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Population Aging and Inequality: Evidence from the People's Republic of China

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Abstract

Population aging has significant economic and social costs, and this paper studies its impacts on inequality, both theoretically and empirically. First, we build a two-period overlapping-generation model with an uncertain lifetime and find that population aging has the overall effect of increasing income and consumption inequality within the society. For the empirical analysis, we use household data from the China Health and Nutrition Survey to assess the age effect on income and consumption inequality in the People's Republic of China and confirm the results predicted by the theoretical model.

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JEL Classification: J11, J14

Contents

1. INTRODUCTION

Population aging has become a major concern in many countries, mainly due to the accompanying economic and social costs. According to the United Nations' population projections, around 600 million people aged 65 or older are alive today, and by 2035 this figure is expected to exceed 1.1 billion, 13% of the total population. This is a natural corollary of the declining birth rate and growing life expectancy. The "old-age dependency ratio," that is, the ratio of old people (aged 65 or above) to labor force (aged 15–64), will grow even faster. From 1960 to 2015, this ratio for the world population increased by more than 46%, from 8.611 to 12.338.[1] By 2050, it is expected to increase to 25, while in rich countries it will be much higher. Japan will have 73 old-age people for every 100 work-age people by 2050, an increase from 35 in 2010.[2] Although developing countries have benefited from a young population structure, they are now starting to struggle with an aging population, as the fertility rates are falling below the natural replacement level. For example, over the same period, the old-age dependency rate in the People's Republic of China (PRC) will more than double from 15 to 36, while Latin America will experience a shift from 14 to 27 (The Economist 2014).

Theoretically, the distributional effect of population aging, triggered by a low birth rate and high life expectancy, can be explained through several channels. First, Friedman's (1957) permanent income hypothesis (PIH) and Modigliani's (1966) life cycle theory both predict that the consumption and income dispersion of any cohort of people born at the same time will increase with age, because individuals' income and consumption are affected by their own history of education, employment, health, idiosyncratic luck, family background, and so on. Under the PIH framework, Eden (1980) proposes that the variance of consumption should increase within cohorts. The statistical evidence that Deaton and Paxson (1994a) presented shows that income inequality tends to increase with age in Taipei,China, Great Britain, and the United States. Slower population growth, by raising the average age of the population, should raise the aggregate inequality through this channel. Second, Higgins and Williamson (2002) suggest that slower population growth tilts the population age distribution toward mature, more experienced cohorts, possibly reducing the experience premium and hence moderating the aggregate inequality. Third, Bussolo, Koettl, and Sinnott (2015) stated that "low or even negative population growth would increase wages relative to returns to capital. Since ownership of capital assets tends to be concentrated, this change in relative factor returns could reduce income inequality. Furthermore, capital holders, usually older people, are likely to lose while young workers gain."

Existing empirical studies explore this relationship mainly within high-income economies. Some findings suggest that population aging accounts for only a small fraction of the overall increase in income inequality (e.g., Bishop, Formby, and Smith 1997; Barrett, Crossley, and Worswick 2000). Several studies show that an aging population affects income inequality through public transfer systems, though the empirical evidence is mixed. Gruber and Wise (2001) analyze the OECD data and conclude that aging has led to a decline in the share of resources allocated to the elderly; similarly, Razin, Sadka, and Swagel (2002) show that a rise in the overall dependency ratio leads to a decline in social transfers. In contrast, Preston (1984) contends that the elderly in the US can claim a disproportionate share of public resources as their number and political power grow. An increasing amount of research

[1] Data source: The World Bank. http://data.worldbank.org/indicator/SP.POP.DPND.OL

[2] Data source: The Economist. http://www.economist.com/node/13611235

focuses on exploring the linkage between an aging population and inequality from the perspective of the PIH. Storesletten, Telmer, and Yaron (2004) explore the US case, suggesting that the age effects on income and consumption inequality within a cohort are consistent with the theoretical predictions of an overlapping-generation general equilibrium model in which households face uninsurable earnings shocks throughout their lifetime. Ohtake and Saito (1998) show that half of the rapid increase in the consumption inequality in Japan during the 1980s resulted from population aging, while one-third was due to the increasing cohort effect. Under the PIH framework, a number of new empirical studies attempt to link changes in consumption inequality in high-income countries to models of partial insurance (e.g., Krueger and Perri 2006; Blundell, Pistaferri, and Preston 2008). More recent empirical evidence from developed and aging countries indicates that age groups tend to become more vulnerable and unequal over their life cycle, because, among people within the same age group, some manage to accumulate more wealth over a longer working life while others risk falling into poverty, with limited savings stretched over a longer retirement period (Bussolo et al. 2015; Attanasio and Pistaferri 2016). Another stream of research employs the regression-based inequality decomposition approach to examine the role of demographic change in income distribution. Using data from Taipei,China, Chu and Jiang (1997) show that the pattern of Gini coefficients is significantly affected by the age composition factor.

