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Future trend of family households and elderly living arrangement in China

1. INTRODUCTION

A number of studies based on 1982, 1990 and 2000 census micro data reveal that the household composition in China has been changing substantially in the past a couple of decades (Zeng and Wang, 2003; Guo, 2003). Those changes are reflected, for example, in the substantial increase of one-person and one-couple-only households, and decrease in average household size. More specifically, the proportion of the elderly not living with children and the proportion of one-couple-only households among the elderly population increased considerably. Changes in household composition have been and will continue to reduce the elderly care capacities of Chinese families, which will increasingly affect social services and economic development. Clearly, family support for the elderly is facing grave challenges in the process of rapid population aging and substantive changes in household structures.

Applying the new ProFamy method (Zeng, Vaupel, and Wang, 1997; 1998; Zeng and Land *et al*., 2006; 2008), its associated computer software[1], and the recent census and survey data mainly collected around the 2000 census, this study projects the future changes in family household size and structure, elderly living arrangements, and population aging in the period of 2000-2050 under the scenarios of medium assumptions on fertility, mortality, rural-urban migration, marriage, and divorce for rural and urban areas in China. As compared to the other previous demographic projection studies concerning the future population in China, this study has two unique features. First, we simultaneously project the trends of population age and sex distributions and project family households and elderly living arrangements. This is useful since dynamic changes in family households, elderly living arrangements, and population age/sex structures occur simultaneously. Second, we conduct the projection of the population classified by rural and urban sectors and take into account the large rural-urban differentials in

[1] Those who are interested in obtaining a trial version of ProFamy software, which was used to conduct the projections presented in this paper, may download it from our Website http://www.profamy.com/.

fertility, mortality, marriage formation and dissolution, as well as the massive migration from rural to urban areas in the process of economic and social development. Dynamic and integrated projection of rural and urban family households, elderly living arrangements, and population aging is helpful for better understanding the future society and investigating the appropriate strategies for sustainable development.

2. A SUMMARY REVIEW ON THE METHOD

The methodological background, accounting equations, procedures for ensuring consistencies between the two sexes and between parents and children, the basic assumptions, discussions, most recent extensions, and validations of the method through projecting U.S. households from 1990 to 2000, *etc*. of the ProFamy model were presented in previous publications (Zeng *et al*., 1997; 1998; Zeng *et al*., 2006), and thus will not be repeated here. In this Section, we briefly summarize the basic ideas of the new ProFamy method used in this paper. Those who are interested in the methodological details of the ProFamy method, please refer to our relevant publications.

Based on Bongaarts' and Zeng's life table models (Bongaarts, 1987; Zeng, 1986; 1988), Zeng *et al*. (1997; 1998) developed a two-sex dynamic macro projection model known as ProFamy. Unlike the life table models, the ProFamy model permits age-sex-specific demographic schedules to change over time and ensures consistency between the two sexes and between parents and children. It follows the harmonic mean approach, which satisfies most of the theoretical requirements and practical considerations for handling consistency problems in a two-sex and parent-child model (Keilman, 1985; Pollard, 1977; Schoen, 1981; Van Imholf and Keilman, 1992; Zeng *et al*., 1997; 1998). All individuals of the population are grouped and projected forward by age, sex, marital status (including cohabitation if distinguished in the application), parity, number of co-residing children and parents, rural or urban, and whether living in a private or institutional household. Unlike most of the other macro-simulation models, which require stringent data on transition probabilities of household type statuses, the ProFamy model requires as input only conventional demographic data, as listed in (1), (2) and (3) in the next Section, to compute the individual groups' status changes. These data can be obtained from vital statistics, censuses, and routinely conducted surveys. We adopted a computational strategy to calculate the individual groups' marital, fertility and co-residence (with parents/children) status changes, which prevents the problems of estimating very high dimensional tables of cross-status transition probabilities. The strategy was originally proposed by Bongaarts (1987) and further justified mathematically and numerically by Zeng (1991: 61-63 and 80-84; Zeng *et al*., 2006).

We follow Brass's (1983) basic concept of "marker" (or "reference person") to identify and classify households based on the marital and co-residence (with parents/children) status of individuals, which are projected forward for all members of the population using the demographic rates listed in (2) and (3) in the next section. For example, a married or cohabiting woman who is not co-residing with parents and whose number of co-residing children is 0 (c=0) is a reference person representing a one-couple only household; if her number of co-residing children is greater than 0 (c>0), she represents a two-generation & couple household of 2+c family members (c>0). If the reference person is not married and not cohabiting (can be a man or woman), he or she represents a single-person alone (c=0) or single-parent household of 1+c family members (c>0).

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 and population by race from 1990 to 2000. We calculated the U.S. starting population for the projections based on the U.S. 1990 census. We use 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, elderly living arrangement, and population age and sex distributions from 1990 to 2000 for the nation (Zeng *et al*., 2006) and for the 50 states and DC of the United States (Zeng *et al*., 2008). Comparisons between the census observed and our projected main measures of household distributions and the population in 2000 of the nation and 50 states and DC of the United States, show that the differences are within a reasonable range. We also performed similar validation test of projecting the Chinese family households and population from 1990 to 2000 and comparing the results of the projection with the 2000 census observations, and the differences are again within a reasonable range. It is clear that the ProFamy method/program for household, elderly living arrangements and population projections works reasonably well.

Criticized by almost all family demographers for a couple of decades (Bell and Cooper, 1990; Mason and Racelis, 1992; Murphy, 1991; Spicer *et al*., 1992), the headship-rate method does not link to demographic rates, projects only a few household types without size, and deals with household "heads" but not other household members. In contrast, ProFamy uses demographic rates as input and projects much more detailed household types and sizes, and living arrangements for the elderly and all other members of the population. Prskawetz *et al*. (2004) and Zeng, Wang and Gu (2005), for example, found that the headship-rate method yields serious misleading projections about increases in automobile use in Austria and the U.S. through multiplying the forecasted number of households without size information by the average number of automobiles per household derived from a recent survey. This is because the future Austrian and American households will comprise many more one- and two-person households (which mostly need only one car) than do today's average households, but the headship-rate method cannot forecast households by size. Prskawetz *et al*. (2004) and Zeng *et al*. (2005) applied the ProFamy method/program and produced much more realistic and detailed projection of future households (by size, types, and age of the reference persons) and automobile use. Dalton *et al*. (2008) applied the ProFamy model to replace the classic treatment of household projection in their U.S. Population-Environment-Technology (PET) equilibrium model analysis on energy and economic growth. Their results demonstrate that using ProFamy in PET model is very useful because household heterogeneity can substantially affect energy use and long-term carbon emissions.

