The Present and Future Dementia Caregiving Demand in China: Kinship-Based Projections and Global Comparisons

Abstract

China has the largest number of patients with dementia in the world, and the rate of growth is expected to escalate further as the population ages. Lacking public support, the majority of dementia patients rely on their families for care and assistance. Using demographic models of kinship, we provide quantitative estimates of the caregiving demands, from 1990 up to 2050, by illustrating the number of kin accessible to dementia patients and the dependency caused by kin with dementia on working-age kin without dementia. We then compare the estimates of dementia caregiving demands across 194 countries and territories, accounting for historical trends in, and projections of future mortality, fertility, and dementia prevalence. Our findings suggest that, unlike other aging societies, China's aging crisis is exacerbated by the fact that, in addition to the alarming rise in the number of elderly in need of care, the number of possible family caregivers is also dropping at an unprecedented pace. This study has important policy implication in understanding the future care network for both aging China and the global aging population. Our approach can also be applied to examine conditions other than dementia using the same mathematical-demographic framework.

Keywords: Aging | Dementia Caregiving | Kinship | Mathematical Demography | China

Introduction

Alzheimer's disease and related dementia (hereafter referred to as dementia) constitute an enormous challenge for patients, their caregivers and family members, and society as a whole. At a population level, numerous studies have documented the causes and consequences of dementia, its variation across time and place, and its growing impact on the economy and healthcare systems (Baumgart et al. 2015; Nichols et al. 2022; Velandia et al. 2022). Dementia profoundly changes the lives of patients and those of their families and relatives (Schulz and Martire 2004). Those effects depend, among other things, on the structure of kinship networks: the numbers, age distributions, and social roles of the relatives of a person with dementia. We provide a new kinship perspective for evaluating the rising caregiving demands of dementia on families and explore its ramifications over several decades in China.

China has the largest number of patients with dementia in the world, and the rate of growth is expected to escalate in the coming years, as the population is aging at an accelerating pace. The number of those living with dementia has increased over fourfold in the past three decades, from 3.68 million in 1990 to 15.33 million in 2019, and this number is expected to triple to 45.54 million in 2050 Nichols et al. 2022. While a significant amount of research has documented the increased rate of dementia cases and the associated economic costs at the national level (Nichols et al. 2022; Chan et al. 2013; L. Jia et al. 2020; Nichols et al. 2019), the familial implications of dementia have not yet been fully explored. For example, little research has examined how many possible family caregivers a person with dementia can expect to have access to and how many of one's family members could be expected to develop dementia over one's life course.

A kinship perspective provides a useful framework for understanding the burden of dementia in China and other fast-aging populations. First, this approach quantifies the number of possible family caregivers by estimating how many families and relatives are affected by having dementia among their kin. The majority of patients living with dementia in China rely on members of their family at home for care and assistance (L. Jia et al. 2020; J. Jia et al. 2016). In spite of the government's efforts to boost the numbers of healthcare personnel and facilities, prior research suggests that China's fiscal capacity is insufficient to care for the impending so-called silver tsunami of the elderly, given the declines in government revenue and dramatic demographic changes (Cai, Wang, and Shen 2018). As a result, family members will continue to play an important part in dementia care in China as the population ages.

Second, the kinship approach helps clarify the demand of caregiving for relatives with dementia that a given individual is expected to experience at different stages of life. While most symptoms of dementia appear at older ages, the experience of having a relative suffering from dementia may occur at any age. For example, an individual may, in young adulthood, have a grandmother with dementia, have a parent with dementia when in middle age, and have a spouse or a sibling with dementia in their own older age. This age pattern may vary across population subgroups stratified by kin type, gender, race, socioeconomic status, and place of residence, and it will likely have significant consequences for social inequality (Alburez-Gutierrez et al. 2022; Chung and Hepburn 2018; Jiang 1995; Song and Mare 2019; Verdery et al. 2020; Zhou, Verdery, and Margolis 2019).

The burden of dementia on families will continue to grow due to China's changing family structure and shrinking kinship size. The three-and-a-half-decade long strict One-Child Policy and rapid economic development have profoundly reshaped China's demographic profile and individuals' preferred family size. As in many Western countries, multigenerational coresidence has declined dramatically in China. The household system has changed from a large unitary single structure to smaller and more diverse forms (Li, Fan, and Song 2020; Song and Chen 2020; Zeng et al. 2008). Critics warned that the One-Child Policy would severely weaken family and kin structures in Chinese families, resulting in the disappearance of many kin ties for the generations of children most affected. For example, an only child has no siblings, and the children of the two only-child parents have no aunts or uncles (Wang, Cai, and Gu 2013; Wang, Gu, and Cai 2016). Some recent estimates show that China has reached an era of peak family, in which the number of extended family members remains high but is projected to drop in the coming years (Eberstadt and Verdery 2021; Verdery 2017). As a result, the overall number of dementia cases is expected to rise due to population aging, at the same time that the number of available family caregivers, particularly those who are not in old age themselves, decreases.

Using a time-varying matrix kinship model (Caswell 2019; Caswell and Song 2021), we provide demographic estimates and policy-relevant knowledge on the dementia caregiving demands on Chinese families and kinship groups. The model projects kinship structure based on observed changes in mortality and fertility schedules beginning in 1950 (see the Methods section). The dramatically changing demography of China makes this time-varying approach especially valuable. Our results indicate that the number of kin with dementia grew dramatically from 1990 to 2019, and this trend is projected to continue even if the age-specific prevalence rate of dementia remains at 2019 levels. For example, the probability that a 25-year-old person has at least one grandparent with dementia tripled from 5% in 1990 to around 15% in 2019, and it is expected to increase to 22% in 2050. The dementia burden on an individual varies by the individual's age and his or her relatedness to different types of kin. Older cohorts will face a greater burden than younger ones. We develop an index that we call the dementia dependency ratio (DDR). For an individual of specified age, the DDR is given by the ratio of the number of kin with dementia to the number of kin without dementia who are potential care-givers. We use the DDR to evaluate the burden of dementia on families at an aggregate level, and we compare the index across a wide range of countries. The results suggest that China will experience among the fastest-growing dementia burdens in the world in the next three decades, reaching by 2050 an unprecedented level of 18 times the level in 1990. We call on policymakers and communities to develop a nationwide healthcare safety net for people living with dementia and their families.

Background

Population Aging and Cognitive Aging in China

China's population is aging at an unprecedented rate. Its three-and-a-half decade long history of the One-Child Policy, along with its dramatic economic take-off following the 1978 economic reforms, has led to a sustained fertility decline and a rapid increase in life expectancy (Cai and Wang 2021; Wang and Mason 2007; Chen and Liu 2009). This ongoing demographic transition will eventually turn China's population pyramid upside-down. Even assuming, against the trend, a gradual and moderate recovery of fertility, the proportion of the population aged 65 years and above is expected to increase from 191 million in 2020 to 395 million in 2050, eventually accounting for 30.1% of the total population (United Nation 2022). This accelerated aging of the population will lead to substantial pressures on the fiscal capacity and the social welfare system in China. Cai, Wang, and Shen (Cai, Wang, and Shen 2018) estimated that, maintaining an average social welfare generosity at the 2014 level, public health spending will more than double and pension spending will more than triple from 2015 to 2050. Assuming that China manages to maintain its economy at the 2020 level, the spending on public health and pension alone would consume as much as 82.8% of the government revenue by 2050. The impact that the COVID-19 pandemic has had on China's birth rate and economy would only precipitate the tipping point of the potential fiscal crisis.

The increasing incidence of dementia is among the greatest challenges that China's aging population may face. China has the largest population of dementia patients (L. Jia et al. 2020), with many of them undiagnosed (Lang et al. 2017), and this number is expected to climb as the population ages. In 2017, dementia became the fifth leading cause of death in China, following stroke, ischemic heart disease, chronic obstructive pulmonary disease, and lung cancer (Zhou et al. 2019). There is no effective cure for dementia, and sufferers eventually require assistance as the disease progresses. The disease thus poses a heavy economic and healthcare burden on patients and their families. A survey of 81 representative hospitals, nursing homes, and care facilities across 30 provinces in China in 2015 indicated that the average annual cost per patient of dementia was US $19,144.36, for an annual national total of US $167.74 billion (J. Jia et al. 2018). Indirect costs, such as financial loss sustained by patients themselves or their informal caregivers account for 51.9% of the total cost, while the direct medical costs (such as medication and hospitalization) and non-medical costs (such as costs of transportation and healthcare equipment) account for 32.5% and 15.6%, respectively.

The Demography of Dementia Caregiving

In addition to the financial burden, dementia places a significant caregiving strain on families, causing additional physical, psychological, and emotional stress for caregivers (Brodaty and Donkin 2022; Ory et al. 1999). In China, most dementia patients live with family members. According to a survey of outpatient departments of 36 randomly selected hospitals throughout China, only 2% of patients who have dementia were receiving formal care from a nursing home or hospital (J. Jia et al. 2016); of the remainder, 84.9% were cared for by family members, 8.3% lived alone, and 4.9% were cared for by hired nannies. A range of factors explain the low utilization rate of formal care in China. First, formal care that is provided by nursing homes or hospitals is not covered by medical insurance in China, and thus many families are unable to afford such costs (Wang, Cheung, and Leung 2019). Second, the dementia care service is inadequate and fragmented, especially in rural and underdeveloped areas (Quail et al. 2020). Third, the positive influence of filial piety produces a burden of guilt on family members who place older adults with dementia in nursing homes (Chang, Schneider, and Sessanna 2011).

The ongoing dramatic demographic and social changes have called the underpinning of traditional family arrangements into question. Despite the long history of preference for large families and intergenerational co-residence in China, the average household size has shrunk from 4.41 in 1982 to 3.44 in 2000 and 2.62 in 2020 (China National Bureau of Statistics (NBS) 2021). Moreover, with a total fertility rate of 1.3 in 2020, China now has one of the lowest fertility rates, similar to its East Asian neighbors (China National Bureau of Statistics (NBS) 2021). The strict One-Child Policy and the changing fertility preferences have significantly altered the kinship network (Wang, Cai, and Gu 2013). Microsimulation studies have predicted that the availability of kin will drop unavoidably (Jiang 1995; Verdery 2017; Hammel et al. 1991; Yang 1992). By the year 2050, two-fifths of the population under 50 will be only children. The kinless population, defined as those without spouses or children, will reach around 25 million (Eberstadt and Verdery 2021; Verdery 2017). Moreover, massive rural-to-urban migration has split families, as many adult children have migrated to metropolitan regions for better opportunities, leaving their elderly parents behind in rural towns (Wang and Mason 2007; Bongaarts and Greenhalgh 1985). The percentage of elderly people over 65 living alone is expected to increase to 14% in rural areas and 11% in urban areas in 2050 (Zeng et al. 2008). Lacking a formal routine caregiver, some elderly patients have to rotate their residencies from one child to another.

Calculating the Burden of Dementia: Individuals, Families, and Populations

Demographers have long been interested in studying the size and composition of kinship networks and assessing how changes in family structure and caregiving arrangements may impact the well-being of older adults (Hammel et al. 1991; Goodman, Keyfitz, and Pullum 1974; Murphy 2010; Ruggles 1993; Verdery and Margolis 2017; Wachter 1997; Wolf 1994). Individual-level kinship data have long been scarce. Recently, with the availability of registry data and high-quality multigenerational surveys, researchers can directly count the size and composition of kinship network, as well as the caregiving arrangements and support networks of older adults (Kolk et al. 2021; Reyes, Schoeni, and Freedman 2021; Song and Campbell 2017). However, these microdata are not widely accessible, especially in developing countries, where the social welfare system is underdeveloped, and the family is the primary source of care for older adults with dementia. In addition, descriptions of kinship networks leave unexamined the roles of the mortality and fertility schedules that produce them. By employing formal demographic models, researchers can better understand the relationship between kinship networks and various demographic rates. Unlike purely descriptive data, these analyses explicitly include the demographic process that shape the kinship network. We use newly developed matrix kinship models (Caswell 2019; Caswell and Song 2021), to assess the burden of dementia in China from a kinship perspective. The matrix kinship model, developed as an alternative to the Goodman, Keyfitz, and Pullum kinship model (Goodman, Keyfitz, and Pullum 1974), is straightforward to implement, has flexible data requirements, and does not require any simulations (Williams et al. 2022).

Our focus on China is motivated by the fact that China has the largest number of dementia patients in the world and has undergone dramatic demographic transitions in fertility, mortality, and living arrangement in recent decades. Despite a large body of research that has documented the economic, physical, and psychological impact of dementia on the family, few studies have quantified this effect by illustrating how large the accessible kinship network is for dementia patients in need of assistance and how many kin members would be affected by having family members with dementia.

We assess the burden of dementia at three levels. At the individual level, we calculate the number of kin with dementia and the probability of having at least one kin member with dementia, for an individual Focal person at any specified age x. A Focal is defined as a randomly selected individual from the population who by any age will have developed a network of kin of different types. We compute the age-specific dementia dependency ratio (DDR(x)) as a function of the age x of Focal, measured as the ratio of the number of kin with dementia to the total number of kin without dementia who are potential family caregivers and in the working age group (16 to 64). The DDR(x) index quantifies the burden of dementia at the family level by taking into account the size and structure of the kinship network. At the population level, we calculate a population weighted dependency ratio, DDR(pop) by averaging DDR(x) over the age distribution of the population. We derive the DDR(pop) for a wide range of countries. This age-weighted indicator can be easily used to compare the burden of dementia across time and place.

Methods

Data. We draw on period fertility and mortality estimates for China and 194 other countries from year 1950 to 2021 documented in the UN's 2022 Revision of World Population Prospects (WPP). The 2022 WPP provides age-specific fertility and mortality estimates for each single-year age group. For projected estimates up to year 2050, we choose the medium-variant projections of fertility and mortality rates provided by the UN. The medium-variant projection refers to the median of several thousand distinct trajectories of each demographic component derived using the probabilistic model that takes into account the historical variability in fertility and mortality of each country (United Nation 2022). According to the medium fertility scenario, China's fertility is expected to rebound gradually and moderately to 1.4 from 2022 to 2050 after reaching a historical low of 1.2 in 2021.

To estimate kin with dementia, we draw on data from the 2019 Global Burden of Disease (GBD 2019), which provides estimates of the prevalence rate of Alzheimer's disease and other types of dementia by age and year. The Global Burden of Disease uses a Bayesian meta regression model to estimate age-specific prevalence rates and provides the mean value out of 1,000 draws from their model. The Bayesian models provides a meta-analysis of 43 published studies on dementia in China. These data can be download through GBD's Data Input Sources Tool. We did not use the public version of the GBD data as the data exclude dementia induced by other clinical disorders, including Down syndrome, Parkinson's disease, clinical stroke, and traumatic brain injury. Instead, we use updated dementia prevalence rates provided in Nichols et al. (Nichols et al. 2022) that include all forms of dementia. We use the mean-value dementia prevalence estimates throughout our analyses. Because the dementia prevalence rates were estimated in the five-year age group, we used linear interpolation to impute single-year age-specific prevalence rates. *Table S1 in the online appendix* summarizes sources, data types, time coverage, and age ranges for data used in our analyses.

