility pattern remaining constant from 1981 to 1991

The 1963 Chinese fertility pattern was used as a scenario because of its high fertility level, the highest observed in China since 1950. The two scenarios differed considerably in their fertility levels. The 1963 Chinese fertility pattern has a total fertility rate of 7.5 compared to the 1981 Canadian total marital fertility rate of 4.4. For the Chinese pattern, it was assumed that the non marital fertility rates are zero, unlike for the 1981 Canadian case in which the total non marital fertility rate is 0.61. The higher overall fertility rate in the second scenario compared to the first one is also reflected quite well in their respective age specific (marital) fertility rates, with one exception - the age group 15-19 for which the Canadian fertility rate of 0.40 is higher than the corresponding Chinese fertility rate of 0.08 (see Table 5. 3.).

Each scenario of fertility was run for each scenario of mortality so that the effect of fertility for different levels of mortality could be examined.

Simulation Results

When the simulation is driven forward under the impact of fertility, with the effect of mortality already realized, the average size of the household is observed to increase. For the initial period of ten years, the average size of the household increases from 3.42 in 1971 to 3.76 in 1981. For the next ten years,

TABLE 5.3 Age-Specific Fertility Rates for Married and Single Women, Canada, 1981, and China, 1963.

Age Group	Marital Fertility Rate Canada,1981 (Scenario I)	Marital Fertility Rate China,1963 (Scenario II)	Single Fertility Rate Canada, 1981 (Scenario I)	Single Fertility Rate China, 1963* (Scenario II)
15-19	0.400	0.079	0.017	0.000
20-24	0.202	0.348	0.031	0.000
25-29	0.166	0.374	0.036	0.000
30-34	0.081	0.326	0.025	0.000
35-39	0.023	0.254	0.010	0.000
40-44	0.004	0.108	0.002	0.000
45-49	0.000	0.012	0.000	0.000
Total Fertility Rate	4.380	7.510	0.605	0.000

*single fertility rates for Chinese women are assumed zero.

Data Source: Vital Statistics, Volume I, Births, Catalogue 84-205 Annual 1981.

Statistics Canada, Intercensal Annual Estimates, 1976-1981, Catalogue 91-519 Occasional.

China Population Information Centre (1984).

1981 to 1991, fertility rates in each scenario were held constant, from 1981 to 1991. The following are some of the observations drawn from the simulation results for this latter period.

In conformity with Kobrin's second hypothesis, the simulation results show that fertility has the effect of increasing the average size of the household, irrespective of the level of mortality over which fertility is superimposed. Under the three mortality scenarios, the average size of the household increases from a (fixed) value of 3.74 in 1981 to 3.92, 3.87 and 3.83, respectively, in 1991 under the fertility scenario I. Corresponding values in 1991 under fertility scenario II are 4.11, 4.04 and 3.95, respectively. However, at low levels of fertility, the three mortality scenarios do not show a consistent trend (see Figure 5. 3.) whereas under the high fertility scenario (Scenario II), the three curves representing the effects of different levels of mortality, show a consistent increasing trend over the entire projection period, 1981 to 1991 (see Figure 5. 4.).

5. 8. Household Formation: The Role of Nuptiality

In this section, the microsimulation approach incorporated one highly schematic rule of household formation, namely, the nuclear family household which is assumed to be tied with the event of marriage.

The Underlying Stochastic Process

Once the birth and death processes have been realized, the stochastic process underlying the formation of households is a household formation-extinction process which is essentially similar to the birth-and-death process. The probability $p_k(t)$ would now refer to the probability in a population of K

FIGURE 5.3.

CHANGES IN AVERAGE HOUSEHOLD SIZE WHEN FERTILITY IS SUPERIMPOSED ON THREE LEVELS OF HOUSEHOLD EXTINCTION AND INDIVIDUAL MORTALITY