Overall, the evidence from high-income economies is in line with the PIH, according to which households can turn to insurance and credit markets to smooth their lifetime consumption against short-term shocks. However, little is known about situations in developing countries, where the financial markets are underdeveloped and the liquidity constraints are pervasive. The population of East and Southeast Asia is aging rapidly as a consequence of demographic transition, triggered by the increase in life expectancy, aging of post-war baby boomers, and declining birth rate. If the life cycle models are correct, population aging is likely to increase inequality. Whereas this largely mechanical effect may not pose a direct threat to welfare, it is important to understand it, even if only to avoid the unnecessary imposition of corrective policies. Kurosaki, Kurita, and Ligon (2009) provide evidence that within-cohort inequality in consumption decreases with age in Thailand, Pakistan, and India. However, Rougoor and Van Marrewijk (2015) forecast that the global income inequality will reach its lowest level around 2017 and rise thereafter as a result of both economic and demographic forces.

The PRC provides a compelling setting to study this issue for several reasons. Since the market-oriented reforms in the early 1980s, the PRC has experienced rapid economic growth, with double-digit annual growth rates, for about three decades. However, this process has also been associated with rapid population aging and soaring inequality. Now the second-largest economy in the world, the PRC's Gini coefficient increased from 0.30 in 1980 to 0.53 in 2010 (Xie and Zhou 2014) and is currently among the highest in the world. Despite a recent moderate decline in inequality, the income distribution in the PRC remains a serious issue, especially in comparison with countries at a similar stage of economic development. High and persistent income inequality can significantly weaken demand, impede growth, induce crises, and erode social cohesion (Berg and Ostry 2011; IMF 2016). At the same time, the PRC is rapidly becoming older as a consequence of the family planning policy and increasing life expectancy. The number of people aged over 60 reached 185 million, or 14% of the total population, at the end of 2011.[3] Moreover, its aging process will

[3] The figure is from the website of the National Bureau of Statistics, available at http://www.stats.gov.cn/english/newsandcomingevents/t20120120_402780233.htm.

continue at a remarkable pace for the next few decades. The PRC's *Fiscal Policy Report* projects that the PRC will become the world's most aged society by 2030 and that by 2050 the number of elderly people in the PRC will have increased to 454 million, 33% of the total population (Chinese Academy of Social Sciences 2010).[4]

Most of the discussion on inequality in the PRC is about inequality of income (Meng 2004; Meng, Gregory, and Wang 2005; Wan, Lu, and Chen 2006) or different components of income. The enlarging income gap is explained from the perspectives of international trade, property value, and even sociology. For example, Han, Liu, and Zhang (2012) investigate the impact of globalization on wage inequality and find that the WTO accession is responsible for the increase in wage inequality. Li, Li, and Ouyang (2017) find that in the PRC, when inequality is measured by wealth that incorporates housing rather than by income, it becomes a much more severe concern. Additionally, from a sociological perspective, the work by Xie (2016) suggests that inequality in the PRC has been greatly influenced by certain collective mechanisms, such as regions and work units, and that most people in the PRC view inequality as an inevitable problem accompanying economic growth.

Despite the strong links between demographic trends and inequality, as implied by the life cycle theory, there is still limited evidence of investigation of this topic within the PRC context. Zhang and Xiang (2014) analyze four rounds of data from the Urban Households' Income and Expenditure Survey (UHIES) and claim that aging contributed around 10% of the rising consumption inequality in urban areas of the PRC between 2003 and 2009. Employing three waves of rural household surveys in the China Household Income Project (CHIP) for the period 1988–2002, Qu and Zhao (2008) investigate the consumption inequality between urban and rural households in the PRC and find that a large consumption disparity exists in the low-income quantiles. Zou, Li, and Yu (2013) explore the impact of birth cohort on consumption inequality, with the use of electronic appliances as a proxy, and show that consumption inequality is higher than income inequality in the PRC. Using the China Health and Nutrition Survey (CHNS) data, Zhong (2011) examines the relationship between income inequality and population aging in rural areas of the PRC and indicates that population aging has recently made a significant contribution to the sharp increase in income inequality in rural areas of the PRC.

