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U.S. family household momentum and dynamics: an extension and application of the ProFamy method

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Abstract. The classic headship-rate method for demographic projections of households is not linked to demographic rates, projects a few household types without size, and does not deal with household members other than heads. By comparison, the ProFamy method uses demographic rates as input and projects more detailed household types, sizes, and living arrangements for all members of the population. Tests of projections from 1990 to 2000 using ProFamy and based on observed U.S. demographic rates before 1991 show that discrepancies between our projections and census observations in 2000 are reasonably small, validating the new method. Using data from national surveys and vital statistics, census microfiles, and the ProFamy method, we prepare projections of U.S. households from 2000 to 2050. Medium projections as well as projections based on smaller and larger family scenarios with corresponding combinations of assumptions of marriage/union formation and dissolution, fertility, mortality, and international migration are performed to analyze future trends of U.S. households and their possible higher and lower bounds, as well as enormous racial differentials. To our knowledge, the household projections reported in this article are the first to have found empirical evidence of family household momentum and to have provided informative low and high bounds of various indices of projected future households and living arrangements distributions based on possible changes in demographic parameters.

Keywords: Household projection, Headship rates, Macrosimulation, ProFamy method

Introduction

Household projection is useful in socioeconomic, actuarial, and welfare planning, in policy analysis, and in market trend studies. For example, several welfare programs in the United States restrict eligibility to single-parent households (Yelowitz 1998). As a result, projecting the costs of such programs depends heavily upon projections of the numbers, types, and sizes of single-parent households in the future (Moffitt 2000). Creating a new household (e.g., by divorce or union dissolution) generates an immediate increase in energy consumption that is larger than an additional birth would cause (Mackellar et al.

1995). Lutz and Prinz (1994: 225) and Mackellar et al. (1995) argue, for example, that household size and structure should be explicitly treated in projection models of population, energy use, environment, and development. For a variety of goods and services, in both public and private sectors, households are more relevant units of demand than individuals because households are the basic units of consumption into which people are organized. Demands for energy (e.g., gas and electricity), automobiles, housing, water, durable goods, and other home-related products and services are determined by changes in households.[1]

Demographers use models for the projection of households based primarily on three types of methods: headship rates, microsimulation, and macrosimulation. Headship rates are computed by dividing the number of persons who are heads (or householders) of households by the total number of persons of the same age and sex. The numbers of households in future years are projected by extrapolating headship rates. Microsimulation models simulate life course events and keep detailed records of demographic status transitions for each individual of the sample population (Hammel et al. 1991, 1981; Ruggles 1987; Wolf 1990, 1988; Wachter 1987). Macrosimulation models deal with individuals grouped by specified attributes, for instance, a group of persons of the same race, sex, age, and marital status. The calculations proceed iteratively, group by group, and time period by time period. Comparisons between micro- and macro-approaches in the context of family household simulation and projection can be found elsewhere (e.g., Van Imhoff 1999; Van Imhoff & Post 1998; Zeng, et al. 1998; see also Panel on a Research Agenda and New Data for an Aging World 2001: 155–199). The choice between a micro or macro model depends on the complexity of the user's task. For detailed analyses of behavioral patterns and complex family kinship relationships, a microsimulation approach may be preferable. For relatively straightforward demographic and household consumption projections based on commonly available data for the purposes of policy analyses, market trends studies, and socioeconomic planning, especially projections used by non-experts, a macrosimulation approach may well be satisfactory.

Most macrosimulation models use the household as the basic unit and require data on transition probabilities among household-type statuses – data that have to be collected in special surveys because they are not available in vital statistics, censuses, or ordinary surveys (Keilman 1988; Ledent 1992; Van Imhoff & Keilman 1992).

As stated by Van Imhoff & Keilman (1992), such a stringent data demand is an important factor in the slow development and infrequent application of these models. Due to the aggregated nature of the household statuses identified in these models, it is impossible to make inferences about groups other than those based on the predefined household-type state space. The distribution of households by size is impossible to project unless the size of the household is explicitly incorporated into the state space (Van Imhoff et al. 1995: 348). Incorporation of household size into the household-type state space would greatly increase the size of the transition probabilities matrices at each age for males and females, which is likely not feasible in practical applications. Furthermore, the household-type status-transition-based model cannot directly link changes in household structure with demographic rates. Thus, it is difficult for such a model to identify the impacts of demographic factors on changes in household structure.

Benefiting from methodological advances in multidimensional demography (Land & Rogers 1982; Rogers 1975; Schoen 1988; Willekens et al. 1982), Bongaarts (1987) developed a nuclear-family-status life table model. Zeng (1991, 1988, 1986) extended Bongaarts's nuclear-family-status life table model into a general family household simulation macro-model that includes both nuclear and three-generation family households. The life table/macro models developed by Bongaarts and by Zeng, using conventionally available demographic rates as input, are female-dominant one-sex models, and assume that input rates are constant. Based on Bongaarts's and Zeng's one-sex life table models, Zeng et al. (1997, 1998) developed a two-sex dynamic macro-projection model known as ProFamy that permits demographic schedules to change over time and requires only conventional data that are available from ordinary surveys, vital statistics, and censuses.

This article first presents extensions of the ProFamy model and a detailed comparison between the ProFamy model and the classic headship-rates method. We then apply the extended ProFamy model to project U.S. households by race from 2000 to 2050. We address important questions such as: How may demographic changes alter the number and proportions of different kinds of households with various types and sizes in future years? How may demographic changes affect the living arrangements of elderly persons? And we provide evidence of the existence of "family household momentum," which is similar to the well-known population momentum.

Methodological issues

In previous publications (Zeng et al. 1997, 1998), we have presented our modelling framework, reasons for using the individual as the basic unit of our household projection model, the mathematics for identifying households based on individuals' characteristics, the computational strategy, accounting equations, and methods for ensuring consistency between males and females and between parents and children. Thus, these basic discussions of the ProFamy model will not be repeated here. In this section, we will focus on presenting extensions of the ProFamy model. We also make an informative comparison between the extended ProFamy method and the still widely-used headship-rate method. We report test projections from 1990 to 2000 using ProFamy, based on observed U.S. demographic rates before 1991, and then compare the projections to the census observations in 2000 to validate the new method.

Extensions of the ProFamy model

There was no race dimension in the initial version of the ProFamy model proposed by Zeng et al. (1997, 1998). We need to include the race dimension due to the existence of subpopulations with large racial differentials in the United States. For example, there are large differences of demographic rates for all races combined in Minnesota and Florida. But a simple standardization of age and race makes these differences mostly disappear, which demonstrates that most of the differences in demographic rates between Minnesota and Florida are due to racial composition rather than different race specific rates (Morgan 2004a). Thus, inclusion of race is an efficient way of capturing most demographic variations in the U.S. We cannot simply run the model separately for each racial group because we need to allow interracial marriages and ensure two-sex consistency. For example, the total number of male marriages of all races should be equal to female marriages of all races (the two-sex model does not account for same-sex marriages). We therefore extended the ProFamy model and reprogrammed all subroutines by adding the race dimension to all computation procedures. The extended model allows interracial marriages/unions and ensures two-sex consistency. This extension has been tested and evaluated through the applications of U.S. household projection by race, as will be described later. Users can choose the number of race groups, or no race classification, based on the degree of racial differentials and availability of race specific data.

In illustrative applications of the initial version of the ProFamy model (Zeng et al. 1998, 1997), four classic marital statuses were distinguished: (1) never-married, (2) married (3) widowed, (4) divorced (see Schoen 1988; Willekens et al. 1982). The four-marital-statuses model requires the least data but it does not include cohabiting, which is increasingly popular in many societies. We extend the ProFamy model herein to include a seven-marital-statuses model: (1) never-married and not cohabiting, (2) married, (3) widowed and not cohabiting, (4) divorced and not cohabiting, (5) never-married and cohabiting, (6) widowed and cohabiting, and (7) divorced and cohabiting (see Figure 1). We employ the seven-marital-statuses model in the U.S. household projections reported here.