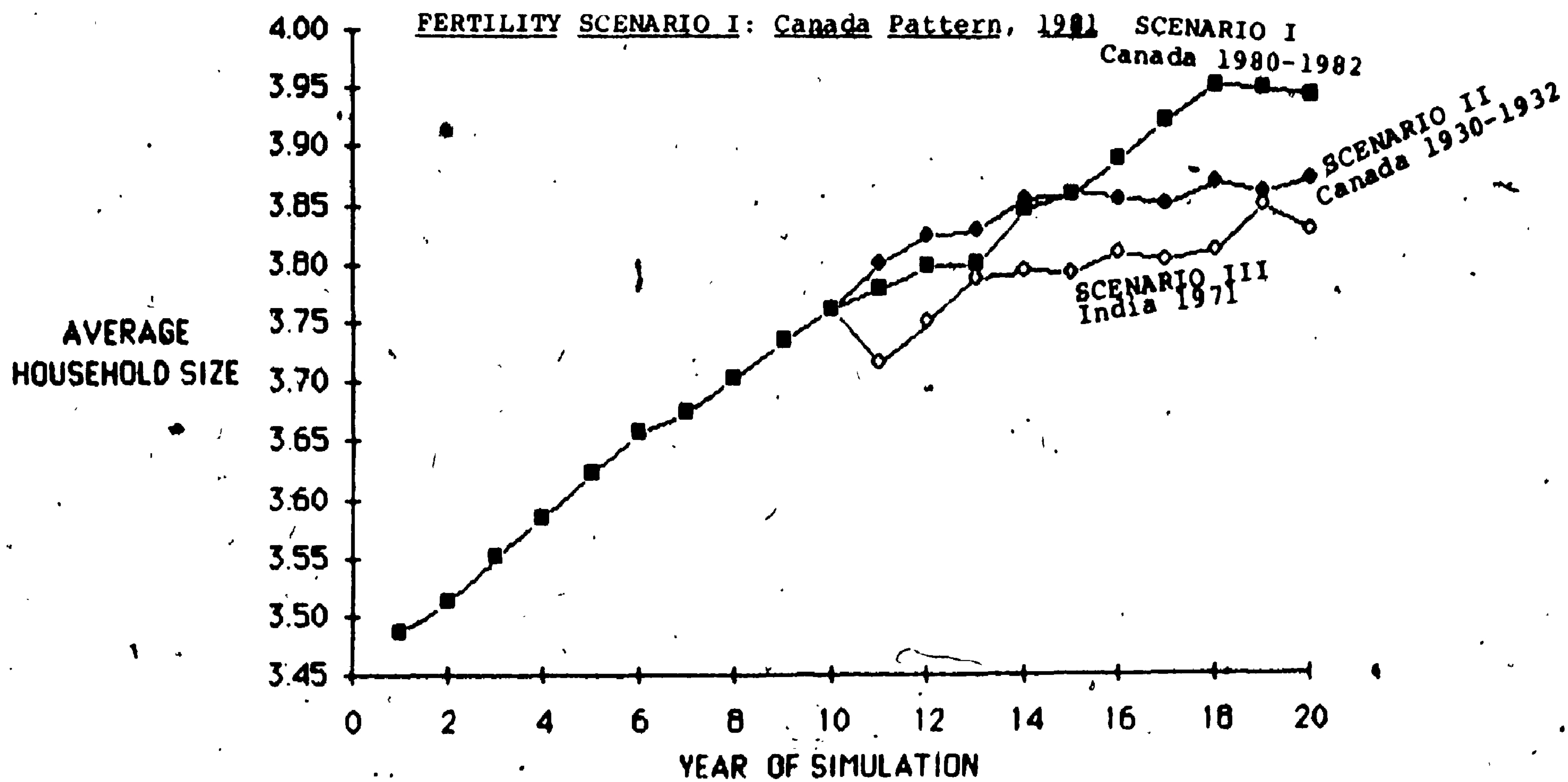
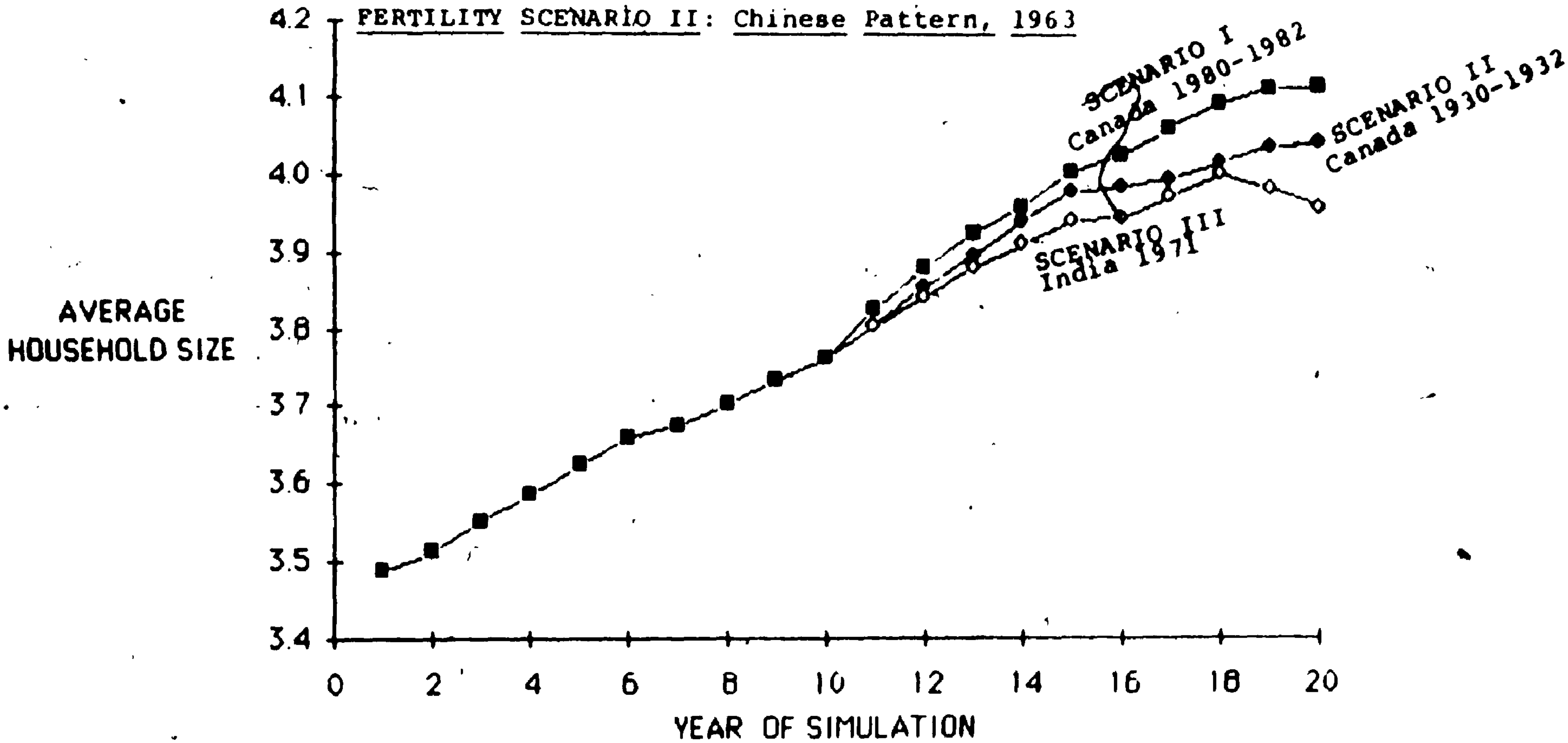


FIGURE 5.4.

CHANGES IN AVERAGE HOUSEHOLD SIZE WHEN FERTILITY IS SUPERIMPOSED ON THREE LEVELS OF HOUSEHOLD EXTINCTION AND INDIVIDUAL MORTALITY



households at the initial time, only k are observed at time t.

The Estimation of the Input Probabilities

The microsimulation uses the age-sex specific probabilities of first marriage, or of household formation, as the input to the model. These probabilities are computed using the conventional method of constructing gross nuptiality tables, in which the probabilities of (first) marriage are independent of the effect of mortality (for details, see Wunsch and Termote, 1978). The marriage probabilities for 1970-1972 and for 1976 that are used in the microsimulation model are computed in Basavarajappa (1978), and for 1911 in Mertens (1976). As in the two previous approaches, first Canadian households are projected forward from 1971 to 1981 under the observed nuptiality conditions in order to add a fourth component in the construction of the observed distribution of Canadian households. For the sensitivity analysis, two nuptiality or household formation scenarios were allowed to operate in the household system for the period 1981 to 1991.

Two Household Formation Scenarios

The two following nuptiality scenarios were superimposed on the 1981 households obtained by simulating the initial 1971 household sample for the effects of household extinction, individual mortality and fertility.

Scenario I: the 1976 Canadian nuclear family household formation pattern remaining constant from 1981 to 1991

Scenario II: the 1911 Canadian nuclear family household formation pattern remaining constant from 1981 to 1991

An interesting feature of these patterns is that first marriage probabilities for both males and females have increased from 1911 to 1976. The increase is concentrated primarily in the 20 to 29 year age group. For instance, the annual probability of first marriage for a male aged 20-24 years has increased from 5.8 per cent in 1911 to 14.1 per cent in 1976. A similar increase, from 10.9 per cent to 19.0 per cent is obtained for a female in the same age group. Another interesting difference between the two scenarios is that whereas in 1911 the female marriage rates were higher than male marriage rates for the age range 15 to 29, in 1976 they were higher for females only for the age range 15 to 24. The nuptiality probabilities in the two scenarios are presented in Table 5: 4.

Simulation Results

The event of household formation, which is tied to the event of marriage, has a direct influence on average household size. As the frequency of new households increases over the simulation period the proportion of smaller households increases correspondingly in the population, thereby decreasing the average size of the household. Note, for example, that average household size falls from 3.42 in 1971 to 3.1 in 1981 under the impact of observed nuptiality conditions. The fall is greater under the first scenario, from 3.1 in 1981 to 2.68 in 1991, than under the second scenario, from 3.1 in 1981 to 2.75 in 1991 (see, Figure 5.5).