3. DATA AND ESTIMATES

The data needed to project family households using ProFamy are listed in (1), (2), and (3) below:

(1) A census sample data set with variables of sex, age, marital status, relationship to the household head or householder, parity (optional), whether living in a private or institutional household, race (optional) and rural/urban residence (optional).

(2) Standard schedules of age-sex-specific demographic rates observed in the recent past:
  - (a) Age-sex-specific (and marital-status specific, if possible) death rates, derived from the recent life tables;
  - (b) Age-sex-specific occurrence/exposure rate (o/e rate) of marital/union status transitions; the o/e rate is defined as the number of events that occurred in the age interval, divided by the person-years lived at risk of experiencing the event in the age interval;
  - (c) Age-parity-specific o/e rates of marital and non-marital fertility;
  - (d) Age-sex-specific net rates of leaving the parental home. One may

provide just two adjacent census micro data 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);

(e) Age-sex-specific (and marital status specific, if possible) rates of emigrants to the rest of the world and age-sex-specific frequency distribution of immigrants from the rest of the world, or the net rates of migration;

(3) Projected or assumed demographic summary measures in future years: parity specific total fertility rates; general rates of marriage/union formation and dissolution (the general rate is the total number of the events that occurred in the year divided by the total number of persons at risk of experiencing the event in the middle of the year), mean age at first marriage and birth, life expectation at birth, total number of male and female immigrants and emigrants, and cohort-specific proportions of adult children who eventually leave the parental home and the cohort specific proportion of elderly parents who live with an adult child and the child's spouse if the child is married (see Appendix B for details).

If rural-urban classifications are requested for the projection, which is what we do in this study, the standard schedules described in (a)-(e) of (2) and the summary measures described in (3) are all rural-urban-specific. We need only one set of the age-specific standard schedules listed in (a)-(e) of (2), based on recent data from the population under study. Using this one set of the standard schedules and the demographic summary measures as listed in (3), ProFamy estimates the time-varying age-sex-status-specific rates in the future years for projection. If the standard schedules for the region or sub-region area under study are not available, one can use the model standard schedules from the national population. This is similar to the well-known application of model life tables to project/estimate death rates when the observed life table for the population under study is not available.

The input data sources and the estimation procedures to apply the ProFamy model for projection of family households, elderly living arrangements, and the population aging of China from 2000 to 2050 are presented in the Appendix A and Appendix B. As presented in Appendix C, we have made educated estimates of the parameters of medium assumptions on fertility and mortality, as well as the other demographic parameters. Based on our analysis on the urbanization process since 1982, we assume that the proportion of urban population will be 36%, 55% and 75% in 2000, 2020, and 2050, respectively. We also assume that the age distribution of the rural-urban migrants will be the same as that observed in the 2000 census. Combining the assumed parameters of fertility, mortality, migration, and the prevalence of the co-residence between elderly parents and children, and the standard schedules, ProFamy estimates the time-varying age-parity-specific occurrence/exposure of fertility, age-sex-specific mortality rates, and age-sex-specific net rates of leaving home and migration (see Zeng *et al*., 1998 and Zeng *et al*., 2006 for more detailed discussions). Because current and future fertility levels in China are an issue that is currently in debate, we discuss our medium fertility assumption in detail, as follows, while we present the estimation and assumptions for the other demographic rates/parameters in Appendixes A, B, and C.

The 2000 Chinese census reported an extremely low *TFR* of 1.22. This is obviously too low to believe, but there is no consensus on the true fertility level in China today. Based on our review of existing related studies, we assume a 25% under-reporting of birth rates, which implies that the *TFR* for rural and urban areas combined in 2000 was about 1.63; and the *TFR* in rural and urban areas was estimated as 1.9 and 1.15. We expect that China will gradually relax its one-child policy, due to the current very low fertility level and the government's concern about future population aging problems[2]. Thus, we assume that the life-time cohort *TFR* will increase to 2.27 and 1.8 in rural and urban areas in and after 2012[3]. Because rapid socioeconomic development in China has been causing young people to delay their marriages and births (see data shown in Figure 1), we assume that the age at the first, second or higher order births will increase by 0.9 and 1.8 years during the years from 2012 to 2030, which constitutes an annual growth rate of 0.05 and 0.1 years, respectively. According to the Bongaarts-Feeney method (Bongaarts and Feeney, 1998; Zeng and Land, 2001; 2002), the projected period *TFR* of the first, second or higher order births in the years 2012 and 2030 will be 5% and 10% lower than the parity-specific cohort *TFR*, due to the fertility timing effects. The overall *TFR* (all parities combined and rural/urban combined) in 2012 and 2030 will be 1.89 and 1.83,

[2] Various provinces in China have already started to gradually relax the one-child policy, such as allowing couples who are only-child (*i.e.* no siblings) – either both parties or one party of the couple – to have two children.

[3] Considering the relatively low level of socioeconomic development in rural areas and the fact that rural couples of minority ethnic groups are allowed to have more than 2 children, the lifetime cohort *TFR* in the rural areas in and after year 2012 is assumed to be 2.27. We assume that the lifetime cohort *TFR* in the urban areas will be 1.8 in and after the year 2012, which implies that we assume that in the urban areas 3% of women are infecund, and 14% voluntarily choose to have only one child.

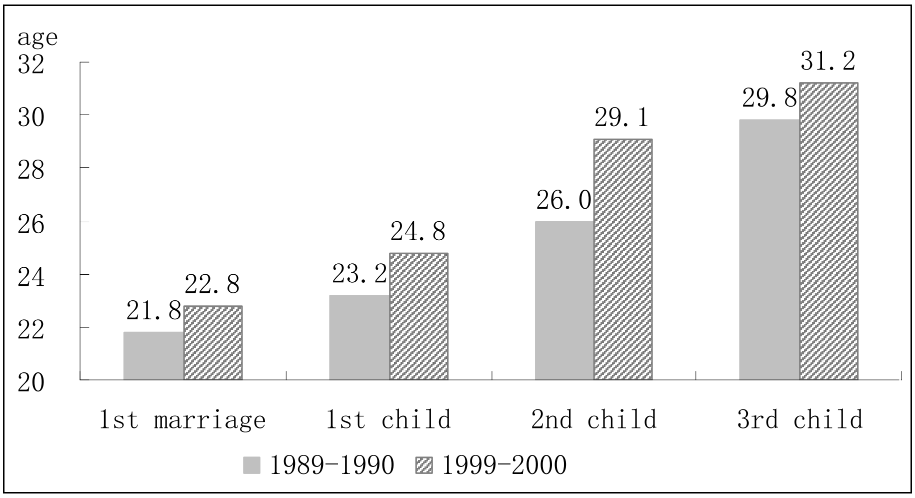
respectively. We assume that the increase in the age at childbearing will cease after year 2030, and by the year 2035, the period *TFR* will be the same as the cohort *TFR* and will remain constant thereafter. As mentioned earlier, we assume that the proportion of the urban population will increase from 36% in 2000 to 55% and 75% in 2020 and 2050, and thus the weighted average period *TFR* for the whole country will be 1.83 and 1.92, in the years 2030 and 2050, respectively (see Table 1).