In this study we first build a two-period overlapping-generation (OLG) model with an uncertain lifetime to illustrate theoretically the overall effects of population aging on income and consumption inequality. In our model, young workers' different levels of productivity lead to income equality within their own age cohort. A young worker also decides how to allocate his first-period income between consumption and saving to maximize his lifetime utility. For an unskilled old worker, the savings from his young age will be his only source of income (and consumption) in the second period, while a skilled old worker can still be employed and earn a wage, albeit at a discounted rate, to supplement his second-period income (and consumption). We find that population aging has an overall effect of increasing inequality within the society and that, within the young cohort, consumption inequality is higher than income inequality.

For the empirical analysis, we employ Deaton and Paxson's (1994a) approach to examine the age effect on income and consumption inequality in both urban and rural areas by using a data set constructed from the nine waves of the China Health and Nutrition Survey (CHNS), conducted between 1989 and 2011. We first investigate how

[4] The Government of the PRC defines the elderly in the PRC as the population aged 60 and over. The data are retrieved from the 2012 revision of the World Population Prospects. See http://esa.un.org/unpd/wpp/Excel-Data/Interpolated.htm.

income and consumption inequality evolve with age in a period of dynamic economic growth accompanied by rapid population aging. Given the widely acknowledged regional disparity in the PRC, we compare the age effect on inequality in rural and urban areas. We assume that skilled labor concentrates in urban areas while the labor in rural areas is mainly unskilled. Regarding the importance of finance in smoothing consumption and income over the life cycle, we also examine the role of financial development in moderating the income inequality triggered by the age effect. To enhance the statistical efficiency, control for changes in household demographics, and examine the impact of finance on inequality, we extend Deaton and Paxson's (1994a) cohort-level model by conducting a household regression analysis. All our empirical findings are consistent with the theoretical predictions.

We expand the research frontier by studying the age effect on both income and consumption inequality. The joint analysis of consumption and income inequality is informative in several ways. First, individuals' utility is related more closely to consumption and leisure than income. Several studies (Cutler and Katz 1992; Johnson and Shipp 1997; Blundell and Preston 1998; Pendakur 1998) show that, compared with income, consumption is a direct and more accurate measure of welfare and long-term earning capacity. Second, the difference between consumption and income reflects the efficiency of the consumption-smoothing mechanism under various credit or insurance arrangements (Blundell et al. 2008; Krueger et al. 2010; Attanasio and Pistaferri 2016). Third, underreporting of income is regarded as a serious challenge for household surveys in the PRC, because people are widely reluctant to report their income outside regular jobs, in particular job-related benefits and "gray" income. In contrast, consumption suffers less from such underreporting problems. By comparing the different dynamics of consumption and income inequality within the same cohort, we can gain insights into the factors governing the intertemporal choice of people in the PRC.

The rest of this paper is structured as follows. Section 2 presents the theoretical model; section 3 describes the data, the construction of the key variables, and the econometric methodology; section 4 provides the descriptive statistics and empirical results; and section 5 concludes the paper.

2. THEORETICAL MODEL

We use a simple two-period overlapping-generation (OLG) model with an uncertain lifetime. For simplicity we assume that each household has one individual person. The level of aptitude, hence productivity, is different among young workers and is assumed to be exogenously given when born. The number of "skilled" young workers is *n*, and so is the number of "unskilled" young workers in the economy. Hence, we have a total size of $2n$ young population.

Each young adult born in Period t works during the first period and earns a wage, w_t^i, where $i = s, u$, which represents different types of worker in productivity. We have that:

$$w_t^u = w_t, \tag{1a}$$

$$w_t^s = ew_t, \tag{1b}$$

where $e > 1$ is exogenously given and reflects the productivity advantage for the wage. Since we normalize the length of time in each period, the wage is also each individual worker's income during the first period. Naturally, if we wish to measure the degree of income inequality within the young cohort in Period t, we can conveniently use *e* for that purpose. A larger *e* indicates a higher degree of income inequality among the young workers.

While young, each adult gives birth to one child, who will eventually replace him in the society; hence, the size of the young population remains constant at 2*n* over time. In this model we assume that everyone lives a full young adulthood with certainty while facing a probability of x, where $0 < x < 1$, of surviving into old age; that is, there is a probability of $1 - x$ of death at the beginning of the second period. This probability profile $(x, 1 - x)$ is exogenous and common knowledge. Hence, the size of the old population in the society is $2xn$, and the total population is $2(1 + x)n$. The ratio of skilled labor to unskilled labor is 1:1, for simplicity, within both young and old populations, as we assume that aging and labor productivity are two factors that are independent of each other. It should be clear that an increase in x represents an overall aging population in the society.