5. 9: Discussion

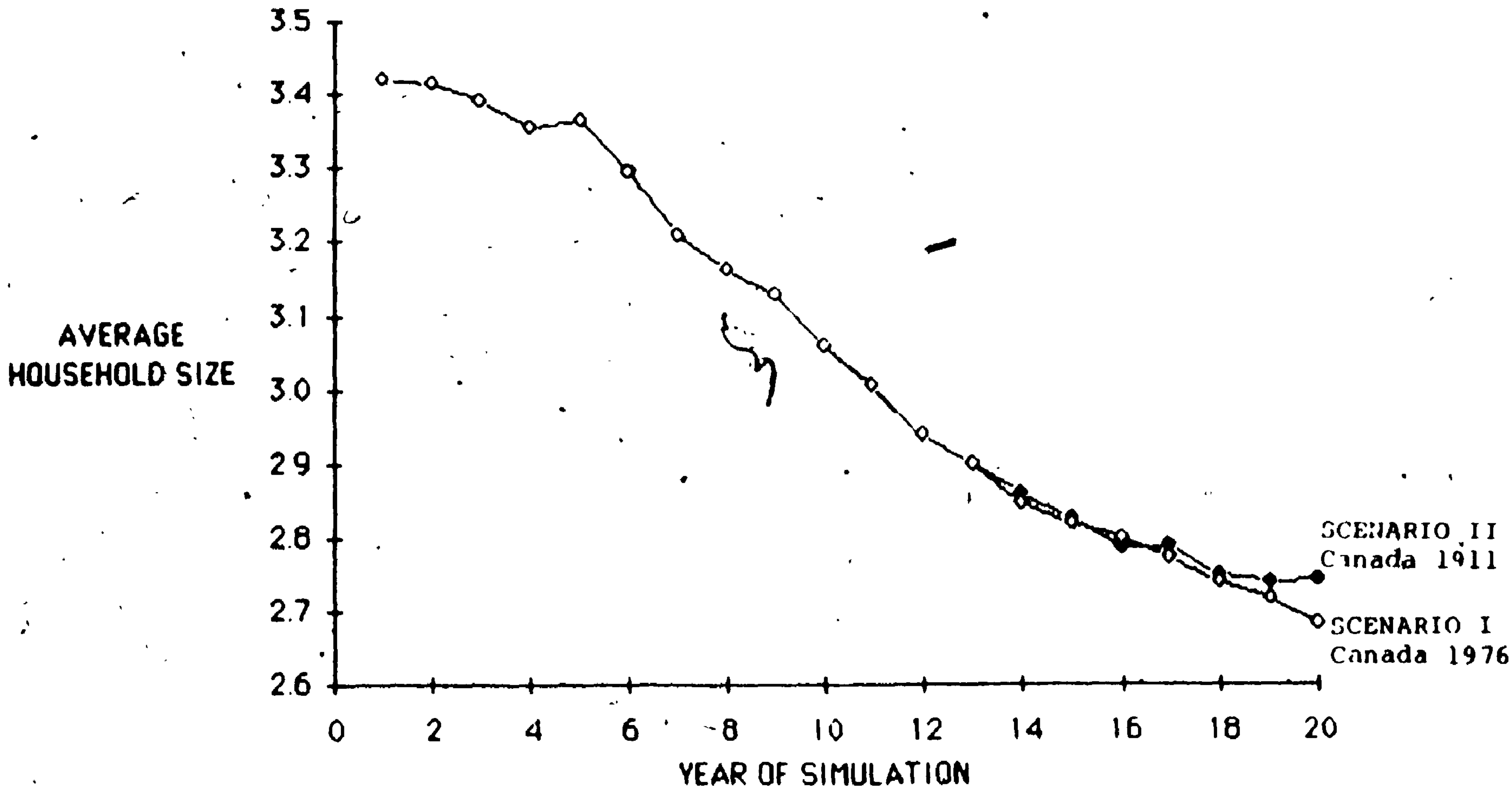
Using the notion of the household cycle, the research reported in this

TABLE 5.4 Age-Sex Specific Nuptiality Probabilities, Canada, 1970-1972, 1976 and 1911.

Age Group	Males 1970-1972	Females 1970-1972	Males 1976	Females 1976	Males 1911	Females 1911
	Probability of getting married in a year					
15-19	0.013	0.049	0.003	0.030	0.012	0.047
20-24	0.113	0.142	0.141	0.190	0.058	0.109
25-29	0.128	0.109	0.154	0.133	0.089	0.110
30-34	0.083	0.063	0.089	0.065	0.080	0.067
35-39	0.053	0.038	0.047	0.036	0.056	0.037
40-44	0.029	0.023	0.031	0.021	0.047	0.026
45-49	0.019	0.012	0.019	0.015	0.040	0.014
50-54	0.014	0.010	0.011	0.009	0.000	0.000
55-59	0.009	0.006	0.010	0.007	0.000	0.000

Data Source: Basavarajappa (1978) and Mertens (1976)

FIGURE 5.5.
EFFECT OF TWO LEVELS OF HOUSEHOLD FORMATION ON AVERAGE HOUSEHOLD SIZE



chapter has extended Kobrin's demographic hypotheses about the relationship between the mortality and fertility of the individual on the one hand and the average size of the household on the other. In particular, her hypothesis about the relationship between mortality and average household size is refined to make it consistent with the formal demography of the household.

Simulation results show that household extinction leads to an increase in the average size of the household as it leads to the elimination of smaller households from the population. Kobrin's first hypothesis is consistent with our findings. On the other hand, when the household is considered as a group of individuals any of whom may die during a given year, the average size of the household declines primarily as a result of an increase in single person households. Fertility and household formation, when introduced sequentially into the microsimulation, have the opposite effect on the average size of the household. Whereas fertility leads to an increase in the average size of the household, as expected on the basis of Kobrin's Second hypothesis II, household formation based on nuptiality leads to its decline: the higher the level of fertility, the higher the growth of the household; the higher the level of nuptiality, the greater the number of new (smaller) households formed and, therefore, the smaller the average size of the household. The results are based on the average of ten runs in each case. The standard errors of these sample averages are not computed. However, the trends of different household parameters remain consistent across three or four simulation runs in different cases. Also, the variation in average household size across the simulation runs in a given case is quite small indicating a good degree of reliability of estimates.

CHAPTER 6

CONCLUSION

6. 1. Summary

This dissertation has focused on the formal demographic aspects of household organization. Based on earlier research, it was argued that the demographic factors act as constraints on the parameters of household organization, such as the average size of the household and the composition of the household. The sociocultural factors, on the other hand, impinge on these demographic constraints to yield the household organization that is actually observed in the population.

Details about the contents of each chapter are summarized below:

Chapter two reviewed the United Nations' definition of the household and basic concepts in formal household demography. It then discussed the characteristics that distinguish formal household demography from conventional formal demography of the individual. A review of the United Nations definition of the household showed that though this definition included the concept of household formation, it made no reference to household extinction. In this sense this definition was considered incomplete. It was argued that the omission of the concept of household extinction from the basic definition of the household was a serious matter, at least from the perspective of the complete and adequate modeling of household organization. Once the concept of household extinction was taken into account, it became imperative to take into consideration the notion of the household cycle, and it was argued that this is the core concept in the formal demography of the household.