The kinship network of individuals. Our results rely on an extension of the formal demographic model of kinship recently developed in Caswell (2019) and Caswell and Song (2021). Prior to this model, kinship analysis was based on the important work of Goodman, Keyfitz, and Pullum (1974), who derived the expected numbers of kin of various kinds at each age of a focal individual. * The new kinship analysis replaced the integration over pathways with the recognition that the kin (of any specified kind) of Focal (at any specified age) are a population. As such, the age structure of those kin are projected as Focal ages, using matrix formulation of rates of survival and fertility. The population of any type of kin is subsidized; that is, new members of the population of one type of kin come not from reproduction of those kin, but from reproduction of some other type of kin. New sisters of Focal arise not from the reproduction of

*Goodman, Keyfitz, and Pullum (1974) calculated numbers of kin by integrating over all the pathways by which kin could arrive to Focal at a given age x. The resulting multidimensional integrals are challenging to implement, limited in the information they can provide, and not easy to extend (see (Caswell 2019) and (Caswell 2020) for a detailed discussion). As a result, their method has rarely been used, but see (Song and Mare 2019).

her current sisters, but from the reproduction of Focal's mother. The model provides not merely the numbers of kin, but their age structure, from which a variety of population properties (numbers of kin, mean ages of kin, prevalence of dementia of kin, etc.)

Kinship with Time-Varying Rates. The time-varying kinship model is based on a sequence of survival matrices $\mathbf{U}_t$ and of fertility matrices $\mathbf{F}_t$, both of dimensions $\omega \times \omega$ (i.e., the number of age groups). For example with $\omega = 3$, we have

$$\mathbf{U}_t = \begin{pmatrix} 0 & 0 & 0 \\ p_{1t} & 0 & 0 \\ 0 & p_{2t} & [p_{3t}] \end{pmatrix} \qquad \mathbf{F}_t = \begin{pmatrix} f_{1t} & f_{2t} & f_{3t} \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \tag{1}$$

where p_{it} refers to age-specific survival probabilities and f_{it} refers to age-specific fertility rates.[†]

Let $\mathbf{k}(x, t)$ denote the age distribution for some specified type of kin:

$$\mathbf{k}(x, t) = \text{ kin of type } \mathbf{k} \text{ at age } x \text{ of Focal at time } t \tag{2}$$

Our goal is to calculate these vectors for all the types of kin in the kinship network, over some specified time span for which we have, or can assume, demographic rates.

The kin at age $x + 1$ of Focal at time $t + 1$ are the survivors of the kin of age x at time t. These survivors are obtained by multiplying the age distribution $\mathbf{k}(x, t)$ by the survival matrix $\mathbf{U}_t$. New individuals are produced according to a subsidy vector $\boldsymbol{\beta}(x, t)$ such that

$$\mathbf{k}(x + 1, t + 1) = \mathbf{U}_t \mathbf{k}(x, t) + \boldsymbol{\beta}(x, t) \qquad x = 0, \ldots, \omega \quad t = 0, \ldots, T \tag{3}$$

The subsidy vector $\boldsymbol{\beta}(x, t)$ has one of two forms. For some kin (e.g., older sisters of Focal), there is no recruitment of new members after the birth of Focal, so that

$$\boldsymbol{\beta}(x, t) = \mathbf{0}. \tag{4}$$

[†]The optional (ω, ω) cell in $\mathbf{U}_t$ describes an open final age interval.

For some kin,

$$\boldsymbol{\beta}(x,t) = \mathbf{F}_t \mathbf{k}^*(x,t) \tag{5}$$

which applies the fertility at time t to the age structure vector of the kin $\mathbf{k}^*$ that provides the subsidy. For example, younger sisters of Focal are produced by reproduction of the mothers of Focal, so

$$\mathbf{n}(x+1,t+1) = \mathbf{U}_t \mathbf{n}(x,t) + \mathbf{F}_t \mathbf{d}(x,t) \tag{6}$$

The two-dimensional dependence on age and time means that the initial condition $\mathbf{k}_0$ is replaced by a set of boundary conditions (for details see (Caswell and Song 2021)). It is also worth noting that because kinship models are projections of the consequences of the demographic rates conditional on these hypotheses, they are not expected to duplicate the results found from empirical censuses of kin (as noted explicitly by (Goodman, Keyfitz, and Pullum 1974)). Rather, they capture the main effects of the demographic structure against which the effects of violations of these assumptions can be evaluated.

For our analyses we used mortality and fertility schedules from the 2022 Revision of the United Nations World Population Prospects (United Nation 2022), starting in the year 1950 and continuing from year 2021 to 2050 as a projection of future rates. The time-zero boundary condition $\mathbf{k}(x,0)$ was obtained by a time-invariant calculation using the rates of 1950 and the distribution of ages at maternity based on the UN's estimate of births by age of mother reported for year 1950. The age-zero boundary condition specifies $\mathbf{k}(0,t)$ for each year; it was calculated from the appropriate kin at time $t-1$ (see Table 1 of (Caswell and Song 2021)). Thus, when we report kinship results for a particular year (e.g., 1990), the results reflect the changing mortality and fertility schedules in China from 1950 up to that year.

Total Numbers of Kin. As presented here, $\mathbf{k}(x,t)$ gives the age structure of female kin in maternal lines of descent. To compute total numbers of kin, both male and female, through all lines of descent, would require a two-sex model incorporating both male and female mortality and fertility schedules (Caswell 2022). However, approximate results for total numbers of kin, assuming that males and females are identical, can be obtained by multiplying the kin vectors by a set of factors suggested by Goodman, Keyfitz, and Pullum (Goodman, Keyfitz, and Pullum 1974), called the 'GKP factors' (Caswell 2022): twice as many children as daughters, four times as many grandchildren as granddaughters, twice as many parents as mothers, four times as many grandparents as grandmothers, twice as many siblings as sisters, four times as many nieces and nephews as nieces, and so on.

We use the newly released `R` package `DemoKin` to carry out the calculations (Williams et al. 2022). This package implements the calculations developed in (Caswell 2019; Caswell and Song 2021; Caswell 2020, 2022) which are presented in those papers as MATLAB programs.

Dementia Status and the Dementia Dependency Ratio. If $\mathbf{\Psi}$ is a vector containing age-specific prevalences of dementia (or any other condition), then the expected number of kin with dementia at age x of Focal at time t is

$$y(x,t) = \mathbf{\Psi}(t)^{\mathsf{T}}\mathbf{k}(x,t) \tag{7}$$

The number of kin with dementia within a specified age range (e.g., kin in the post-retirement ages 60 and above) is given by restricting $\mathbf{\Psi}$ to those ages; e.g., $\mathbf{\Psi}_{16-64}$ denotes the prevalence vector with all entries except those from 16 to 64 set to zero.

From the numbers of kin with dementia we calculate the probability that Focal, at age x and time t, has at least one kin of that type with dementia, using a Poisson approximation, as in (Song and Mare 2019; Song, Campbell, and Lee 2015). If the expected number of kin with dementia at time t is $y(t)$, under the Poisson assumption the probability of having at least one such kin is

$$P(\text{at least one kin with dementia}) = 1 - e^{-y(t)}. \tag{8}$$

The familiar demographic dependency ratio is calculated as the ratio of those not considered part of the labor force (younger than 15 or older than 65) relative to those considered to be part of the labor force (16–64) and thus supporting the dependant ages. Here we calculate a corresponding dementia dependency ratio for each type of kin:

$$\text{DDR}(x,t) = \frac{\text{kin with dementia}}{\text{kin without dementia aged 16–64}} = \frac{y(x,t)}{(\mathbf{1} - \boldsymbol{\Psi}_{16-64})^{\mathsf{T}}\mathbf{k}(x,t)}. \tag{9}$$

The dementia dependency ratio can be interpreted as a measure of the burden that kin with dementia place on kin without dementia in working ages.

The population burden of dementia. The vector $\mathbf{k}(x,t)$ gives the age distribution of the kin, of type $\mathbf{k}$, of Focal at age x. Thus the dementia prevalence and the dementia dependency ratio capture the expected burden of dementia within a family.

A population can be thought of as a collection of Focal individuals with an age structure given by, say, $\mathbf{n}(t)$. The kinship structure can be weighted by averaging over the age distribution. Define the proportional age distribution as

$$\mathbf{w}(t) = \frac{\mathbf{n}(t)}{\|\mathbf{n}(t)\|} \tag{10}$$

Then the age-weighted, population dependency ratio is

$$\text{DDR(pop)} = \sum_x w_x(t)\text{DDR}(x,t). \tag{11}$$

This quantity is the expected dementia dependency ratio of an individual selected at random from the population. The calculation can be restricted to a subset of ages by including only those ages in $\mathbf{n}$ (e.g., asking for the age-weighted kin structure of that part of the population over 65 years of age).

Results

We use the age-specific dementia prevalence rates in 1990, 2019, and 2050 estimated by the Dementia Forecasting collaborators in the Global Burden of Disease Study (Nichols et al. 2022). The sources of data are described in Methods section and Table S1 in the online appendix. Per age, dementia prevalence grew considerably between 1990 and 2019 (online appendix, Figure S1-A). For example, 7 out of 100 people aged 80 had dementia in 1990, and this number increased to 10 out of 100 in 2019. The rise in dementia prevalence in China over the last three decades has been well reported, reflecting increased longevity and improved diagnostic criteria (Chan et al. 2013; L. Jia et al. 2020). Between 2019 and 2050, the projected age-specific dementia prevalence rate shows only a small increase. However, the proportion of people with dementia in the population is expected to increase dramatically by 2050, because the population as a whole is expected to be much older (online appendix Figures S1-B and S1-C).

We begin with estimates of changing kinship structures in China using 1990, 2019, and 2050 as exemplary years.[‡] Table 1 presents the expected number of kin of various kin types at Focal's ages of 60, 70, and 80 years. These estimates imply the maximum number of available kin of specific types that could possibly provide care when Focal develops dementia. [§] For most types of kin, the expected number of kin decreases dramatically from 1990 to 2050 (except for aunts/uncles and cousins). For example, at 80 years old, Focal was expected to have 15.49 grandchildren in 1990, 7.69 grandchildren in 2019, but only 2.69 grandchildren in 2050. In 2050, in particular, we observe that Focal at the age of 80 has more kin than Focal at younger ages. This pattern reflects the long-term trend in declining fertility, such that generations born earlier had a higher level of fertility. Nevertheless, as Focal at the age of 40 in 2019 reaches

[‡]We have also estimated kinship structure in years between these three anchoring years. Some aggregated results are presented in online appendix Figure S5. More detailed results are available upon request.

[§]We show the total number of kin across all ages of kin, but the calculation can be limited to a subset of ages of kin (e.g. only kin aged between 16 to 64).

80, they will have fewer accessible kin of various types, such as children or grandchildren, than Focal at age 80 in 2019.

Figure 1 in the provides a fuller picture of the expected numbers of kin of various types by individuals' ages in three selected years. Compared to 1990, Chinese people in 2019 have fewer grandchildren and great-grandchildren but are more likely to have living parents, grandparents, and great-grandparents. For example, individuals at age 30 in 2019 have fewer children, siblings, aunts/uncles, nieces/nephews, and cousins compared to their counterparts in 1990. However, for the older group, the change between 1990 and 2019 is not linear. For example, individuals aged 60 and above have more siblings, cousins, aunts, and uncles in 2019 than in 1990. This nonlinear pattern is largely the result of the rise and fall of fertility rates since the 1950s: the immediate fertility drop following the Great Leap Forward Famine (1959–1961), the baby boomers born from 1962 to 1964, the subsequent long-running fertility decline following the Later-Longer-Fewer family planning campaign in the 1970s, and the more stringent One-Child Policy between the 1980s and 2016 (Cai 2010, 2008; Feeney and Wang 1993; Peng 1987; Whyte, Wang, and Cai 2015).

Next, we multiply the age-specific prevalence of dementia by kinship structure to compute the expected number of kin with dementia integrated over ages of kin. Figure S2 in online appendix presents the expected number of kin with dementia as a function of Focal's age in 1990, 2019, and 2050. These results suggest that the number of kin with dementia has increased dramatically between 1990 and 2019 and is expected to further increase over the next three decades. Over time, individuals will tend to have more grandparents and great-grandparents with dementia at younger ages, parents and aunts/uncles with dementia at middle age, and children, siblings, nieces/nephews, and cousins with dementia at older ages. As individuals live longer and have older kin, they will not only tend to experience dementia themselves but also become subject to the ripple effect of dementia within their kinship networks.

To better characterize the prevalence of dementia in one's kinship network, we convert the number of kin into the probability of having at least one kin member with dementia by kinship type as a function of the age of Focal. We assume that the number of kin with dementia, conditional on the survival of Focal, follows a Poisson distribution (Song and Mare 2019). For example, assuming that the expected number of siblings with dementia of an individual at age a is $S(a)$, the probability of having at least one sibling with dementia is $1 - e^{-S(a)}$.

Figure 2*A* presents some striking trends in the life-course patterns of having kin with dementia. For instance, nearly half of individuals born in 2050 can expect to have at least one great-grandparent with dementia at birth. Among individuals at age 30 in 2050, one-fourth will have at least one grandparent with dementia; among those at age 60, more than 15% will have parents with dementia; and among those aged 75, more than 15% of them will have siblings with dementia, 25% will have aunts and uncles with dementia, and 70% will have cousins with dementia. Given the elevated prevalence of dementia within kinship networks, it is highly possible that the majority of the population will experience its direct or indirect consequences at some point in their lives.

The increase in the number of kin with dementia is a result of both the rising prevalence of dementia and population aging. We use the Kitagawa decomposition method (Kitagawa 1955) to assess change in the number of kin with dementia across time as a result of the changing rate of dementia (rate effect) and the changing age distributions of kin (age effect). Figures 2*B* and 2*C* present the result of the decomposition for eight different types of kin as a function of Focal's age for two time periods. Between 1990 and 2019, increases in the rate and the age effects jointly determine the increase in dementia cases. However, the age effect, or the contribution of changing kin's age distributions, dominates the increase in kin with dementia between 2019 and 2050 across all types of kin.

Because the degree of kin's relatedness may affect how having a relative with dementia affects an individual, we aggregate different types of kin into three degrees according to their relatedness to the Focal (Caswell 2019; Song and Caswell 2022) (online appendix Figure S3). First-degree kin include children and parents, second-degree kin include siblings, grandparents, and grandchildren, and third-degree kin include great-grandchildren, great-grandparents, aunts/uncles, and nieces/nephews. We find that individuals aged 45 and 75 have the largest number of first-degree kin with dementia in all three years. However, this group is least likely to have second-degree kin with dementia relative to other age groups. Individuals aged 20–40 are likely to have second-degree kin with dementia, such as their grandparents. Similarly, individuals above age 75 also have a large number of kin with dementia, but these kin are likely to be their siblings. The age profile of third-degree kin with dementia shows a U-shaped curve, suggesting that individuals at younger ages are likely to have great-grandparents and aunts/uncles with dementia, while those at older ages are more likely to have great-grandchildren, nieces/nephews, and cousins with dementia. All of these age patterns are more pronounced in 2019 than in 1990 and are likely to be even more significant in 2050.