An unskilled old worker will not work in the second period, because his weakened physical condition will no longer qualify him for a blue-collar job; as a result, his only income at this stage will come from his young-age savings. A skilled old worker, on the other hand, has the opportunity to take a light, white-collar job and supplement his income. Nonetheless, the loss of cognitive ability and physical strength associated with aging means that his productivity remains a fraction of that when he was young. Thus, we have:

$$v_{t+1}^{s} = \lambda w_{t+1}. \tag{1c}$$

We use v_{t+1}^{s} to denote the wage of an old skilled worker in Period $t + 1$ (hence, he was a young skilled worker in Period *t*), where $0 < \lambda < 1$ is exogenously given and indicates his disadvantage in competing with young workers on the competitive labor market.

A young worker needs to decide how to allocate his first-period budget/income between consumption and savings to maximize his lifetime utility. Such an intertemporal decision-making process of a representative young worker in Period *t* and his preference are described by the following utility function:

$$u_t^i = \ln c_t^i + \beta x \ln d_{t+1}^i. \tag{2}$$

For this young worker of type *i* in Period *t*, we use c_t^i to denote his consumption in the first period and d_{t+1}^i to indicate his anticipated second-period consumption. We factor in two additional considerations: x, the probability of surviving into the second period, and $\beta \in [0,1]$, the usual time discount. The budget constraint of this young worker of type *i* in Period *t* is as follows:

$$c_t^i + s_t^i = w_t^i. \tag{3}$$

We further assume that all savings are invested in the financial market and that the gross rate of return for those surviving to old age is r_{t+1}/x, where r_{t+1} is the risk-free interest rate in the competitive capital market. The budget constraint for an old agent is therefore:

$$d_{t+1}^u = \frac{s_t^u r_{t+1}}{x}, \tag{4a}$$

$$d_{t+1}^s = \frac{s_t^s r_{t+1}}{x} + v_{t+1}^s. \tag{4b}$$

We now examine the optimization problem faced by a young worker in Period *t*. Combining (2), (3), and (4a), we first have the following objective function for an unskilled young worker:

$$\max_{s_t^u} u_t^u = \ln(w_t^u - s_t^u) + \beta x \ln\left(\frac{s_t^u r_{t+1}}{x}\right). \tag{2.u}$$

Deriving the first-order condition (FOC), we arrive at the following results:

$$s_t^u = \frac{\beta x}{\beta x+1} w_t, \tag{5a}$$

$$c_t^u = \frac{1}{\beta x+1} w_t. \tag{5b}$$

It is straightforward that, when β or x increases, c_t^u decreases while s_t^u increases, both of which make intuitive sense.

Next, combining (2), (3), and (4b), we have the following objective function for a skilled young worker:

$$\max_{s_t^s} u_t^s = \ln(w_t^s - s_t^s) + \beta x \ln\left(\frac{s_t^s r_{t+1}}{x} + v_{t+1}^s\right). \tag{2.s}$$

Deriving the first-order condition (FOC), we arrive at the following results:

$$s_t^s = \frac{\beta x}{\beta x+1} e w_t - \frac{\lambda w_{t+1}}{(\beta x+1)\frac{r_{t+1}}{x}}, \tag{6a}$$

$$c_t^s = \frac{1}{\beta x+1} e w_t + \frac{\lambda w_{t+1}}{(\beta x+1)\frac{r_{t+1}}{x}}, \tag{6b}$$

If we compare (5b) and (6b), it is easy to see that

$$c_t^s / c_t^u = e + \frac{\lambda w_{t+1}}{w_t} \frac{x}{r_{t+1}}. \tag{7}$$

As long as the economy is growing, the consumption inequality has the following property:

$$c_t^s / c_t^u > w_t^s / w_t^u = e. \tag{8}$$

This result reports that, within the young cohort, consumption inequality is higher than income inequality. There is an intuitive explanation behind it: the unskilled young worker needs to save more today for the future, since there will be no other source of income when he becomes old.

As for the old cohort, it should be pointed out that, due to the nature of this OLG model with no bequest motive, consumption should always equal income in the second stage, and we have:

$$d_{t+1}^u = \frac{r_{t+1}}{x} \frac{\beta x}{\beta x+1} w_t,$$

$$d_{t+1}^s = \frac{r_{t+1}}{x} \frac{\beta x}{\beta x+1} e w_t + \frac{\beta x}{\beta x+1} \lambda w_{t+1}.$$

We can fairly easily derive that:

$$d_{t+1}^{s}/d_{t+1}^{u} = e + \frac{\lambda w_{t+1}}{w_t}\frac{x}{r_{t+1}}. \quad (9)$$

This is not a surprising result in the context of the intertemporal framework of making a decision.