As Keyfitz (1972) pointed out, projections with trend extrapolation of each age specific rate can result in an excessive concession to flexibility, and can readily produce erratic results. Thus, we focus on the projection of demographic summary measures. We also use the age–sex specific standard schedules of demographic rates to define the age patterns of demographic processes. The standard schedules can be assumed either to be stable or to include systematic changes in timing and shapes in the projection years (Zeng et al. 2000).[2] In the previous version of the ProFamy model and program (Zeng et al. 1998, 1997), we used period multistate life table propensities of marital status transitions as summary measures of marriage formation and dissolution. This restricted the practical applicability of the model because data

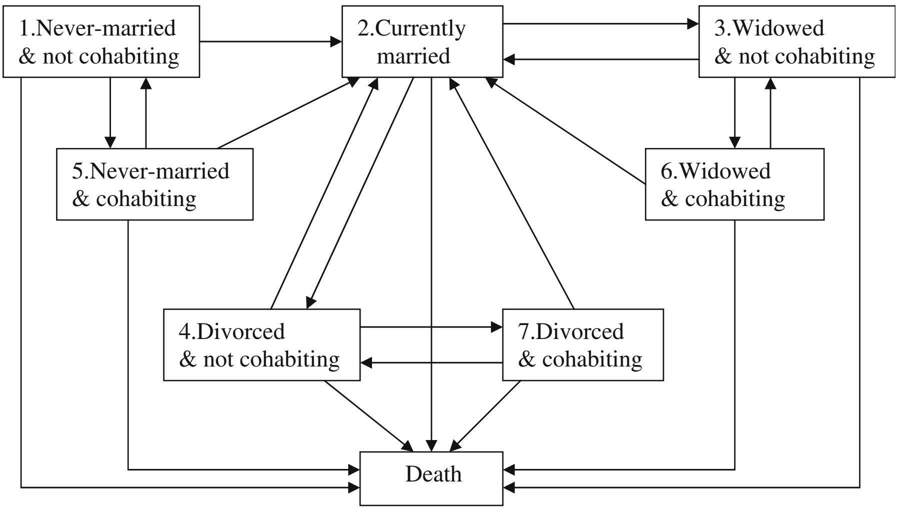

Figure 1. Seven-marital-statuses model.

for constructing period multistate life tables to estimate the propensities are most likely not available at the provincial/state level, and are sometimes not even available for populations at the national level. We now use much more practically applicable summary measures of general rates of marriage/union formation and dissolution, which are usually available at national and provincial/state levels.[3]

The general rates of marriage/union formation and dissolution in the year t are defined by dividing the total number of events of marriage/union formation and dissolution occurring in the year t by the total number of persons who are at risk of experiencing these events. Two important points must be clarified in defining general rates in our family household projection model.

First, we use the most recent census-counted sex–age–marital/union status distributions (i.e., the base population of the household projection) as the "standard" to compute general rates in future projection years. Following the language used in Preston et al. (2001: 24), the general rate in the future projection year t is the estimated general rate in year t if it retained its sex–age specific o/e rates in year t but had the age distribution of the most recent census year (i.e., the base year of the projection). Employing the standardized general rates in future projection years, we eliminate the distortions of measuring changes in the levels of marriage/union formation and dissolution due to changes in population structure. For example, the unstandardized general marriage (or divorce) rate would decrease/increase solely due to the structural growth/decline of the numbers of elderly persons even if the age specific marriage (or divorce) rates did not change. This is because the risks of marriage (or divorce) of the elderly are substantially lower than those of younger people.

Second, we cannot employ sex specific general marriage/union formation and dissolution rates as projected (or assumed) summary measures in future years because it would be impossible to ensure that the projected sex specific general rates are consistent with the two-sex constraints. This is because the two-sex constraints also depend on the unknown (to-be-projected) sex–age–marital status distributions in future years. We therefore define the general rates of marriage/union formation and dissolution for males and females combined. Consequently, gender differentials of the age specific marriage/union formation and dissolution rates are determined by the sex–age specific standard schedules of o/e rates of marital status transitions and projected future years' population structure by age, sex, and marital status, while meeting the two-sex constraints.

A comparison of the ProFamy method and the classic headship-rate method

The classic headship-rate approach suffers serious shortcomings and has been criticized widely by demographers for more than a decade (Bell & Cooper 1990; Burch, personal communication; Mason & Racelis 1992; Murphy 1991; Spicer et al. 1992). The headship-rate method is, however, still widely used for household projection by statistical offices and market analysis agencies, and thus deserves a detailed comparison with our new ProFamy method.

Conceptual issues

Headship-rate method: The designation of a household head is vague, ill-defined, and an arbitrary choice, making projections difficult (Murphy 1991). Trends in headship rates are thus not easy to model (Mason & Racelis 1992: 510). For instance, an increase in female headship rates may occur because the census or survey was carried out in the daytime, when more women were available to complete the questionnaire than were men. Some of these women also may have wished to show their power by classifying themselves as the household head. Or the increase may be due to an actual increase in women's socioeconomic status. But in either case, it is not due to real changes in demographic conditions.

ProFamy has no such conceptual problems.

Linkage with demographic rates

Headship-rate method: There is no way to link headship rates to demographic rates; it is impossible to incorporate the projected or assumed propensity/timing of demographic processes into headship rates (Mason & Racelis 1992; Spicer et al. 1992).

ProFamy uses demographic rates as input for household projections, and thus facilitates analysis of the effects of changes in demographic rates on family household structure. As Morgan (2004b), for example, indicates, ProFamy provides a framework/tool to assess which of the demographic changes in marriage, divorce, fertility, and so on, have affected family households most in the past decade or two and in future years. Thus, ProFamy allows one to rank the demographic components most responsible for recent changes in and most likely to impact future family households.

Household members other than heads
Headship-rate method: One of the most problematic features of the headship-rate method is that it lumps all household members other than heads into one category "non-head" with no projected information (Burch, 1999). This makes it impossible to study family households, marital status and living arrangements of the elderly, adults, and children who are "non-head" and constitute the large majority of the population. This is a disadvantage for business/academic/policy analysis and planning.

ProFamy projects the marital status and living arrangements of all members of the entire population. For example, this includes the number and percentage of the elderly living alone, with spouse only, with children and/or others, in a private household or institution, and so on. This is useful for business and governmental planning and analysis of elderly care needs, poverty, welfare, social security, insurance, banking, credit cards services, and the like.

Information produced and adequacy for planning
Headship-rate method: The information on households produced by headship-rate projections is very limited and inadequate for purposes of more detailed planning and analysis (Bell & Cooper 1990). A typical well-done national household projection using the headship-rate method projected only five household types by age groups of household head or householder (Bureau of the Census 1996), with no projected household sizes available at all (see Table 1).[4] This is, again, disadvantageous since households with various sizes differ substantially in their needs for products and services.

ProFamy provides more detailed projected household types and sizes by age of reference persons (see Table 2) than does the headship-

Table 1. Household types projected by headship-rate method (Bureau of Census 1996)

Type code	Household types	Household sizes
1	Married couple household	Not available
2	Female-headed & no spouse household	Not available
3	Male-headed & no spouse household	Not available
4	Female non-family household	Not available
5	Male non-family household	Not available

Table 2. Household types and sizes projected by ProFamy

Type code	Household types	Household sizes
One-generation households		
1–3	One man only by marital status	1
4–6	One woman only by marital status	1
7–9	One man & other/non-relative by marital status of the man	2, 3, 4, 5, or 6+
10–12	One woman & other/non-relative by marital status of the woman	2, 3, 4, 5, or 6+
13	One married couple only	2
14	One cohabiting couple only	2
15	One married couple & other/non-relative	3, 4, 5, 6, or 7+
16	One cohabiting couple & other/non-relative	3, 4, 5, 6, or 7+
Two-generation households		
17	Married couple & children/other	3, 4, 5, 6, 7, 8, or 9+
18	Cohabiting couple & children/other	3, 4, 5, 6, 7, 8, or 9+
19–21	Single-mother & children/other by marital status of the single mother	2, 3, 4, 5, 6, 7, 8, or 9+
22–24	Single-father & children/other by marital status of the single father	2, 3, 4, 5, 6, 7, 8, or 9+
Three-generation households		
25	Married (or cohabiting) couple with children and 1 or 2 grandparents	4, 5, 6, 7, 8, or 9+
26	Single-parent & children & 1 or 2 grandparents	3, 4, 5, 6, 7, 8, or 9+

rate method. For example, the "female-headed and no spouse" households projected by the headship-rate method (Table 1, household type code 2) mix households of one woman only and households of a not-married mother with children into one group without marital status and household size information. In contrast, ProFamy classifies female-headed and no spouse into different types plus sizes of households (e.g., one woman only, a not-married mother with child[ren]), all by the woman's marital status and household size (Table 2, household type codes 4–6, 10–12, 19–21).

Prskawetz et al. (2004) found that the headship-rate method yields misleading results regarding the increase in automobile use in Austria. This is because future Austrian households will comprise many more one- and two-person households (which mostly need only one car) than do today's households, but the headship-rate method projects household numbers without information on household sizes. Prskawetz et al. (2004) applied the ProFamy method and produced more realistic and detailed projections of future households by household types/sizes/ age of householders and automobile use. As compared to the headship-rate method, this advantage of ProFamy also applies to other business analyses, for example, of energy (Dalton et al. 2005) and housing (Wang et al. 2006) in the U.S. and other countries for which future trends indicate many more one- and two-person households.

Two recent articles published in *Nature* show that a rapid increase in households of smaller size, which results in higher per capita energy consumption, implies a threat of a larger demand for resources (Keilman 2003), and poses serious challenges to biodiversity conservation (Liu et al. 2003). This further supports the usefulness of household forecasts including size using ProFamy in contrast to the headship-rate method, which excludes size.