From this point on, this dissertation focused on modeling the household cycle. The rest of the second chapter provided the proximate processes of fission, fusion, and fission-fusion, that lead to the formation, growth, and extinction of the household. That the household should form the basic unit of analysis in formal household demography has also been stressed here. It was, however, pointed out that the focus on the household as a unit of analysis in formal household demography did not mean that the individual was not to be considered at all. Rather, individual life histories are very much part of household modelling to the extent that they are encompassed by the household cycle of their affiliation. Even though such modeling must necessarily take into account the beginning and end points of the household cycle, the analytical attempts in the literature have not shown an explicit recognition of this fact. Two approaches to modeling household units were identified in this chapter, namely, the individual tagging approach and the household marker approach. In the final section of the chapter, it was pointed out that the use of the household cycle in household demography represents its distinctive feature as compared to conventional individual demography.

Chapter three of this dissertation provided a critique of measures of the average household size for three types of household organization: the nuclear family, the extended family households type I and II. These measures which were used by Coale (1965) and Burch (1970) in the case of the stationary or the stable population case were given complete formal expressions in this chapter. An assumption referring to the case when the ego's mother dies prior to ego's marriage in the case of the nuclear family household that had been overlooked in Burch's (1970) and Coale's (1965) studies was also identified in this chapter. A new measure of the extended family household type II was also formulated in this chapter.

Chapter four first formalized Ryder's model of the household cycle in the case of the nuclear family household, and then extended it to two cases: the extended family household cycle with a foster mother and the extended family household cycle without a foster mother. In the formalization and extension of Ryder's model, the probabilities of various events occurring within the household were expressed in household durations rather than just in terms of ages and marital durations of individual household members. In each type of household cycle; measures of average household size were developed in terms of demographic parameters such as gross fertility, expectation of life, age at household formation, and the net reproduction rate. This chapter also provided partial derivatives of the average size of the household with respect to the gross level of fertility and to the net reproduction rate. The results of these developments were illustrated for the three types of societies - high equilibrium, disequilibrium, and low equilibrium - The results indicated that the average size of the household was highest in the disequilibrium society, irrespective of the type of the household structure prevailing in it. Furthermore, the gross level of fertility was found to have only a minimal differential effect across the three societies in the case of the nuclear family household cycle. The gross level of fertility was observed to have the greatest effect on the average size of the extended family household without a foster mother. Finally, the nuclear family household cycle in the high equilibrium society was found to be most sensitive to changes in the net reproductive rate. The average size of the extended family household without a foster mother was also conspicuously sensitive to the gross level of fertility across the three scenarios.

A demographic microsimulation of Canadian households was developed in Chapter five. This approach to modeling, as was argued in the chapter, makes more realistic the analytical one-sex based models of Chapters three and four. This chapter has modeled the demographic component of the Canadian household. Three demographic processes associated with the household were modeled in this chapter - extinction, growth, and formation. First households were projected from 1971 to 1981 under the observed conditions of household extinction due to mortality and then this projection was carried to 1991 under three different scenarios of risk of household extinction: the 1980-1982 Canadian extinction pattern, the 1930-1932 Canadian household extinction pattern, and the 1971 Indian household extinction pattern. A similar procedure was used with other demographic processes that were subsequently incorporated into the model in the following sequence: individual mortality, (individual) fertility, and household formation. Just as in the case of household extinction, three scenarios of individual mortality were introduced into the simulation model: the 1980-1982 Canadian mortality pattern, the 1930-1932 Canadian mortality pattern, and the 1971 Indian mortality pattern. In the case of fertility, however, two scenarios were used: the 1981 Canadian fertility pattern, and the 1963 Chinese fertility pattern. Similarly, in the case of household formation, or equivalently, in the case of nuptiality, two scenarios were considered: the 1976 Canadian nuclear family household formation pattern, and the 1911 Canadian nuclear family household formation pattern.

In each case, the stochastic process underlying the realization of demographic events was specified along with the procedure of estimating the input probabilities. The simulation results obtained from these procedures are very interesting indeed. They were further discussed in the chapter with reference to the testing of Kobrin's modified hypotheses described in the beginning of the chapter. Kobrin's two hypotheses about the relationship between household extinction and fertility on the one hand, and the average size of the household on the other, was supported by the simulation data. However, an interesting and counterintuitive finding of the simulation model was that mortality has a dual effect on average household size. On the one hand, household extinction, per se, results in an increase in average household size because smaller households have a higher probability of extinction than larger households, holding other factors constant. On the other hand, the mortality of the individual, independent of household extinction, leads to a decrease in the average size of the household. These results indicate that the overall influence of mortality on households would depend on the net outcome of these two contradicting effects at the two levels of analysis - the household and the individual. The simulation results on the relationship between fertility and average household size, and that between household formation and average household size were in the expected directions.

6. 2. The Salient Contributions of this Dissertation

The following points summarize the contribution of this dissertation to the existing literature.

1. It identifies the household cycle as the core concept of the formal demography of the household.

2. It identifies and provides analytical definitions of the proximate processes - the fission, fusion, and fission-fusion of households - that govern the size-distribution of households and, therefore, the average size of the household.

3. Cross-sectional measures of the average size of the household are critically appraised. Complete mathematical formulas of the average size of the household in the case of the nuclear family household, the extended family household with a foster mother, and the extended family household without a foster mother are provided. In addition some implicit assumptions in the use of these measures are also identified.

4. A new measure of the average size of the extended family household cycle type II is formulated in chapter 3.

5. Ryder's (1975) formula of the average size of the nuclear family household is formalized in terms of the gross level of fertility, net reproduction rate, and probabilities of survival. The various demographic parameters are expressed in terms of household durations as well as ages of individual household members. The results are discussed with reference to the three types of societies.

6. Ryder's formula of the average size of the nuclear family household is extended to two types of household cycle - extended family with a foster mother and extended family without a foster mother. The results are discussed for the three types of societies that he describes.

7. Kobrin's (1976) hypotheses about the relationship between mortality and fertility on the one hand, and the average size of the household, on the other are extended in order to make them consistent with formal household demography, that is, with the household cycle perspective.

8. A demographic microsimulation model of the household cycle is developed with special relevance to the Canadian case.

6. 3. Directions for Future Research

The research on the demographic aspects of household organization in this dissertation has focused on some very preliminary work in formal household demography. Several possibilities exist for building on the research developed in this dissertation.

1. A general sociocultural as well as stochastic theory explaining the fission, fusion, and fission-fusion of households can be developed from this dissertation.

2. The models and measures developed in this research were based on various assumptions which could be relaxed to make the existing models more generalizable. More varieties of household organization, for example, could be modeled using the analytical approaches developed in this dissertation. In addition, one could derive average household size measures using nonstationary

models.

3. The sensitivity of average size of the household with respect to mortality could be computed by using the various formulas for the average size of the household that are developed in Chapter 4.