The total population of young unskilled workers is *n* in the economy. The total size of young skilled workers is *n* as well, which provides a total of en, where $e > 1$, units of unskilled labor equivalent. We also know that skilled old workers in the economy provide a total of λxn, where $0 < \lambda, x < 1$, units of unskilled labor equivalent; hence, the total stock of labor available in this economy in Period *t*, for aggregation production, measured in unskilled labor equivalent, is as follows:

$$L_t = (1 + e + \lambda x)n. \quad (10)$$

As for the physical capital market, the total capital stock is funded through savings by young workers, both skilled and unskilled, in the previous stage, as follows:

$$K_{t+1} = ns_t^s + ns_t^u. \quad (11)$$

Conditions (10) and (11) also serve as the factor market clearing conditions when we later solve for the equilibrium in the economy.

The aggregate production is represented by the following Cobb–Douglas production function on a perfectly competitive output market:

$$Y_t = AK_t^{\alpha}L_t^{1-\alpha}, \text{ where } 0 < \alpha < 1. \quad (12)$$

In this production function, $A > 0$ is the conventional technology level. As the firm rents inputs on perfectly competitive factor markets, where w_t and r_t are the respective factor prices in Period *t*, the optimization problem for a profit-maximizing firm is as follows:

$$\max_{K_t, L_t} \Pi_t = AK_t^{\alpha}L_t^{1-\alpha} - r_tK_t - w_tL_t. \quad (13)$$

We let $k_t = K_t/L_t$ be the capital per worker (measured in unskilled labor equivalent), and we have the following two FOCs:

$$w_t = (1-\alpha)Ak_t^{\alpha}, \quad (14)$$

$$r_t = \alpha Ak_t^{\alpha-1}. \quad (15)$$

We now proceed to derive the equilibrium in this economy. Combining (5a), (6a), (10), and (11), we have the following dynamic equation for capital:

$$k_{t+1} = \frac{K_{t+1}}{L_{t+1}} = \frac{1}{1+e+\lambda x}\left(\frac{\beta x(e+1)w_t}{1+\beta x} - \frac{\lambda x w_{t+1}}{(1+\beta x)r_{t+1}}\right).$$

Next, we replace w_t, w_{t+1}, and r_{t+1} with (14) and (15) and obtain the following equation, which represents the law of motion of capital per worker within the economy:

$$k_{t+1} = \frac{1}{1+e+\lambda x}\left(\frac{\beta x(e+1)(1-\alpha)Ak_t^{\alpha}}{1+\beta x} - \frac{\lambda x(1-\alpha)k_{t+1}^{\alpha}}{(1+\beta x)\alpha k_t^{\alpha-1}}\right). \quad (16)$$

Assuming perfect foresight, the steady state is defined as follows:

$$k^* = \left(\frac{A(1-\alpha)\alpha(1+e)\beta x}{\alpha+\alpha e+\lambda x+\alpha\beta x(1+e+\lambda x)}\right)^{\frac{1}{1-\alpha}}. \quad (17)$$

We also have:

$$\frac{\partial k^*}{\partial x} > 0, \frac{\partial k^*}{\partial \beta} > 0, \frac{\partial k^*}{\partial e} > 0, \frac{\partial k^*}{\partial \lambda} < 0. \quad (18)$$

Simple proof can be seen in the Appendix. These results make intuitive sense. A longer life expectancy induces a higher saving rate and hence higher capital per worker in the economy; similarly, a lower discount rate (i.e. a future value is worth more in the present term) provides an incentive for higher savings, and a higher wage, albeit only for skilled workers, allows higher savings on average. Of course, if an old skilled worker expects to be paid more, his incentive to save while young will naturally decline.

Our main interest remains with the income/consumption inequality as well as how the aging population in the society affects it. For reporting convenience we create an inequality index, denoted as Ψ, to measure the degree of income or consumption inequality at different ages (young and old) within each cohort, defined as follows:

$$\Psi_{y,inc} = w_t^s/w_t^u, \Psi_{y,con} = c_t^s/c_t^u, \Psi_o = d_{t+1}^s/d_{t+1}^u. \quad (19)$$

Combining (7), (9), (14), and (15), we have that $\frac{\partial \Psi_{y,con}}{\partial x} = \frac{\partial \Psi_o}{\partial x} = \frac{\partial}{\partial x}\left(e + \frac{\lambda w_{t+1}}{w_t}\frac{x}{r_{t+1}}\right)$, so $\frac{\partial \Psi^*_{y,con}}{\partial x} = \frac{\partial \Psi^*_o}{\partial x} = \frac{\partial}{\partial x}\left(\frac{\lambda}{\alpha A}(k^*)^{1-\alpha}x\right) = \frac{\lambda}{\alpha A}\left(\frac{x(1-\alpha)}{(k^*)^{\alpha}}\frac{\partial k^*}{\partial x} + (k^*)^{1-\alpha}\right)$. Given (17) and (18), we have that:

$$\frac{\partial \Psi^*_{y,con}}{\partial x} > 0 \ , \frac{\partial \Psi^*_o}{\partial x} > 0. \quad (20)$$

This result suggests that the consumption inequality within the young population increases when an aging population is anticipated; the overall impact is similar within the old population for both income and consumption inequality.