Finally, we construct the dependency ratio DDR(x) to examine the burden of dementia.[¶] This measure gives the ratio of kin with dementia (Figure 3*A*) to kin without it aged between 16 to 64 (Figure 3*B*). The age-specific DDR(x) values presented in Figure 3*C* indicate that the individuals tend to have a higher DDR before the age of 25 and after the age of 60. Notably, the age pattern is more evident in 2050, when age-specific DDR values skyrocket. The dramatic increase in DDR is driven by two factors: the increase in the number of kin who have dementia and the decline in kinship size as the population ages.

To assess the severity of the dementia burden in China, we situate China in a global context. To do this, we calculate the dementia burden index DDR(pop) for the entire population, by

[¶]Chung and Alexander (Chung and Alexander 2019) proposed a similar Kin Dependency Ratio (KDR) index, which is defined as the ratio of the number of plausibly dependent kin at Focal age x to the number of plausibly non-dependent kin at Focal age x.

averaging DDR(x) over the age distribution of the total population at any given year. We apply this method to data from China and other countries, using available dementia estimates in the Global Burden of Disease database and demographic rates from the United Nations (Nichols et al. 2022; United Nation 2022). Table S2 in the online appendix displays the estimated age-weighted DDR(pop) across 194 countries and territories in 1990, 2019, 2030, 2040, and 2050. In 1990, age-weighted DDR(pop) was high in Europe and North America, with the highest values appearing in Sweden, with a level of 2.0. China had one of the lowest levels of age-weighted DDR(pop) at the time, with 0.5, similar to Mexico and Libya in that year. In 2019, the global ranking of DDR(pop) shifted, and Japan was in the lead, with a DDR(pop) level of 6.8. The age-weighted DDR(pop) of China was 1.9, similar to Ireland and Chile in that year. In 2050, the DDR(pop) of China is projected to be among the highest around the world at 8.2, above many well-known aging societies such as Germany and France. Figure S4 in the online appendix shows the heat maps of age-weighted DDR(pop) by countries in 1990, 2019, 2030, 2040, and 2050.

Figure 4 depicts the change in the age-weighted DDR(pop) from 1990 to 2050. China's age-weighted DDR(pop) in 2050 will be approximately 18 times higher than it was in 1990, making its increase one of the fastest ever observed, following only Singapore's, which will climb roughly 24 times. However, due to China's massive population size and underdeveloped public health support system, the challenges it faces will be far greater than those of other countries.

Discussion

China has the highest number of people living with dementia in the world. As China's population continues to age, dementia is expected to remain a significant social and public health concern for the foreseeable future. While the majority of elderly with dementia are cared for by family members, shrinking family size and changing kinship structures are undermining the traditional family care arrangements. Furthermore, a recent study has revealed that the unit cost of dementia care in China has doubled from 2000 to 2019 and is predicted to double again within the next two decades (Velandia et al. 2022). The compound effects of increasing dementia cases, smaller families, and rising costs may exacerbate the impact on individuals, families, and the wider society. With the rising demand for dementia care in China, the present study illustrates the evolving accessibility of care provided by family members, who offer an alternative care source to professional providers and healthcare institutions.

Using demographic models of kinship, we estimate kin availability and prevalence of dementia among individuals' kinship networks. We find the probability that an individual has a close family member with dementia rises dramatically. For example, among people aged 30, the likelihood of having at least one living grandparent with dementia grew from 5% in 1990 to nearly 30% in 2050, whereas among those aged 50, the likelihood of having at least one living parent with dementia climbed from 3% to 11%. Furthermore, the number of kin available to elderly persons for caregiving will plummet over the next three decades.

Factoring in changing kinship sizes and structures, our kin-based DDR indices shed more light on the impact of demographic change on the dementia caregiving demand. Our results suggest that the dementia caregiving burden in China is expected to climb 18-fold, one of the most dramatic changes around the world. For example, in 1990, a Focal individual of age 80 would have had 0.4 kin with dementia (considering all types of kin and kin of different ages) and 35.1 working-age, dementia-free kin (defined as kin aged 16 to 64 without dementia). In 2019, an 80-year-old Focal would have had 1.2 kin with dementia and 29.9 kin who were dementia-free and could have been care-providers. Looking ahead to 2050, these figures are expected to change to 2.2 kin with dementia but only 11.6 dementia-free kin.

This study highlights important directions for future research. First, our study treats the population as a homogeneous group, with a single set of demographic rates and dementia prevalences. However, fertility and mortality rates and dementia prevalences vary significantly across education, income, *hukou* status, place of residence and other sociodemographic indicators (Crimmins et al. 2018; Jiang 1995; Yang 1992). These factors would lead to variations in the estimates of kinship structure and dementia burden that are overlooked in the current study. For example, in rural-to-urban migration in China, the working-age rural population tends to move to large cities in response to growing labor demand and economic opportunities, which has resulted in millions of elderly people left behind in rural areas (Chen and Liu 2009). Although rural older adults have larger kinship networks than their urban counterparts, they are in poorer health and often have no primary family members nearby who can provide dementia care. Future research should investigate the complex interaction between kinship and other social factors to identify the most vulnerable, hard-to-reach groups that have limited access to health coverage. Extending our approach using multistate matrix kinship models (Caswell 2020) is a promising approach.

Researchers should also pay attention to whether the increasing prevalence of dementia among kinship networks will produce new social inequalities for those providing care and those at risk of having kin with dementia. From a life course perspective, having grandparents or parents with dementia at younger ages may temporarily disrupt an individual's work as he or she takes time off or adjust work schedules to provide care for family members, or even lead to long-term consequences for reduced work performance, diminished career prospects, and financial strain. Another potential limitation of our findings is that we omitted spouses as potential caregivers in the calculation of DDR. Spouses are more likely than children and other biological kin to live with the person with dementia and are often better equipped to provide care due to their closer emotional bond with the dementia patient. Yet, because of the dynamic nature of marriage and cohabitation relationships, we are unable to incorporate estimates of spouses into the kinship and DDR calculations. Future research with family- and household-level microdata may provide valuable insights into the impact of dementia on spouses. Finally, we offer a broad definition of kin availability, which includes not only close family such as children and siblings, but also extended kin, such as cousins and nieces/nephews. While contact and care support are common among extended family members in China, the extent to which this tradition will continue, after decades of dramatic demographic and economic transformations, is unknown. A robustness check that limits the types of kin to only children, siblings, and parents shows a similar significant rise of DDR in China when compared to other countries as those presented in the Figure 4 (see results in online appendix Figure S5 and S6).

Our findings have policy implications for national healthcare systems and family well-being. Although China is not the only country anticipated to see a rapid increase in the DDR, the challenge it faces is formidable given the sheer size of its elderly population and inadequate health capacity. According to the OECD Health Statistics (Organisation for Economic Co-operation and Development (OECD) 2023), there were 12.1 practicing nurses per 1,000 people in Japan, 8.4 in Korea, and only 3.3 in China in 2020 (China National Bureau of Statistics (NBS) 2021). Our findings suggest an urgent need for China to expand its healthcare infrastructure, increase the size of the professional, community, and public health workforce, and improve early dementia diagnosis and intervention for the middle-aged and elderly, as well as risk reduction programs targeted at younger age groups. In addition, future policies should strengthen social and governmental support for family caregivers, who will soon find that there are fewer family members to share the mounting financial, physical, and emotional responsibility as more of their close relatives develop dementia in the coming decades.

Reference

Alburez-Gutierrez, Diego, Nicola Barban, Hal Caswell, Martin Kolk, Rachel Margolis, Emily Smith-Greenaway, Xi Song, Ashton M Verdery, and Emilio Zagheni. 2022. "Kinship, Demography, and Inequality: Review and Key Areas for Future Development." *SocArXiv.*

Baumgart, Matthew, Heather M Snyder, Maria C Carrillo, Sam Fazio, Hye Kim, and Harry Johns. 2015. "Summary of the evidence on modifiable risk factors for cognitive decline and dementia: A population-based perspective." *Alzheimer's & Dementia* 11 (6): 718–726.

Bongaarts, John, and Susan Greenhalgh. 1985. "An alternative to the one-child policy in China." *Population and Development Review* 11 (4): 585–617.

Brodaty, Henry, and Marika Donkin. 2022. "Family caregivers of people with dementia." *Dialogues in Clinical Neuroscience.*

Cai, Yong. 2008. "An assessment of China's fertility level using the variable-r method." *Demography* 45, no. 2 (May): 271–281. https://doi.org/10.1353/dem.0.0003.

———. 2010. "China's Below-Replacement Fertility: Government Policy or Socioeconomic Development?" *Population and Development Review* 36 (3): 419–440. https://doi.org/10.1111/j.1728-4457.2010.00341.x.

Cai, Yong, and Feng Wang. 2021. "The Social and Sociological Consequences of China's One-Child Policy." *Annual Review of Sociology* 47:587–606.

Cai, Yong, Feng Wang, and Ke Shen. 2018. "Fiscal Implications of Population Aging and Social Sector Expenditure in China." *Population and Development Review* 44 (4): 811–831. https://doi.org/10.1111/padr.12206.

Caswell, Hal. 2019. "The Formal Demography of Kinship: A Matrix Formulation." *Demographic Research* 41:679–712.

———. 2020. "The Formal Demography of Kinship II: Multistate Models, Parity, and Sibship." *Demographic Research* 42:1097–1144.

———. 2022. "The Formal Demography of Kinship IV: Two-sex Models and Their Approximations." *Demographic Research* 47:359–396.

Caswell, Hal, and Xi Song. 2021. "The Formal Demography of Kinship III: Kinship dynamics with time-varying demographic rates." *Demographic Research* 45:517–546.

Chan, Kit Yee, Wei Wang, Jing Jing Wu, Li Liu, Evropi Theodoratou, Josip Car, Lefkos Middleton, et al. 2013. "Epidemiology of Alzheimer's disease and other forms of dementia in China, 1990–2010: A systematic review and analysis." *The Lancet* 381, no. 9882 (June): 2016–2023. https://doi.org/10.1016/S0140-6736(13)60221-4.

Chang, Yu-Ping, Joanne Kraenzle Schneider, and Loralee Sessanna. 2011. "Decisional conflict among Chinese family caregivers regarding nursing home placement of older adults with dementia." *Journal of Aging Studies* 25 (4): 436–444.

Chen, Feinian, and Guangya Liu. 2009. "Population aging in China." In *International handbook of population aging,* 157–172. Springer.

China National Bureau of Statistics (NBS). 2021. "China Statistical yearbook 2021." *China Statistics Press,* Table 2–7.

Chung, Pil H, and Monica Alexander. 2019. "Kin Dependency Ratios: An Extension and Application of the Goodman Method for Estimating the Availability of Kin." *Presented at the Population Association of America's 2019 Annual Meeting.*

Chung, Pil H, and Peter Hepburn. 2018. "Mass Imprisonment and the Extended Family." *Sociological Science* 5:335–360.

Crimmins, Eileen M, Yasuhiko Saito, Jung Ki Kim, Yuan S Zhang, Isaac Sasson, and Mark D Hayward. 2018. "Educational differences in the prevalence of dementia and life expectancy with dementia: Changes from 2000 to 2010." *The Journals of Gerontology: Series B* 73 (suppl_1): S20–S28.

Eberstadt, Nicholas, and Ashton Verdery. 2021. "China's Shrinking Families." *Foreign Affairs.*

Feeney, Griffith, and Feng Wang. 1993. "Parity Progression and Birth Intervals in China: The Influence of Policy in Hastening Fertility Decline." *Population and Development Review* 19 (1): 61–101. https://doi.org/10.2307/2938385.

Goodman, Leo A, Nathan Keyfitz, and Thomas W Pullum. 1974. "Family Formation and the Frequency of Various Kinship Relationships." *Theoretical Population Biology* 5 (1): 1–27.

Hammel, Eugene A, Carl Mason, Kenneth Wachter, Feng Wang, and Hongqui Yang. 1991. "Rapid population change and kinship: The effects of unstable demographic changes on Chinese kinship networks, 1750–2250." In *Consequences of Rapid Population Growth in Developing Countries,* 243–272. Taylor & Francis.

Jia, Jianping, Cuibai Wei, Shuoqi Chen, Fangyu Li, Yi Tang, Wei Qin, Lina Zhao, et al. 2018. "The Cost of Alzheimer's Disease in China and Re-estimation of Costs Worldwide." *Alzheimer's & Dementia: The Journal of the Alzheimer's Association* 14 (4): 483–491.

Jia, Jianping, Xiumei Zuo, Xiang-Fei Jia, Changbiao Chu, Liyong Wu, Aihong Zhou, Cuibai Wei, et al. 2016. "Diagnosis and treatment of dementia in neurology outpatient departments of general hospitals in China." *Alzheimer's & Dementia* 12, no. 4 (April): 446–453. https://doi.org/10.1016/j.jalz.2015.06.1892.

Jia, Longfei, Meina Quan, Yue Fu, Tan Zhao, Yan Li, Cuibai Wei, Yi Tang, et al. 2020. "Dementia in China: Epidemiology, clinical management, and research advances." *The Lancet Neurology* 19, no. 1 (January): 81–92. https://doi.org/10.1016/S1474-4422(19)30290-X.

Jiang, Lin. 1995. "Changing kinship structure and its implications for old-age support in urban and rural China." *Population Studies* 49 (1): 127–145.

Kitagawa, Evelyn M. 1955. "Components of a difference between two rates." *Journal of the American Statistical Association* 50 (272): 1168–1194.

Kolk, Martin, Linus Andersson, Emma Pettersson, and Sven Drefahl. 2021. "The Swedish Kinship Universe—A demographic account of the number of children, parents, siblings, grandchildren, grandparents, aunts/uncles, nieces/nephews, and cousins using national population registers." *Stockholm Research Reports in Demography* 28:1–46.

Lang, Linda, Angela Clifford, Li Wei, Dongmei Zhang, Daryl Leung, Glenda Augustine, Isaac M Danat, Weiju Zhou, John R Copeland, Kaarin J Anstey, et al. 2017. "Prevalence and Determinants of Undetected Dementia in the Community: A Systematic Literature Review and a Meta-Analysis." *BMJ Open* 7 (2): e011146.

Li, Ting, Wenting Fan, and Jian Song. 2020. "The Household Structure Transition in China: 1982–2015." *Demography* 57, no. 4 (June): 1369–1391. https://doi.org/10.1007/s13524-020-00891-7.

Murphy, Michael. 2010. "Family and Kinship Networks in the Context of Ageing Societies." In *Ageing in Advanced Industrial States,* edited by Shripad Tuljapurkar, Naohiro Ogawa, and Anne H. Gauthier, 263–285. New York, NY: Springer.