Table 1 – *Rural and urban period* TFR*, and weighted average period* TFR *of rural and urban combined (using % of rural and urban as weights)*

	2000	2012	2030	2035	2050
Rural	1.90	2.09	2.09	2.27	2.27
Urban	1.15	1.67	1.67	1.80	1.80
Total	**1.63** **(1.83)**	**1.89** **(2.05)**	**1.83** **(1.98)**	**1.96** **(1.96)**	**1.92** **(1.92)**

Note: Figures in the parentheses are the *TFR* if there were no changes in mean age at birth, estimated by the Bongaarts-Feeney method.

Figure 1 – *Average age at 1st marriage, 1st, 2nd, and 3rd birth: a comparison between 1989-1990 and 1999-2000*



The general rates of marriage and divorce are assumed to be constant at the 2000 level. One common approach in forecasting is to hold some of the current rates constant throughout the forecasting horizon (e.g., Day, 1996; Treadway, 1997). Smith, Tayman and Swanson (2001:83-84) argue that holding some of the rates and proportions constant when forecasting can be justified on either of two grounds. The first is when future rates and proportions are unlikely to differ much from the current level. The second is when 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 reliable bases 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.

Our educationally projected demographic parameters in the next five decades are listed in the Appendix C. A sensitivity analysis on what the impact of high or low fertility, mortality, marriage, and divorce scenarios would be out of the scope of this paper, given the main objective of this paper is to provide a general profile of our projections of the future trends of family household and elderly living arrangements in the context of rapid population aging.

4. PROFILE OF THE FUTURE TRENDS

4.1 Rapid population aging

The very large size of the elderly population is a unique characteristic of population aging in China. In 2000, there were 88 million elderly persons age 65 and over. By the years 2030 and 2050, there will be 238 million and 338 million elderly people in China, respectively, under the medium mortality assumption and based on the latest baseline data derived from the 2000 census (see Figure 2).

Although the proportion of elderly aged 65 and above is not very high now (6.9% in 2000) in China, the speed of population aging will be extremely fast in the first half of the 21st century. Under the medium fertility and mortality assumptions, the Chinese elderly aged 65 and older will account for 16.4 and 23.9 percent of the total population by 2030 and 2050, respectively (see Figure 3). The projections under the medium fertility and medium mortality assumptions by the United Nations and other scholars inside and outside China show similar general trends of future numbers and proportions of the Chinese elderly population (e.g. U.N, 2005), which confirms the likelihood of extremely rapid population aging in China in the first half of 21th century.

Figure 2 – *Projected number of elderly aged 65+ and oldest-old aged 80+, rural-urban combined, 2000-2050*

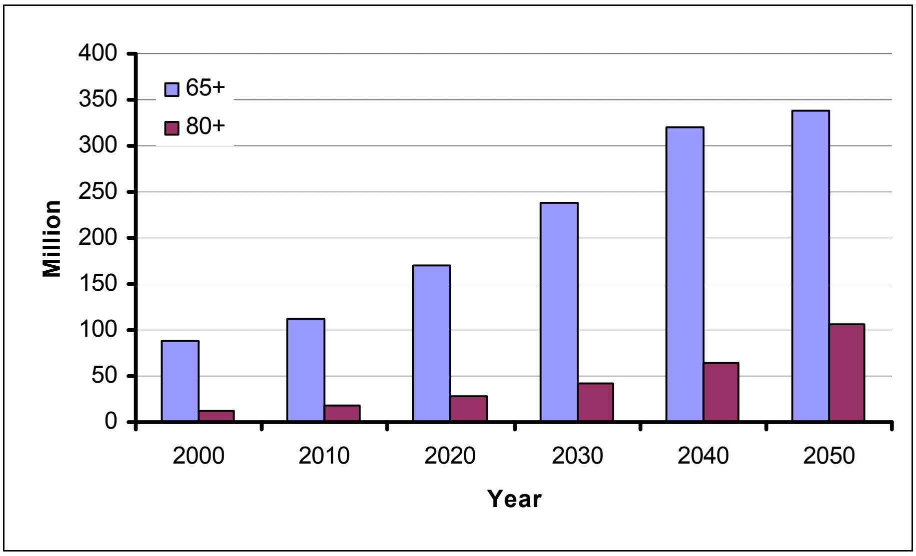
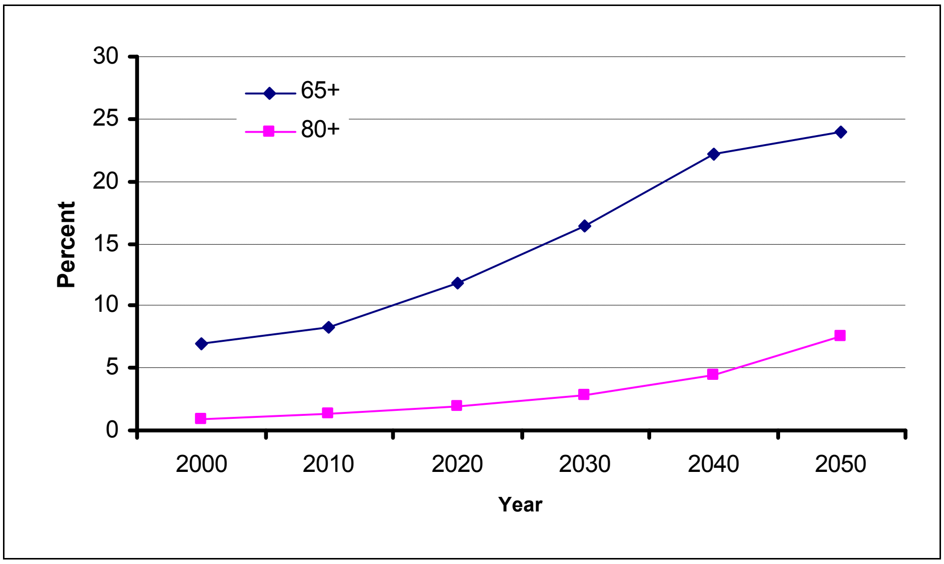