To summarize the results of our theoretical study, we obtain the following two key findings: (a) consumption inequality is higher than income inequality within the cohort of young workers; and (b) an aging population has an overall impact of increasing inequality within the society. These theoretical results are largely in alignment with our empirical findings, presented in the next sections.

3. DATA AND EMPIRICAL METHODOLOGY

3.1 Data Source and Key Variables

To investigate the intertemporal choice of consumers and its impact on inequality, an ideal data set should contain panel data on income and consumption covering a large number of households for a long period of time (Blundell, Pistaferri, and Preston 2008; Kurosaki, Kurita, and Ligon 2009). If no such ideal data sets are available, it is imperative to use a repeated cross-section data set of household income and consumption expenditure covering as many years as possible (Deaton and Paxson 1994a). In the PRC, several household survey data sets are used to study inequality, including the China Family Panel Study (CFPS), Chinese General Social Survey (CGSS), China Household Income Project (CHIP), Chinese Household Finance Survey (CHFS), and China Labor Force Dynamic Survey (CLDS). However, most of them cover very short periods of time. For example, the launching years of the CGSS, CFPS, CHFS, and CLDS are 2003, 2010, 2011, and 2012, respectively. The CHIP was launched in 1988 but does not contain longitudinal data, and the respondents are different for each round of the survey. Moreover, only five rounds of the survey have been conducted so far.

The data used in this paper come from an ongoing, open-cohort, longitudinal study—the China Health and Nutrition Survey (CHNS). This is a collaborative project by the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. Nine waves of the survey[5] have been conducted since 1989 on 4,400 households with a total of 26,000 individuals in 15 PRC provincial units[6] that vary substantially in geography, economic development, public resources, and health indicators. Employing such data, which represent a third of the country's population, we are released from the limitation of using data from an otherwise small, geographically restricted region that may be unrepresentative of the larger setting. Moreover, our data cover a long period of 22 years, allowing us to track the development process of inequality and the aging population during a period of rapid economic growth in the PRC. We stratify the counties in all the provinces by income, and then we adopt a multistage, random-cluster process to select four counties from each province. The sample is made up of 36 suburban neighborhoods and 108 towns. The CHNS asks respondents questions regarding individual and household demographics, education, health and nutrition, occupations and labor force participation, income, use of health services, housing and asset ownership, time use, and so on. The characteristics of the households in the sample are comparable to the national averages. One main advantage of the CHNS data is that they provide detailed information about almost all potential sources of household income, including wage income, retirement income, subsidies, earnings from sources of business, farming, fishing, gardening, livestock, and others. It has better coverage of urban subsidies, an important source of income for non-farm self-employment. Moreover, the longitudinal master files created by the CHNS enable us to trace the evolution of respondents' income and consumption over time. In addition, the CHNS data have a good number of overlapping cohorts across rounds, which are a great advantage in estimating the age effects on inequality. Figure 1 plots the population pyramid of the CHNS sample by age for the four years 1989, 1997, 2006, and 2011, and it clearly indicates the rapid process of population aging in the PRC in the last three decades.[7]

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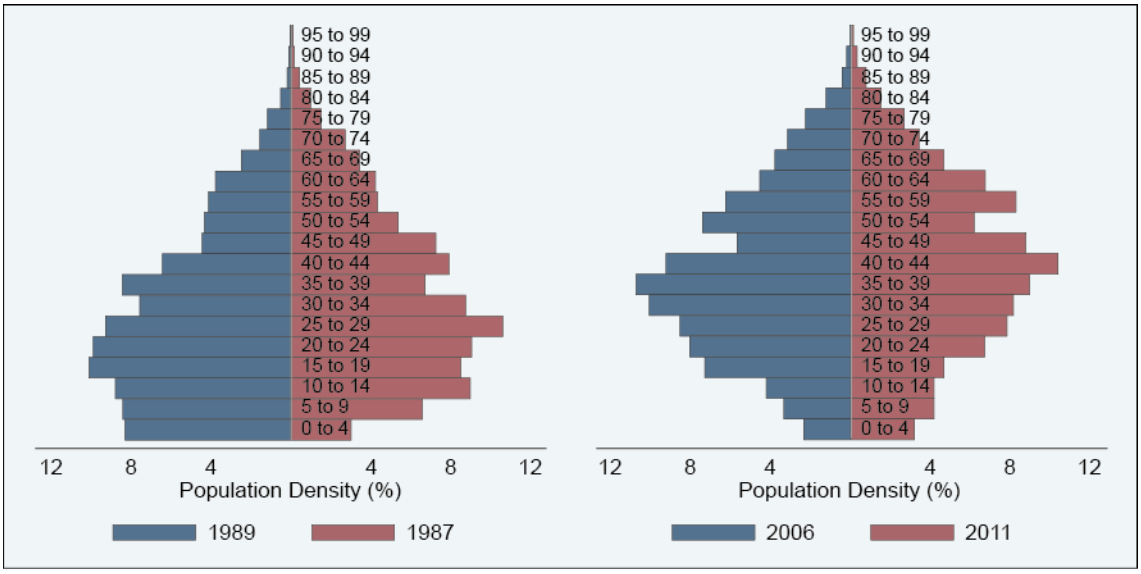
[5] Those surveys were completed in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011, respectively.