4. The microsimulation model of the household cycle has considerable potential for further development. There is the need to incorporate more demographic variables such as divorce and remarriage which, in addition to household extinction, individual mortality, fertility, and nuptiality, also influence household organization. In addition, the work done in chapter five could be replicated with more scenarios and more parameters of the household organization such as the proportion of consumers to earners within the household or the size-distribution of households. One could also use microsimulation to test Beaujot's (1976) finding that household and family projections are most sensitive to population growth and changing age structure.

5. Using the methodologies developed here, one could examine how changes in demographic parameters influence not only the household cycle but also some of the socioeconomic variables associated with it such as income distribution.

APPENDIX

FORTRAN Program for the Microsimulation of Household Cycles

Note: In developing the microsimulation model, I have used a combination of SPSS and FORTRAN routines. I am currently preparing a FORTRAN program for the microsimulation of household cycles. Please contact me for details.

```
[illegible]
      PROGRAM [illegible] (INPUT,OUTPUT,TAPE[illegible],TAPE[illegible]3,TAPE5,TAPE6,TAPE7,TAPE[illegible],TAPE[illegible])
      DIMENSION I[illegible](300),JM(300),[illegible](300),II1(2200),II2(2200),
     1II3(2200),II[illegible](2200),II[illegible](2200),II[illegible](2200),II7(2200),
     1II[illegible](2200),II[illegible](2200),A[illegible](2[illegible]),[illegible](206),
     1[illegible](200),A[illegible]1(200)
     1A[illegible](200),X[illegible](200),X[illegible]1(200),A[illegible]T1(200),
     1JJF1(2200),JJF2(2200),JJF3(2200),JJF4(2200),
     1JJF5(2200),JJF[illegible](2200),JJM1(2200),JJM2(2200),
     1JJM3(2200),JJM[illegible](2200),JJM5(2200),JJM6(2200)
     1,M[illegible](2200),I[illegible](400),MTCHM(2200),MTCHF(2200)
     1,JJF[illegible](2200),JJM[illegible](2200)

      DO 90 I=1,100
      READ(7,80) I[illegible](I),JM(I)
   80 FORMAT(I3,F9.7)
   90 CONTINUE
      DO 91 I=1,100
      READ([illegible]) I[illegible](I),[illegible](I)
   91 CONTINUE
      K=0
      K[illegible]=3
      [illegible]
      [illegible]
      [illegible]
      DO 10 I=1,[illegible]
      READ(5,[illegible]) X[illegible]1(I), X[illegible]1(I)
   61 FORMAT(F[illegible],1X,F[illegible])
      K[illegible]=K[illegible]+[illegible]
   10 CONTINUE
      IK[illegible]=[illegible]
      DO [illegible] I=1,[illegible]
      READ(9,[illegible]) X[illegible]1(I),X[illegible]1(I)
      IK[illegible]=IK[illegible]+[illegible]
   [illegible]2 CONTINUE
      [illegible]
      [illegible]
      DO [illegible] I=1,[illegible]
      READ([illegible],11) II1(I), II2(I),II3(I),II[illegible](I),II5(I),
     1II6(I),II7(I), II[illegible](I),II[illegible](I)
   11 FORMAT(I[illegible],I3,I1,I[illegible],2I1,I2,I3,I[illegible])
      IF(II[illegible](I) .[illegible]. 5) II[illegible](I)=[illegible]
   2[illegible] CONTINUE
      AMR[illegible]T=[illegible]
      AMR[illegible]1=0.
      AMR[illegible]T2=0.
      DO [illegible] I=1,[illegible]X
      IF(II[illegible](I[illegible]) .[illegible]. 1)AMR[illegible]1=[illegible](II[illegible](I[illegible])+1)+AMR[illegible]T1
      IF(II3(I[illegible]) .[illegible]. 2)AMR[illegible]T2=[illegible](II[illegible](I[illegible])+1)+AMR[illegible]T2
 [illegible] CONTINUE
```

```
      DO 21 I=1,NX
      CALL PRNT(I3,II4,II6,II7,F,GF,NYR,NUTM,I)
21    CONTINUE

      PRINT 2111
2111  FORMAT(1X,//////)
      GO TO 115
      DO 22 I=1,NX
      CALL PRT(II1,II2,II3,II4,II5,II6,II7,II8,
     1AFNM,AFMR,K,KK,NYR,NX,I)
22    CONTINUE
      PRINT 2112
2112  FORMAT(1X,//6)
      PRINT 9932
      ISTRT=KK-NX
      DO 23 I=1,KK
      IF(I .LE. NX) GO TO 23
      CALL SXA(SA)
      II3(I)=SA
23    CONTINUE
      DIMENSION II4(2200),GF(4000),II6(2200),II7(2200),
     1GM(4000),II8(2200)
      IF(II7(I) .NE. 0) GO TO 71
      IF(II8(I) .EQ. 1) GO TO 100
      IF(R .GT. GF(II4(I)+1)) GO TO 150
      II7(I)=0
      GO TO 71
150   II7(I)=NYR
      NUTM=NUTM+1
      IF(II6(I) .EQ. 1) II6(I)=2
      GO TO 71
100   IF(R .GT. GM(II4(I)+1)) GO TO 990
      II7(I)=0
      GO TO 71
990   II7(I)=NYR
      NUTM=NUTM+1
      IF(II6(I) .EQ. 1) II6(I)=2
71    CONTINUE
      RETURN
      END
      SUBROUTINE FER (II1,II2,II3,II4,II5,II6,II7,II8,
     1AFNM,AFMR,K,KK,NYR,NX,I)
      DIMENSION II1(2200),II2(2200),II3(2200),II4(2200),
     1II5(2200),II6(2200),II7(2200),II8(2200),AFNM(4000),
     1AFMR(2200)
      IF(II7(I) .EQ. 0) GO TO 51
      GO TO 20
51    IF(II8(I) .EQ. 1) GO TO 20
```

```
      IF(II4(I) .LE. 15) GO TO 20
      IF(II4(I) .GE. 50) GO TO 20
      R=RANF()
      I1=II4(I)
      IF(II6(I) .EQ. 1) GO TO 70
      IF(R .LE. XFNM(I1)) GO TO 30
      II5(I)=000
      GO TO 20
70    IF(R .LE. XFMR(I1)) GO TO 30
      II5(I)=000
      GO TO 20
30    K=K+1
      KK=NAA+K
      II8(I)=100+NYR
      II9(KK)=NYR
      II7(KK)=00
      II1(KK)=KK
      II2(KK)=II2(I)
      II3(KK)=0
      II4(KK)=0
      II5(KK)=3
      II6(KK)=2
20    CONTINUE
      RETURN
      END
      ... II5,II4,II5,II6,II7,II9,XNPF,
     1XNPM,JJF0,JJF1,JJF2,JJF3,JJF4,JJF5,JJF6,JJM0,JJM1,JJM2,JJM3,
     1JJM4,JJM5,JJM6,NMRM,NMRF,NNYR,I)
      DIMENSION II2(2200),II3(2200),II4(2200),II5(2200),
     1II6(2200),II7(2200),II9(2200),XNPF(200),II1(2200),
     1XNPM(200),JJF1(2200),JJF2(2200),JJF3(2200),JJF4(2200),
     1JJF5(2200),JJF6(2200),JJM1(2200),JJM2(2200),JJM3(2200),
     1JJM4(2200),JJM5(2200),JJM6(2200)
     1,JJM0(2200),JJF0(2200)
      IF(II4(I) .LT. 15) GO TO 20
      IF(II4(I) .GE. 50) GO TO 20
      IF(II6(I) .EQ. 1) GO TO 20
      IF(II7(I) .NE. 1) GO TO 20
      R=RANF()
      IF(II3(I) .EQ. 1)GO TO 19
      IF(R .LT. XNPF(II4(I))) GO TO 150
      II5(I)=00
      GO TO 20
150   II9(I)=NNYR
      NMRF=NMRF+1
      II5(I)=1
      JJF1(NMRF)=NMRF
      JJF2(NMRF)=II2(I)
      JJF3(NMRF)=II3(I)
      JJF4(NMRF)=II4(I)
      JJF5(NMRF)=II5(I)
      JJF6(NMRF)=1
      JJF0(NMRF)=II1(I)
      GO TO 20
19    IF(R .LT. XNPM(II4(I))) GO TO 151
      II9(I)=00
      GO TO 20
151   II9(I)=NNYR
      NMRM=NMRM+1
```

```
      II5(I)=1
      JJM1(NMP1)=NMX
      JJM2(NMP1)=II2(I)
      JJM3(NMP1)=II3(I)
      JJM4(NMP1)=II4(I)
      JJM5(NMP1)=II5(I)
      JJM6(NMP1)=1
      JJM6(NMP1)=II2(I)
      GO TO [illegible]
20    CONTINUE
71    NKKX=KK
      DO 73 K=1,NRM
      IF (K .EQ. [illegible]) GO TO [illegible]
      IF (K .EQ. [illegible]) GO TO 77
      NKKX=NKKX+1
      IMAX=IMAX+1
      II2(JJM6(M[illegible](K)))=IMAX
      II5(JJM6(MIC-M(K)))=1
      II1(NKKX)=NKKX
      II2(NKKX)=IMAX
      II3(NKKX)=2
      II4(NKKX)=[illegible](K)
      II[illegible](NKKX)=2
      II6(NKKX)=1
      NKKX=NKKX+1
      IMAX=IMAX+1
      II2(JJM6(MIC-M(K)))=IMAX
      II5(JJM6(MIC-M(K)))=2
      II1(NKKX)=NKKX
      II2(NKKX)=IMAX
      II3(NKKX)=1
1[illegible]  CONTINUE
```

```
      ANG=(I-C.)*...5.+?.00
      IDIFF=A..
      II4(NKKA)=IDIFF+JJ+4(K)
      IF(II4(NKKA) .LE. 1. .OR. II4(NKKA) .GT. 79) GO TO 10
      II5(NKKA)=1
      II6(NKKA)=1
      GO TO 73
77    IMAX=IMAX+1
      NKKA=NKKA+1
      II2(JJML(K))=IMAX
      II5(JJML(K))=1
      II1(NKKA)=NKKA
      II2(NKKA)=IMAX
      II3(NKKA)=2
      II4(NKKA)=IMSX(K)
      II5(NKKA)=2
      II6(NKKA)=2
      GO TO 73
7-    IMAX=IMAX+1
      II2(JJML(MTC-M(K)))=IMAX
      II5(JJML(MTC-M(K)))=1
      II2(JJML(MTC-F(K)))=IMAX
      II5(JJML(MTC-F(K)))=2
      GO TO 73
73    CONTINUE
61    CONTINUE
      RETURN
```