Methodology

Headship-rate method: The projection conducted by the Bureau of the Census (1996), which is a typical well-done household projection using the headship-rate method, performed 100 sets of time series regression models to project age–sex specific headship rates in future years (the 100 sets = 10 age groups × 2 marital statuses × 5 household types). The two marital statuses are never-married and ever-married. The five household types are listed in Table 1. The dependent variables in the 100 sets of regression models are logistic transformations of the headship rates, and the independent variable is time. The future trends of headship rates are based purely on the regression of calendar time (with no connection to demographic rates), which could be unreasonably extrapolated into future years. Therefore, the household projection was arbitrarily adjusted using the slopes of the regression line that were less extreme than those obtained from the 100 regression models. For example, slopes indicating changes in the percentage of never-married under age 35 were reduced by two-thirds; slopes indicating changes in the percentage of married-couple households for all ages were reduced by one-third; slopes indicating changes in the remaining household types were simply left at their 1990 levels. The adjustments made the projection look more reasonable, but the mechanisms behind these adjustments appear arbitrary (Bureau of the Census 1996).

ProFamy does not include any arbitrary adjustment of the slopes of the regression line. One needs to prepare age–sex specific standard schedules of demographic rates or to employ the existing age–sex specific model standard schedules of demographic rates (see (2) in Table 5). One then projects or assumes the demographic summary measures (see (3) in Table 5) based on time series or expert opinions. The standard schedules formulate the age pattern of demographic processes. ProFamy can take into account anticipated changes in the age pattern, such as delaying or advancing marriage and fertility, by adjusting the schedules to match the projected mean ages of the demographic events in future years. Based on standard schedules and demographic summary measures, ProFamy generates estimates of the age–sex specific demographic rates needed for projecting households and the population in future years. Projecting future demographic summary measures can be done using the statistical software of time series analysis or expert opinion approaches. Users may even want to include time series data of other related socioeconomic covariates (e.g., average income, labor force participation, education, urbanization) in the projection of demographic summary measures. Projections based on time series analysis or assumptions based on expert opinion are made about the components of changes in demographic factors that produce household distributions in future years. This is analogous to, and a substantive extension of, the classic population projection model.

Data requirements and costs of time and resources

Headship-rate method: This method requires less data than does the ProFamy model. It requires a considerable amount of time and resources if one follows the usual approach of extrapolation, for example, estimating the 100 regression equations, as the U.S. Bureau of the Census (1996) did. It is very simple and requires little time and resources if one assumes all sex–age specific headship rates remain constant over time. But such a static approach may not provide acceptable accuracy of projections, especially in societies such as the U.S. where demographic and socioeconomic changes are underway. As shown by the empirical evidence of "Family household momentum", even if U.S. demographic rates were to remain constant in future years, the age specific headship rates would not be unchanged because the older cohorts, who had more traditional family patterns, would be replaced by younger cohorts with modern family patterns.

ProFamy: It takes a substantial amount of time and resources to prepare age–sex specific standard schedules. Once reliable age–sex specific standard schedules for a country have been estimated (and updated every few years or so, depending on new data) by a researcher, however, others could simply employ these standard schedules as "model standard schedules" for household forecasting at the country or provincial/state level. This is because, while demographic summary measures are crucial, forecasting results are not substantially sensitive to age specific model standard schedules as long as they reveal the general age pattern of the demographic process of the population. This statement is corroborated by the following exercise. We performed U.S. household forecasts by race from 1990 to 2020 under two scenarios with all demographic summary measures identical to each other, but one scenario uses the race–sex–age specific rates observed in the 1990s and another scenario uses the race–sex–age specific rates observed in the 1980s. We then compared the 17 main indices of the forecasts in 2000, 2010, and 2020 between these two scenarios. The 17 main indices of the forecasts include the total number of households, average household size, percentage of 1-, 2-, 3-, 4-, and 5+-person households, percentage of married couple households, total population size, percentage of children and elderly, percentage of people living in group quarters, and dependent ratios. The results show that, while the projected input summary measures are identical, using the standard schedules observed in the 1980s and using the standard schedules observed in the 1990s produced almost the same forecasts. About two-thirds of the differences in the main indices of the forecasts under these two scenarios are less than 1% and one-third of the differences are 1.0–3.4% (see Table A1 and Table A2 in Appendix A).

Thus, using existing model standard schedules and projected (or assumed) demographic summary measures such as TFR, life expectancy at birth, general rates of marriage, divorce, cohabitation, and union dissolution, as well as the ProFamy software, one can conveniently perform household forecasting at national and provincial/state levels. Of course, someone needs to produce the age–sex specific model standard schedules for those (including himself or herself) who deal with the same or similar populations to use.

While we agree with many other demographers' criticisms about the headship-rate method (e.g., Bell & Cooper 1990; Burch 1999; Mason & Racelis 1992; Murphy 1991; Spicer et al. 1992), we believe that the choice between methods with different degrees of comprehensiveness depends on the user's needs. For a simple static projection of the number of households with limited types without household size information using only easily accessible cross-sectional data at a low cost of time and resources, the headship-rate approach may be satisfactory. For more detailed projections/analyses of household types, sizes, and elderly living arrangements using various demographic rates, the new ProFamy method is preferable.

Validation of the ProFamy method/program

One useful way to validate a model and computer program for projections is to project between two past dates for which the observations are known, and then compare the observed data with the projected data. We tested the ProFamy method/program through projecting U.S. households by race from 1990 to 2000. We calculated the U.S. starting population for the projections based on the 1990 U.S. census. We then conducted two kinds of tests. The first is to apply the ProFamy method/program and the race–sex–age specific standard schedules observed in the 1980s and the projected demographic summary measures in the 1990s through extrapolations based on time series data from 1970 to 1990 (Gu et al. 2004). This test assumes that we have no data after 1990 and conduct the forecast based solely on data before 1991 and the ProFamy model. This exercise tests the accuracy of the forecasts using the ProFamy model in the real world (assuming the accuracy of the 2000 census observations). The second test uses the ProFamy method/program and the race–sex–age specific standard schedules and summary measures observed in the 1990s as input to project U.S. households from 1990 to 2000. This test validates the simulation properties of the ProFamy model based on the assumptions that the input data (observed in the 1990s) and the 2000 census observations (outcome in this exercise) are correct.

Comparisons between the census observed and the projected main measures of the U.S. household distributions in 2000, derived from the above described testing exercises, show the differences are within reasonable ranges (see Tables 3 and 4). More specifically, in the first and second tests, respectively, the relative differences between the observed and projected total number of households are 0.9% and 0.4%; the projected average household sizes are 2.7% and 2.4% smaller than the observed one. In the first and the second tests, the absolute values of the relative difference between the projected and observed proportions of households with 1, 2, 3, or 4 persons, which constitute a large majority of U.S. households, are 0.9–9.3% and 2.4–9.4%; the differences between projected and observed percentages of married couple households are 4.1% and 3.9%; the relative

Table 3. Comparing ProFamy-projected and census-observed U.S. households and population in 2000, employing the ProFamy method/program and the race–sex–age specific standard schedules observed in the 1980s and the projected demographic summary measures in 1990s through extrapolation based on time series data before 1991

	Households				Population		
	Census	ProFamy	Diff.%		Census	ProFamy	Diff.%
Total number of households	105,480,101	106,474,544	0.9	Total population	281,421,906	277,170,688	−1.5
Average household size	2.59	2.52	−2.7	Percent of:			
				children age <18	25.69	25.53	−0.6
Percent of:				elderly aged 60+	16.27	16.87	3.7
1-person household	25.82	26.05	0.9	elderly aged 65+	12.43	13	4.6
2-person household	32.63	33.01	1.2	oldest-old aged 80+	3.26	3.6	10.3
3-person household	16.53	18.06	9.3	people in group quarters	2.76	2.72	−1.5
4-person household	14.20	13.57	−4.4				
5+-person household	10.83	9.30	−14.1	Dependent ratio of:			
				children	0.42	0.42	1.2
				old	0.20	0.21	4.5
Married couple family	51.66	53.76	4.07	children and old	0.62	0.63	2.26

Table 4. Comparing ProFamy-projected and census-observed U.S. households and population in 2000, employing the ProFamy method/program and the race–sex–age-specific standard schedules and the demographic summary measures observed in the 1990s

	Households				Population		
	Census	ProFamy	Diff.%		Census	ProFamy	Diff.%
Total number of households	10,548,0101	105,901,696	0.4	Total population	281,421,906	276,417,600	−1.8
Average household size	2.59	2.53	−2.4	Percent of:			
				children age < 18	25.69	25.33	−1.4
Percent of :				elderly aged 60 +	16.27	16.92	4.0
1-person household	25.82	25.19	−2.4	elderly aged 65 +	12.43	13.04	4.9
2-person household	32.63	33.81	3.6	oldest-old aged 80 +	3.26	3.61	10.6
3-person household	16.53	18.09	9.4	people in group quarters	2.76	2.73	−1.3
4-person household	14.20	13.80	−2.8				
5 + -person household	10.83	9.11	−15.9	Dependent ratio of			
				children	0.42	0.41	−1.2
				old	0.20	0.21	4.5
Married couple family	51.66	53.69	3.92	children and old	0.62	0.62	0

