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Are Older Persons in China Living More Years in an Independent Living Arrangement? Estimates Using Multistate Life Tables

Zachary Zimmer and Chi-Tsun Chiu

ABSTRACT Adopting a multistate life table approach, this study estimates number of years the very old in China expect to live in an independent living arrangement (alone or with spouse only)—an estimate we term "independent living life expectancy" (ILLE)—as opposed to in coresidence with adult children or others. We also estimate how ILLE and proportion of total life expectancy (TLE) residing independently has changed over time. The backdrop for this study is a society experiencing both increasing longevity and social changes that influence the tendency to live in an independent living arrangement. The study concentrates on assessing whether changes in ILLE match or surpass gains in TLE experienced by oldest-old Chinese adults. Data are from the 2002–2014 Chinese Longitudinal Healthy Longevity Survey, and estimation is conducted using the Stochastic Population Analysis for Complex Events software. Results suggest that on balance, gains in ILLE are proportionately greater than gains in TLE, indicating an expansion of ILLE for most Chinese elders. Males, septuagenarian females, and disabled septuagenarians are the most likely to be living proportionately longer lives in an independent living arrangement. In contrast, extremely old (nonagenarian and centenarian) females and extremely old disabled individuals are least likely to have experienced dramatic changes in proportion of life residing independently. The findings imply some support for the hypothesis that given the maintenance of family solidarity in China, those in greatest need are least likely to encounter the most extreme changes toward independent living arrangements.

KEYWORDS Aging • China • Households • Life expectancy • Oldest-old

Introduction

Increasing longevity in China, as elsewhere around the world, means that people are living to older and older ages. Adopting a multistate life table approach, the current study examines number of years the very old in China can expect to live in an independent living arrangement (alone or with spouse only)—which we term "independent living life expectancy"—as opposed to in coresidence with adult children or with others. In the process, we address the notion of increasing longevity by assessing whether years of life gained are spent in an independent living arrangement. We derive estimates for males and females across four old-age groups—septuagenarians, octogenari-

ans, nonagenarians, and centenarians—and for married and nonmarried persons with and without disabilities.

These estimations take place in a milieu where coresidence between an older person and one or more adult children has been a long-standing and continuing practice and a fundamental way of structuring households (Bongaarts and Zimmer 2002; Chen 2005; Logan and Bian 1999; Martin 1989; Treas and Chen 2000; United Nations 2005; Wu and Schimmele 2008; Zeng and George 2001; Zeng and Wang 2003; Zhang 2004). For instance, Li et al. (2009) reported that about 68% of the oldest-old (those aged 77+) in China lived with one or more adult child in 1998. Sereny (2011) reported that about 64% of Chinese aged 65 and older lived with an adult child in 2005, whereas only about 31% lived alone or with spouse only. A number of more recent reviews confirmed that coresidence remains a prominent household formation for older persons in China and that independent living arrangements are less prevalent (Fan et al. 2018; Ren and Treiman 2015; Zhang et al. 2014; Zhou et al. 2018).

At a population level, the prominence of coresidential living arrangements in China, as elsewhere in the developing world, is often explained with some combination of sociological and economic perspectives. Sociologically, coresidential living with adult children allows for support to be provided to older adults in close proximity and has traditionally been considered an appropriate way of expressing filial piety (Qi 2015; Silverstein et al. 2006; Whyte 2003; Zhang et al. 2014). In addition, older persons who are living with their adult children can contribute in instrumental ways to their family through grandparenting and other such caretaking or homecare assistance roles (Chen and Liu 2011; Chen et al. 2011; Silverstein et al. 2007). Economically, given the tendency of developing countries like China to have fairly weak formal systems of social security, filial piety expressed through coresidential living is a way of informally supporting the older segment of the population and consequently maintaining an acceptable standard of living for a nonworking subset of the population (Frazier 2006; Liu and Sun 2016; Wang 2006).

Research has also explained such arrangements by examining proximate causes. Frequently cited determinants of coresidence are age, sex, marital status, disability or other health status, rural versus urban residence, family size, and level of education (Chen 2005; Chen and Short 2008; Cong and Silverstein 2010; Logan and Bian 1999; Logan et al. 1998; Silverstein 1995; Silverstein and Angelelli 1998; Silverstein et al. 2006). Similarly, longitudinal analyses have examined determinants of transitions into and out of coresidence. Korinek et al. (2011) found that a rise in the probability of living coresidentially follows life course changes, such as the transition to widowhood among older Chinese adults. Others have found that older adults in China, especially women, are likely to transition out of independent living into coresidence when their health deteriorates (Zhou et al. 2018; Zimmer 2005). These transition studies suggest that living arrangements are shaped by factors related to the personal need for support. For instance, older people who experience progressively worsening health are increasingly likely to require instrumental help. Widowhood can remove a primary source of instrumental assistance, creating support needs. Widowhood can influence financial resources in other ways as well. Pension systems in China are rapidly being reformed, but research has indicated that inequalities remain. Those living in rural areas, those in urban areas without jobs, housewives, women, and rural migrant workers are less likely than others to be protected by formal pension plans (Liu and Sun

2016; Queisser et al. 2016; Zhu and Walker 2018). Worsening health or becoming a widow could prompt a change in living situation to coresidence. Similarly, staying in good health or continuing to live with a spouse may keep an older person living in an independent arrangement or even provide the impetus to move from a coresidential to an independent living arrangement.

Chinese Context

Part of the impetus for the current analysis relates to macro level forces that promote independent living arrangements for older adults in China by putting pressure on normative ways of structuring support. First, demographic forces can affect independent living. Population aging is particularly rapid in China (Chen and Liu 2009), largely as a result of fertility declines in recent decades that produced smaller younger cohorts relative to older cohorts. Partly a function of its well-known one-child policy that was introduced in 1979, China's total fertility rate fell from nearly 6.5 to 1.5 children per woman between the 1960s and the mid-1990s (United Nations 2018). As children from higher fertility regimes move into old age, their numbers swell relative to the total. In 1960, those 70 and older in China constituted about 2% of the total population. The percentage passed 5% by 2010 and is projected to reach about 20% by 2050. The oldest-old are growing faster than any other segment in proportional terms. In 1960, those aged 80 and older in China accounted for less than 0.2% of the total population. This figure reached about 1.5% by 2010, and it is expected to pass 8% by 2050 and continue to rise thereafter. A reduction in younger relative to older persons may reduce opportunities to coreside, thus promoting independent living.