Nichols, Emma, Jaimie D Steinmetz, Stein Emil Vollset, Kai Fukutaki, Julian Chalek, Foad Abd-Allah, Amir Abdoli, Ahmed Abualhasan, Eman Abu-Gharbieh, Tayyaba Tayyaba Akram, et al. 2022. "Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: An analysis for the Global Burden of Disease Study 2019." *The Lancet Public Health* 7 (2): e105–e125.

Nichols, Emma, Cassandra E I Szoeke, Stein Emil Vollset, Nooshin Abbasi, Foad Abd-Allah, Jemal Abdela, Miloud Taki Eddine Aichour, et al. 2019. "Global, regional, and national burden of Alzheimer's disease and other dementias, 1990–2016: A systematic analysis for the Global Burden of Disease Study 2016." *The Lancet Neurology* 18, no. 1 (January): 88–106. https://doi.org/10.1016/S1474-4422(18)30403-4.

Organisation for Economic Co-operation and Development (OECD). 2023. "Nurses (indicator)." *OECD Data (https://data.oecd.org/healthres/nurses.htm).*

Ory, Marcia G, Richard R Hoffman III, Jennifer L Yee, Sharon Tennstedt, and Richard Schulz. 1999. "Prevalence and impact of caregiving: A detailed comparison between dementia and nondementia caregivers." *The Gerontologist* 39 (2): 177–186.

Peng, Xizhe. 1987. "Demographic consequences of the Great Leap Forward in China's provinces." *Population and Development Review* 13 (4): 639–670.

Quail, Zara, Angelina Wei, Vicky Fan Zhang, and Mark McLean Carter. 2020. "Barriers to dementia diagnosis and care in China." *BMJ Case Reports CP* 13 (3): e232115.

Reyes, Adriana M, Robert F Schoeni, and Vicki A Freedman. 2021. "National estimates of kinship size and composition among adults with activity limitations in the United States." *Demographic research* 45:1097–1114.

Ruggles, Steven. 1993. "Confessions of a microsimulator: Problems in modeling the demography of kinship." *Historical Methods: A Journal of Quantitative and Interdisciplinary History* 26 (4): 161–169.

Schulz, Richard, and Lynn M Martire. 2004. "Family caregiving of persons with dementia: prevalence, health effects, and support strategies." *The American journal of geriatric psychiatry* 12 (3): 240–249.

Song, Qian, and Feinian Chen. 2020. "Living Arrangements, Offspring Migration, and Health of Older Adults in Rural China: Revelation from Biomarkers and Propensity Score Analysis." *Journal of Aging and Health* 32 (1-2): 71–82.

Song, Xi, and Cameron D Campbell. 2017. "Genealogical microdata and their significance for social science." *Annual Review of Sociology* 43:75–99.

Song, Xi, Cameron D Campbell, and James Z Lee. 2015. "Ancestry matters: Patrilineage growth and extinction." *American Sociological Review* 80 (3): 574–602.

Song, Xi, and Hal Caswell. 2022. "The Role of Kinship in Racial Differences in Exposure to Unemployment." *Demography* 59 (4): 1325–1352.

Song, Xi, and Robert D Mare. 2019. "Shared lifetimes, multigenerational exposure, and educational mobility." *Demography* 56 (3): 891–916.

United Nation. 2022. *World Population Prospects: The 2022 Revision.* United Nations, New York.

Velandia, Paola Pedroza, Molly K Miller-Petrie, Carina Chen, Suman Chakrabarti, Abigail Chapin, Simon Hay, Golsum Tsakalos, Anders Wimo, and Joseph L Dieleman. 2022. "Global and regional spending on dementia care from 2000–2019 and expected future health spending scenarios from 2020–2050: An economic modelling exercise." *EClinicalMedicine* 45:101337.

Verdery, Ashton M. 2017. "Modeling the future of China's changing family structure to 2100." In *China's Next Big Demographic Problems: Urbanization and Family Structure,* 23–78. Washington, DC: The American Enterprise Institute.

Verdery, Ashton M, and Rachel Margolis. 2017. “Projections of white and black older adults without living kin in the United States, 2015 to 2060.” *Proceedings of the National Academy of Sciences* 114 (42): 11109–11114.

Verdery, Ashton M, Emily Smith-Greenaway, Rachel Margolis, and Jonathan Daw. 2020. “Tracking the Reach of COVID-19 Kin Loss with a Bereavement Multiplier Applied to the United States.” *Proceedings of the National Academy of Sciences* 117 (30): 17695–17701.

Wachter, Kennethl W. 1997. “Kinship resources for the elderly.” *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences* 352 (1363): 1811–1817.

Wang, Feng, Yong Cai, and Baochang Gu. 2013. “Population, Policy, and Politics: How Will History Judge China’s One-Child Policy?” *Population and Development Review* 38:115–129.

Wang, Feng, Baochang Gu, and Yong Cai. 2016. “The End of China’s One-Child Policy.” *Studies in Family Planning* 47 (1): 83–86.

Wang, Feng, and Andrew Mason. 2007. “Population aging in China: Challenges, opportunities, and institutions.” In *Population in China at the Beginning of the 21st Century,* 177–196. Oxford, UK: Oxford University Press.

Wang, Shanshan, Daphne Sze Ki Cheung, and Angela YM Leung. 2019. “Overview of dementia care under the three-tier long-term care system of China.” *Public Health Nursing* 36 (2): 199–206.

Whyte, Martin King, Feng Wang, and Yong Cai. 2015. “Challenging Myths About China’s One-Child Policy.” *The China Journal* 74 (July): 144–159. https://doi.org/10.1086/681664.

Williams, Iván, Diego Alburez-Gutierrez, Xi Song, and Hal Caswell. 2022. *DemoKin: An R Package to Implement Demographic Matrix Kinship Models (https://github.com/IvanWilli/DemoKin).*

Wolf, Douglas A. 1994. “The elderly and their kin: patterns of availability and access.” *Demography of aging,* 146–194.

Yang, Haiou. 1992. “Population dynamics and kinship of the Chinese rural elderly: A microsimulation study.” *Journal of Cross-Cultural Gerontology* 7 (2): 135–150.

Zeng, Yi, Zhenglian Wang, Leiwen Jiang, and Danan Gu. 2008. “Future trend of family households and elderly living arrangement in China.” *Genus* 64 (1/2): 9–36.

Zhou, Maigeng, Haidong Wang, Xinying Zeng, Peng Yin, Jun Zhu, Wanqing Chen, Xiaohong Li, Lijun Wang, Limin Wang, Yunning Liu, et al. 2019. “Mortality, morbidity, and risk factors in China and its provinces, 1990–2017: A systematic analysis for the Global Burden of Disease Study 2017.” *The Lancet* 394 (10204): 1145–1158.

Zhou, Zhangjun, Ashton M Verdery, and Rachel Margolis. 2019. "No Spouse, No Son, No Daughter, No Kin in Contemporary China: Prevalence, Correlates, and Differences in Economic Support." *The Journals of Gerontology: Series B* 74, no. 8 (October): 1453–1462.

Tables and Figures

Table 1. Expected Number of Kin in Named Type for a Randomly Selected Individual by Age and Year

Focal's Age at 60							
Year	Children	Grandchildren	Siblings	Aunts/Uncles	Nieces/Nephews	Cousins	Parents
1990	4.42	7.08	3.06	1.50	15.57	23.63	0.22
2019	2.00	2.91	3.81	2.71	9.18	27.11	0.52
2050	1.67	1.26	1.83	4.31	3.08	15.19	1.12
Focal's Age at 70							
Year	Children	Grandchildren	Siblings	Aunts/Uncles	Nieces/Nephews	Cousins	Parents
1990	3.99	11.75	2.28	0.52	15.17	18.14	0.03
2019	2.87	5.04	3.20	1.15	11.45	24.14	0.11
2050	1.70	2.17	2.17	2.17	4.37	17.66	0.26
Focal's Age at 80							
Year	Children	Grandchildren	Siblings	Aunts/Uncles	Nieces/Nephews	Cousins	Parents
1990	3.71	15.49	1.34	0.11	13.76	11.91	0.00
2019	3.96	7.69	2.20	0.31	13.64	17.98	0.00
2050	1.79	2.69	2.38	0.61	6.67	16.61	0.01

Data sources: United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition.
Notes: The table presents the expected number of kin of various kinds for a Focal individual at ages 60, 70, and 80 living in 1990, 2019, and 2050. The estimation details are described in the Methods section. The expected number of kin for individuals at other ages can also be derived from the method and are presented in the online appendix Figure S2.

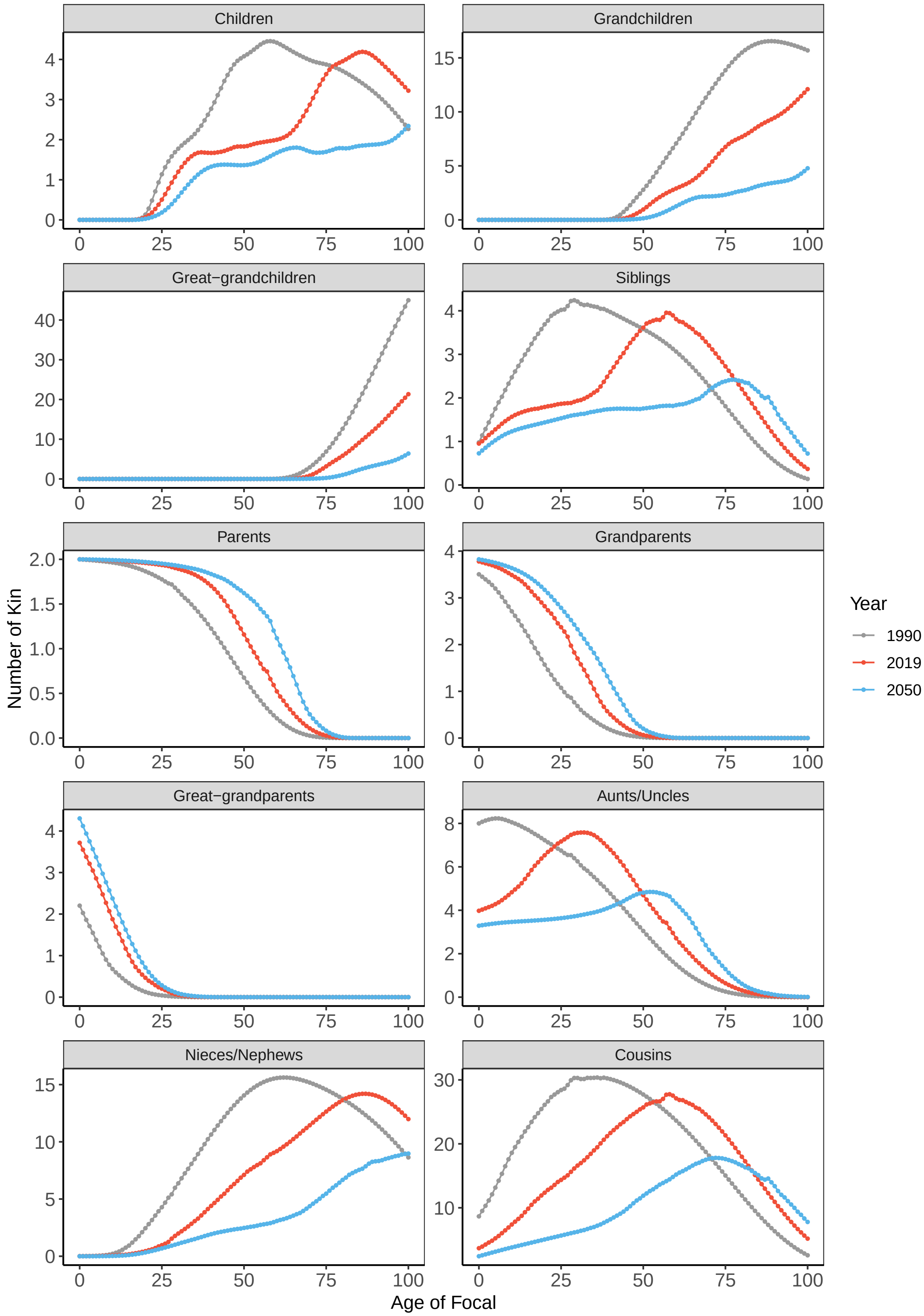
Children
Grandchildren
Great−grandchildren
Siblings
Parents
Grandparents
Great−grandparents
Aunts/Uncles
Nieces/Nephews
Cousins
Number of Kin
Age of Focal
Year
1990
2019
2050

Fig. 1. Expected Numbers of Kin of Various Kinds as a Function of the Age of Focal in 1990, 2019, and 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators Nichols et al. 2022.

Notes: The figure presents the expected numbers of living kin of various types as a function of the age of Focal in 1990, 2019, and 2050, respectively. The living kin are estimated from the time-varying kinship model using period age-specific fertility and mortality rates from 1950 to 2050 from the UN's 2022 Revision of World Population Prospects United Nation 2022. The results in a particular year reflect the changing mortality and fertility schedules in China from 1950 up to that year. The methodology is described in the Materials and Methods section. To estimate the number of all kinds of kin from both paternal and maternal ancestry, we assume that the demographic rates of female and male kin are equal.