Table 5. Data needed in general to project households using ProFamy and data resources for the U.S. household projection by race

Data needed in general to project households using ProFamy	U.S. data resources
(1) Base population. A census or a large survey sample data set with a few variables of sex, age, marital status, relationship to the household head or householder, parity (optional),[a] whether living in a private household or institutional household, race (optional) and rural/urban residence (optional). If a sample data set is used, 100% tabulations of age–sex distributions of the entire population and those living in group quarters, as well as the total number of households, derived from the census data must be provided. This is to ensure the accurate total population size and age/sex distributions and total number of households in the starting year of the projection, while the sample data set provides more detailed information	2000 and 1990 census 5% microdata files and the 100% censuses tabulations
(2) Standard schedules	
(a) Age–sex–specific (and marital-status specific, if possible) death rates	The same as those used by Census Bureau in federal population projection
(b) Age–sex specific o/e rates of marriage/union formation and dissolution	Pooled NSFH, NSFG, CPS, SIPP data sets, see Section 3.1
(c) Age–parity specific o/e rates of marital and non-marital fertility[b]	
(d) Age–sex specific net rates of leaving the parental home. One may just provide two adjacent census microdata files. The ProFamy program will estimate the age–sex specific net rates of leaving home based on a method initially proposed by Coale (1984, 1985), Coale et al. (1985), and generalized by Stupp (1988). This method was applied to estimate age–sex-specific net rates of leaving the parental home in the U.S., China, France, Sweden, Japan, and South Korea (Zeng et al. 1994)	2000 and 1990 census microdata files

Table 5. Continued

(e) Age–sex specific (and marital status specific, if possible) frequencies of emigrants to the rest of the world and immigrants from the rest of the world, or the age–sex specific frequencies of the net migration	The same as those used by Census Bureau in federal population projection
(3) Summary measures in projection years based on time series or expert opinion	
(a) Total Fertility Rates (TFR) by parity[c]	The same as those used by Census Bureau in federal population projection
(b) Life expectancies at birth	
(c) Total numbers of male and female emigrants, immigrants, and net migrants	
(d) General rates of marriage and general rates of divorce	Based on vital statistics for all races and pooled survey data for race decomposition
(e) Mean age at first marriage and births	
(f) General rates of cohabiting and general rates of cohabitation union break	Based on pooled NSFH and NSFG data sets, see Section 3.1

[a]If no parity information is available, we assume that birth rates depend on age, marital status, and number of children living at home.
[b]If non-marital fertility is not negligible and the age–parity specific o/e rates of non-marital fertility are not available, the ratios of the general fertility rates of non-married women to the general fertility rate of the married women will be needed. If the non-marital fertility is negligible in the population under study, one may assume that the age–parity specific fertility rates for non-married women are equal to zero.
[c]In the U.S. application, the race specific TFRs without parity classification are the same as the ones used by Census Bureau in federal population projection; the parity decompositions of TFR by race are based on the pooled NSFH, NSFG, CPS, SIPP data sets (Zeng et al. 2002).

differences between the observed and projected percentages of persons who live in group quarters are −1.5% and −1.3%. The absolute values of the relative discrepancies between the observed and projected total population sizes, percentages of children less than 18 years old, percentages of elderly aged 65+, and the dependent ratios are 0.6–4.6% and 0.6–4.9%, respectively. The discrepancy rates of two measures concerning the smaller groups of oldest-old and big households are relatively large: the percentages of oldest-old aged 80 or older are 10.3% and 10.6%; the percentages of big households with five or more persons are −14.1% and −15.9%. We are not sure whether the discrepancies listed in Tables 3 and 4 are due mainly to the model specification, or to inaccuracies of the census and survey data, or to a combination of these. It is, however, clear that the ProFamy method/program works reasonably well.

U.S. household projection by race

Data and estimates

Data requirements, in general, for household projections using ProFamy and the data resources for the U.S. application are listed in Table 5. If race classifications are included for the projections, as in the U.S. application, the age specific standard schedules described in (a) through (e) of section (2) of Table 5 and the demographic summary measures described in section (3) of Table 5 are all race specific. We need only one set of the age specific standard schedules. Ideally, the standard schedules should be based on recent data from the population under study. They can be taken from another population that has similar age patterns of demographic rates as compared to the study population (especially for provinces or states) if the needed data are not available (see 'Data requirements and costs of time and resources' for justification and discussions).

We follow the Census Bureau's most recent classification to distinguish four racial/ethnic groups in the U.S. household projection by race using the ProFamy method: (1) white non-Hispanic, (2) black non-Hispanic, (3) Hispanic, and (4) Asian and others non-Hispanic (Hollmann et al. 2000).[5] The data resources are listed in the last column of Table 5. Standard schedules of mortality, net migration, and summary demographic measures (TFR, life expectancy at birth, and number of net migrants) are taken from the Bureau of the Census 1999–2100 population projection (Hollmann et al. 2000). The base population and standard schedules of net rates of leaving the parental home are derived from census microdata files; all are very straightforward. General rates of marriage/union formation and dissolution are derived from pooled survey data in combination with vital statistics. The standard schedules of race–sex–age specific o/e rates of marriage/union formation and dissolution and race–age–parity specific o/e rates of marital and non-marital fertility are estimated based on pooled survey data; these deserve special attention.

Morgan et al. (1999) found serious problems in vital statistics estimates of race/parity differentials of fertility. Vital registration numerators are obtained from birth certificates. The denominators are obtained from the census and population projections. The vital registration and census forms do not ask demographic questions in an identical manner. Thus, the race specific numerators and denominators used in computing demographic rates by race are not fully compatible. Sample survey data have no such problems, however. Furthermore, vital statistics could not provide adequate information on the risk population (exposure) of demographic events, which are necessary for estimating the standard schedules of the o/e rates needed for household projections. Therefore, we must use the survey data. We pooled data on the required variables from four national sampling surveys because subsample sizes for minority groups are too small if we use only one survey data set to estimate detailed o/e rates. The four national surveys are: (a) the 1980, 1985, 1990, and 1995 Current Population Surveys (CPS); (b) the 1987–88 and 1992–94 National Survey on Family Households (NSFH); (c) the 1982, 1988, and 1995 National Survey on Family Growth (NSFG); and (d) the 1996 Survey on Income and Program Participation (SIPP). The pooled data set has a total sample size of 296,988 women and 97,803 men. The basic concepts and definitions of age, sex, race, marital status, parity, dates of births, and events of marriage/union formation and dissolution, which are the only data we need to estimate demographic rates, are the same in the four national surveys. Hence, there are no problems of inconsistency in the definitions of needed data in our pooled data sets. Note that the 1987–88 and 1992–94 NSFH and the 1982, 1988, and 1995 NSFG collected event history data on cohabitation, in addition to marriage, divorce and fertility.

A more detailed description of the pooled data set and the race–sex–age specific o/e rates of marriage/union formation and dissolution and the race–age–parity specific fertility o/e rates for married, cohabiting, and not-married/not-cohabiting women are presented in a report by Zeng et al. (2002). The report includes the detailed estimates of the race–sex–age–status specific time-varying demographic rates for the periods of 1970–79, 1980–89, and 1990–96. The estimates of age specific fertility rates and TFR for all races, parities, and marital statuses combined in the 1970s, 1980s, and 1990s based on the pooled data are almost identical to the estimates based on vital statistics (Zeng et al. 2002). The multistate marital status life table measures based on age–sex specific o/e rates of marital status transitions for all races combined from the pooled survey data are quite consistent for 1990–96 and mostly consistent for 1980–89 with the estimates without race classification by Schoen and Standish (2001) based on vital statistics. We are, thus, confident in using our 1990–96 estimates of race–sex–age specific o/e rates of marriage/union formation and dissolution, and race–age–parity specific o/e rates of births for married, cohabiting, and not-married/not-cohabiting women as standard schedules for the U.S. household projection by race.[6]

The survey data do not have the problems of inconsistency of race classifications in the numerators and denominators that are intrinsic to vital statistics estimates (Morgan et al. 1999). The survey data are, however, likely subject to some sampling errors and recalling/reporting biases, especially in retrospective information collected for the periods well before the survey date, as well as geographic and time-lines coverage (Cherlin & McCarthy 1983). Yet vital registration data are generally supposed to be collected for all events of marriages and divorces in a population (Handcock et al. 2000: 187). It is therefore desirable to combine vital statistics and survey data to improve survey-based estimates of detailed o/e rates whenever it is appropriate and necessary. We use the all-races-combined estimates by Schoen and colleagues, which are generally reliable, to adjust our race–sex–age specific o/e rates of first marriage, remarriage, and divorce. The objective of the adjustment is to ensure that the integrated all-races-combined propensities of first marriage, remarriage, and divorce based on the pooled survey data (with classification of race and cohabitation) are equal to the corresponding all-races-combined propensities estimated by Schoen and colleagues using vital statistics (without classification of race and cohabitation). The adjustment procedure is presented in Zeng et al. (2003).