Second, economic growth and globalization can promote independent living. Globalization has transformed China, causing changes in the structure of labor, increased migration, rapid urbanization, alteration of family dynamics, transformations of socioeconomic conditions, and a host of other social and economic realities (Biao 2006; Bloom et al. 2006; Breznitz and Murphree 2011; Changmin 2000; Fenggan 2000; Gallagher 2011; Giles et al. 2010; Guo et al. 2009; He and Ye 2014; Meng and Yamauchi 2017; Meyerhoefer and Chen 2011; Ngai 2016; Sheng and Settles 2006; Wang et al. 2015; Ye et al. 2013). Opportunities for work are increasing in urban centers, greatly expanding urban populations and prompting younger persons to migrate, often leaving older persons behind (He and Ye 2014). These labor opportunities, along with changes in the nature of labor and types of jobs available, are increasing incomes and levels of education, leading to a growing middle class. These changes can shift values toward independence and self-reliance rather than dependence on the family for survival. Although changes in economic conditions and subsequent norms and values could reduce younger adults' interest in living with parents, movement up the socioeconomic ladder could also mean that older persons are more likely to be supported through remittances rather than through proximate living.

This said, whether older persons are "left behind" in the face of these demographic and economic changes is also a function of specific political and cultural factors unique to China. First, starting in the late 1980s, China began implementing major housing reforms aimed at promoting property rights and private ownership within a rapidly developing housing market. Many of the reforms that took effect within the time frame

considered in the current study have helped to increase private ownership (He et al. 2017; Wang et al. 2020). For instance, the Economic and Comfortable Housing program modified in 2007 increased the availability of moderately sized housing units in urban areas (Deng et al. 2011). However, China has also experienced sharply rising housing prices (Sato et al. 2013; Sicular et al. 2017), and homeownership continues to favor those in the public sector (Gu et al. 2016).

Second, these housing changes are taking place within a complex and changing social environment. Family solidarity remains robust, and living coresident with adult children remains common (Cong and Silverstein 2008; Silverstein et al. 2012; Zeng and Wang 2003; Zhang 2004; Zimmer and Kwong 2003). But, some research suggests that values are changing such that older persons increasingly prefer to live independently if they have the ability to support themselves (Cornman et al. 2003; Sereny 2011). Social security and pension systems are slowly being strengthened, allowing greater economic independence (Liu and Sun 2016). At the same time, rapid population aging, and especially increases in numbers of the very old, places pressures on healthcare systems and both formal and informal support systems. An extensive set of healthcare reforms in China, many of which were implemented during the period under study, have expanded access to health insurance, provided older citizens with better access to quality and affordable healthcare, and expanded public health in response to the aging of the country (Beard and Bloom 2015; Yip et al. 2019). These reforms are complicated by a *hukou* system, which requires individuals to register as a resident of an area and a household identified as being rural or urban (Chan 2019; Chan and Zhang 1999). The difficulty in obtaining services, such as healthcare, when moving out of one's area of registration may be a factor in keeping some adult children in rural areas living at least near their older parents if not with them.

Concurrently, China is undergoing epidemiological changes. China's life expectancy at birth for both sexes combined was approximately age 44 around 1960 and surpassed age 76 in 2015—a level almost on par with the United States (United Nations 2018; Zimmer et al. 2015). Increases in life expectancy at birth means that more people will reach old age. However, life expectancy for those already in old age has also been on the rise. Life expectancy for those aged 80 was about 3.2 years in 1960, hit about 7.0 in 2015, and is projected to increase further. Of concern to those studying the influence of population aging combined with increasing longevity on societies are the consequences for older persons most in need of support, often the very old. These researchers ask questions such as, does the trend toward living to increasingly older ages impact household structures in China, and are these impacts associated with other demographic, social, and economic changes that take place concurrently? In particular, do demographic, social, and economic forces in China increase the prevalence of independent living arrangements even among the very old, who may be in ill health and widowed, or do values regarding family solidarity override societal transformations, keeping these older persons in coresidential situations?

Current Study

In the current analysis, we contribute to this discourse by focusing on the tendency of older persons to live in an independent living arrangement, either alone or with

a spouse only. We examine trends for males and females, dividing older adults into four age groups: septuagenarians, octogenarians, nonagenarians, and centenarians. Employing a multistate life table method, we investigate not only how the tendency to live in an independent living arrangement has been changing over time but also how changing inclinations operate within the context of increasing longevity. A multistate life table technique is especially appropriate for examining an outcome that is subject to frequent transitions over time, such as when a large proportion of the population being investigated can expect to live part of their remaining lives in the various states under scrutiny. This is the case with independent living arrangements: past research has shown that older persons in China frequently shift between living arrangement states, especially when influenced by changes in health and marital status, and that the oldest-old are particularly vulnerable to such shifting (Zimmer and Korinek 2010). We therefore assess the degree to which longer life simultaneously translates into additional years of life spent in an independent living arrangement versus coresiding with adult children or in some other coresidential arrangement.

We address three research questions. First, is there a trend toward a longer independent living life expectancy (ILLE) among the old in China? Second, given gains in total life expectancy (TLE), are older adults living a greater proportion of life in an independent living arrangement? That is, are gains in ILLE keeping up with gains in TLE? Third, are changes in ILLE sensitive to factors shown in past research to be important for shaping transitions between independent living arrangements—namely, age, sex, marital status, and disability status?

In investigating the third research question, we control for rural/urban residence, education, and number of living children. Given realities of the changing Chinese environment, our main hypothesis is that gains in ILLE are surpassing gains in TLE, which we refer to as an *expansion* of ILLE. At the same time, because of the nature of filial piety in China and the tendency toward family solidarity, we secondarily hypothesize that expansion of ILLE is less pronounced or is constrained among more vulnerable groups, including the oldest-old (nonagenarians and centenarians), the unmarried, and disabled persons.

Methods

Data

Because of its concentration on the oldest-old and longitudinal panel nature of its data collection strategy, the China Longitudinal Healthy Longevity Study (CLHLS) is an ideal source for addressing our research questions. The CLHLS was conducted across 22 provinces of China, covering 85% of its population, and contains multiple waves of data. The first wave was gathered in 1998. Follow-ups in 2000, 2002, 2005, 2008, 2011, and 2014 involved survivors from earlier waves plus add-ins to account for mortality and other attrition. The age of the sample was 80+ when the study was launched but was expanded to 65+ in 2002. The current analysis employs survey and survival data from four waves of the CLHLS: 2002, 2005, 2011, and 2014.