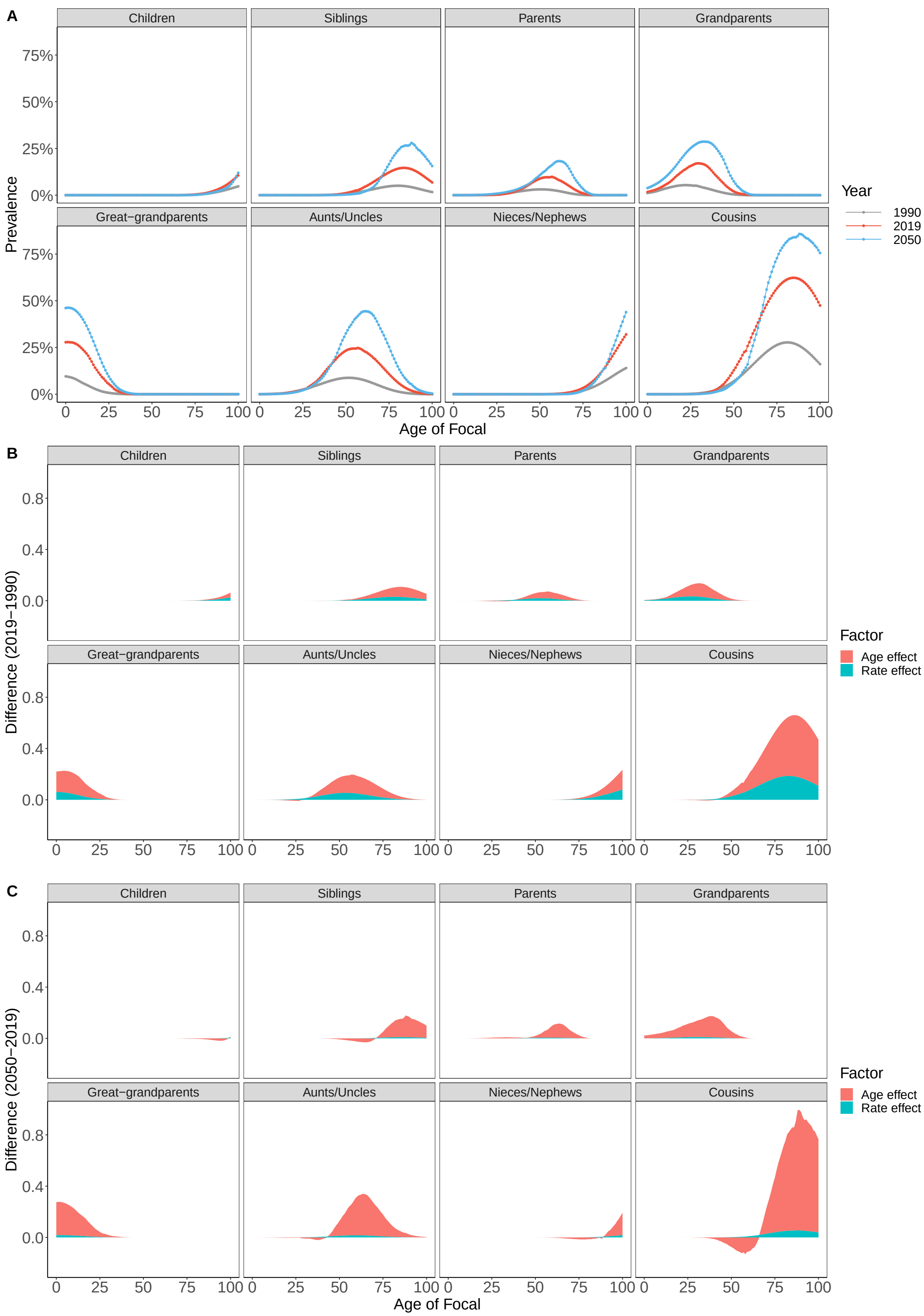
A
Children
Siblings
Parents
Grandparents
Great−grandparents
Aunts/Uncles
Nieces/Nephews
Cousins
Prevalence
75%
50%
25%
0%
0
25
50
75
100
Age of Focal
Year
1990
2019
2050
B
Difference (2019−1990)
0.8
0.4
0.0
Factor
Age effect
Rate effect
C
Difference (2050−2019)
Age of Focal

Fig. 2. (A) Estimated Probabilities of Having at Least One Kin with Dementia as a Function of the Age of Focal in 1990, 2019, and 2050. (B) Decompose the Difference in the Number of Kin with Dementia between 1990 and 2019. (C) A Decomposition of the Difference in the Number of Kin with Dementia between 2019 and 2050.

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition.

Notes: Section A shows the probability that an individual has a certain type of kin with dementia by age of the individual in 1990, 2019, and 2050. These numbers are estimated from time-varying age-specific fertility, mortality, and prevalence of dementia in the population. The estimation details are described in the Methods section. Section B and C present the Kitagawa's decomposition results. The total area of each graph gives the difference in the number of kin with dementia between 1990 and 2019 (B), 2019 and 2050 (C), partitioned into contributions from the difference in age structure of kin and the difference in age-specific dementia rate.

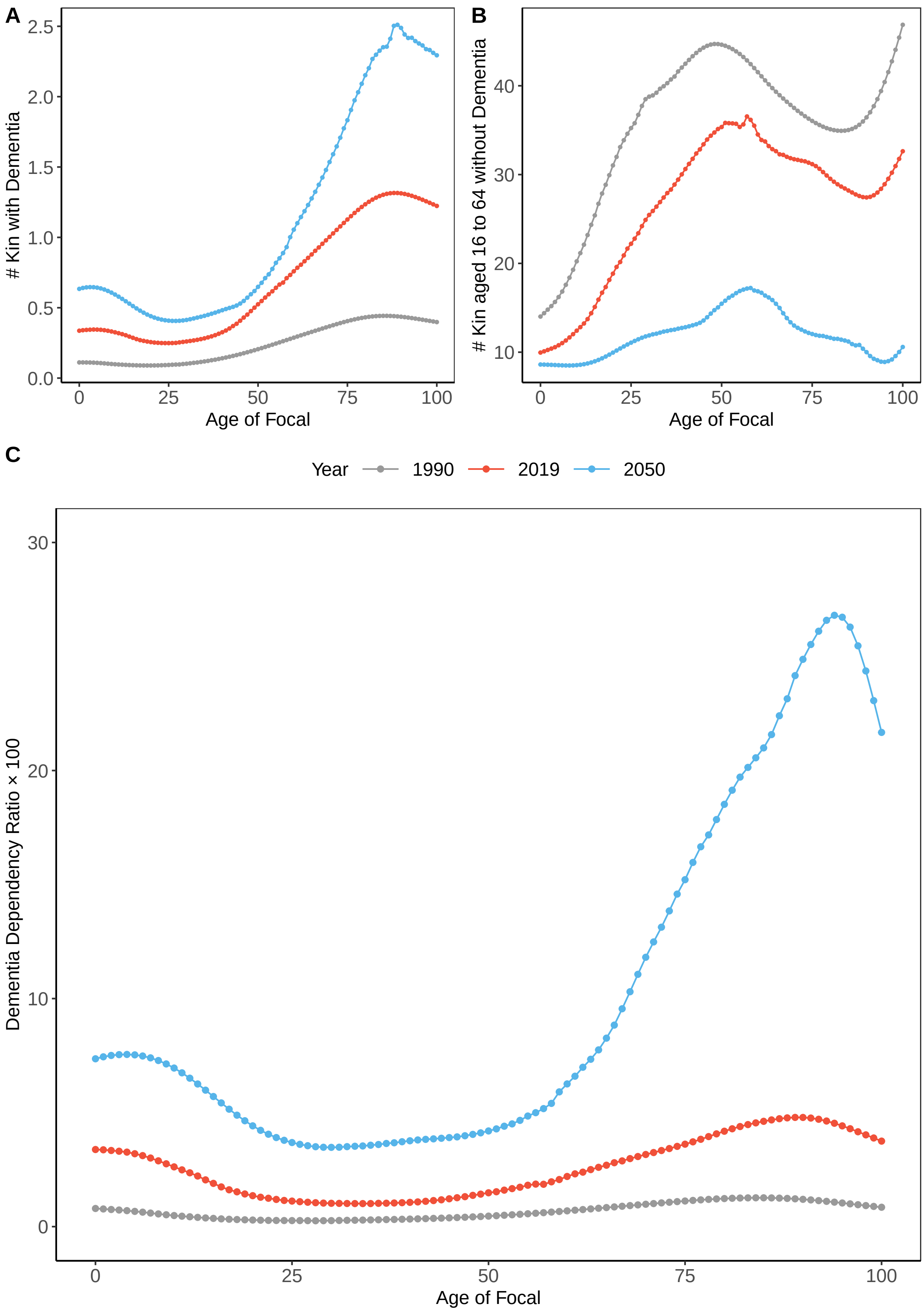
A
B
C
Kin with Dementia
Kin aged 16 to 64 without Dementia
Dementia Dependency Ratio × 100
Age of Focal
Year
1990
2019
2050

Fig. 3. (A) The Number of Kin with Dementia. (B) The Number of Kin aged 16-64 without Dementia. (C) The Dementia Dependency Ratio (DDR(x)) as a Function of the Age of Focal in 1990, 2019, and 2050.

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition.

Notes: These figures show the estimated number of kin with dementia, the number of kin aged 16-64 without dementia, and the estimated dementia dependency ratio (DDR) by age of individuals in 1990, 2019, and 2050. DDR refers to the proportion of family members with dementia to family members without dementia who are at risk for provide family care. The mathematic definition of DDR is discussed in the Methods section.

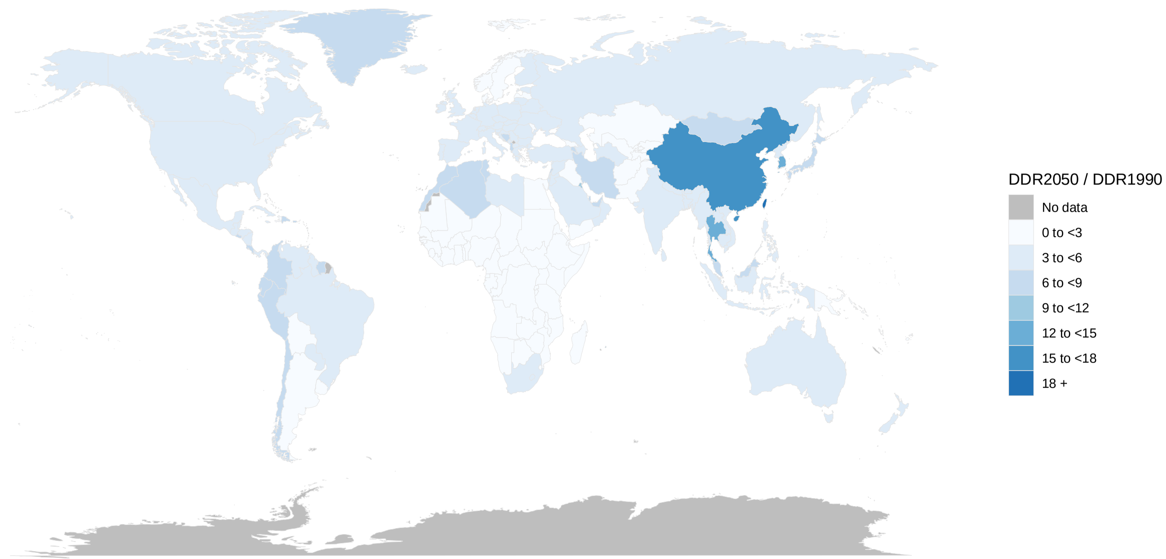

Fig. 4. Change in the Age-Avereaged Dementia Dependency Ratio DDR(pop) by Country and Region from 1990 to 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition.

Notes: This figure presents a heat map of changes in the age-weighted Dementia Dependency Ratio from 1990 to 2050 for countries of the world.We apply the method used for estimates for China to other countries with dementia data available in the Global Burden of Disease database and demographic rates estimated by the United Nation. A dark blue color indicates a rapidly increasing dementia burden on kin, whereas a light blue color indicates a slowly increasing burden caused by dementia on kin over time.

Supplementary appendix for

The Present and Future Dementia Caregiving Demand in China: Kinship-Based Projections and Global Comparisons

This PDF file includes:

Data Description

Figs. S1 to S6

Tables S1 to S2

References and Notes

Contents

S1 Input Data Used for Kinship Estimates

S1.1 Demographic Inputs for Analysis

The World Population Prospects (WPP) 2022 serves as the primary data source for the analysis. The kinship models utilize annual single-year age-specific fertility and mortality rates spanning the years from 1950 to 2100 for 195 countries and territories. As we discussed in the Materials and Methods section, the time-varying kinship model also relies on a time-zero boundary condition $\mathbf{k}(x, 0)$, which was obtained by the distribution of mother's ages at childbirth at time 0 implied by the stable population assumption (see equation (3) in Caswell 2019 [1]). Specifically, we derived this distribution by dividing age-specific birth counts by the total number of births in a specific year.

S1.2 Data Sources and Estimation Methods

The age-specific demographic estimates for the years 1950 to 2022 are derived from a comprehensive range of data sources, including 2,890 nationally representative sample surveys, 1,758 censuses, vital registration systems, and surveys conducted between 1950 and 2022. The WPP 2022 applies additional techniques such as smoothing and adjustment methods to address missing values and generate single-year estimates. These methods aim to enhance the accuracy and reliability of the demographic data used in the analysis.

S1.3 Population Projection Method

The WPP 2022 employs probabilistic projection methods to project population changes from 2022 to 2100. This projection method takes into consideration historical patterns in migration, death, and fertility rates. Various estimates are produced by the WPP 2022 based on different assumptions, allowing for a range of possible population scenarios. For our calculations, we rely on the medium-variant projection, as it represents the most likely future trend among the different projections presented by the WPP 2022.

S1.4 Medium-Variant Projection

The medium scenario, based on the WPP medium-variant projection, takes into account specific trends for fertility and life expectancy. It predicts a continued decline in fertility rates in countries where women have, on average, two or more children during their lifetime. Conversely, it assumes a slight increase in fertility rates in countries where women are currently having fewer than two children. Additionally, the medium scenario assumes a general improvement in life expectancy across all countries. Demographic rates based on these assumptions jointly determine the projected population changes in the medium-variant projection.

S1.5 Methodological Details

For a more detailed explanation of the methodologies utilized in the World Population Prospects 2022, we recommend referring to the WPP 2022 Methodology Report [2]. This report provides comprehensive descriptions and insights into the specific methodologies employed in estimating historical and projected fertility and mortality rates. The Materials and Methods section in our main text provides an overview of the demographic models of kinship utilized in our analysis. However, for a more comprehensive introduction to the models and additional model extensions, we recommend referring to the series of publications on the formal demography of kinship [1, 3, 4, 5]. These publications delve into detailed explanations and advancements related to the demographic models employed in our study.

S2 Dementia Prevalence

S2.1 Dementia Prevalence Inputs, Definition, and Interpolation

Our analyses draw on datasets of female age-specific prevalence rates of Alzheimer's and other dementia (hereafter referred to as dementia) for 195 countries and territories. These prevalence rates, covering the years 1990, 2019, 2030, 2040, and 2050, were estimated by the Global Burden of Disease (GBD) 2019 Dementia Forecasting Collaborators and published in [6] (see also [7, 8]).

It is important to note that the dementia prevalence rates used for 1990 and 2019 exhibit a slight deviation from the estimates provided in the online GBD Results Tool. The online GBD Results Tool employs a narrower definition, excluding dementia caused by some clinical diseases. Nicols et al. [6] adopted a broader definition of dementia, encompassing not only Alzheimer's disease and other dementia but also dementia caused by Down syndrome, Parkinson's disease, clinical stroke, and traumatic brain injury. We followed the inclusive definition of dementia in this study as it enables a more comprehensive assessment of the overall burden of dementia [9].

The original dementia prevalence provided by the GBD Dementia Collaborators is grouped into five-year age intervals. We applied linear interpolation to estimate the prevalence rates for single-year age groups up to the age of 100.

S2.2 Data Sources and Estimation Methods

The GBD (2019) systematically collected all available data on dementia prevalence from cross-sectional studies, cohort studies, and administrative claims databases. The GBD 2019 identified 522 sources that reported on dementia prevalence, covering 18 out of 21 world regions. In the case of China, the prevalence estimate was derived from 43 empirical studies. All the data sources used in the GBD 2019 are accessible at: http://ghdx.healthdata.org/

gbd-2019/data-input-sources.

To estimate dementia prevalence by age, sex, andyear for 195 countries and territories, the GBD study utilized the Disease Modelling Meta-Regression (DisMod-MR) 2.1, a Bayesian meta-regression tool commonly used for nonfatal modelling [10]. In addition to the prevalence input, two country-level covariates were incorporated into the analysis. Age-standardized education was considered as a proxy for general brain health, which could potentially have a protective effect against dementia. Age-standardized smoking prevalence was also included as a covariate, as existing literature has shown a positive relationship between smoking and dementia.