Medium projections

Our medium projections use the time-varying race specific medium mortality (e_0), medium fertility (TFR),[7] and medium international net migration adopted by the Census Bureau's most recent population projection (Hollmann et al. 2000).

The race specific general rates of marriage, divorce, cohabitation, and cohabitation-union dissolution and the race specific mean age at first marriage and at births (of all orders combined) are derived based on the observations in 1990–1996 from vital statistics and pooled survey data (see 'Data and estimates'), and are assumed to be constant from 2001 to 2050 (see Table A3 in Appendix A). The race–sex specific proportions of people eventually leaving the parental home, race–sex–age specific proportions of people living in institutional households, race–sex–age–marital–status specific proportions of elderly living with children are derived from the 2000 census microfile, and are assumed to remain unchanged.

One common approach in population projection is to hold some of the current demographic rates constant throughout the projection horizon (e.g., Treadway 1997; Day 1996). Smith et al. (2001: 83–84) argued that holding some of the rates and proportions constant in the demographic projections can be justified on either of two grounds. One is that future rates and proportions are not likely to differ much from the current level. Another justification for holding the rates and proportions constant is the belief that neither the direction nor the magnitude of future changes can be predicted accurately. The argument here is not so much that the current rates will remain constant, but rather that scientific theories and past history do not provide a reliable basis for predicting how those rates will change. If upward or downward movements are equally likely the current rates provide a reasonable forecast of future rates. In addition to the two justifications for assuming constant rates proposed by Smith et al. (2001: 83–84) and others (e.g., Day 1996; Treadway 1997), we have one more reason for doing so in our medium projections: we have conducted low (decreasing) and high (increasing) bounds of the rates and households projections (to be discussed in 'Racial differentials in dynamics of households and living arrangements'); these projections, together with the medium variant, formulate a blanket of possible changes in the rates and households in the future.

Under the medium projections, as shown in Figure 2, the average household size would decrease from 2.59 in 2000 to 2.41 in 2020, and remain stable afterwards; one-person and two-person households would increase from 25.8% and 32.5% in 2000 to 28.5% and 35.6% in 2020, and to 29.2% and 35.1% in 2050. Husband–wife households would decrease from 54.9% in 2000 to 49.9% in 2020, a relative decline of 9.1%, and become 47.6% in 2050. Cohabiting-couple households would increase from 4.9% in 2000 to 5.9% in 2020, a relative increase of 19.2%, and become 6.1% in 2050. Single-parent households among the two-generation households would increase from 24.6% in 2000 to 28.6% in 2020, and to 31.1% in 2050.

Under the medium projections, there would be 14.6 and 22.7 million elderly aged 65 and older living alone in the years 2020 and 2050 respectively, in contrast to 10.1 million in 2000. The proportion of elderly aged 65+ living alone within the total population will increase by 23.2% and 53.4% in 2020 and 2050, respectively, as compared

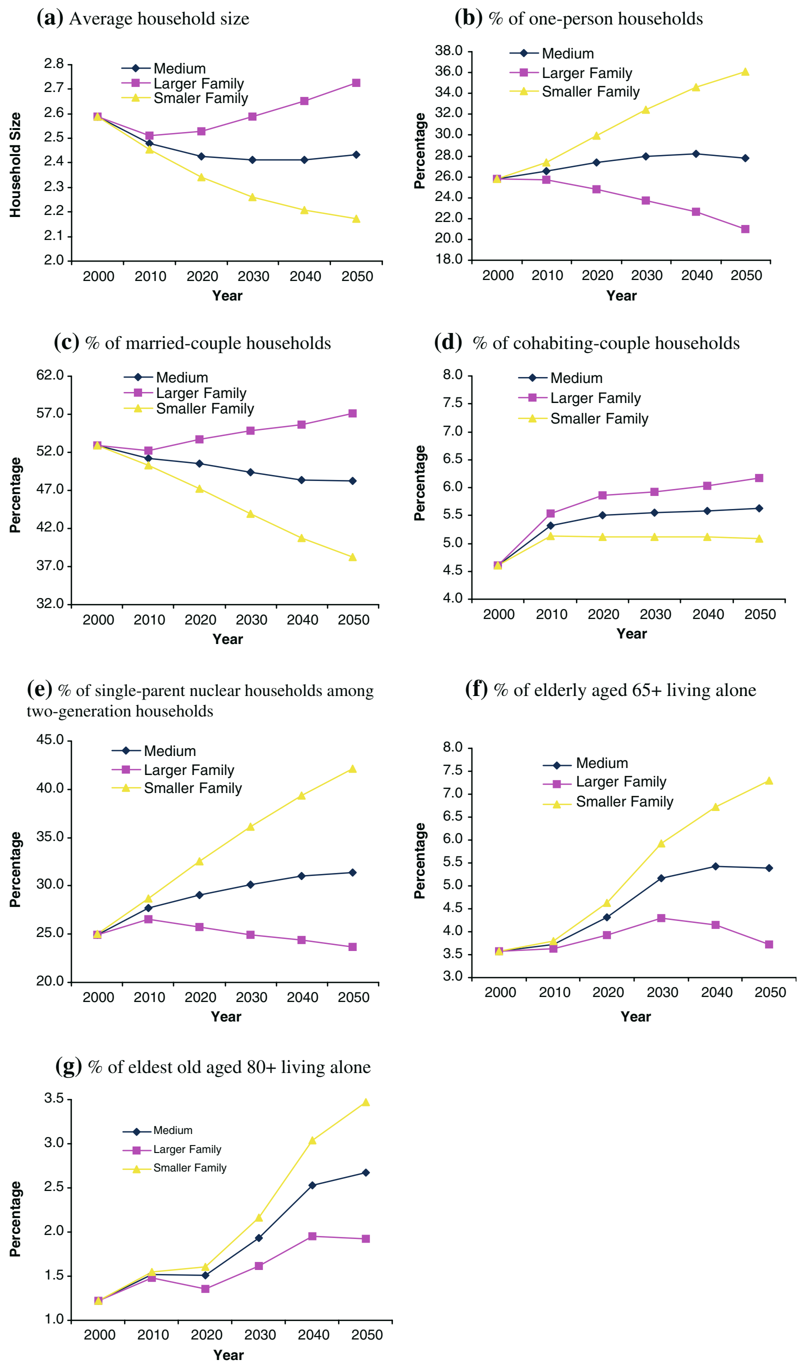

Figure 2 Medium, low, and high bounds of households and living arrangements projection.

with 2000. The number of the oldest-old persons aged 80+ living alone would be 3.4, 5.1, and 11.3 million in 2000, 2020, and 2050, respectively. Although the age–sex specific proportions of the elderly living in institutions are assumed to remain unchanged, the number of those elders aged 65+ living in institutions in 2050 would be 2.5 times as large as in 2000.

The large increase in the number and percentage of the elderly living alone among the total population is due to the mixed effects of the increase in the proportion of the elderly population in general and changes in marital status and living arrangements across cohorts and periods. Changes in the relative percentage distributions of marital status and living arrangement within age groups of the elderly reflect primarily the effects of changes in marriage/union formation and dissolution across cohorts and periods. The percentage of those who are divorced and living alone among the elderly aged 65+ would be 4.8, 8.9, and 10.5 in 2000, 2020, and 2050; the percentage of those who are cohabiting with a partner among elderly aged 65+ is 1.3, 3.5, and 3.7 in 2000, 2020, and 2050, respectively. The proportion of elderly who are widowed and not cohabiting decreases steadily, perhaps mainly because more widowed elderly will tend to cohabit with partners.

Family household momentum

As summarized above and depicted in Figure 2, under the medium projections, the proportional distributions of household types/sizes and elderly living arrangements would change considerably from 2000 to 2020, and remain more or less stable after 2020 (except that the percentage of the oldest-old living alone continues to increase substantially after 2020). As discussed earlier, however, the medium projections assume that from 2000 to 2050, general rates of marriage/union formation and dissolution remain constant. Even under a constant scenario with everything (marriage union formation and dissolution, fertility, mortality, migration, etc.) after 2000 assumed to remain the same as in 2000, the proportional distributions of household types/size and living arrangements of the elderly change considerably until 2020 or so and remain stable afterwards. Why would distributions of households and elderly living arrangements change considerably from 2000 to 2020 while the demographic parameters remain constant in the same period? Our explanation is that *family household momentum* plays an important role.