Two qualities of the CLHLS data make it particularly suitable for this analysis. First, the CLHLS was originally designed to contain adequate samples within 10-year age

Table 1 Sample size by baseline year, sex, and baseline age group

		2002 Baseline		2011 Baseline		
Age Group	Age at Baseline	Female	Male	Female	Male	Total
Septuagenarian	70–79	1,372	1,415	1,066	1,186	5,039
Octogenarian	80–89	1,849	1,868	1,198	1,205	6,120
Nonagenarian	90–99	1,909	1,383	1,280	939	5,511
Centenarian	100–105	1,964	544	609	180	3,297
Total		7,094	5,210	4,153	3,510	19,967

groups. In earlier waves, all centenarians within study areas were targeted in addition to one octogenarian and one nonagenarian who lived nearby the centenarian respondent, which assured large numbers within age groups. The result is a data set that has suitable sample sizes for each of four 10-year age groups under scrutiny in this analysis: septuagenarians (ages 70–79), octogenarians (ages 80–89), nonagenarians (ages 90–99), and centenarians (100+). Data are representative within age groups but not across age groups. Thus, for instance, results for septuagenarians may be generalizable to septuagenarians but not to the total population aged 70+. The CLHLS provides probability weights that can be used to generalize to the total older population. Weights are applied in all procedures to follow.

Second, the technique we employ necessitates calculating transition probabilities across data waves, which requires panel data with a baseline and follow-up observation. We use 2002 as the baseline wave for the earlier period, with 2005 as the follow-up; we use 2011 as a second baseline wave for the later period, with 2014 as the follow-up. Individuals are categorized into age groups for the analysis based on their age at baseline. Table 1 provides the sample size for males and females across periods by baseline age. The 2002 baseline contains a sample of 12,304 individuals who are followed up in 2005. The 2011 baseline has a sample of 7,663 individuals who are followed up in 2014. The data contain a large number of very old individuals and a greater number of octogenarians, nonagenarians, and centenarians than would be the case if sampling were executed in a way that exactly represented the population. Note that the centenarian group is limited to ages 100–105 at baseline because CLHLS information suggests that exact age is not reliable beyond age 105.

Information on data quality can be found on the study's website (http://sites.duke.edu/centerforaging/programs/chinese-longitudinal-healthy-longevity-survey-clhls). The data have been tested for reliability (Zeng and George 2001; Zeng and Gu 2008; Zeng et al. 2002). The CLHLS has become a critical data source for studying the oldest-old in China, having been used for a multitude of peer-reviewed published articles, as well as theses and dissertations. A number of these studies have examined issues related to life expectancy (Dupre et al. 2008; Gu et al. 2009; Zimmer et al. 2015).

Measures

The outcome is whether an individual is in an independent living arrangement based on a household roster. Those living in an independent living arrangement are liv-

Table 2 Descriptive statistics for study variables showing percentages or means, with standard deviations shown in parentheses

	Baseline 2002		Baseline 2011	
	Females (N=7,094)	Males (N=5,210)	Females (N=4,153)	Males (N=3,510)
Age				
% Septuagenarians	19.3	27.2	25.7	33.8
% Octogenarians	26.1	35.9	28.9	34.3
% Nonagenarians	26.9	26.6	30.8	26.8
% Centenarians	27.7	10.4	14.7	5.1
% Married	13.5	45.6	21.8	54.1
% With a Disability	37.1	22.7	28.5	20.0
% Rural	56.5	56.0	52.2	48.6
Mean Number of Living Children	2.9 (2.0)	3.4 (2.2)	3.8 (1.9)	3.8 (1.8)
Mean Years Education	0.6 (2.0)	3.2 (3.9)	0.8 (2.2)	3.5 (3.8)

ing either alone or with a spouse only. All others are coresident. Most coresidential arrangements are with children, but a small percentage live with others either in addition to, or instead of, children. A small percentage (about 3%) living in institutions are placed in the coresident category because they are not living independently. At baseline, an individual is coded as living in an independent living arrangement or not. At follow-up, the individual may be living in an independent living arrangement, coresident, or deceased. Decedent status, as monitored by the CLHLS team and recorded at follow-up, has been found to be valid (Dupre et al. 2009; Dupre et al. 2008; Gu 2007; Yi et al. 2001; Zeng et al. 2011).

We estimate TLE and ILLE across age, sex, marital status, and disability status while controlling for rural/urban residence, education, and number of living children. Age and sex are standard demographic variables. Past research has shown that disability and marital status are associated with life expectancies and living arrangements (Hsu and Chang 2015; Williams and Umberson 2004), and these variables are particularly important in establishing support needs and predicting changes in coresidential living arrangements (Korinek et al. 2011). Common frameworks for disablement conceptualize disability as either the end result of, or integrated within, a process that also involves chronic disorders, impairments, and functional limitation. Disability is therefore a broad indicator of health (Verbrugge and Jette 1994; World Health Organization 2001). Disabled individuals tend to require assistance in completing daily activities because of reduced physical functioning or cognitive disorders. Not living with a spouse eliminates the single most important source of instrumental support that is available to an older person.

Marital status is a dichotomous measure, with married and living with partner being one category and either being unmarried (e.g., widowed) or being married but not living with spouse as a second category. Disability status is based on six activities of daily living (Katz et al. 1963): eating, toileting, bathing, dressing, transferring, and continence. Those having trouble and needing assistance with any one of these items are coded as having a disability. Education is entered into equations as years of schooling. Number of living children is a control; the opportunity for coresidence is expected to

be greater as the number living children increases. Rural/urban residence is dichotomously coded. Table 2 provides descriptive statistics for the study variables by baseline year and sex.

Analytical Strategy

ILLE is defined as the number of years one can expect to live in an independent living arrangement, either alone or with a spouse only; TLE is the total number of years an individual can expect to live. All other living arrangements, whether with children or others, are not independent. To assess whether ILLE has expanded, we examine the ratio of ILLE to TLE, or the proportion of total remaining life expected to be lived in an independent living arrangement. We compare these estimates across periods: the 2002 baseline (or *earlier*) period versus the 2011 baseline (or *later*) period. If extra years of life gained between the earlier and later period are distributed proportionately into independent and nonindependent living arrangements, then there will be no change in the ratio over time. An *expansion* of the independent living arrangement is indicated by an increasing ratio. A *contraction* of the independent living arrangement is indicated by a decreasing ratio. An expansion provides support for our main hypothesis. However, our secondary hypothesis suggests that an expansion is expected to be less evident, or constrained, for the very old (e.g., nonagenarians and centenarians), the unmarried, and disabled individuals; therefore, the increasing ratios are expected to be lower or muted for these groups.