The data sources for Western Europe, East Asia, high-income Asia-Pacific, and high-income North America were more abundant compared to other regions. However, there was a lack of available input data for Oceania, central Asia, or southern sub-Saharan Africa. To address this limitation, the GBD 2019 used predictions based on surveys that collected data on cognitive tests and functional limitations. This approach aimed to expand data coverage and provide additional information in regions where data on dementia prevalence were scarce.

The DisMod-MR 2.1 model incorporated these covariates and leveraged information from locations within the same region that had available data to generate estimates for locations with little or no input data. This methodology allowed for more comprehensive estimation of dementia prevalence across various regions.

S2.3 Dementia Prevalence Projection

To project dementia prevalence rates beyond 2019, our analysis relied on forecasted rates for 2030, 2040, and 2050 from data provided in Nichols et al. 2022 [6] by the GBD 2019 Dementia Forecasting Collaborators. The forecasting method involves two key components: (1) forecasting dementia prevalence attributable to risk factors and (2) forecasting risk-deleted dementia prevalence. The final total forecasted dementia prevalence was obtained by combining these two components.

The GBD first forecasted changes in the prevalence of dementia from 2019 to 2050 attributable to three well-known risk factors: high body-mass index, high fasting plasma glucose, and smoking. Additional risk factors, such as low physical activity, high blood pressure, low education, alcohol use, and exposure to air pollution, were evaluated for their association with dementia prevalence. If these risk factors demonstrated significance and their effect direction aligned with previous evidence, they were included in the forecasting model. The GBD first forecasted the prevalence of these risk factors from 2019 to 2050 and then predicted risk-attributable dementia prevalence globally, by world region, and by country.

To quantify risk factors other than education, the GBD developed a summary exposure value (SEV), which is a risk-weighted prevalence of a particular risk factor exposure. SEV values range from 0 to 1, with a value of 0 indicating no risk in a population and a value of 1 indicating a maximum risk. The GBD first computed the yearly rate of change in SEV on a logit scale for different locations, age groups, sexes, and previous years. Future rates of change were estimated using a weighted average of previous rates observed throughout the time series. Years closer to the projected year were given higher weights, indicating their greater influence on the estimation. Conversely, more distant years were assigned lower weights, implying their relatively lesser impact on the projected rates of change.

For predicting risk-deleted dementia prevalence, the GBD used linear regression models for males and females separately. The model included 5-year age groups, world region, and years of education as predictors. Years of education are assumed to be unchanged after the age of 25 and are held constant within a specific birth cohort based on location and sex.

In order to account for uncertainty, the GBD 2019 employed an additional method of conducting 1,000 draws at each calculation step. This approach enabled the propagation of uncertainty arising from different sources, including input data, correction for measurement errors, and estimates of nonsampling error. The resulting 95% uncertainty intervals were defined as the range between the 2.5^{th} and 97.5^{th} ordered values of the draws. For our analysis, we utilized the mean prevalence estimate derived from these 1,000 draws as the point estimate.

S3 Figures and Tables

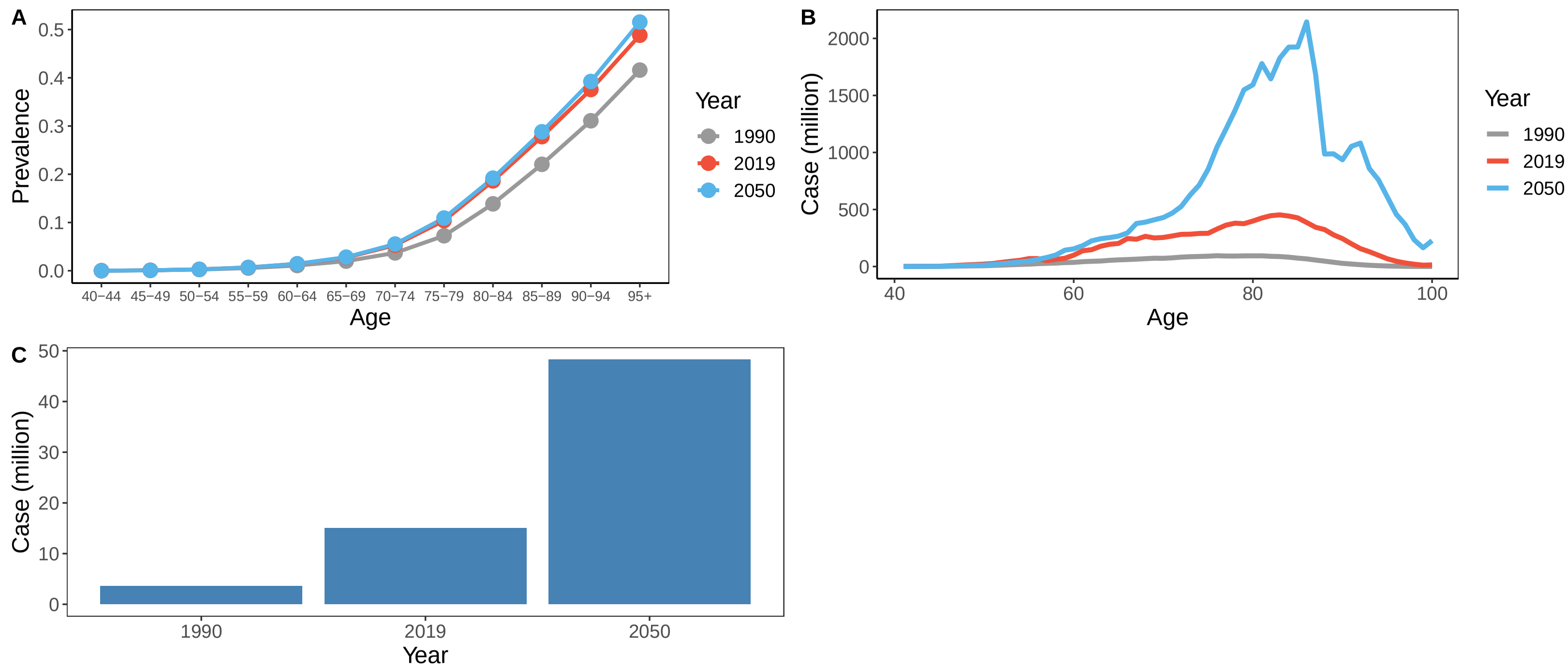

Fig. S1. The Age-Specific Dementia Prevalence Rate and the Number of Dementia cases in 1990 and 2019, and 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021. GDB 2019 Dementia Forecasting [6].

Notes: Panel A shows the age-specific prevalence rate of dementia in 1990, 2019, and 2050; Panel B shows the number of dementia cases (in million) in 1990, 2019, and 2050; and Panel C shows the total number of dementia cases (in million) in 1990, 2019, and 2050. These numbers are calculated using dementia prevalence estimates from the GDB 2019 Dementia Forecasting Collaborators [6]

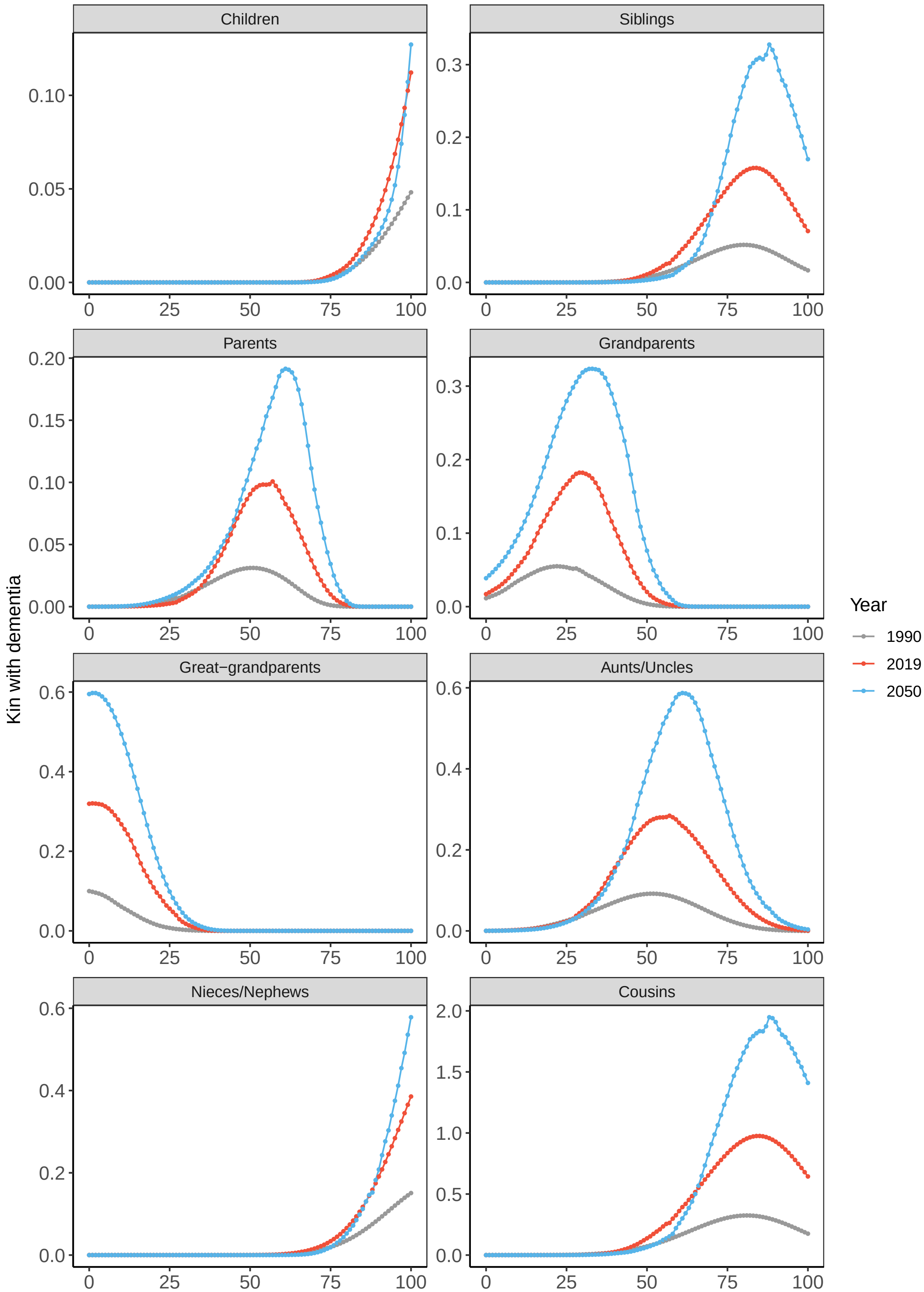
Children
Siblings
Parents
Grandparents
Great−grandparents
Aunts/Uncles
Nieces/Nephews
Cousins
Kin with dementia
Year
1990
2019
2050

Fig. S2. Expected Number of Kin with Dementia as a Function of the Age of Focal in 1990, 2019, and 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators [6].

Notes: The figure shows the approximate probability that an individual of a specified age will have at least one kin with dementia, in the population in 1990, 2019, and 2050. These probabilities are estimated from the expected numbers of kin with dementia using a Poisson approximation. The calculation details are described in the Materials and Methods section in the main text.

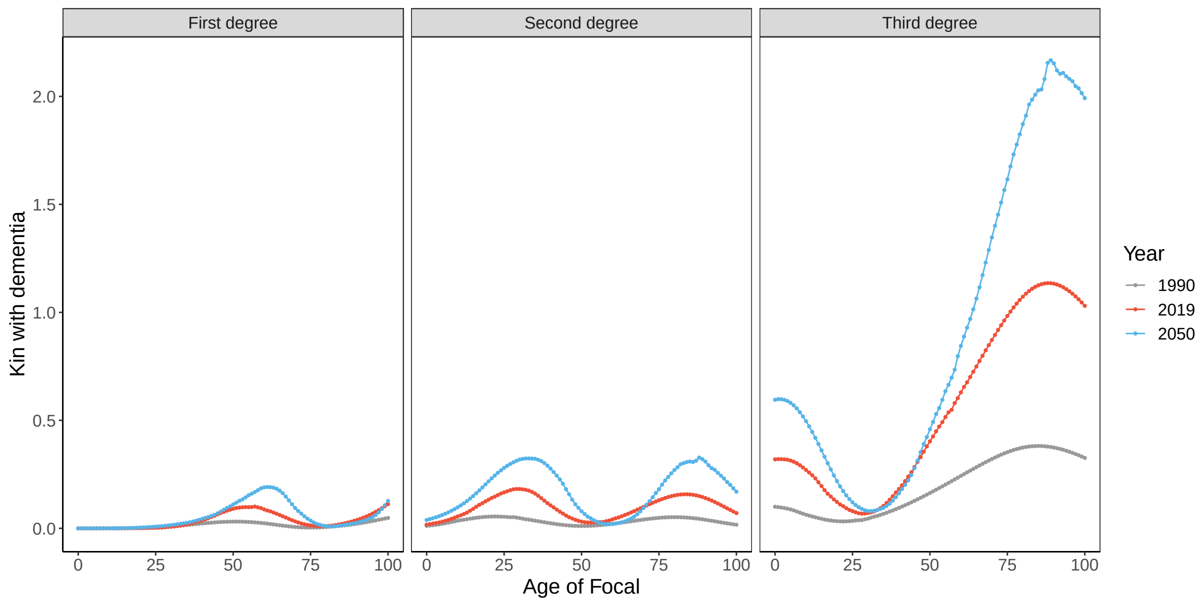

Fig. S3. Estimated Number of Kin with Dementia, by Degrees of Relatedness, as a Function of the Age of Focal in 1990, 2019, and 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators [6].

Notes: The figure shows an individual's numbers of first-degree kin, second-degree kin, and third-degree kin with dementia by age of the individual in 1990, 2019, and 2050, respectively. First-degree kin include children and parents; second-degree kin include grandchildren, grandparents, and siblings; and third-degree kin include great-grandchildren, great-grandparents, aunts, uncles, nieces, and nephews.