REFERENCES

Astra-Meesook, O. (1982). A note on income distribution and the life cycle of individuals. In Yoram Ben-Porath (Ed.) Income Distribution and the Family: A Supplement to Volume 8, Population and Development Review. (pp. 151-156).

Bailey, N. T. J. (1964). The Elements of Stochastic Processes. New York: John Wiley and Sons.

Basavarajappa, K. G. (1978). Marital Status and Nuptiality in Canada. Catalogue No. 99-704 Volume V-Part: 1. 1971 Census of Canada.

Beaujot, R. P. (1976). Sensitivity of household and family projections to population growth and changing age structure. Canadian Studies in Population, 3, 19-27.

Bender, D. R. (1967). A refinement of the concept of household: families, co-residence and domestic function. American Anthropologist, 69(5). 493-504.

Berkner, L. K. (1972). The stem family and the developmental cycle of the peasant household: an eighteenth century example. American Historical Review, 77, 398-418.

Bongaarts, J. (1984). The formal demography of families and househods. IUSSP

Newsletter, 17, 27-42.

Bourbeau, R. & Legare, J. (1982). Evolution de la mortalite au Canada et au Quebec 1831-1931. Essai de measure par generation. Montreal: Les Presses de l'Universite de Montreal.

Brass, W. (1984). The formal demography of the family: An overview of the proximate determinants. Paper presented at a joint workshop on Methods of Family Demography held at The Population Council, New York, under the joint auspices of the IUSSP-Population Council. December, 1985.

Burch, T. K. (1970). Some demographic determinants of average household size: An analytic approach. Demography, 7(1), 61-69.

Burch, T. K. (1979). Household and family demography: A bibliographic essay. Population Index, 45(2), 173-195.

Burch, T. K. (1980). Household size and structure in demographic transitions. Proceedings of the Social Statistics Section, American Statistical Association, Washington, D. C.: American Statistical Association, 149-153.

Cain, M. T. (1978). The household life cycle and economic mobility in rural Bangladesh. Population and Development Review, 4(3), 421-438.

Caldwell, J. C. (1982). Theory of fertility decline. New York: Academic Press.

Carnap, R. (1968). Introduction to Symbolic Logic and Its Applications. New york: Dover.

Carter, A. T. (1984). Household histories. In R. M. Netting, R. R. Wilk, and and E. J. Arnould (Eds.). Households: Comparative and Historical Studies of the Domestic Group. Berkeley: University of California.

Chayanov, A. V. (1924). On the theory of non-capitalist economic systems. In D. Thorner, B. Kerblay, and R. E. F. Smith (Ed.). On the Theory of Peasant Economy. Homewood, Ill: American Economic Association.

Chaudacoff, H. P. (1978). Newlyweds and family extension: The first stage of of the family life cycle in Providence, Rhode Island, 1864-1865 and 1879-1880. In T. K. Hareven, M. A. Vinovskis (Eds.). Family and Population in Nineteenth-Century America. Princeton: Princeton University Press.

Cherlin, A. (1983). Changing family and household: Contemporary lessons from historical research. Annual Review of Sociology, 9, 51-66.

China Population Information Centre (1984). Analysis on China's National One-Per-Thousand-Population Fertility Sampling Survey. Beijing: China Population Information Centre, P. O. Box 2444, Beijing, China.

Clark, S. C. (1986). Succession and survival: Some demographic characteristics of the British Landed Aristocracy. Talk given at a demography colloquium at the Centre for Canadian Population Studies, University of Western Ontario, London, Ontario, N6A 5C2, Canada.