We estimate TLE and ILLE with the Stochastic Population Analysis for Complex Events (SPACE) software (Cai et al. 2010; Chiu 2018; Saito et al. 2014). SPACE estimates TLE and ILLE in two stages. In the first stage, multinomial regressions are fitted to determine the probability of a transition from a starting state (in this case, either an independent or a nonindependent living arrangement) to one of three outcome states (independent living arrangement, nonindependent living arrangement, or deceased) across baseline and follow-up waves by age and other covariates. These models are run on data converted from wide format, in which each individual has multiple observations, into long format, in which each observation occupies one line of data. Each line of data includes the individual's age and living arrangement status, as well as values for any other covariates in the model. Because an individual's age changes across subsequent observations and values for other covariates, such as marital and disability status, can change over time, these variables are considered to be time-varying. Each line of data represents one year of life, and therefore transition probabilities are calculated annually. However, data are not necessarily collected annually. SPACE fills in gaps with pseudo-data that represent successive years. For instance, an individual aged 80 at baseline will be 83 at follow-up, and the data for that individual are inputted as two lines (for ages 80 and 83). SPACE creates two additional lines of pseudo-data (for ages 81 and 82). If baseline and follow-up status are the same, the filled-in data assume that status. If baseline and follow-up status differ, the filled-in data assume one transition at a random time. Separate models are estimated for males and females for earlier and later periods from each baseline state, yielding eight models in total, each of which produces six transition probabilities for each combination of age and other covariates.

We begin by analyzing a model that includes only age to provide an initial look at the living arrangement trends for the total population. Then we run a full equation model that takes the following form:

$$\begin{aligned}\mathrm{Ln}\theta_{a\to z} = {} & constant_t + Age_t + Mar_t + Dis_t + (Age_t \times Dis_t) \\ & + (Age_t \times Mar_t) + (Dis_t \times Mar_t) + R/U + \#Ch + \#Edu.\end{aligned}$$

The equation is estimated separately for each baseline state. This equation indicates that the log odds of a transition, which is transformed into an annual probability, from baseline state a to one of the three follow-up states z is a function of an intercept (constant), age, marital status (*Mar*), disability status (*Dis*), the interaction between age and disability, the interaction between age and marital status, the interaction between disability and marital status, rural/urban residence (*R*/*U*), the number of children (#*Ch*), and years of education (#*Edu*). The subscript t indicates the time-varying nature of some variables. The interaction effects, which were tested and found to be significant in preliminary runs, indicate that transitions are a function of a unique combination of factors such that probabilities associated with disability differ across age groups and by marital status, and the probabilities associated with marital status differ across age groups.

In a second stage, the probabilities are used in a simulation of a hypothetical population of 100,000 whose living arrangement status is assessed yearly. For each subgroup of individuals, SPACE randomly assigns an initial living arrangement status at age x based on the weighted living arrangement status for the subgroup in the data. Then it begins to simulate their status at age $x+1$ based on the transition probabilities assigned to a person with their particular set of characteristics (e.g., age, disability, and marital status) as determined by the model. This process continues for each hypothetical person one year of age at a time until they are simulated to die. A data set is created from this simulation, with each line of data indicating a living arrangement for a hypothetical person at a specific age. This data set is then used to estimate life expectancy in each living arrangement state. Life expectancy for someone with a given set of characteristics, for instance, can be determined by the mean expected age at death in this simulated data set. To assess the stability of estimates, we derive standard errors through bootstrapping that executes repeated estimates through random draws.

By subtraction, we derive the difference between estimates of TLE, ILLE, and the proportion of life independent across the earlier and later periods. This provides a way of determining the extent to which time has an influence on the estimates. Standard errors for these differences are determined through bootstrapping, and 95% confidence intervals for the distribution of the differences are constructed based on the range from the 2.5th to the 97.5th percentile for the bootstrapped distributions.

Results

Population Trends and Transitions in Longevity and Living Independently

Table 3 shows the average annual mortality rate and the percentage in an independent living arrangement by baseline year, sex, and age group. The sample mortality

Table 3 Average annual mortality rate and average prevalence of independent living by age, sex, and period, showing relative percent change across periods

		Baseline Year		
	Baseline Age Group	2002	2011	Relative Percentage Change
Mortality Rate				
Males	Septuagenarian	47.4	41.6	–12.2
	Octogenarian	130.0	77.0	–20.3*
	Nonagenarian	252.9	197.7	–11.5
	Centenarian	341.3	266.2	–11.0
Females	Septuagenarian	43.2	29.1	–32.7†
	Octogenarian	116.7	77.0	–34.0*
	Nonagenarian	224.2	197.7	–11.8†
	Centenarian	339.0	266.2	–21.5*
Percentage in Independent Living Arrangement				
Males	Septuagenarian	52.6	57.5	9.4**
	Octogenarian	42.6	55.0	29.2**
	Nonagenarian	29.7	35.4	19.1**
	Centenarian	24.3	13.5	–44.3**
Females	Septuagenarian	42.4	49.7	17.2**
	Octogenarian	31.1	40.0	28.5**
	Nonagenarian	22.1	21.9	–0.9
	Centenarian	11.6	15.2	30.4**

†$p < .10$; *$p < .05$; **$p < .01$

rate decreased substantially over the study period, and these decreases are statistically significant across age groups for females and for male octogenarians. For instance, mortality dropped 20.3% for octogenarian males and 34.0% for octogenarian females, although less for other age groups. Estimates of death rates calculated from U.N. data for similar years indicate a drop of about 15% to 20% for female septuagenarians and octogenarians and about 10% for male septuagenarians and octogenarians (United Nations 2018). The CLHLS data are a little higher but not completely out of line with the U.N. data.