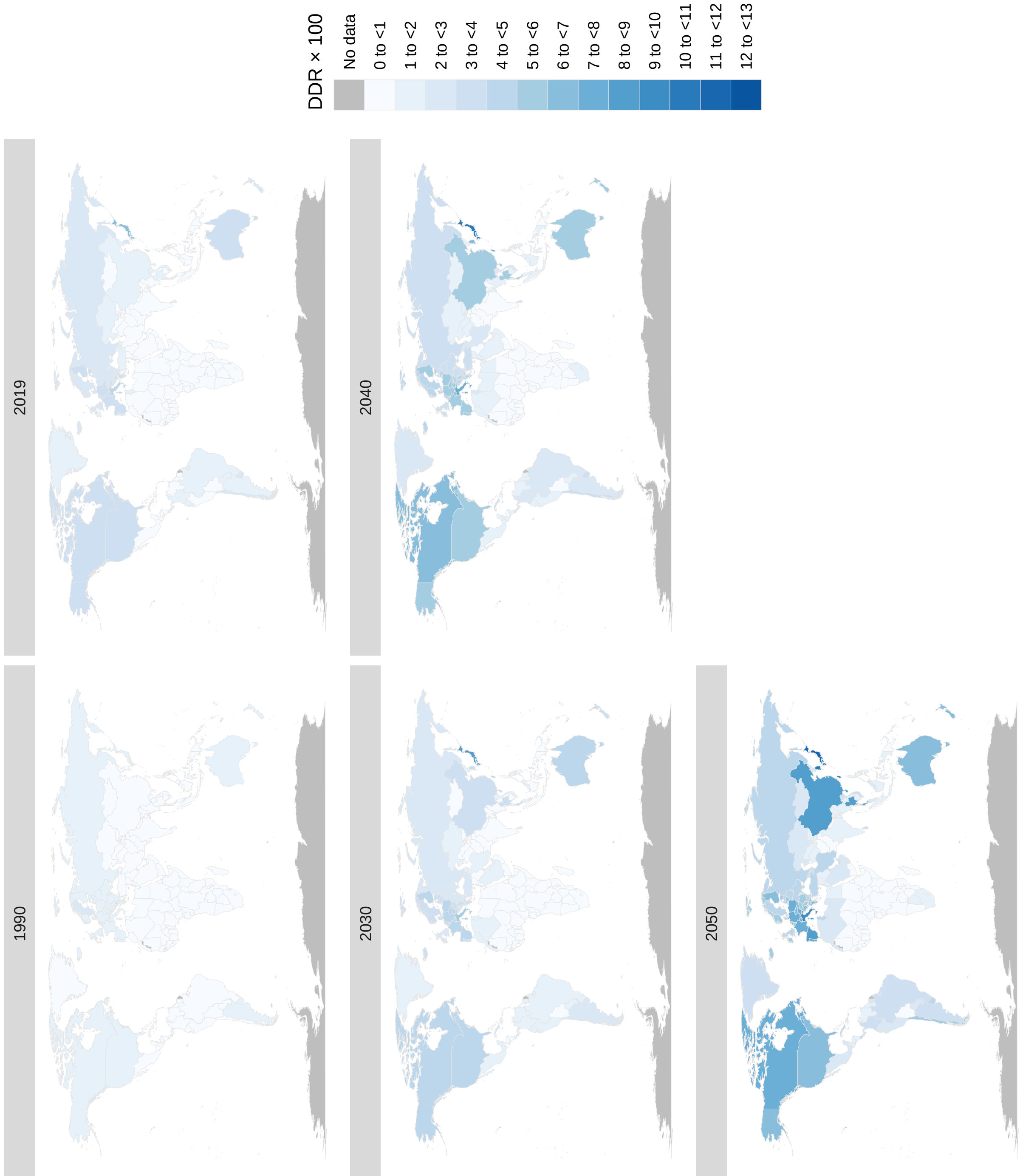
1990
2019
2030
2040
2050
DDR × 100
No data
0 to <1
1 to <2
2 to <3
3 to <4
4 to <5
5 to <6
6 to <7
7 to <8
8 to <9
9 to <10
10 to <11
11 to <12
12 to <13

Fig. S4. Population-Averaged Dementia Dependency Ratio DDR(pop) by Country and Region in 1990, 2019, 2030, 2040, and 2050

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators [6].

Notes: This figure presents five heat maps of DDR(pop) for countries of the world in 1990, 2019, and 2050. We apply the method used for estimating the DDR index for China to other countries. The indexes draw on dementia data from GDB 2019 Dementia Forecasting Collaborators and data of fertility and mortality rates in the UN's 2022 Revision of World Population Prospects [11]. A darker blue color indicates a higher caregiving burden caused by dementia on kinship groups, whereas a lighter blue color indicates a lower caregiving burden caused by dementia on kinship groups. The detailed DDR estimates are presented in Appendix Table S2.

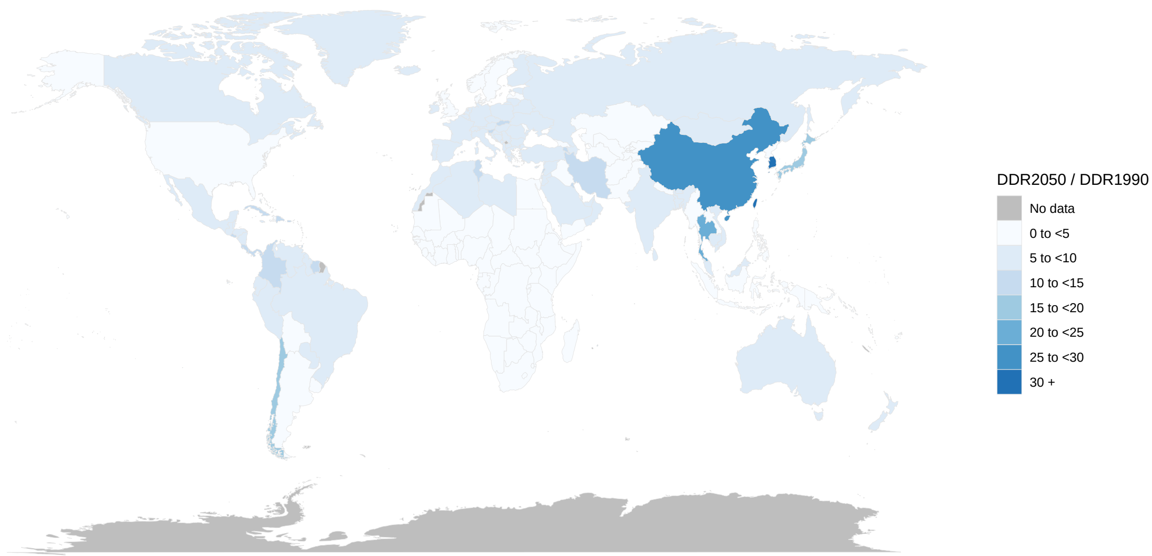

Fig. S5. Change in the Population-Averaged Dementia Dependency Ratio DDR(pop) by Country and Region from 1990 to 2050, Limiting Kin Types to Parents and Siblings

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators [6].

Notes: This figure presents a heat map of change in DDR(pop) by country from 1990 to 2050. As a robustness check, in this graph we limit the kin types to parents and siblings, conditioning on the survival of Focal. To calculate the DDR(x), the denominator is the number of siblings aged 16 to 64 without dementia, while the numerator is the number of parents and siblings with dementia, irrespective of their age. We apply the method used for estimating the DDR(x) index for China to other countries. The indexes draw on dementia data from GDB 2019 Dementia Forecasting Collaborators and data of fertility and mortality rates in the UN's 2022 Revision of World Population Prospects [11]. A darker blue color indicates a rapidly increasing dementia burden on kin, whereas a lighter blue color indicates a slowly increasing burden caused by dementia on kin over time.

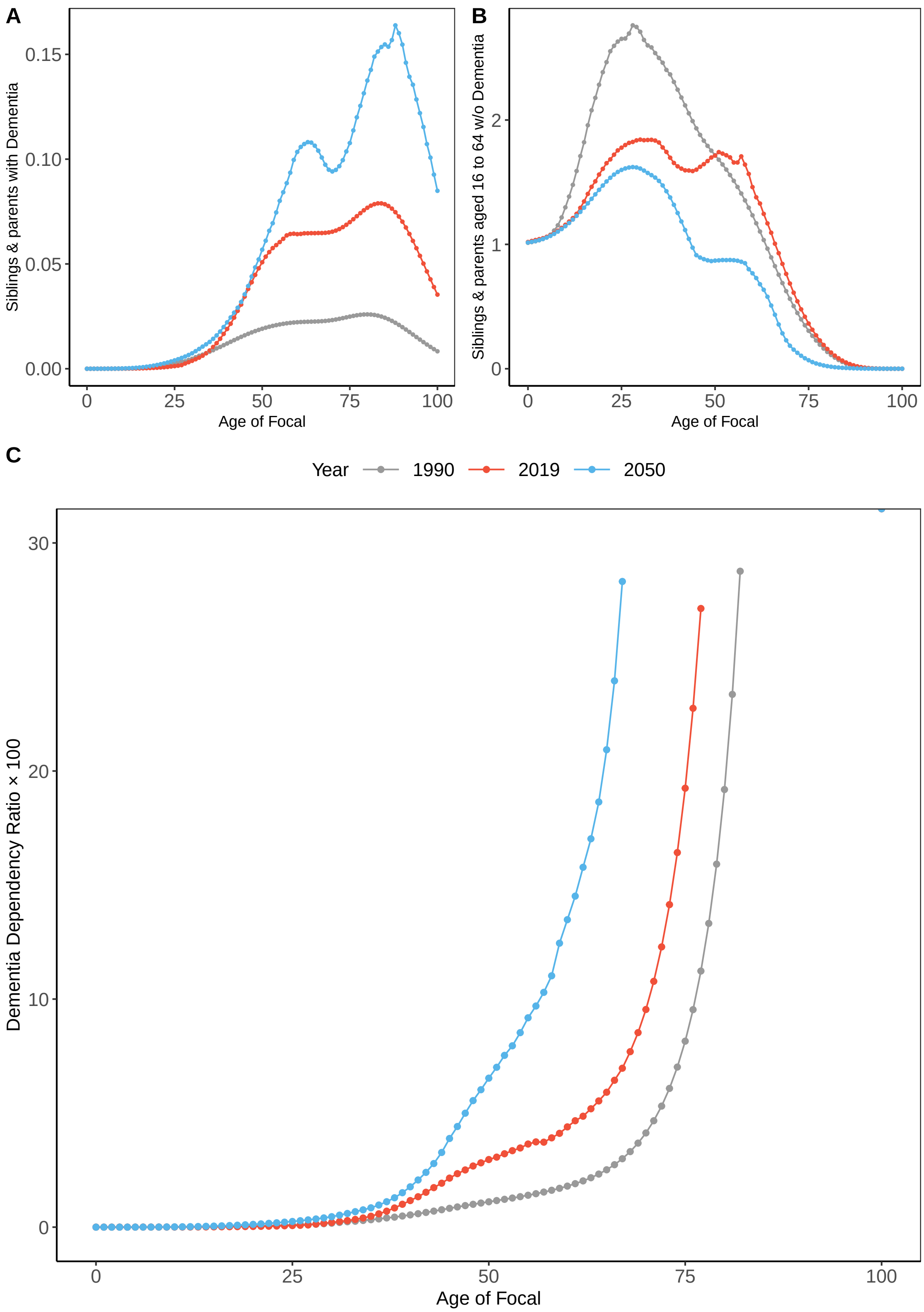

Fig. S5. (A) The Number of Parents with Dementia. (B) The Number of Siblings Aged 16–64 Without Dementia. (C) The Dementia Dependency Ratio (DDR(x)), restricted to

parents and siblings, as a Function of the Age of Focal in China in 1990, 2019, and 2050.

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition.

Notes: These figures show the estimated number of siblings and parents with dementia, the number of siblings and parents aged 16-64 without dementia, and the estimated dementia dependency ratio (DDR) by the age of Focal in 1990, 2019, and 2050. The DDR refers to the proportion of siblings and parents with dementia to siblings and parents without dementia who are at risk for provide family care, conditioning on the survival of Focal. To calculate the DDR, the denominator is the number of siblings aged 16 to 64 without dementia, while the numerator is the number of parents with dementia, irrespective of their age. The mathematical definition of DDR is discussed in the Materials and Methods section.

Table S1. Data Sources for Kinship and Dementia Estimates

Data Source	Data Type	Sex	Year	Age Range
(1) Mortality, q_x				
UN's 2022 World Population Prospects	Survey record/Estimate	Female	1950–2021	0–100
UN's 2022 World Population Prospects	Medium variant	Female	2022–2050	0–100
(2) Fertility, f_x				
UN's 2022 World Population Prospects	Survey record/Estimate	Female	1950–2021	15–49
UN's 2022 World Population Prospects	Medium variant	Female	2022–2050	15–49
(3) Alzheimer's disease and other dementias				
GDB 2019 Dementia Forecasting Collaborators	Meta analysis/Estimate	Female	1990, 2019, 2050	0–100

Notes: The medium-variant projection refers to the median of several thousand distinct trajectories of each demographic component derived using the probabilistic model of the variability in changes over time based on the Population Division of the UN; The Global Burden of Disease (GBD) uses the Bayesian meta-regression tool to estimate prevalence rate, and provide the mean value out of 1,000 draws from their model. We used a revised dementia prevalence estimates and the 2050 projection directly from the GDB 2019 Dementia Forecasting Collaborators. Compared to the estimates from the GBD 2019 public database, the estimates we used also include dementia that is caused by other clinical diseases such as clinical stroke, Parkinson's disease, Down syndrome, and traumatic brain injury. See details in [6]. We use the mean-value estimation of dementia prevalence throughout our analysis. The input data sources for estimating dementia prevalence in China was derived from a meta-analysis of 43 peer-reviewed journal articles.