Coale, A. J. (1965). Appendix: Estimates of average size of households. In A. J. Coale, L. A. Fallers, M. J. Levy, Jr., D. M. Schneider, & S. S. Tomkins (Ed.) Aspects of the Analysis of Family Structure (pp. 64-69), Princeton: Princeton University Press.

Colluver, A. (1963). The family cycle in India and the United States. American Sociological Review, 28, 86-96.

Daftuar, A. K. & Chattopadhyay. (n. d.). Abridged life tables for India, 1971-72. DRU Publication Number 8. Demography Research Unit, Indian Statistical Unit, 203, Barrackpore Trunk Road, Calcutta 700 035.

Durkheim, E. (1893/1964). The Division of Labor in Society. New York: Free Press.

Espenshade, T. J. & Braun, R. E. (1982). Life course analysis and multistate demography: An application to marriage, divorce, and remarriage. Journal of Marriage and the Family, 44(4), 1025-1036.

Fortes, M. (Ed.). (1949). Social Structure. Oxford: Oxford University Press.

Friedmann, H. (1978). Simple commodity production and wage labor in the

American Plains. The Journal of Peasant Studies, 6(1).

Friedmann, H. (1980). Household production and the national economy: Concepts for the analysis of agrarian formations. The Journal of Peasant Studies, 7(2), 158-184.

Glick, P. C. (1947). The life cycle. American Sociological Review, 12, 164-174.

Glick, P. (1955). Family Statistics. In P. M. Hauser & O. D. Duncan (Eds.), The Study of Population: An Inventory and Appraisal. Chicago: Chicago University Press.

Glick, P. (1977). Dimensions of the field of family demography. International Population Conference, Section: Methods in Measuring the Family Life Cycle, Volume 1, pp. 389-404.

Glick, P. (1984). Les menages aux Etats-Unis, 1960-1970-1982. Population, 39(4-5), 787-806.

Glick, P. C. & Parker, R. (1965). New approaches in studying the life cycle of the family, Demography, 2, 187-202.

Goodman, L. A., Keyfitz, N., & Pullum, T. W. (1974). Family formation and the frequency of various kinship relationships. Theoretical Population Biology, 5, 1-27.

Goodman, L. A., Keyfitz, N., & Pullum, T. W. (1975). Addendum to "Family formation and the frequency of various kinship relationships." Theoretical Population Biology, 8, 376-381.

Goody, J. (Ed.). (1958). The Developmental Cycle in Domestic Groups. Cambridge: Cambridge University Press.

Hajnal, J. (1982). Two kinds of preindustrial household formation system. Population and Development Review, 8(3), 449-494.

Hammel, E. A. (1961). The family cycle in a coastal Peruvian slum and village. American Anthropologist, 63, 989-1005.

Hammel, E. A. (1984). On the *** of studying household form and function. In R. M. Netting, R. R. Wilk, and E. J. Arnould. (Ed.). Households: Comparative and Historical Studies of the Domestic Group. Berkeley: University of California.

Hammel, E. A., Hutchinson, D. W., Wachter, K. W., Lundy, R. T., & Deuel, R. Z. (1976). The SOCSIM Demographic-Sociological Microsimulation Program: Operating Manual Research Series, No. 27. Institute of International Studies. Berkeley: University of California.

Hanada, K. (1984). A household micro-simulation model for health and welfare administration. Document number 21. In Demography of the Family: Inter-centre Cooperative Research Programme. Project number 2: Final

Report. (pp. 31-32). Paris: CICRED.

Harevan, T. K. (1974). The family as process: The historical study of the family cycle. Journal of Social History, 7.

Harris, J. (Ed.). (1982). Rural Development: Theories of Peasant Economy and Agrarian Change. London: Hutchinson University Press.

Horvitz, D. G., Giesbrecht, F. G., Shah, B. V., & Lachenbruch, P. A. (1966). POPSIM - A Demographic Microsimulation Model Proceedings of International Union for the Scientific Study of Population, General Conference, London, September 1969.

Hyrenius, H. & Adolfsson, I. (1964). A Fertility Simulation Model (DM1). Gothenburg, Sweden: Demographic Institute, University of Gothenburg.

Keyfitz, N. (1973). Mathematics and Population. SIAM Review, 15(2), 370-375.

Keyfitz, N. (1985). Applied Mathematical Demography. Second Edition. New York: Springer-Verlag.

Kobrin, F. (1976). The fall in household size and the rise of the primary individual in the United States. Demography, 13(1), 127-138.

Kono, S. (1973). Marriages and the formation of households. Liege: World Population Conference.

Kono, S. (1977). The concept of the family life cycle as a bridge between demography and sociology. International Population Conference, Mexico, 1977, Volume I. (pp. 355-370). Liege: IUSSP.

Krishnamoorthy, S. (1979). Classical approach to increment-decrement life tables: An application to the study of the marital status of United States females. Mathematical Biosciences, 44, 139-154.

Kuznets, S. (1982). Distribution of households by size. Differences and trends. Research in Population Economics, 4, 1-47. Greenwich: JAI Press.

Kuznets, S. (1981). Size of households and income disparities. Research in Population Economics, 3, 1-40. Greenwich: JAI Press

Kuznets, S. (1978). Size and age structure of family households: Exploratory comparisons. Population and Development Review, 4(2), 187-223.

Kuznets, S. (1976). Demographic aspects of the size distribution of income: An exploratory essay. Economic Development and Cultural Change, 25(1).

Kuznets, S. (1974). Income-related differences in natural increase: Bearing on growth and distribution of income. In David, P. A. & Reder, M. W. (Eds.), Nations and Households in Economic Growth: Essays in honor of Moses Abramovitz (pp. 127-146).

Lesthaeghe, R. (1983). A century of demographic and cultural change in Western

Europe: An exploration of underlying dimensions. Population and Development Review, 9(3), 411-435.

McFarland, D. D. (1972). Comparison of alternative marriage models. In T. N. E. Greville (Ed.). Population Dynamics. Proceedings of a Symposium Conducted by the Mathematics Research Center, The University of Wisconsin, Madison, June 19-21, 1972. New York. Academic Press.

McMillen, D. B., and Herriot, R. A. (1984). Toward a longitudinal definition of households. Proceedings of the American Statistical Association Meetings 1984 (Social Statistics Section), (pp. 49-54). Washington: American Statistical Association.

Maisel, H. & Gnugnoli, G. (1972). Simulation of Discrete Stochastic Systems Chicago: Science Research Associates.

Mertens, W. (1965). Methodological aspects of the construction of nuptiality tables. Demography, 2, 317-348.

Mertens, W. (1976). Canadian nuptiality patterns: 1911-1961. Canadian Studies in Population, 3, 57-71.

Muhsam, H. V. (1982). What is family demography and why is it required? IUSSP Paper No. 25. In S. Torrado (Ed.), Family Types and Fertility in Less Developed Countries. Liege: IUSSP.

Muhsam, H. V. (1984). The transition probabilities in the demography of the family. In Demography of the Family, Inter-Centre Cooperative Research Programme, Project No. 2: Final Report (pp. 37-43). Paris: CICRED.