Concurrently, the percentage in an independent living arrangement increased significantly. For instance, the percentage of octogenarian males in an independent living arrangement increased from 42.6% to 55.0%. For octogenarian females, the increase was from 31.1% to about 40.0%. Males were more likely to be in an independent living arrangement than females. In addition, the percentage living independently is lower with increasing age, such that centenarians and nonagenarians are less likely to be living in an independent arrangement than are octogenarians and septuagenarians.

Unadjusted transition probabilities for the total population by sex and period are shown in Table 4. The chance of remaining in the same state over time is greater than the chance of being in a different state, but many change. For instance, 70.1% of males in an independent living arrangement at baseline in 2002 remained independent at follow-up in 2005, 16.3% were coresident at follow-up, and 13.6% died. Moreover,

Table 4 Transitions in living arrangements from 2002 baseline to 2005 follow-up and from 2011 baseline to 2014 follow-up

		2002 Baseline Living Arrangement		2011 Baseline Living Arrangement	
	Follow-Up Living Arrangement	Independent	Coresident	Independent	Coresident
Males	*N*	2,063	3,147	1,666	1,844
	Independent	70.1	19.9	70.0	22.6
	Coresident	16.3	58.2	15.6	58.4
	Deceased	13.6	21.9	14.4	19.0
	Total	100.0	100.0	100.0	100.0
Females	*N*	1,859	5,235	1,380	2,773
	Independent	61.1	13.8	68.4	17.6
	Coresident	24.0	66.3	21.3	66.1
	Deceased	15.0	19.9	10.3	16.3
	Total	100.0[a]	100.0	100.0	100.0

[a] The total does not sum precisely to 100.0 because of rounding.

movements occurred in all directions. For instance, 19.9% of males who were coresident at baseline in 2002 were in an independent arrangement by follow-up. The chances of being deceased at follow-up are larger for coresidents at baseline, likely reflecting that health differences between those living independently and those in other arrangements.

Population TLE and ILLE Estimates by Age, Sex, and Baseline Year

Estimates for TLE and ILLE for the total population by age, sex, and year of baseline are shown in Figure 1. For males, both TLE and ILLE were higher across the entire age range in the later period. For females, TLE and ILLE were much higher in the later period at age 70, with differences across time declining with age so that little difference is evident by about age 90. On the whole, with the exception of extremely old females, the figure indicates that gains occurred over time in both years of life and years of life in an independent living arrangement.

Selected specific estimates are summarized in Table 5, which shows results at exact ages 70, 80, 90, and 100. Also shown in the table are the net change and whether this change is statistically significant. Previous analyses of mortality in the CLHLS data indicate some underreporting among octogenarians but reliable reporting for other age groups (Gu and Dupre 2008). The life expectancies for octogenarians shown in this table are indeed slightly higher than published estimates, and life expectancies at other ages are reasonable. In 2002, males aged 80 could expect to live 7.11 more years, of which 3.21 were in an independent living arrangement. By 2011, the TLE for males aged 80 increased to 7.87, and the ILLE increased to 4.05. Both of these increases are statistically significant, meaning that there were gains in both. Similar

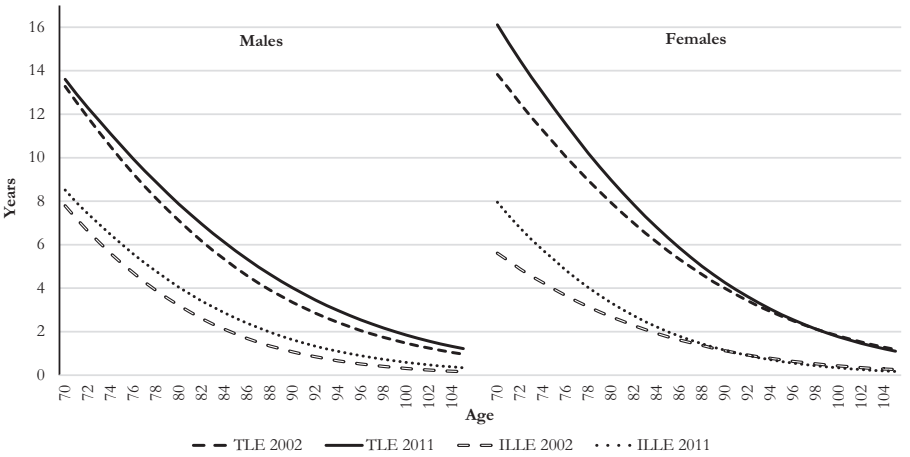

Fig. 1 TLE and ILLE estimates by baseline year, age, and sex

results are found for several other age groups and for females, with some interesting variations. Males aged 70, 90, and 100 and females aged 90 gained TLE, but these increases are not statistically significant. Centenarian females had about the same TLE across the two periods, and females in the two oldest age groups did not experience much change in ILLE.

We assess the expansion or contraction of ILLE by plotting the ratios of ILLE to TLE in Figure 2. Asterisks by the age in the *x*-axis show whether the difference in the ratio for that age and sex is statistically significant. ILLE for males clearly expanded—a statistically significant finding for those ages 80, 90, and 100. For instance, males aged 90 showed a statistically significant increase in the ratio from 0.32 to 0.41. Across all ages, males in China are living increasing proportions of life in an independent living arrangement, with gains in life expectancy more than being made up for by years in an independent living arrangement. The situation for females is a little different. A significant increase in the ratio is seen for those aged 70, for whom the proportion of life in an independent living arrangement rose from .41 to .49. For other ages, no statistically significant changes are evident, indicating that any gains in TLE were about matched by gains in ILLE.

In sum, older Chinese adults have experienced gains in both TLE and ILLE. In relative terms, the gains in ILLE for males have been greater, meaning that extra years of life are being lived alone or with spouse only; independent living arrangements showed additional gains, indicating an expansion of ILLE. For females, expansion is seen at younger old-ages. Females at the very oldest ages have experienced neither an expansion nor a contraction in independent living.