Figure 3 – *Projected percentage of elderly aged 65+ and oldest-old aged 80+ among total population under the medium fertility and mortality scenario: rural and urban combined, 2000-2050*

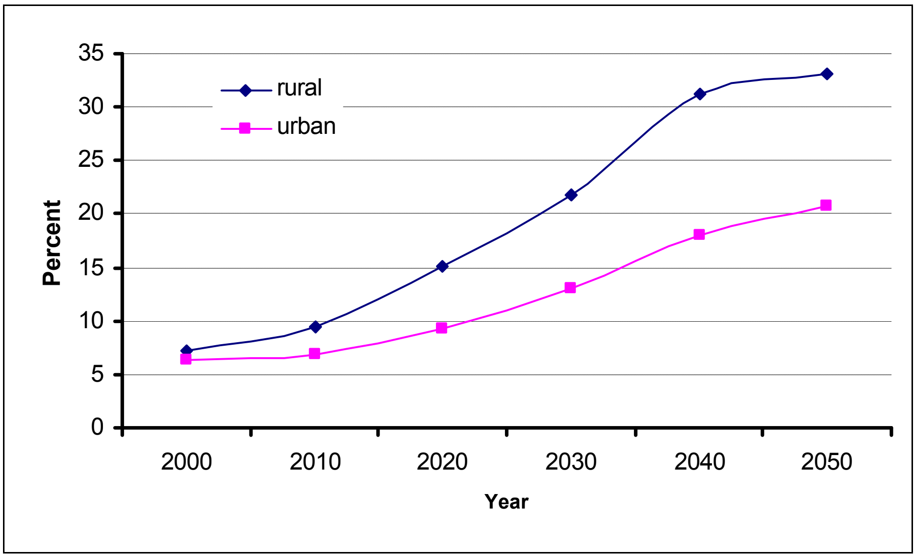


There were about 12 million oldest-old aged 80 and over in 2000, but the number of oldest-old will climb rapidly to about 27, 65, and 107 million in the years 2020, 2040 and 2050, respectively, under the medium mortality assumption (see Figure 2). The average annual increase in the rate of the oldest old between 2000 and 2050 will be 4.5 percent. The percent share of the oldest-old among the elderly population in 2030 and 2050 will be 1.26 and 2.33 times as large as that in 2000. From 2000 to 2040, this share will increase by approximately 1.7 percentage points per 10 years. But in the 10 years from 2040 to 2050, that share will increase by 11.5 percentage points mainly because China's baby boomers born in the 1950's and 60's will fall into the oldest-old age category at that time. Despite the uncertainties in accurately forecasting the oldest-old population, it is certain that the oldest-old will increase tremendously in the next century in China (also see Mayer *et al*., 1992:81-82), and that the middle of the next century will be a hard time for the country due to serious problems associated with population aging.

In European societies, the aging transition has been spread over one century or more. In China, however, this change will take place within a few decades and will reach more or less the same level of population aging by the middle of the next century as in most developed countries. The proportion of elderly in China will increase much faster than in almost all other countries in the world. According to U.N. population projections (U.N., 1999), it will take about 20 years for the elderly population to increase from 10 to 20 percent of the population in China (2017-2037), compared to 23 years in Japan (1984-2007), 61 years in Germany (1951-2012), 64 years in Sweden (1947-2011), and 57 years in the United States (1971-2028). Japan is regarded as a country with very rapid population aging, but the aging process of the Chinese population will be even faster than that of Japan (Ogawa, 1988).

Although fertility in rural areas in China is much higher than in urban areas, aging problems will be more serious in rural areas because of the continuing massive rural-urban migration of young people. Under the medium fertility and mortality assumptions, the proportion of the elderly in rural and urban areas will be 33.1 and 20.8 percent, respectively, by the middle of this century (see Figure 4). In 2050, the percent of oldest-old in rural areas may be twice as high as that in urban areas (see Figure 5). It is important to note that these projected figures are under the assumption that the age distribution of the rural-urban migrants in the next a few decades will be the same as that observed in the 2000 census. This suggests that if Chinese rural-urban migration continues to include young people only, with elderly parents remaining in rural areas, as was indicated in the 2000 census, the percent of elderly in general and the oldest-old in particular will be too high for rural society to manage in just a few decades. Thus, China needs to investigate and adopt policies to encourage rural-to-urban family migration or family reunions after the young migrants settle in urban locales, to avoid the "elderly village" phenomenon spreading throughout rural areas, and to prevent resulting serious social problems.

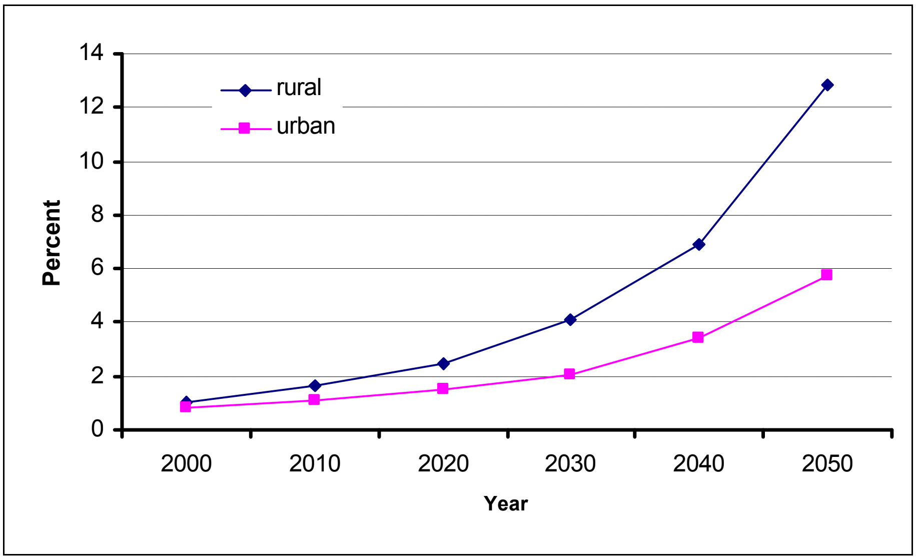
Figure 4 – *Projected percentage of elderly aged 65+ among rural and urban total population under the assumption of medium fertility and mortality: a comparison between rural and urban areas, 2000-2050*