Table S2. Dementia Dependency Ratios and Change in Dementia Dependency Ratios by Country and Year

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
Afghanistan	0.29	0.37	0.69	1.29	1.83	2.36
Albania	0.90	1.84	6.53	2.06	3.54	7.29
Algeria	0.40	0.78	2.94	1.94	3.77	7.33
American Samoa	0.50	0.61	1.54	1.24	2.51	3.10
Andorra	1.87	3.30	8.85	1.77	2.68	4.73
Angola	0.42	0.43	0.61	1.03	1.40	1.45
Antigua and Barbuda	0.72	1.48	4.43	2.05	2.99	6.11
Argentina	1.19	1.87	3.22	1.58	1.72	2.72
Armenia	0.84	1.80	5.18	2.14	2.88	6.17
Australia	1.53	3.17	6.73	2.07	2.12	4.39
Austria	1.52	2.94	7.16	1.93	2.44	4.70
Azerbaijan	0.63	1.04	3.30	1.66	3.17	5.27
Bahamas	0.61	1.15	3.08	1.90	2.67	5.06
Bahrain	0.56	0.99	3.60	1.76	3.63	6.39
Bangladesh	0.27	0.44	1.56	1.65	3.51	5.79
Barbados	0.69	1.51	3.77	2.17	2.50	5.44
Belarus	1.52	2.14	4.73	1.41	2.21	3.12
Belgium	1.66	3.12	5.73	1.87	1.84	3.44
Belize	0.47	0.64	1.77	1.34	2.79	3.75
Benin	0.36	0.34	0.46	0.94	1.36	1.28
Bermuda	0.89	2.54	6.11	2.87	2.40	6.89
Bhutan	0.23	0.34	1.30	1.48	3.79	5.60
Bolivia (Plurinational State of)	0.34	0.46	0.93	1.34	2.01	2.70
Bosnia and Herzegovina	1.02	2.12	6.26	2.09	2.95	6.16
Botswana	0.40	0.46	1.02	1.13	2.25	2.55
Brazil	0.67	1.30	3.99	1.94	3.07	5.95
Brunei Darussalam	0.47	0.90	2.96	1.92	3.28	6.31
Bulgaria	1.53	2.40	4.79	1.57	1.99	3.12
Burkina Faso	0.31	0.29	0.43	0.93	1.47	1.37
Burundi	0.33	0.33	0.45	1.00	1.36	1.37
Côte d'Ivoire	0.27	0.29	0.46	1.08	1.58	1.71
Cabo Verde	0.31	0.66	2.41	2.15	3.68	7.90
Cambodia	0.33	0.58	1.54	1.75	2.63	4.60
Cameroon	0.37	0.32	0.43	0.87	1.34	1.16
Canada	1.66	3.23	7.79	1.95	2.41	4.69

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
Central African Republic	0.46	0.50	0.53	1.08	1.05	1.14
Chad	0.33	0.27	0.33	0.82	1.19	0.98
Chile	0.64	2.02	5.63	3.18	2.78	8.85
China	**0.46**	**1.91**	**8.22**	**4.15**	**4.30**	**17.86**
China, Taiwan Province of China	0.55	2.24	11.04	4.06	4.93	19.98
Colombia	0.45	1.01	3.38	2.24	3.34	7.49
Comoros	0.35	0.34	0.57	0.96	1.67	1.60
Congo	0.49	0.47	0.70	0.96	1.48	1.43
Costa Rica	0.60	1.33	4.15	2.21	3.13	6.90
Croatia	1.58	3.05	6.02	1.94	1.97	3.82
Cuba	0.77	1.58	4.44	2.04	2.81	5.74
Cyprus	0.91	2.00	5.18	2.19	2.59	5.66
Czechia	1.43	3.10	6.21	2.17	2.00	4.34
Dem. People's Republic of Korea	0.62	1.15	2.63	1.84	2.30	4.23
Democratic Republic of the Congo	0.44	0.48	0.51	1.11	1.06	1.17
Denmark	1.70	2.55	4.62	1.50	1.81	2.71
Djibouti	0.37	0.41	0.91	1.10	2.22	2.44
Dominica	0.56	0.76	2.42	1.36	3.20	4.34
Dominican Republic	0.35	0.91	2.35	2.56	2.59	6.65
Ecuador	0.41	1.00	2.76	2.46	2.75	6.77
Egypt	0.67	0.77	1.54	1.15	2.00	2.30
El Salvador	0.36	0.85	2.35	2.33	2.76	6.46
Equatorial Guinea	0.44	0.47	0.66	1.05	1.41	1.48
Eritrea	0.32	0.42	0.77	1.31	1.84	2.41
Estonia	1.70	3.06	5.96	1.80	1.95	3.51
Eswatini	0.35	0.39	0.67	1.11	1.71	1.90
Ethiopia	0.32	0.38	0.70	1.18	1.86	2.20
Fiji	0.35	0.56	1.04	1.60	1.86	2.98
Finland	1.34	3.44	6.27	2.57	1.82	4.69
France	1.48	3.72	7.05	2.52	1.90	4.77
Gabon	0.75	0.60	0.92	0.81	1.54	1.24
Gambia	0.36	0.37	0.49	1.03	1.32	1.36
Georgia	1.24	1.83	3.50	1.48	1.91	2.83
Germany	1.63	3.41	7.43	2.09	2.18	4.57
Ghana	0.32	0.37	0.70	1.16	1.87	2.17
Greece	1.70	3.07	6.70	1.81	2.18	3.94
Greenland	0.47	1.26	3.39	2.71	2.69	7.29

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
Grenada	0.50	0.98	2.44	1.97	2.50	4.91
Guam	0.51	1.66	3.84	3.25	2.31	7.50
Guatemala	0.35	0.67	1.60	1.91	2.37	4.53
Guinea	0.37	0.37	0.50	1.01	1.34	1.35
Guinea-Bissau	0.38	0.33	0.45	0.87	1.36	1.19
Guyana	0.32	0.68	1.60	2.09	2.38	4.96
Haiti	0.34	0.37	0.65	1.07	1.77	1.89
Honduras	0.32	0.48	1.37	1.54	2.83	4.35
Hungary	1.55	2.77	5.08	1.78	1.83	3.27
Iceland	1.38	2.38	5.03	1.72	2.12	3.65
India	0.31	0.50	1.28	1.60	2.57	4.12
Indonesia	0.45	0.68	1.67	1.51	2.48	3.74
Iran (Islamic Republic of)	0.47	0.90	4.05	1.90	4.51	8.55
Iraq	0.58	0.55	1.06	0.95	1.92	1.82
Ireland	0.91	1.84	5.11	2.02	2.78	5.62
Israel	0.95	1.96	3.41	2.06	1.74	3.58
Italy	1.94	4.18	9.67	2.16	2.31	4.99
Jamaica	0.56	0.63	1.89	1.13	2.99	3.38
Japan	1.49	6.83	12.69	4.59	1.86	8.52
Jordan	0.41	0.66	1.96	1.60	2.97	4.75
Kazakhstan	0.76	1.09	2.07	1.44	1.90	2.74
Kenya	0.39	0.43	0.74	1.08	1.73	1.88
Kiribati	0.36	0.48	0.81	1.33	1.68	2.23
Kuwait	0.57	1.05	5.21	1.83	4.97	9.11
Kyrgyzstan	0.64	0.80	1.66	1.26	2.06	2.59
Lao People's Democratic Republic	0.36	0.44	1.14	1.24	2.58	3.21
Latvia	1.82	2.69	4.62	1.48	1.72	2.55
Lebanon	0.56	1.50	4.92	2.68	3.27	8.77
Lesotho	0.50	0.47	0.66	0.93	1.42	1.32
Liberia	0.28	0.31	0.45	1.13	1.43	1.62
Libya	0.46	0.66	2.16	1.45	3.27	4.72
Lithuania	1.62	2.80	5.34	1.73	1.90	3.29
Luxembourg	1.54	2.65	5.29	1.72	1.99	3.44
Madagascar	0.30	0.43	0.76	1.43	1.77	2.53
Malawi	0.44	0.45	0.66	1.02	1.47	1.50
Malaysia	0.44	0.91	2.85	2.09	3.13	6.54
Maldives	0.42	0.63	2.92	1.50	4.66	7.01

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
Mali	0.26	0.28	0.36	1.11	1.26	1.40
Malta	0.79	3.07	8.30	3.90	2.70	10.54
Marshall Islands	0.31	0.37	0.87	1.18	2.39	2.82
Mauritania	0.29	0.33	0.53	1.13	1.61	1.81
Mauritius	0.48	1.41	4.51	2.92	3.20	9.33
Mexico	0.51	0.80	2.23	1.58	2.79	4.39
Micronesia (Fed. States of)	0.37	0.56	1.34	1.50	2.41	3.61
Mongolia	0.37	0.62	2.47	1.70	3.99	6.77
Montenegro	1.54	2.37	5.34	1.54	2.26	3.48
Morocco	0.43	0.73	2.99	1.72	4.09	7.02
Mozambique	0.35	0.34	0.49	0.97	1.46	1.42
Myanmar	0.39	0.56	1.39	1.43	2.49	3.56
Namibia	0.45	0.55	0.81	1.21	1.47	1.78
Nepal	0.28	0.38	0.95	1.36	2.48	3.38
Netherlands	1.55	3.13	6.27	2.02	2.01	4.05
New Zealand	1.27	2.71	6.66	2.13	2.45	5.23
Nicaragua	0.34	0.61	1.90	1.81	3.11	5.61
Niger	0.23	0.31	0.35	1.34	1.16	1.54
Nigeria	0.29	0.25	0.32	0.87	1.25	1.08
North Macedonia	1.00	1.91	5.20	1.91	2.72	5.19
Northern Mariana Islands	0.45	1.03	3.70	2.31	3.58	8.29
Norway	1.80	2.76	5.37	1.54	1.95	2.99
Oman	0.60	0.71	2.17	1.17	3.07	3.59
Pakistan	0.27	0.31	0.56	1.15	1.79	2.06
Panama	0.59	1.31	3.51	2.21	2.67	5.89
Papua New Guinea	0.37	0.41	0.77	1.11	1.89	2.10
Paraguay	0.52	1.02	2.21	1.96	2.18	4.28
Peru	0.34	0.78	2.30	2.28	2.96	6.75
Philippines	0.36	0.61	1.35	1.70	2.22	3.79
Poland	1.40	2.98	7.01	2.12	2.35	4.99
Portugal	1.24	2.70	7.30	2.17	2.70	5.86
Puerto Rico	0.93	2.16	6.32	2.33	2.93	6.81
Qatar	0.51	0.82	3.40	1.62	4.13	6.67
Republic of Korea	0.79	2.14	11.61	2.70	5.43	14.69
Republic of Moldova	1.09	1.35	2.81	1.24	2.08	2.57
Romania	1.24	2.32	5.27	1.87	2.27	4.25
Russian Federation	1.48	2.15	4.53	1.45	2.11	3.05

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
Rwanda	0.29	0.28	0.66	0.98	2.34	2.29
Saint Lucia	0.44	0.64	2.49	1.46	3.88	5.66
Saint Vincent and the Grenadines	0.56	1.03	2.84	1.85	2.75	5.10
Samoa	0.32	0.58	1.20	1.83	2.05	3.74
Sao Tome and Principe	0.33	0.40	0.71	1.24	1.75	2.17
Saudi Arabia	0.49	0.72	2.73	1.48	3.78	5.61
Senegal	0.28	0.34	0.67	1.22	2.00	2.44
Serbia	1.43	2.73	5.20	1.91	1.91	3.63
Seychelles	0.56	1.13	3.18	2.00	2.81	5.64
Sierra Leone	0.37	0.31	0.47	0.82	1.55	1.27
Singapore	0.55	2.38	13.46	4.34	5.64	24.48
Slovakia	1.28	2.42	6.46	1.90	2.67	5.07
Slovenia	1.53	3.76	8.23	2.45	2.19	5.37
Solomon Islands	0.35	0.42	0.78	1.21	1.85	2.25
Somalia	0.33	0.35	0.40	1.07	1.13	1.21
South Africa	0.46	0.84	1.56	1.85	1.85	3.41
South Sudan	0.29	0.31	0.46	1.10	1.47	1.61
Spain	1.89	3.11	8.58	1.64	2.75	4.53
Sri Lanka	0.77	1.32	3.85	1.71	2.91	4.98
State of Palestine	0.40	0.62	1.51	1.53	2.46	3.77
Sudan	0.42	0.55	0.96	1.33	1.73	2.29
Suriname	0.31	0.73	2.01	2.37	2.76	6.54
Sweden	2.01	2.89	4.63	1.44	1.60	2.30
Switzerland	1.88	3.53	7.28	1.88	2.06	3.87
Syrian Arab Republic	0.48	0.67	1.59	1.41	2.36	3.33
Türkiye	0.97	1.42	4.51	1.47	3.17	4.66
Tajikistan	0.55	0.59	1.37	1.08	2.32	2.50
Thailand	0.57	1.76	8.21	3.10	4.68	14.50
Timor-Leste	0.28	0.45	0.77	1.58	1.72	2.72
Togo	0.27	0.27	0.44	1.00	1.65	1.66
Tonga	0.42	0.66	1.24	1.56	1.88	2.94
Trinidad and Tobago	0.47	1.16	3.72	2.45	3.21	7.85
Tunisia	0.52	1.24	4.30	2.39	3.47	8.32
Turkmenistan	0.52	0.68	1.66	1.30	2.44	3.17
Uganda	0.34	0.26	0.40	0.76	1.53	1.17
Ukraine	1.64	2.25	4.99	1.38	2.22	3.05
United Arab Emirates	0.51	0.81	3.37	1.58	4.16	6.56

	Dementia Dependency Ratio × 100			Relative Change in DDRs		
	1990	2019	2050	From 1990 to 2019	From 2019 to 2050	From 1990 to 2050
United Kingdom	1.43	2.37	4.58	1.65	1.94	3.20
United Republic of Tanzania	0.39	0.46	0.74	1.17	1.61	1.89
United States of America	1.89	3.14	6.19	1.66	1.97	3.27
Uruguay	1.62	2.52	4.48	1.55	1.78	2.77
Uzbekistan	0.61	0.70	1.77	1.16	2.52	2.92
Vanuatu	0.34	0.53	0.98	1.56	1.84	2.88
Venezuela (Bolivarian Republic of)	0.44	0.88	1.96	2.01	2.23	4.50
Vietnam	0.62	1.16	3.47	1.89	2.99	5.64
Yemen	0.52	0.45	0.81	0.87	1.78	1.54
Zambia	0.39	0.31	0.50	0.80	1.59	1.27
Zimbabwe	0.40	0.44	0.66	1.09	1.51	1.65

Data sources: Institute for Health Metrics and Evaluation (IHME). Findings from the Global Burden of Disease (GBD) Study 2019. Seattle, WA: IHME, 2021; United Nations, Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022 Revision, Online Edition; GDB 2019 Dementia Forecasting Collaborators [6] .

Notes: The table presents dementia dependency ratios (DDRs) for 195 countries and territories in 1990, 2019, and 2050 and changes in DDRs between years. We measure the DDR by the ratio of kin with dementia to kin without dementia in working ages (16–64). The DDR can be interpreted as a measure of the possible caregiving burden that kin with dementia place on kin without dementia in working ages. We estimate the DDR for each age group and then weight it by the age distribution of the total population in the observed year to derive the overall burden at the population level.

References

[1] Caswell H (2019) The formal demography of kinship: A matrix formulation. *Demographic Research* 41:679–712.

[2] United Nation (2022) *World Population Prospects 2022: Methodology of the United Nations population estimates and projections*. (United Nations, Department of Economic and Social Affairs, Population Division).

[3] Caswell H (2020) The formal demography of kinship II: Multistate models, parity, and sibship. *Demographic Research* 42:1097–1144.

[4] Caswell H, Song X (2021) The formal demography of kinship III: Kinship dynamics with time-varying demographic rates. *Demographic Research* 45:517–546.

[5] Caswell H (2022) The formal demography of kinship IV: Two-sex models and their approximations. *Demographic Research* 47:359–396.

[6] Nichols E, et al. (2022) Estimation of the global prevalence of dementia in 2019 and forecasted prevalence in 2050: an analysis for the global burden of disease study 2019. *The Lancet Public Health* 7(2):e105–e125.

[7] GBD 2019 Collaborators (2021) Global mortality from dementia: Application of a new method and results from the global burden of disease study 2019. *Alzheimer's & Dementia: Translational Research & Clinical Interventions* 7(1):e12200.

[8] Nichols E, et al. (2019) Global, regional, and national burden of alzheimer's disease and other dementias, 1990–2016: a systematic analysis for the global burden of disease study 2016. *The Lancet Neurology* 18(1):88–106.

[9] GBD 2019 Dementia Collaborators and others (2021) The burden of dementia due to down syndrome, parkinson's disease, stroke, and traumatic brain injury: a systematic analysis for the global burden of disease study 2019. *Neuroepidemiology* 55(4):286–296.

[10] Flaxman AD, Vos T, Murray CJ (2015) An integrative metaregression framework for descriptive epidemiology.

[11] United Nation (2022) *World Population Prospects: The 2022 Revision*. (United Nations, New York).