TLE and ILLE Estimates Across Disability and Marital Status

Estimates by disability status and marital status are summarized in Table 6 for four ages (70, 80, 90, and 100). We first present some overarching observations. TLE

Table 5 TLE and ILLE estimates at select ages, by baseline year and sex, showing net change across periods

		Males			Females		
	Age	2002	2011	Net Change	2002	2011	Net Change
TLE	70	13.28	13.60	0.33	13.83	16.11	2.18*
	80	7.11	7.87	0.76*	7.93	8.97	1.04*
	90	3.35	4.01	0.66	3.99	4.26	0.27
	100	1.47	1.84	0.37	1.80	1.76	–0.04
ILLE	70	7.79	8.51	0.72	5.61	7.96	2.35*
	80	3.21	4.05	0.84*	2.85	3.33	0.65*
	90	1.07	1.62	0.55*	1.13	1.15	0.02
	100	0.31	0.59	0.28*	0.43	0.34	–0.09

*The change over time is significant at $p < .05$.

is highest in the uppermost panel for married persons and without a disability, and it is lowest in the lowermost panel for unmarried and with a disability. The same is true of ILLE. Having a disability decreases the number of years expected in an independent living arrangement. For instance, for the 2011 baseline, an 80-year-old married female can expect to spend 4.63 years in an independent living arrangement if she does not have a disability and 3.54 years if she has a disability. An unmarried female of the same age can expect to spend 3.35 years in an independent living arrangement if she does not have a disability and only 1.19 years if she does. Of course, as age increases, both TLE and ILLE decrease. A 90-year-old unmarried female with a disability, for instance, has a life expectancy in 2011 of 2.98 years, of which only 0.41 years are expected to be spent in an independent living arrangement.

Finding statistically significant changes over time is difficult, largely because small cell sizes cause some substantial net changes to be deemed nonsignificant. Rather than concluding no change in TLE or ILLE, we cautiously assess patterns, which are informative. For instance, males of all ages gained ILLE regardless of marital and disability status (with the exception of married disabled males aged 100). Females aged 70 and 80 gained ILLE regardless of marital and disability status, but females aged 90 and 100 witnessed small declines in ILLE.

The proportionate interplay between gains or losses in TLE and ILLE is seen in the ratios plotted in Figure 3. The left side of each graph in the figure shows results for males, and the right side shows results for females. Again, although small sample sizes result in mostly nonsignificant ratio differences, patterns are nonetheless informative. The following are important findings:

- Males with a disability aged 70 and 80 experienced an expansion of ILLE. For instance, 70-year-old married males with a disability had a ratio of 0.47 in the 2002 baseline period, which increased to 0.68 in the 2011 period. For otherwise similar males who were unmarried, the increase was from 0.41 to 0.68.

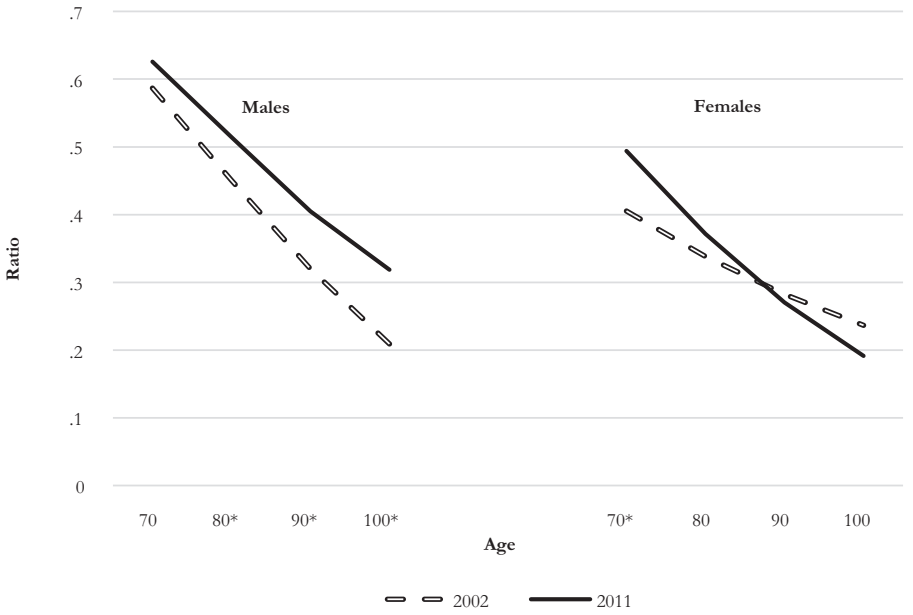

Fig. 2 Ratio of ILLE to TLE by select ages, sex, and period. *The increase or decrease in the ratio over time is statistically significant at $p < .05$.

- Married males without a disability experienced expansion of ILLE across all ages, but the ratio for unmarried males without a disability changed little. For instance, 90-year-old married males without a disability had a ratio of 0.50 in the earlier period, which increased to 0.59 in the later period. The ratio for unmarried nondisabled males increased only from 0.22 to 0.26.
- ILLE consistently contracted for females at very old ages regardless of disability and marital status. For instance, the ratio for 90-year-old married females without a disability declined from 0.49 to 0.43, whereas ratios for the same-aged but unmarried females with a disability dropped from 0.15 to 0.14.
- For 70-year-old disabled females, ILLE expanded. Married disabled females aged 70 had a ratio of 0.53 at the 2002 baseline, which increased to 0.65 by the 2011 baseline. For unmarried disabled females aged 70, the increase was from 0.26 to 0.42.

In sum, considering marital and disability status as predictors of ILLE results in heterogeneous findings. The predominant trend points to more net ILLE years for males and for younger females. An expansion of ILLE is seen in younger age groups (septuagenarians and octogenarians) with disabilities. The very oldest of females (nonagenarians and centenarians) experienced a contraction of ILLE, but the same is not true for the very oldest of males, who generally experienced neither an expansion nor a contraction. One group that likely needs support is unmarried disabled individuals. Males and female septuagenarians as well as male octogenarians in this category experienced an expansion of ILLE. Male nonagenarians and cen-

Table 6 TLE and ILLE estimates at selected ages, by baseline year, sex, disability, and marital status