[6] The survey started with the nine provincial units of Liaoning, Heilongjiang, Jiangsu, Shandong, Henan, Hubei, Hunan, Guangxi, and Guizhou in 1989. Three mega-cities, Beijing, Chongqing, and Shanghai, have joined this cohort since 2011. Three more provinces, Shaanxi, Yunnan, and Zhejiang, have joined since 2015.

[7] To understand the representativeness of the CHNS data, we compare the age distribution figures of the CHNS in the years 1989, 1997, 2006, and 2011 with those of the PRC Census data in the years 1989, 1990, 2000, and 2010 and find that the population pyramid of the CHNS data is close to that of the Census data and that our analysis will be able to reflect the real situation in the PRC. The population pyramid of the PRC Census data is available on request.

Figure 1: Population Distribution by Age in the PRC, 1989–2011



However, the CHNS does not contain data on nondurables' consumption, like expenditure on food (Benjamin et al. 2007). Hence, we pay special attention to the inequality of the consumption of durable goods, including electronic appliances and means of transportation. The consumption of durable goods is important in assessing consumption inequality thoroughly, since it accounts for a large share of household expenses. While consumption categories involving small and infrequent purchases are more vulnerable to poor reporting, large expenses on durable goods are often reported sufficiently well. In addition, durables' consumption relies heavily on the liquidity facilitated through financial institutions. McKenzie (2005) shows that, in the absence of household consumption data, household ownership of certain durable assets can be a reasonable proxy for inequality in living standards. Using Mexican data, he proves that inequality measured with asset indicators can predict the nondurables' consumption inequality very well. Employing two alternative sources of data, Hassett and Mathur (2012) find that the trend of inequality measured using nondurables' consumption is comparable to inequality measured using durables' consumption in the US.[8]

To construct the variables to use in this study, we first select households that have valid and complete information on income and durables' consumption and are aged between 20 and 75. We then collect information on the household heads' age, gender, educational attainment, and employment status in addition to the household total disposable income, value of durable goods, household registration (*hukou*) status, province of residence, and so on. The real income per capita for each household is calculated as the ratio of the total net household income to the number of household members, adjusted by the consumer price index of 2011.[9] The CHNS survey includes detailed information on the stock and current value of the electronic appliances and

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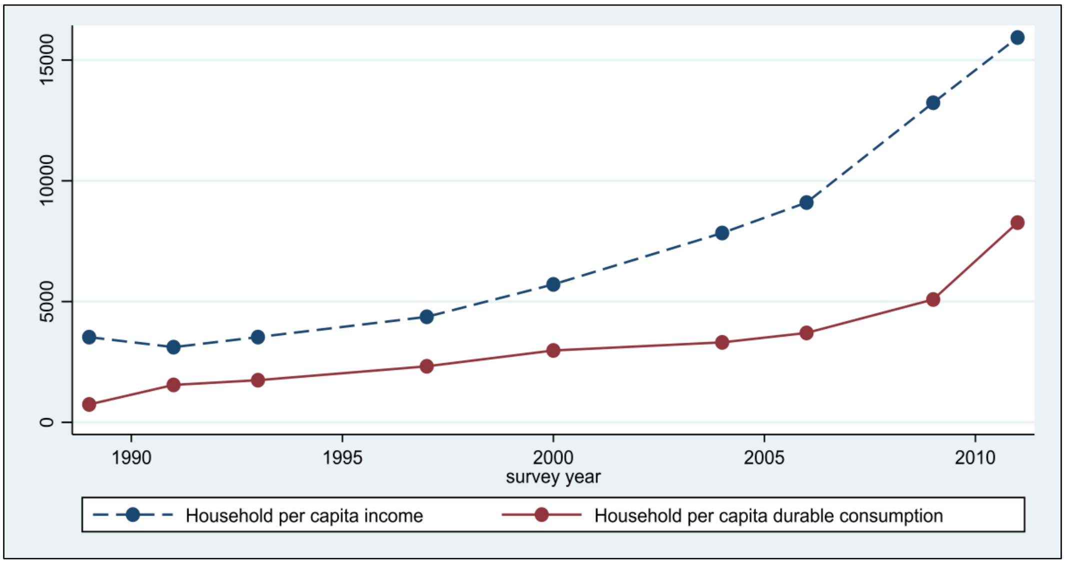
8 Hassett and Mathur (2012) compute inequality in nondurables' consumption with data from the Consumer Expenditure Survey (CEX), which provides a continuous and comprehensive flow of data on the buying habits of American consumers and contains detailed expenditure data on small and frequently purchased items, such as food. They calculate inequality in durables' consumption with data from the Residential Energy Consumption Survey, which includes questions on households' use of appliances such as microwaves, dishwashers, computers, and printers.