4.2 Projection of family household structure and size

According to our projections, the average household size of China will continuously decrease from 3.46 persons per household in 2000 to 2.96 and 2.67 in 2020 and 2050 (see Figure 6). The annual projections of the household size distributions show that there will be proportionally more small households (one or two persons) and fewer large households (6 or more persons) in the future years as compared to the year 2000. Note that the Chinese family household has dramatically transferred from a larger unit before the late 1970s to a smaller one in the early 21st century and will continue to devolve to an even smaller size in the next a few decades. We believe that this phenomenon was caused by a tremendous fertility decline plus substantial changes in social attitudes and economic mobility related

Figure 5 – *Projected percentage of elderly aged 80+ among rural and urban total population under the assumptions of medium fertility and mortality: a comparison between rural and urban areas, 2000-2050*

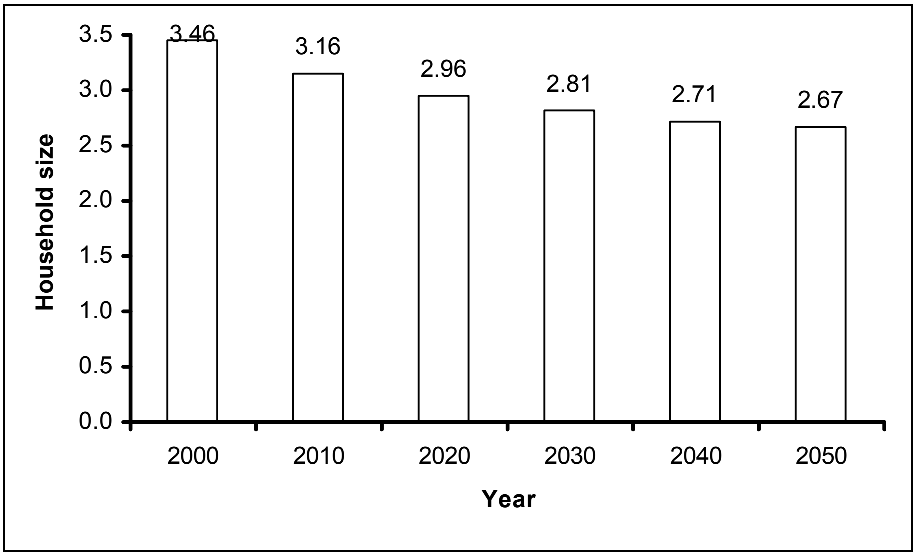


to co-residence between elder parents and adult children. Clearly, the government's policy on birth control is one of the preeminent causes of the family revolution in China, characterized mainly by the trend toward much lower fertility, later marriage, and smaller household size. This is, in general, in agreement with the arguments of Wolf (1986).

The projected proportions of households with various types among the total number of households under the medium fertility and mortality assumptions are given in Table 2. Our projections show that the proportion of the households with at least one person aged 65+ (we may call such households "elderly households") will increase dramatically in China in the next few decades. In 2030 and 2050, the percentage of households with one-elder living alone will be 2.17 and 4.08 times as high as that in 2000; the percentage of households with one-old-couple without other family members living together will be 2.02 and 2.98 times as high as that in 2000. The overall proportion of the elderly households (including one-generation of elder(s), two-generation and three-generation household with at least one elder) in 2030 and 2050 will be 30.0% and 84.6% higher than that in the year 2000.

Households with one-person-only aged less than 65 will increase from 6.8% in 2000 to 12.4% in 2050. However, the percentage of households

Figure 6 – *Changes in average family household size under the medium fertility and medium mortality assumptions*



with one-couple and child(ren) without elderly parents living together will decrease from 51.8% in 2000 to 34.6% in 2030 and 27.7% in 2050, respectively. The share of the one-couple-only households and the households of one-single-parent and child(ren) without elderly parents living together will somewhat increase in the period 2000-2030 and then decline considerably thereafter. The overall percentage of the households without elders aged 65+ will decrease from 76.0% in 2000 to 68.8% and 55.7% in 2030 and 2050, a substantial decrease, respectively (see Table 2). The substantial decrease in the percentage of young or relatively young households (*i.e.* those households without an elder member(s) aged 65+) and the dramatic increase in elderly households, clearly indicate that Chinese family households will be aging rapidly and substantially in the next a few decades.

4.3 Proportion of elderly who live in the empty-nest households

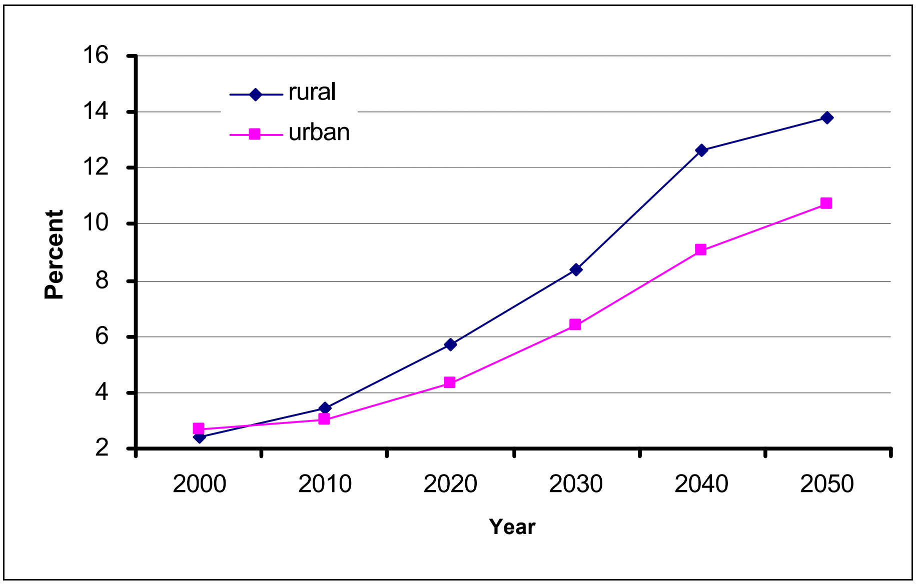
By the year 2030 and 2050, the rural-urban combined proportion of elderly aged 65 and above living in empty-nest households without children living together among the total population will be 2.9 and 4.6 times of that in 2000, under the medium fertility and mortality assumptions. The increase in percentages of the oldest-old aged 80+ living in empty-nest households

Table 2 – *Percentages of households by type among the total number of households under the medium fertility and medium mortality assumption*