		Males			Females		
	Age	2002	2011	Net Change	2002	2011	Net Change
1. Married Without a Disability							
TLE	70	14.79	15.37	0.58	14.54	17.27	2.73*
	80	8.31	9.35	1.04	8.37	9.81	1.44
	90	4.03	5.08	1.05	4.23	4.64	0.40
	100	1.71	2.48	0.78	1.92	1.82	–0.10
ILLE	70	9.07	9.97	0.90	7.20	9.20	1.99*
	80	4.59	5.77	1.19*	4.04	4.63	0.59
	90	2.01	2.98	0.98	2.07	1.98	–0.09
	100	0.79	1.41	0.63	1.01	0.75	–0.26
2. Married With a Disability							
TLE	70	8.27	6.67	–1.61	11.96	11.35	–0.61
	80	4.93	4.20	–0.73	6.73	7.34	0.62
	90	2.78	2.73	–0.05	3.43	4.27	0.85
	100	1.51	1.85	0.33	1.64	2.26	0.62
ILLE	70	3.85	4.52	0.67	6.33	7.40	1.07
	80	2.19	2.33	0.14	3.13	3.54	0.41
	90	1.21	1.18	–0.03	1.38	1.54	0.16
	100	0.65	0.58	–0.08	0.57	0.69	0.11
3. Unmarried Without a Disability							
TLE	70	11.99	14.31	2.32*	14.46	17.35	2.89*
	80	7.10	8.54	1.44*	9.15	10.28	1.13*
	90	4.04	4.53	0.49	5.28	5.37	0.09
	100	2.28	2.17	–0.11	2.78	2.51	–0.28
ILLE	70	5.71	6.66	0.96	4.69	7.28	2.59*
	80	2.42	3.02	0.60	2.90	3.35	0.45
	90	0.88	1.20	0.32	1.66	1.30	–0.36
	100	0.28	0.44	0.15	0.87	0.42	–0.45
4. Unmarried With a Disability							
TLE	70	5.56	6.19	0.63	8.67	8.54	–0.13
	80	3.72	3.68	–0.04	5.34	5.06	–0.28
	90	2.55	2.61	0.05	3.12	2.98	–0.13
	100	1.80	2.07	0.27	1.77	1.76	–0.01
ILLE	70	2.29	4.19	1.91	2.23	3.56	1.33
	80	1.03	1.51	0.48	1.06	1.19	0.13
	90	0.43	0.52	0.08	0.46	0.41	–0.05
	100	0.18	0.18	0.01	0.19	0.16	–0.03

*The change over time is significant at $p < .05$.

tenarians and female octogenarians experienced neither expansion nor contraction. Female nonagenarians and centenarians in this category experienced contraction.

Conclusion

China has experienced the types of rapid demographic, economic, and social changes that can influence household formation. Population aging is leading to ever greater proportions at older ages, with the fastest growing segment being the extremely old.

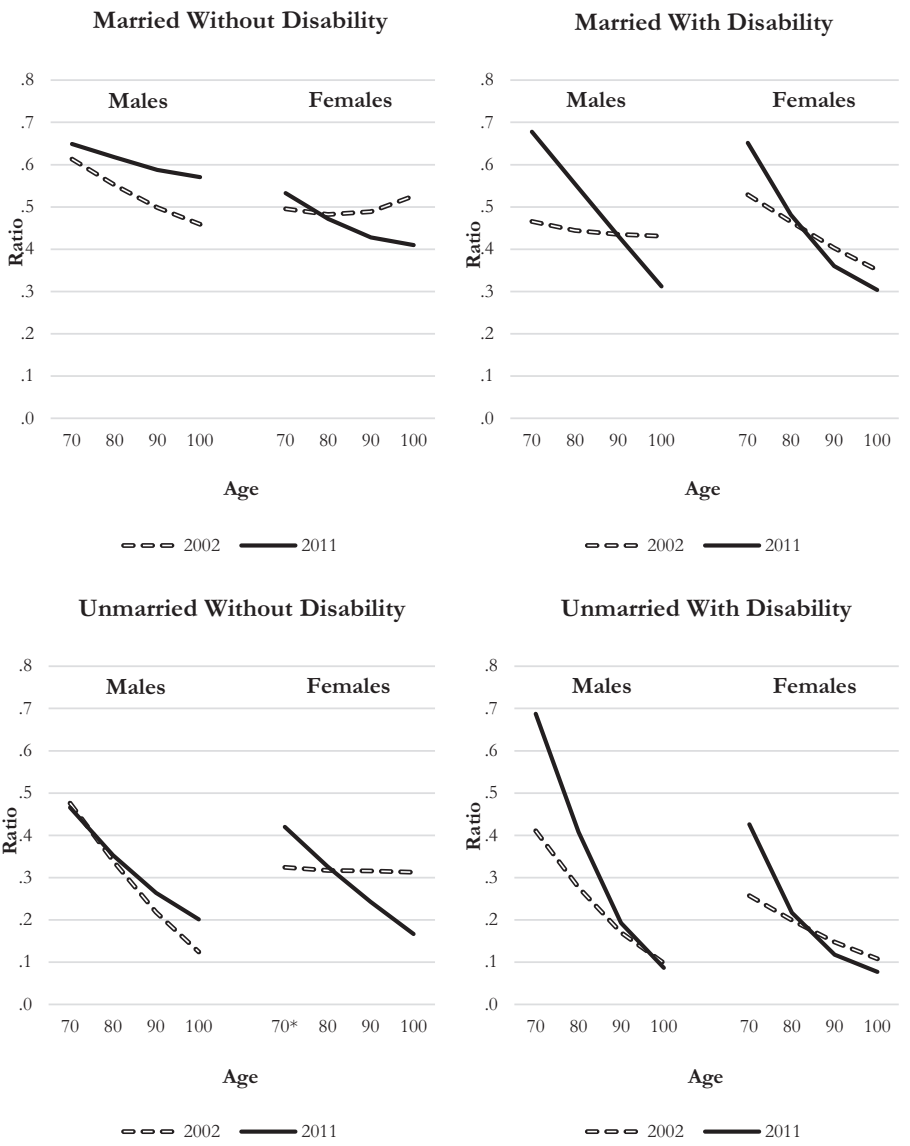

Fig. 3 Ratio of ILLE to TLE by age, sex, period, disability, and marital status. *The increase or decrease in the ratio over time is statistically significant at $p < .05$.

Economic growth and migration is resulting in younger persons leaving households and communities where their older parents live. Normative views of family are being impacted while new policies are expanding availability of housing ownership in urban areas and healthcare. We might expect the combination of these changes to reduce the long-standing tendency of older persons to live with an adult child. Yet, the situation is complicated by strong notions of family solidarity, filial piety, and a *hukou* system that may still discourage some from moving out of rural areas. Much of the research on

the topic concludes that Chinese values remain robust and, in particular, respond to the needs of older persons such that the very old, the unmarried, and those with disabilities remain highly likely to be living with others, less likely to shift from a coresidential to an independent living arrangement, and more likely to move in with adult children (Chen 2005; Zhou et al. 2018; Zimmer 2005; Zimmer and Korinek 2010).