Cohorts who were younger in 2000 experienced and will experience stabilized (or constant) higher rates of marriage/union disruption and lower marriage/union formation than cohorts who were older in 2000 and had already completed most of their family life course. Profiles of households and elderly living arrangements in 2000 represent the mixed cumulative life course experiences of younger and older cohorts in the past few decades. Although the marriage/union formation and dissolution rates are assumed to remain constant during the period of 2000–2050, the distributions of households and elderly living arrangements would change considerably because older cohorts, who had more traditional family patterns, will be replaced by younger cohorts with more recent family patterns. Such family household momentum is similar to the well-known population momentum identified by Keyfitz (1971) over three decades ago, in which population size could continue to increase after fertility is equal to or even below the replacement level. The ProFamy method/program and our medium projections (and constant scenario) have provided a tool and empirical evidence to numerically illustrate family household momentum.

Low and high bounds of household and living arrangements projections

In order to explore the possible low and high bounds of household and living arrangements projections, we examined smaller and larger family scenarios. The *smaller family scenario* assumes that, as compared to the medium projections, the general rates of divorce and of cohabiting-union dissolution are higher by 15% in 2020 and 25% in 2050; the general rates of marriage and of cohabitation are lower by 15% in 2020 and 25% in 2050. General rates between 2000, 2020, and 2050 are derived through linear interpolation. This scenario employs the low fertility, low mortality, and low international net migration adopted by the Census Bureau's latest population projection (Hollmann et al. 2000). The smaller family scenario assumes increasing marriage/union dissolution, decreasing marriage/union formation, decreasing fertility and mortality,[8] and receipt of fewer international immigrants. We expect that such a combination of demographic rates may result in the low bounds of household size and percentages of married- or cohabiting-couple households, and the high bounds of percentages of one-person households, single-parent households, and so on.

The *larger family scenario* assumes that, as compared to the medium projections, the general rates of divorce and of cohabiting-union dissolution are lower by 15% in 2020 and 25% in 2050; general rates of marriage and of cohabitation are higher by 15% in 2020 and 25% in 2050. General rates between 2000, 2020, and 2050 are derived through linear interpolation. This scenario employs the high fertility, high mortality, and high net international migration adopted by the Census Bureau's latest population projection. The larger family scenario assumes that the family will regain its traditional values with decreasing marriage/union dissolution, increasing marriage/union formation, and increasing fertility, accompanied by high mortality and a larger number of international immigrants. The combination of demographic rates in the larger family scenario may result in high bounds of household size and percentages of married- or cohabiting-couple households, and low bounds of percentages of one-person households, single-parent households, and so on.

The assumptions that there will be 15% and 25% increases (or decreases) in general rates of marriage, divorce, cohabitation, and union dissolution in 2020 and 2050 constitute educated guesses about the largest possible changes in marriage/union formation and dissolution in the next few decades. Although we made these guesses with reference to the time series data of the general rates from 1970 to 2002 (Gu et al. 2004), they are largely arbitrary because of uncertainties about future trends. Nevertheless, similar to the conventional deterministic population projections of low and high variants that formulate the possible bounds of population growth, our smaller and larger family scenarios formulate the possible low and high bounds of future household and living arrangements distributions.

As shown in Figure 2a, the average U.S. household size may be 2.3–2.5 and 2.2–2.7 in 2020 and 2050 respectively. The percentage of one-person households may likely be in the ranges of 26.0–31.1 and 22.5–37.3 in 2020 and 2050 (Figure 2b). In 2020, the percentage of married-couple and cohabiting-couple households would be 46.8–53.1 and 5.5–6.4, respectively; and the corresponding figures in 2050 would be 38.1–55.9 and 5.3–6.8, respectively (Figure 2c and 2d). The possible range of percentages of single-parent households among the two-generation households would be quite large: 25.4–31.9 in 2020 and 23.8–41.0 in 2050 (Figure 2e).

Figures 2f and 2g shows that the percentages of elderly aged 65+ living alone among the total population would be 4.1–4.5 in 2020 and 4.2–6.8 in 2050; the percentages of oldest-old aged 80+ living alone among the total population would be 1.4–1.6 in 2020 and 2.2–3.2 in 2050. It is clear that the effects of demographic rates on future elderly living arrangements are substantial.

Projected numbers of households in future years are practically useful in market trends analysis and socioeconomic planning for the consumption of housing, energy, automobile, and other household-related goods and services. Table 6 shows the projected possible ranges of the grand total numbers of households and total numbers of households by types as well as total numbers of elderly living alone, based on the smaller, medium, and larger family scenarios. We present only the total numbers in this article due to space limitations. As discussed in Section 3.2, however, the numbers of households and living arrangements are classified by household type/size, race, age, sex, and marital status in our ProFamy household projection output files, which can be used for the purposes of market analysis and socioeconomic planning.

Racial differentials in dynamics of households and living arrangements

Figure 3 presents racial/ethnic differentials of the projected dynamics of households and living arrangements from 2000 to 2050 under medium projections. Figure 3a shows that the white non-Hispanic category has the smallest average household size; the Hispanic and the Asian/other non-Hispanic categories have much larger average household sizes than white and black categories throughout the first half of the century. Black average household size is considerably

Table 6. Projected possible ranges of the numbers of households by types as well as total numbers of elderly living alone (unit: million)

Year	Number of households					Elderly living alone	
	Total	One-person	Single-parent	Cohabiting-couple	Married-couple	Age 65+	Age 80+
2000	105.2	27.1	11.3	5.2	57.8	3.6	1.2
2010	120.9–122.3	32.6–34.2	13.2–13.7	6.6–7.3	61.0–64.0	3.7–3.8	1.5–1.5
2020	133.0–137.4	35.7–41.4	14.2–15.4	7.2–8.7	62.3–73.0	4.1–4.5	1.4–1.6
2030	142.8–153.2	38.3–48.1	15.8–17.1	7.7–10.0	61.9–82.6	4.7–5.7	1.8–2.1
2040	149.5–171.7	41.2–53.6	18.1–18.5	8.1–11.5	60.4–93.6	4.6–6.3	2.2–2.8
2050	152.8–192.0	43.2–57.0	19.6–20.5	8.1–13.1	58.2–107.3	4.2–6.8	2.2–3.2

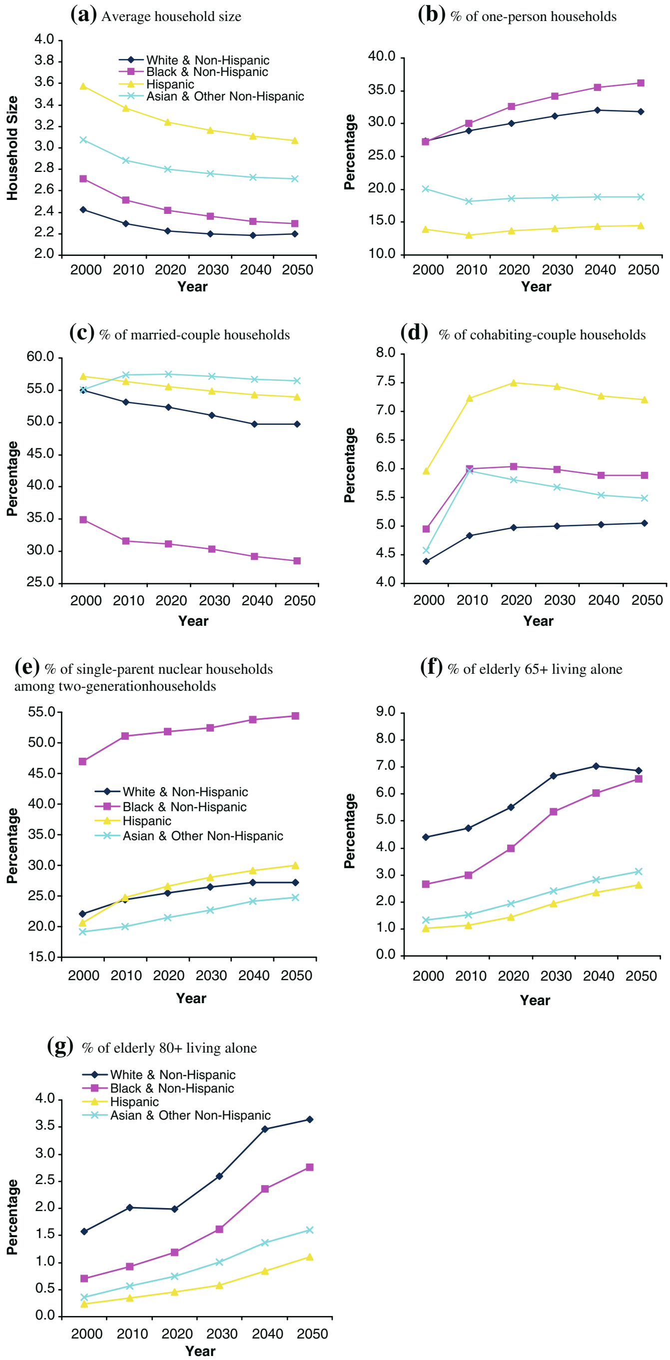

Figure 3. Racial differentials of households and living arrangements based on the medium projection.

larger than the white average up to 2030, but the difference becomes smaller by 2050. The black non-Hispanic and white non-Hispanic categories have much higher percentages of one-person households than the Hispanic and the Asian/other non-Hispanic categories, and the difference tends to grow larger – the black and white percentages would be about twice as large as the percentages of Hispanics and Asian/other non-Hispanics in 2040–2050. The black and white percentages of one-person households are fairly close to each other up to 2010, with the black percentage becoming larger than the white afterwards.