Household types	2000	2030	2040	2050
Households without elderly persons				
One person	6.78	13.16	12.93	12.36
One couple (no elderly parents, or children)	10.75	13.38	11.72	10.19
Couple with at least one child, but no elderly parents	51.81	34.55	28.83	27.65
Single parent with at least one child, but no elderly parents	6.70	7.71	5.86	5.52
Sub total	*76.04*	*68.80*	*59.34*	*55.72*
Households with at least one elderly person				
One person only	2.54	5.51	8.06	10.37
One couple, only	2.74	6.06	8.08	8.16
One couple with at least one child	0.03	3.69	5.62	5.59
Single parent with at least one child	0.06	4.86	8.90	10.68
Three or more generations with one or two elderly parents	18.61	11.06	10.02	9.48
Sub total	*23.98*	*31.18*	*40.68*	*44.28*
Total	**100.00**	**100.00**	**100.00**	**100.00**

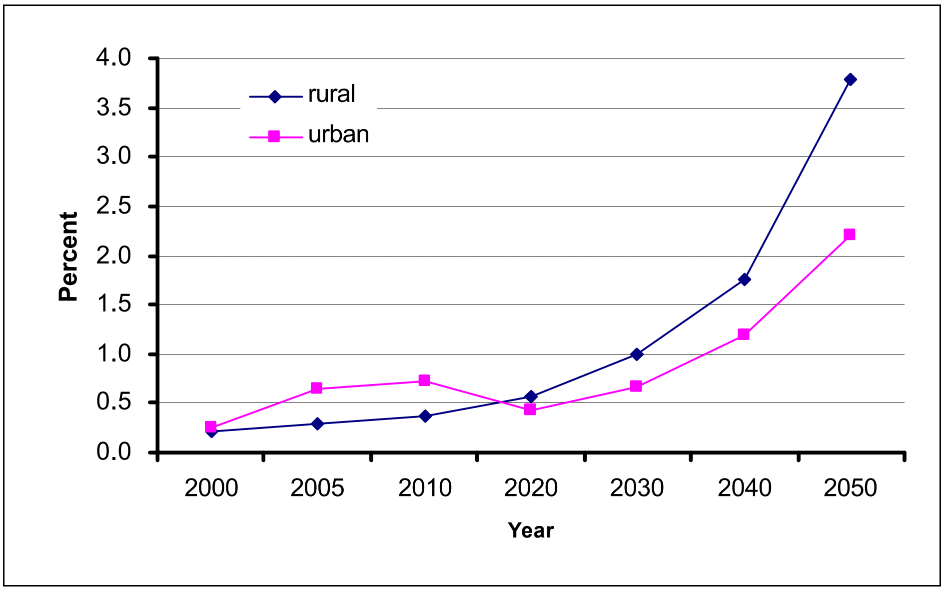
will be even more dramatic: 3.4 and 11.1 times in 2030 and 2050 as high as that in the year 2000. Figures 7 and 8 depict the rural-urban differentials in percentages of the elderly aged 65+ and the oldest-old living in empty-nest households. The rural and urban curves are very close to each other in 2000, and the gap becomes very large after 2030.

Figure 7 – *Projected percentage of elderly aged 65+ who are living in empty-nest household among the rural and urban total population: a comparison between rural and urban areas, 2000-2050*



Note that in our household and population projection, we have assumed that the preference of co-residence between old parents and adult children declines rather slowly. Thus, the large increase in the percentage of elderly living in empty-nest households is mainly due to the effects of fertility decline, which, on one hand, substantially increases the overall proportion of the elderly among the total population, and on the other hand, results in a much smaller resource of offspring, which is one of the determinants of co-residence between older parents and children. In other words, in China in the future, considerable numbers of elderly persons may not be able to co-reside with children, even if they wish to do so, due to the shortage of children.

Figure 8 – *Projected percentage of oldest-old aged 80+who are living in empty-nest household among the rural and urban total population under the assumptions of medium fertility and mortality: a comparison between rural and urban areas, 2000-2050*



4.4 Demographic window of opportunity up to 2030 and serious challenges thereafter

One of the most widely used demographic indices to approximately measure the relative productive and dependency potential is the dependency ratio. The child dependency ratio is defined as the ratio of children under age 15 to the population aged 15-64, and the old-age dependency ratio is defined as the ratio of elderly aged 65 and over to the population aged 15-64. The sum of the child and the old-age dependency ratio is called the total dependency ratio (Smith, 1992:14). This conventionally defined dependency ratio assumes that an average child and an average elderly person depend equally on the working-age population. This, however, may not be accurate in reality, especially in the societies where elders' remaining life span is and will be continuously and substantially prolonged. Clark and Spengler (1978) reported that a broader survey of the costs of public support in the U.S. revealed that the average ratio of government expenditures for elderly to government expenditures for children was 1:0.33. The average ratio of total expenditures, including governmental and family costs for the elderly to those for children was found to be 1:0.58 in Germany (U.N., 1973), and 1:0.31 in France (Rix and Fisher, 1982). Three different surveys conducted in China gave estimates of the average ratio of total expenditures for the elderly to those for children as 1:0.40 (Liu, 1984), 1:0.55 (World Bank, 1984) and 1:0.53 (Yu, 1992). We simply take the average of these three estimates, namely 1:0.5, as the elderly/children expenditure ratio in China. Keeping the sum of the weights for the old-age dependency ratio and child dependency ratio equal to 2 which is the same as that of the un-weighted total dependency ratio, and using the average ratio of the total expenditures for elderly to those for children as 1:0.5, we can compute:

Weighted total dependency ratio = (0.6667 x child dependency ratio) +
1.333 x elderly dependency ratio).

Note that not all of the persons aged 15-64 work, and not all elderly persons aged 65+ do not work, and the average estimate of 1:0.5 as the elderly/children expenditure ratio, based on the three Chinese survey studies, may not be accurate for future years. Therefore, the estimates of the dependency ratios to be discussed below can only be regarded as proxies for the productive and dependency potential in the first half of the 21st century.

With the medium fertility and medium mortality assumptions, the old-age dependency ratio in China in 2020 and 2030 will increase by 7 and 15 percentage points, as compared to the year 2000. However, the child dependency ratio will decrease by 12 and 14 percentage points in the same period. Offsetting the increase in the old-age dependency ratio by a decrease in child dependency ratio, the un-weighted total dependency ratio in China in 2020 will be smaller than that in 2000 by 5 percentage points, and in 2030 the un-weighted total dependency ratio will be the same as that in 2000. When we take into account that the elderly need more support than children, the Chinese weighted total dependency ratio will increase by 2 and 11 percentage points in 2020 and 2030, respectively, as compared to 2000. Either the un-weighted total dependency ratio or the weighed total dependency ratio will increase dramatically after 2030 due to a large increase in the old-age dependency ratio and a stabilisation of the child dependency ratio (see Table 3).