What the literature has not addressed is the interplay between increasing longevity in China, or gains in total life expectancy, and changes in independent living versus coresidential living arrangements. The current study assessed this using multistate life table methods. We computed both total (TLE) and independent living life expectancies (ILLE) across two periods over which these other changes were occurring, and we examined whether gains in independent living arrangements were keeping pace with, or outpacing, gains in total life. By calculating the ratio of the two expectancies to examine the proportion of life individuals are expected to be living independently, we were able to explore whether independent living showed an expansion or a contraction. A specific advantage of the data we used for these calculations is their concentration on the oldest-old. The data contain substantial numbers of individuals in four older age groups—septuagenarians, octogenarians, nonagenarians, and centenarians—providing a distinctive opportunity to assess how living arrangements changed for very old individuals in age ranges that, because of a lack of data, are not often studied. Given that the oldest-old are also likely the ones requiring support, having large samples at uppermost ages allowed us to evaluate whether the expansion of independent living is equally a phenomenon among those most in need.

The results pointed to population-level gains in TLE and ILLE across the period under scrutiny. Importantly, gains in ILLE generally matched or exceeded gains in total life, resulting in *expansion* of the independent living arrangement. Thus, on average, older Chinese individuals became *more likely to be living alone or with spouse only when we adjusted for gains in longevity*. This finding supports our overarching hypothesis of an expansion of the independent living arrangement relative to population-wide gains in TLE. In contrast, living with others became less likely, and a smaller proportion of total life was spent living with others. Supplementary analysis of our data indicate that the great majority of those not in an independent arrangement lived with adult children, although the decline in coresidence is similar regardless of with whom the older persons are living.

However, we also found variations to this overarching finding that are critical for fully understanding how household formation in China is changing. *Males much more so than females are experiencing expansion*. We examined potential variation by age group, marital, and disability status. We hypothesized that under a family solidarity framework, there would be less expansion among extremely old, unmarried, and disabled individuals, in line with our framework predicting less change for those most in need of support. Support for this hypothesis is mixed. Sex of the older person is a determining factor: the hypothesis seems to hold for the very oldest males with disabilities and for the very oldest females. However, other characteristics matter as well. *The greatest expansion in ILLE is generally being experienced by septuagenarian females and males with disability whether married or not, octogenarian males with disability whether married or not, and married males of all ages without disability*. Thus, the younger age groups with disability are in particular more likely to live alone if unmarried and with spouse only if married—a result that is particularly contrary to expectations.

The overall implications of our findings are consequential for a society like China that is experiencing rapid population aging accompanied by increases in the prevalence of disability. Our finding of an expansion in independent living among some age groups with disability runs contrary to the idea that China's system of family solidarity maintains structures for older adults who are in greatest need. Yue and Ng (1999) suggested a new cultural protocol in China that involves respecting older persons but not necessarily in the same traditional ways, which may ultimately influence coresidential living. One consequence of this change is a greater number of older adults requiring assistance from alternate resources. Certainly, healthcare, pensions, and other resources that can provide assistance for older persons in China are rapidly developing and changing, generally providing greater potential for maintaining independence (Liu and Sun 2016; Tang et al. 2008; Yip et al. 2019; Yip and Mahal 2012). Evidence suggests that formal caregiving is increasing and targeted to those with the greatest health needs (Li et al. 2019). Although little research has explored use of assistive technology among older persons in China, some research in Hong Kong suggests greater usage and increased acceptance (Chen and Chan 2014). Yet, it is also possible that coresidential living arrangements are being replaced by near-residential living, wherein older persons live independently but nearby their adult children. If so, research needs to examine more closely whether changes in the family's form match changes in its function. That is, it is possible that the structure of the household is changing while patterns of support remain robust.

The current results may also indicate that those with disabilities are merely catching up to those without in terms of proportion of life spent living independently rather than any overriding changes in feelings toward those with disabilities. Perhaps more support for these persons is being provided outside of the family, that remittances by nonpresent adult children who have moved elsewhere are helping, or that older disabled persons are moving into nursing home facilities more frequently. The latter is rare in China. Although the data we use sampled in nursing homes, only a small percentage were living in nursing homes, and this percentage did not rise over the period of the current study.

Estimates we obtained from SPACE are based on transition probabilities derived by observing living arrangements at two points in time. A limitation of this is the assumption that only one event occurs across observation periods and that living arrangement is discrete rather than fluid, which statistically is similar to assuming that any change in living arrangement occurs midway between observation periods. Different software for multistate life expectancy calculations handle this assumption differently (Cai et al. 2010; Willekens and Putter 2014). SPACE takes the traditional approach, assuming that events occur once across a period. The degree to which this assumption biases our findings is unclear but is likely minor. Earlier assessments of bias due to missed events have considered the application of multistate life table estimation to changes in functional status (Gu and Zeng 2004; Wolf and Gill 2009), but changes in functional status likely occur more frequently than changes in living arrangement. The limitation will not have a large impact if the timing of events is random and spaced evenly across an observation period. More bias is likely in cases of a transition to being deceased, given that earlier research using these same data has suggested that shifts in living arrangements occur more frequently shortly before death than at any other time (Zimmer and Korinek 2010).

A limitation in reporting findings from multistate life tables is that analyses can become quite unwieldy when large numbers of covariates are used. In our analysis, we looked at independent living by age, sex, disability status, and marital status. Disability status is a broad measure of health—one that, in our conceptualization, is an indicator of the need for instrumental support and thereby encompasses a wide range of potential physical and cognitive health disorders. However, we understand the need to examine cognitive status independently of disability and suggest that future research should examine how cognitive decline might impact upon independent living.

In sum, the proportion of life being lived independently among the very old is still relatively small in China: about 30% for octogenarian, married males or females without disability; only about 20% for nonagenarian, unmarried males with disability; and only about 10% for nonagenarian, unmarried females with disability. It is generally very low for the extremely old, especially if unmarried. Clearly, the tendency to live with adult children or others in a coresidential situation remains normative. At the same time, the gain in total years of life in China mostly translates into extra years expected in an independent living arrangement, either alone (if not married) or with a spouse. Monitoring this expectation into the future will be important for determining whether the current trends in living arrangement will continue. ■

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Zachary Zimmer (corresponding author)
zachary.zimmer@msvu.ca

Zimmer • Mount Saint Vincent University, Halifax, NS Canada

Chiu • Academia Sinica, Taipei, Taiwan