The black non-Hispanic population category has the lowest percentage of married-couple households (either with or without children) throughout the first half of this century; the white non-Hispanic category has the second lowest; the Asian/other non-Hispanic category has the highest; racial differentials are very large (see Figure 3c). Figure 3d shows that the proportion of cohabiting-couple households (either with or without children) is the highest within the Hispanic population category, and the lowest among white non-Hispanics. Throughout the first half of this century, the black non-Hispanic percentage of single-parent households among two-generation households is dramatically higher than that of any other race group (see Figure 3e).

The white non-Hispanic category has much higher percentages of elderly aged 65+ living alone and oldest-old aged 80+ living alone than any other racial/ethnic groups have; the percentage of elderly (including the oldest-old) living alone among black non-Hispanics is substantially lower than that among the white non-Hispanics, but much higher than that among Hispanic and Asian/other non-Hispanics.

Concluding remarks

The classic headship-rate method for household projection, which is still widely used despite more than a decade of criticism by demographers, is not linked to demographic rates, projects a few household types without size, and does not deal with household members other than heads. The new ProFamy method, initially proposed by Zeng et al. (1998, 1997) and substantially extended in this article, uses demographic rates as input and projects much more detailed household types, sizes, and living arrangements for all members of the population under study.

Our U.S. household projection scenarios have shown that, even assuming constant demographic rates, the distributions of households and elderly living arrangements will continue to change considerably in the next couple of decades. We have named this demographic trend "family household momentum." It will occur because older cohorts, with more traditional family patterns, will be replaced by younger cohorts with contemporary family patterns even if current demographic rates remain unchanged. Our household projections also show expected large race/ethnic differentials in household types/sizes and living arrangements in the first half of this century, due to racial differentials in demographic rates in the past and for the next few decades. Our smaller and larger family scenarios formulate the low and high bounds of the future household and living arrangements distributions. This is useful because it provides informative ranges of possibilities of future trends rather than one set of figures involving too many uncertainties.

To our knowledge, the household projections we report using the ProFamy method/program and demographic rates as input are the first to have found empirical evidence of family household momentum, and they provided informative low and high bounds of various indices of projected future households and living arrangements distributions based on possible changes in demographic parameters.

The ProFamy model and its associated computer program produce a large number of output tables and graphics of household types and sizes for each of the projection years (see Table 2). ProFamy also projects the entire population cross-classified by race, sex, age, marital status (including cohabitation), whether living with one or two parents or not living with parents, and by number of co-residing children. Due to space limitations, however, we have here presented only the main output of the general trends and the racial differentials. More detailed output of households and living arrangements, which could be useful in household consumption projections for business market analysis and socioeconomic planning, can be obtained. For example, one can combine the numbers of households by types, sizes, and ages of the reference person projected by ProFamy with the percentage distributions of income and average home ownership rates classified by the number of bedrooms (or square meters categories) and household types, sizes, ages, and income distributions (observed from the survey or census) to forecast housing consumption. Similar forecasts of household and consumption using the ProFamy method/

program can be conducted for vehicles, energy, durable goods, home-based services, and the like.

It is important to distinguish between using the ProFamy model for forecasting and using it for simulation. In this article, we follow the time series analysis and expert opinion approach for projecting national future demographic summary measures; this serves reasonably well for the purpose of demographic simulation. Within the ProFamy model framework, however, future demographic summary measures can be forecasted using the statistical software of time series analysis. Further research may also need to include time series data of other related socioeconomic covariates in the forecasting of demographic summary measures. It should always be noted that the accuracy of the household forecasts relies heavily on the validity of assumptions regarding the demographic summary measures. Erroneous assumptions can quickly lead to forecasts that are far off the mark. Forecasts with less than 20 years of time horizon may be used for business and governmental planning, but any results beyond that should be considered to be simulations only, due to large uncertainties after more than 20 years.

The work reported in this article also indicates that substantial further research is needed to overcome the limitations of our present study. First, because household forecasting involves multiple dimensions of sex, age, fertility, marriage/union formation and dissolution, leaving the parental home, and other factors, which require substantial programming and computation, wide practical application is not possible without user-friendly software. Thus, development of user-friendly software for household projections using demographic rates as inputs is necessary for non-experts to apply the new method.

Second, developing a database of model standard schedules of the race–age–sex specific demographic rates, which are similar to the model life tables, is crucial for wide applications of the ProFamy method/software to household projections at the provincial/state level, at which such detailed data are less likely to be available. Model standard schedules include reliably estimated race–sex–age specific o/e rates of marriage/union formation and dissolution, race–age–parity–marital status specific o/e rates of births based on pooled survey data in combination with vital statistics, and race–sex–age specific net rates of leaving the parental home, based on census data. We believe that the following two approaches may help to produce reasonable forecasts of households for provinces or states: (1) using the proportions of racial/ethnic groups in the provinces/states as weights and the national race–sex–age specific model standard schedules to estimate the weighted average model standard schedules for all races combined at the state level; and (2) using the national race–sex–age specific model standard schedules. As Rayer (2004) reported, a majority of existing population projections at state and small area levels deal with all races combined due to subsample size constraints of minority groups in estimating race–sex–age specific demographic rates. As discussed by Morgan (2004a), most of the differences in demographic rates between provinces/states are due to racial composition rather than to different race specific rates. Thus, strategy (1), using race composition as weights, and strategy (2), using the national race–sex–age specific model standard schedules plus the race specific summary measures in the state, are reasonable and practical ways to household-forecast at the province/state level. This expectation is based on the fact that demographic summary measures are crucial, but forecasting results are not substantially sensitive to the age specific model standard schedules as long as the schedules reveal the general age pattern of the demographic processes of the population. This argument was tested and verified through the two scenario exercises described in 'Data requirements and costs of time and resources'. Thus, using existing model standard schedules and projected (or assumed) demographic summary measures such as TFR, life expectancy at birth, general rates of marriage, divorce, cohabitation, and union dissolution, as well as the ProFamy software, one can conveniently perform household forecasting at national and provincial/state levels.[9] One of our further research tasks is to produce the race–sex–age specific model standard schedules for wide applications of household forecasting at national and provincial/state levels.

Third, stochastic household forecasts with probabilistic distributions of the outcome and statistical confidence intervals are needed to address the uncertainties better than do the deterministic medium forecasts with "low and high boundaries" presented in this article. To our knowledge, such stochastic household projections are not yet available because they include more demographic dimensions and are much more complicated than stochastic population projections. We believe that the ProFamy software for household projections using conventional demographic input parameters can provide a realistic modeling framework and tool for the scientific research of stochastic household projections.

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Notes

1. Household projection reports are among Statistics Canada's best sellers (George 1999: 8–9).
2. When fertility is being postponed to later ages or advancing to earlier ages, for example, one may shift the age specific standard schedule of fertility to the right or left by the amount of increase or decrease in the mean age at childbearing, while the shape of the fertility schedule remains unchanged. One may also assume that fertility would be delayed or advanced while the curve becomes more spread or more concentrated through parametric modelling (Zeng et al. 2000). Zeng et al. (2002) recently estimated the U.S. race–age–sex specific o/e rates of marital status transitions and the race–age–parity–marital-status specific o/e rates of fertility in the 1970s, 1980s, and 1990s. This work is based on the pooled data from 10 waves of four major national surveys conducted from 1980 to 1996 (with a total sample size of 394,791 women and men). The estimates show empirically that the basic shapes of the demographic schedules remained reasonably stable from the 1970s to 1990s, while the timing was changing. We thus may reasonably assume that in normal circumstances the basic shapes of the standard schedules remain stable, while the changes in timing are modelled through the changing mean age at marriage and fertility in the family household projection.
3. ProFamy will also compute and show the multistate life table propensities implied by the general rates and the sex–age specific standard schedules in the starting year and projection years to provide clear expressions of intensities of marriage/union formation and dissolution.
4. Decennial census data could provide a more detailed stratification of headship rate in household projection than what was done by the Bureau of the Census, if one assumed that the sex–age specific headship rates are constant over the projection time horizon. This would produce more detailed household projections, but the static approach of assuming constant sex–age specific headship rates departs from the real world and may not be accepted by researchers and policymakers.