Clearly, a demographic window of opportunity (or demographic bonus or dividend) is open in the next a couple of decades, due to the increasing large labor force population, decreasing number of children, and not yet very high proportion of elderly. However, the Chinese demographic window of opportunity will be closed after 2030 with serious challenges due to rapid population aging and a large decrease in family support capacities and resources.

Table 3 – *Un-weighted and weighted total dependency ratios*

	2000	2010	2020	2030	2040	2050
Child depend. ratio	0.46	0.34	0.34	0.32	0.32	0.34
Elderly depend. ratio	0.11	0.12	0.18	0.26	0.38	0.42
Un-weighted tot depend. ratio	0.57	0.46	0.52	0.57	0.69	0.75
Weighted tot depend. ratio	0.45	0.39	0.47	0.56	0.72	0.79

5. CONCLUDING REMARKS

Fertility in China has declined dramatically from more than 6 children per woman in the 1950s and 1960s to about 1.6 to 1.7 children per woman today, significantly lower than that in the U.S. Average life expectancy at birth for both sexes combined in China has increased from about 41 years in 1950 to 68.4 years in 1990, 71.4 years in 2000, and 73.0 years in 2005 and will continue to increase in the future. Large cohorts of baby boomers born in the 1950s and 1960s will become elderly in a couple of decades. Demographic regimes have determined that China, the most populous country in the world with 1.27 billion people in 2000, is aging at a rapid speed and to a large scale, especially the oldest-old population aged 80+.

The Chinese family household has transformed from a larger unit before the late 1970s to a much smaller one in the early 21st century, and will continue to evolve to an even smaller size in the next few decades. We believe that this phenomenon was and will continue to be caused by a tremendous fertility decline plus substantial changes in social attitudes and economic mobility related to co-residence between elderly parents and adult children. Under our medium fertility and mortality scenarios we show that the proportion of elderly households with at least one person aged 65+ will increase dramatically in China. For example, the overall proportion of elderly households in 2030 and 2050 will be 30% and 85% higher than that in the year 2000. At the same time, the percentage of young or relatively young households (*i.e.* those households without old member(s) aged 65+) will substantially decrease. This indicates that Chinese family households will be aging rapidly and substantially in the first half of the 21st century.

By the year 2030 and 2050, the proportion of the elderly aged 65 or above living in empty-nest households without co-residing children among the total population will be 2.9 and 4.6 times of that in 2000. The increase in the percentage of the oldest-old aged 80+ living in empty-nest households will be even more dramatic: 3.4 and 11.1 times in 2030 and 2050 as in the year 2000.

Although fertility in rural areas in China is much higher than that in urban areas, aging problems with respect to proportions of elderly and elderly households, as well as proportions of elderly living in empty-nest households will be much more serious in rural areas, because of the continuing massive rural-urban migration. Such anticipated trends are based on the assumption that the age distribution of the rural-urban migrants in the future will be the same as that observed in the 2000 census, namely, that almost all rural-urban migrants will be young people. Our study strongly suggests that China needs to adopt policies to encourage rural-to-urban family migration or family reunion after the young migrants are settled in urban areas, to avoid the "elderly village" phenomenon in rural areas, which portends serious social problems in the future.

Our projection also indicates a demographic widow of opportunity is open in the next a couple of decades, due to a large labor force, decreasing numbers of children, and not yet burdensome proportion of elderly. During this "golden-age" period, it is possible for China to mobilize large amount of individual savings and state capital for building a solid financial and institutional base of social security programs in both rural and urban areas. However we have to act now because this demographic widow of opportunity will be closed around 2030 at which time it will be too late to start to resolve China's looming serious social and economic problems.

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Appendix A
Data sources and estimates of the sex-age-specific occurrence/exposure rates in rural and urban areas in China

The sex-age-specific occurrence/exposure (o/e) rates are defined as the number of demographic events (*i.e.* first marriage, divorce, remarriage, and parity-specific fertility) divided by the person-years lived at risk of experiencing the events in the age group and period.

A1. Standard schedules of the sex-age-specific occurrence/exposure rates of first marriage in rural and urban areas

The Chinese 2000 census collected the date (year and month) of first marriage for all persons aged 15 and above. Using these data, we have estimated the standard schedules of the sex-age-specific average o/e rates of first marriage in the period 1990-2000 in rural and urban areas. Because our objective is to estimate the o/e rates, which represent the first marriage propensity in 2000, we first multiply the standard schedules of the sex-age-specific o/e rates of first marriage by the sex-age-specific numbers of never-married persons derived from the 2000 census to get the "implied" total number of first marriages. We then compare it to the published total number of first marriages, and proportionally adjust the sex-age-specific standard schedules of the o/e rates of first marriage to estimate the o/e rates of first marriage in 2000, which match the published total number of first marriages in 2000.

A2. Standard schedules of the sex-age-specific occurrence/exposure rates of divorce and remarriage in rural and urban areas

Based on the Chinese Longitudinal Healthy Longevity Survey conducted in 1998, 2000, and 2002, the only nation-wide data source of event history of divorce and remarriage after the In-Depth Fertility Surveys conducted in 1985 in Shanghai, Hebei, and Shannxi in 1985. Using the In-Depth Fertility Survey and the CLHLS data sources, we estimated the standard schedules of the sex-age-specific occurrence/exposure rates of divorce and remarriage in rural and urban areas. In order to estimate the sex-age-specific o/e rates in 2000, which is the starting year of our family household projection, we multiply the standard schedules of sex-age-specific o/e rates of divorce and remarriage by the sex-age-specific numbers of currently married, divorced and widowed persons derived from the 2000 census to derive the "implied" total numbers of divorce and remarriage; we then compared them to the published total numbers of divorces and remarriages, and proportionally adjusted the sex-age-specific average o/e rates of divorce and remarriage to estimate the o/e rates of divorce and remarriage in 2000, which match the published total numbers of divorces and remarriages in 2000.

A3. Standard schedules of the age-parity-specific o/e rates of marital fertility in rural and urban areas

Age-parity-specific o/e rates of marital fertility in rural and urban areas are estimated based on the 1997 and 2001 national sampling surveys on reproductive health. We assume that births outside of marriage are negligible.

A4. Standard schedules of the sex-age-specific frequencies distributions of rural-urban net migration

The sex-age-specific frequency distributions of rural-urban net migration are estimated based on the 2000 census data. The sum of the age-specific frequencies of rural-urban net migration is equal to one. We derive the sex-specific total number of rural-urban net migrants in future years using the projected proportion of the urban population and the projected sex ratio of migrants. Multiplying the total number of these projected sex-specific rural-urban migrants by the standard schedules of the sex-age-specific frequencies, we derive the sex-age-specific numbers of rural-urban net migrants in future years.