Muhsam, H. V. (1985). The projection of families by the transition matrix. Paper presented in a session on Advances in Demographic Projections, at the IUSSP XXth General Conference at Florence

Naylor, T. H., Balintfy, J. L., Burdick, D. S., and Chu, K. (1968). Computer Simulation Technique. New York: John Wiley & Sons.

Nilsson, T. (1985). Households in Sweden, 1960-1980. Population, 40(2), 223-247.

Norton, A. J. (1974). The family life cycle updated. Components and uses. In R. F. Winch & Sparrier, G. B. (Eds.). Selected Studies in Marriage and the Family (pp. 162-169) Fourth Edition. New York. Holt, Rinehart, and Winston.

Notestein, F. W. (1945). Population-The long view. In Schultz, T. W. (ed.). Food for the World (pp. 36-57).

Orcutt, G. H., Greenberger, M., Korbel, J., & Rivlin, A. M. (1961). Microanalysis of Socioeconomic Systems: A Simulation Study. New York: Harper and Row.

Peron, Yves & Lapierre-Adamcyk, E. (1984). Family structure and family life cycle: An application to the families from Quebec in 1971 (Document no. 3). In Demography of the Family: Inter-Centre Cooperative Research Programme, Project no. 2, Final Report (pp. 46-48). Paris CICRED.

Potter, R. G., & Skoda, J. M. (1966). A computer model of family building based on expected values. Demography, 3(2), 450-461

Pullum, T. W. (1984). Some mathematical models of kinship and the family. paper presented at a workshop on Methods of Family Demography held in December, 1985, under the joint auspices of the IUSSP-Population Council held at The Population Council, New York.

Ridley, J. C., & Sheps, M. C. (1966). The effects of changing mortality on natality: Some estimates from a simulation model. Milbank Memorial Fund Quarterly, 45(1), 77-97.

Rogers, A. and Ledent, J. (1976). Increment-decrement life tables: A comment. Demography, 13, 287-290.

Roussel, L. (1983). Les menage d'une personne: l'evolution recente. Population, 38(6), 995-1016.

Ryder, N. B. (1975). Reproductive behaviour and the family life cycle. In The Population Debate: Dimensions and Perspectives. Papers of the World Population Conference, Bucharest, 1974, Volume 2 (pp. 278-288). Population

Studies, No. 57, ST/ESA/SER.A/57/Add 1. Sales No. E/F/S.75. XIII.5. Department of Eco. and Social Affairs. New York: United Nations.

Ryder, N. B. (1985). Recent developments in the formal demography of the family. In International Population Conference, 1985 Florence, Volume 3, Session on Family Demography, Life Cycle, & Nuptiality (pp 207-220). Liege: IUSSP.

Santow, G. (1978). A Simulation Approach to the Study of Human Fertility. Publication of the Netherlands Interuniversity Demographic Institute & the Population and Study Centre. Volume 5. Leiden: Martinus Nijhoff Social Science Division.

Schoen, R. and Land, K. (1979). A general algorithm for estimating a Markov-generated increment-decrement life table with applications to marital status patterns. Journal of the American Statistics Association, 74(368), 761-776.

Schoen, R. and Nelson, V. E. (1974). Marriage, divorce, and mortality: A life-table analysis. Demography, 11(2), 267-290.

Schoen, R. (1975). Constructing increment-decrement life tables. Demography, 12(2), 313-324.

Schoen, R. (1976). Reply to Rogers and Ledent. Demography, 13(2), 291.

Schoen, R. (1979). Calculating increment-decrement life tables by estimating mean

durations at transfer from observed rates. Mathematical Biosciences, 47, 255-269.

Shanin, T. (1982). Polarization and cyclical mobility: the Russian debate over the differentiation of the peasantry. In J. Harriss (Ed.) Rural Development: Theories of Peasant Economy and Agrarian Change. London. Hutchinson University Library for Africa.

Shanin, T. (1971). A Russian peasant household at the turn of the century. In Shanin, T. (Ed.). Peasants and Peasant Societies: Selected Readings (pp. 30-36). Penguin Books.

Smith, J., Wallerstein, I., & Evers, Hans-Dieter. (Eds.). (1984). Households and the World-Economy. California: Sage Publications.

Statistics Canada. (1973). Households: Household and Family Status of Individuals: 1971 Census of Canada. Catalogue 93-712. Vol. II-Part 1 (Bulletin 2.1-12).

Statistics Canada. (1974). Life Tables, Canada and Provinces, 1970-1972. Catalogue 84-532. Ottawa: Minister of Supply & Services Canada.

Statistics Canada. (1979). Life Tables, Canada and Provinces, 1975-1977.

Catalogue 84-532. Ottawa: Minister of Supply & Services Canada.

Statistics Canada. (1984). Life Tables, Canada and Provinces, 1980-1982. Catalogue 84-532 Occasional. Ottawa: Minister of Supply & Services, Canada.

Stone, L. (1977). The Family, Sex, and Marriage in England 1500-1800. London.

Stone, L. O. (1985, August 15). personal communication.

Thadani, V. (1978). The logic of sentiment: the family and social change. Population and Development Review, 4(3), 457-499.

Uhlenberg, P. R. (1974). A study of cohort life cycles: Cohorts of native born Massachusetts women, 1830-1920. Population Studies, 23(3), 407-420.

United Nations. (1973a). Families and Households. In Determinants and Consequences of Population Trends: New Summary of Findings on Interaction of Demographic, Economic, and Social Factors, Volume I. (pp.336-367). Population Studies, No. 50. ST/SOA/SER.A/50. Sales No. E.71.xiii.5. Department of Economic and Social Affairs.

Wachtel, P. (1984). Household saving and demographic change, 1950-2050. Research in Population Economics, Volume 5, 217-233.

Wachter, K. (1985). Simulation of household cycles. Paper presented at the IUSSP-Population Council workshop on family demography.

New York: Population Council.

Wallerstein, I. (1974). The Modern World-System I: Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century. New York: Academic Press.

Wallerstein, I. (1978). The Modern World System II: Mercantilism and the Consolidation of the European World Economy. New York: Academic Press

Wargon, S. (1978). Household and family in Canada: A general review of recent demographic trends. International Journal of Sociology of the Family, 8, 53-68.

Weber, M. (1904-1905/1958). The Protestant Ethic and the Spirit of Capitalism. New York: Charles Scribner's Sons.

Willekens, F. J. (1985). The marital status life table. Paper presented at a joint workshop on Methods of Family Demography held at The Population Council, New York, under the joint auspices of the IUSSP-Population Council, in December, 1985.

Willekens, F. J., Shah, I., Shah, J. M., & Ramachandran, P. (1980). Multi-state analysis of marital status life tables: theory and application. Population Studies, 36(1), 129-144.

Wunsch, G. J., & Termote, M. G. (1978). Introduction to Demographic Analysis:

Principles and Methods. New York: Plenum Press.

Yanagisako, S. J. (1979). Family and household: The analysis of domestic groups. Annual Review of Anthropology, 8, 161-205.