5. We do not consider multiple or mixed races in this study. If a person reported his or her race as white or black plus another race in the 2000 census, we consider the person to be white or black.
6. Using the pooled survey data, we tried to estimate the race–age specific o/e rates of marriage, union break, and fertility by parity for never-married and cohabiting, widowed and cohabiting, and divorced and cohabiting persons separately. But the results are not satisfactory due to problems of subsample sizes for minority groups that are too small. We thus combine relevant data and use the same race–age specific o/e rates of marriage, union break, and fertility by parity for three different kinds of cohabiting people. The race–age specific o/e rates of cohabitation union formation and fertility by parity for never-married, widowed, and divorced persons are estimated separately with general satisfaction.
7. We also include the modest increase in mean age at birth and first marriage.
8. Low mortality may (1) reduce the U.S. average household size through increasing number of elderly households that are mostly small (one or two persons), and (2) increase the size of some households by increasing the survivorship of adults and children in these larger households. The effects of (2) may be smaller than those of (1) because a further decrease in adult and child mortality in the U.S. is limited, but the prolongation of elderly life span may have larger impacts.
9. This is also similar to the practice in which one uses age specific rates of fertility, mortality, and migration at the national level as "model standard schedule," and the TFR, e_0, and number of migrants for the province or state or small area under study to perform the subregion population projection.

Appendix

Table A1. Comparing the main indices of ProFamy forecasts of household numbers, types/sizes between using the standard schedules observed in the 1980s and using the standard schedules observed in the 1990s, while the projected input summary measures are identical

	2000			2010			2020		
	80 Stand	90 Stand	Diff.%	80 Stand	90 Stand	Diff.%	80 Stand	90 Stand	Diff.%
Total number of households	105,779,128	105,901,696	0.1	120,269,184	120,454,376	0.2	134,421,136	134,627,744	0.2
Average household size	2.53	2.53	−0.1	2.47	2.47	−0.2	2.44	2.44	−0.2
Percentage of:									
1-person households	25.77	25.19	−2.3	26.85	26.09	−2.9	27.36	26.52	−3.1
2-person households	32.95	33.81	2.6	34.68	35.77	3.2	35.72	36.95	3.4
3-person households	18.02	18.09	0.4	17.22	17.33	0.7	16.36	16.48	0.8
4-person households	13.98	13.8	−1.3	12.38	12.17	−1.7	11.74	11.48	−2.2
5+-person households	9.28	9.11	−1.9	8.86	8.64	−2.6	8.83	8.58	−2.9
Married couple families	53.85	53.69	−0.3	47.36	47.20	−0.3	42.38	42.23	−0.3

Table A2. Comparing the main indices of ProFamy forecasts of population between using the standard schedules observed in the 1980s and using the standard schedules observed in the 1990s, while the projected input summary measures are identical

	2000			2010			2020		
	80 Stand	90 Stand	Diff%	80 Stand	90 Stand	Diff%	80 Stand	90 Stand	Diff%
Total population	276,483,456	276,417,600	0.0	306,898,912	306,896,384	0.0	339,270,464	339,189,344	0.0
Percentage of children age <18	25.35	25.33	−0.1	24.30	24.31	0.0	23.92	23.91	0.0
Percentage of 60+	16.92	16.92	0.0	19.00	19	0.0	22.93	22.93	0.0
Percentage of 65+	13.03	13.04	0.1	13.60	13.6	0.0	16.74	16.75	0.1
Percentage of 80+	3.61	3.61	0.0	4.15	4.15	0.0	4.27	4.27	0.0
Percentage of group quarters	2.73	2.73	0.0	2.84	2.84	−0.1	2.85	2.86	0.0
Dependent ratio of:									
children	0.41	0.41	0.0	0.39	0.39	0.0	0.40	0.40	0.0
old	0.21	0.21	0.0	0.22	0.22	0.0	0.28	0.28	0.0
children and old	0.62	0.62	0.0	0.61	0.61	0.00	0.69	0.69	0.0

Table A3. Major parameters of the medium forecasts, smaller and larger family household scenarios

	White & non-Hispanic			Black & non-Hispanic			Hispanic			Asian & other non-Hispanic		
	2000	2025	2050	2000	2025	2050	2000	2025	2050	2000	2025	2050
Medium mortality												
Male e_0	74.9	77.8	81.1	68.7	73.6	78.5	77.4	80.0	83.0	79.7	81.9	84.6
Female e_0	80.3	83.6	86.4	75.4	80.5	84.6	83.8	86.1	88.4	85.9	87.6	89.7
Low mortality												
Male e_0	74.9	79.2	83.5	68.8	75.3	81.3	77.4	81.5	85.5	79.7	83.4	86.9
Female e_0	80.3	84.5	88.0	75.5	81.7	86.5	83.9	87.1	90.0	86.0	88.6	91.2
High mortality												
Male e_0	74.8	76.9	79.5	68.5	72.4	76.6	77.2	79.0	81.4	79.6	81.0	83.0
Female e_0	80.2	82.6	84.8	75.3	79.3	82.7	83.8	85.1	86.8	85.8	86.6	88.0
Medium fertility												
TFR-all births	1.84	2.03	2.04	2.08	2.12	2.11	2.97	2.68	2.56	2.26	2.18	2.16
TFR(1)-1st birth	0.80	0.87	0.88	0.82	0.77	0.77	0.95	0.94	0.90	0.96	0.91	0.91
TFR(2)-2nd birth	0.66	0.71	0.71	0.67	0.66	0.66	0.90	0.81	0.77	0.73	0.70	0.69
TFR(3)-3rd birth	0.26	0.30	0.31	0.38	0.39	0.39	0.55	0.50	0.48	0.37	0.35	0.35
TFR(4)-4th birth	0.09	0.10	0.10	0.14	0.18	0.18	0.28	0.25	0.24	0.12	0.13	0.13
TFR(5)-5+ birth	0.03	0.05	0.05	0.07	0.12	0.12	0.20	0.18	0.18	0.08	0.08	0.08
Low fertility												
TFR-all births	1.82	1.73	1.67	2.06	1.80	1.73	2.96	2.28	2.09	2.23	1.86	1.76
TFR(1)-1st birth	0.79	0.74	0.72	0.81	0.66	0.63	0.94	0.80	0.73	0.95	0.78	0.74

TFR(2)-2nd birth	0.65	0.60	0.58	0.67	0.56	0.54	0.89	0.69	0.63	0.72	0.59	0.57
TFR(3)-3rd birth	0.26	0.26	0.25	0.37	0.33	0.32	0.55	0.42	0.39	0.37	0.30	0.29
TFR(4)-4th birth	0.09	0.09	0.08	0.14	0.15	0.14	0.28	0.21	0.20	0.12	0.11	0.11
TFR(5)-5+ birth	0.03	0.04	0.04	0.07	0.11	0.10	0.20	0.16	0.14	0.08	0.07	0.07
High fertility												
TFR-all births	1.86	2.33	2.42	2.10	2.44	2.50	2.99	3.08	3.03	2.28	2.51	2.56
TFR(1)-1st birth	0.81	0.95	0.95	0.82	0.89	0.91	0.95	0.95	0.95	0.96	0.95	0.95
TFR(2)-2nd birth	0.67	0.84	0.90	0.68	0.76	0.78	0.90	0.90	0.90	0.74	0.86	0.89
TFR(3)-3rd birth	0.26	0.36	0.38	0.38	0.45	0.46	0.56	0.66	0.63	0.38	0.43	0.45
TFR(4)-4th birth	0.09	0.12	0.13	0.14	0.20	0.21	0.28	0.33	0.32	0.13	0.16	0.17
TFR(5)-5+ birth	0.03	0.05	0.06	0.07	0.14	0.15	0.20	0.24	0.23	0.08	0.10	0.11
Medium marriage/union formation & dissolution												
General marriage rate	0.0704	0.0704	0.0704	0.0362	0.0362	0.0362	0.0593	0.0593	0.0593	0.0676	0.0676	0.0676
General divorce rate	0.0292	0.0292	0.0292	0.0308	0.0308	0.0308	0.0184	0.0184	0.0184	0.0214	0.0214	0.0214
General cohabiting rate	0.1094	0.1094	0.1094	0.0775	0.0775	0.0775	0.0996	0.0996	0.0996	0.1187	0.1187	0.1187
General union break rate	0.2992	0.2992	0.2992	0.3612	0.3612	0.3612	0.2013	0.2013	0.2013	0.3341	0.3341	0.3341
Male mean age 1st mar.	27.59	28.45	28.45	29.99	30.57	30.57	27.38	28.14	28.14	30.54	31.12	31.12
Female mean age 1st mar.	25.45	26.16	26.16	28.57	29.18	29.18	25.83	26.68	26.68	28.25	28.92	28.92
Mean age at births	27.56	28.07	28.07	25.74	26.19	26.19	26.88	27.61	27.61	28.77	29.22	29.22

Note: The medium/low/high mortality and medium/low/high fertility are assumed by the Census Bureau in their latest population projection (Hollmann et al. 2000).

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