A5. Standard schedules of the age-sex-specific net rates of leaving the parental home

Based on the 1990 and 1982 census micro data files, we ran the ProFamy program to estimate the standard schedules of the age-sex-specific net rates of leaving home, using a method initially proposed by Coale (1984; 1985), Coale *et al*. (1985), and generalized by Stupp (1988). Note that we did not use the 2000 micro data file for estimating leaving home rates because we discovered that the 2000 micro data file quality is not as good for this purpose as the 1990 and 1982 census micro data files. Using the 1990 and 1982 census micro data files to estimate the leaving home rates does not negatively affect the quality of our family household projection, because, while the demographic summary measures are crucial, the projection results are not substantially sensitive to the age-specific standard schedules as long as they reveal the general age pattern of the demographic process of the population (see Zeng *et al*., 2006, p.12 for empirical validation).

Appendix B
Estimation of proportion of adult children who eventually leave parental home and proportion of old parents who do not live with adult child, while taking into account the effects of changes in fertility

Let's define the following variables:

n_2 Proportion of old parents who do not live with adult child among those who have at least one adult child, due to preference of independent living or children's mobility or other socioeconomic reasons;

n_3 Proportion of old parents who are not able to live with adult child even if they wish to do so among those who have at least one adult child, due to shortage of children (*i.e.* number of members of the children generation is smaller than number of members of the parental generation);

n_0 Probability of dying of both parents before their children reach average age at birth;

n_1 Proportion of life-time infecundity;

M Proportion of adult children who eventually marry;

$P(m)$ Male and female combined probability of surviving up to average age at childbearing of women;

G Index of offspring resource with respect to co-residence between old parents and adult children; G is defined as the sum of average number of couples of the children generation per elderly parents and the elderly parents' average number of adult children who were never-married for whole life.

$$G = 0.5M \cdot TFR \cdot P(m) + (1 - M) \cdot TFR \cdot P(m)$$

S Proportion of adult children who live with old parents in the long-term;

L Proportion of adult children who eventually leave parental home;

N Proportion of old parents who live with an adult child (and the child's spouse if the child is married).

B1. Estimation S *and* L *for the generation of adult children*

$$S = \frac{1 - n_0 - n_1 - n_3 - [1 - n_0 - n_1 - n_3] \cdot n_2}{G} \quad \text{[B-1]}$$

$$n_2 = 1 - \frac{S \cdot G}{1 - n_0 - n_1 - n_3} \quad \text{[B-2]}$$

$$L = 1 - S$$

$$0 \le S \le 1; \quad G \ge 0; \quad n_0 \ge 0; \quad n_1 \ge 0; \quad n_2 \ge 0; \quad n_3 \ge 0;$$

$$\begin{aligned} &\text{If } G \ge (1 - n_0 - n_1), n_3 = 0. \\ &\text{If } G \le (1 - n_0 - n_1), n_3 = 1 - n_0 - n_1 - G. \end{aligned} \quad \text{[B-3]}$$

Therefore, we only need $P(m)$, M, n_0, n_1, n_2 and cohort-specific *TFR* to estimate S and L, which are needed for family household projection. $P(m)$, M, n_0, n_1, and *TFR* can be easily estimated from demographic data sources, which is straightforward, but estimation of n_2 needs some more discussion. We may consider the census or survey observed proportion of adult children aged 35-39 who live with parents as an approximation of S, so that we can estimate the n_2 of the parents of children cohort aged 35-39 at the census time, using the formula [B-2] in either the case (1) or (2) as follows:

(1) If $G \ge (1 - n_0 - n_1)$, $n_3 = 0$, and $n_2 = 1 - \frac{S \cdot G}{1 - n_0 - n_1}$;

(2) If $G \le (1 - n_0 - n_1)$, $n_3 = 1 - n_0 - n_1 - G$, and

$$S = \frac{1 - n_0 - n_1 - 1 + n_0 + n_1 + G - (1 - n_0 - n_1 - 1 + n_0 + n_1 + G) \cdot n_2}{G}$$

$$= \frac{G - G \cdot n_2}{G} = 1 - n_2$$

$$n_2 = 1 - S.$$

Once we estimated the n_2 of the parents of children cohort aged 35-39 at the census time, we can estimate or project (or assume) the n_2 for other older and younger cohorts, and then estimate their S and L.

Using the estimated S and L and the sex-age-specific standard schedules of net rates of leaving the parental home, we estimate the sex-age-specific net rates of leaving home for each of the cohorts, and we then transfer (or reorganize) the cohort rates into period sex-age-specific net rates of leaving home for family household projection.

B2. Estimating N *for the generation of old parents*

$$N = 1 - n_1 - n_3 - (1 - n_1 - n_3) \cdot n_2 . \qquad \text{[B-4]}$$

We can estimate the *N*, using the formula [B-4] in either the case (1) or (2) as follows:

(1) If $G \geq (1 - n_1), n_3 = 0,$

$N = 1 - n_1 - (1 - n_1) \cdot n_2 .$

(2) If $G \leq (1 - n_1), n_3 = 1 - n_1 - G,$

$N = 1 - n_1 - 1 + n_1 + G - (1 - n_1 - 1 - n_1 + G) \cdot n_2 = G - G \cdot n_2 .$

N is an average proportion of the old parents who live with an adult child (and the child's spouse if the child is married), and *N* represents the overall level of co-residence between old parents and adult children. In the same time, we estimate the sex-age-marital status-specific proportions of elderly living with children as a standard schedule based on the census (or survey) data. Using the estimated *N* for each of the elderly cohorts and the sex-age-marital status-specific standard schedules of proportions of elderly living with children, we estimate the sex-age-marital status-specific proportions of living with children for each of the elderly cohorts, and we then transfer (or reorganize) the cohort proportions into period proportions.

Appendix C

Table C1 - *Assumptions of demographic parameters of mortality, marriage and divorce and sex ratios at birth*

Parameters	Rural			Urban		
	2000	2020	2050	2000	2020	2050
Male LE at birth	68.0	70.8	75.0	72.0	74.6	78.6
Female LE at birth	72.0	74.8	78.9	76.0	78.6	82.5
General rate of marriage	0.0674	0.0674	0.0674	0.0601	0.0601	0.0601
General rate of divorce	0.0022	0.0022	0.0022	0.0056	0.0056	0.0056
Sex ratio at birth	118.0	110.7	107.0	113.0	108.3	106.0

Note: The net international migration was assumed to be negligible.