9 The total net household income is the summation of the net income from household business, farming, fishing, gardening, livestock, subsidies, pensions, wages, and other sources.

means of transportation owned by each household.[10] Similarly, we compute the per capita real consumption of durables as the ratio of the total value of durable goods to the number of households, adjusted with the consumer price index of 2011.

Figure 2: Income vs. Durables' Consumption in the PRC



Data source: China Health and Nutrition Survey, 1989–2011.

Figure 2 plots the growth paths of household income and durables' consumption in the PRC during the years from 1989 to 2011. The real income increased from 3,528 yuan to 15,933 yuan, while the durables' consumption grew considerably from 741 yuan to 8,270 yuan. In terms of trends, the household income and durables' consumption moved in tandem until around 2004, but the gap seems to have widened thereafter.

3.2 Methodology

To assess the age and cohort effects on inequality, we construct age dummies for those household heads aged between 20 and 75. We drop the dummy variable for the youngest group to avoid multicollinearity among the age dummies. Based on the birth year or age of the respondents in 1989, we define cohort dummies based on five-year age bands, specifically 1920–1924, 1925–1929, 1930–1934, 1935–1939, 1940–1945, 1946–1949, 1950–1954, 1955–1959, 1960–1964, 1965–1969, and 1970–1974, respectively. Given the age and the time of the survey, we determine a cohort as b=a–t+1989, where *a* represents age and t represents the year of the survey. Similarly, we drop the dummy variable for the youngest cohort to avoid multicollinearity among cohort dummies.

[10] The electronic appliances listed in the CHNS survey questionnaire include VCR, TV set, washing machine, refrigerator, air conditioner, sewing machine, electric fan, computer, camera, microwave oven, electric rice cooker, pressure cooker, telephone, cell phone, VCD or DVD, and satellite dish, while the means of transportation include tricycle, bicycle, motorcycle, and automobile. The survey asks the respondents questions such as "Does your household own this type of appliance/transportation?"; "How many are owned?"; and "What is the total value of the appliance/transportation?"

We employ the variances of log consumption and log income as the main measures of inequality, a widely adopted method (Deaton and Paxson 1994a; Ohtake and Saito 1998). With a data set running for 22 years, we are able to observe earnings and consumption for a range of different cohorts and separate the cohort effect from the age effect. Following Deaton and Paxson (1994a), we estimate the household model as follows:

$$(logI_{ict} - log\bar{I}_{ct})^2 = \sum_c \alpha_c Cohort_{ic} + \sum_n \beta_n Age_{ict} + \gamma X_{ict} + \varepsilon_{ict}, \quad (21)$$

where $log\bar{I}_{ct}$ is the logarithm value of the average per capita real income or durables' consumption for cohort *c* in year t and $Cohort_c$ and Age_n are the cohort and age dummies, respectively. In this regression the coefficients α_c reflect the cohort effect while the coefficients β_n represent the age effect and trace the evolution of within-cohort inequality over the lifetime. X_{ict} is a vector of control variables that describe household *i*'s characteristics in year *t*, such as the gender of the household head or the size of the household. By including X_{ict} we can directly control for the changes in household demographic features and the sampling design of each survey to achieve gains in statistical efficiency. Table 1 provides the summary statistics of the key variables.

Table 1: Summary Statistics of the Key Variables

Variables	Definition	Obs.	Mean	Std Dev.	RSD	Min.	Max.
Income	Household net income per capita	27,812	7,892.82	9,210.35	1.17	174.85	79,066.27
Durables	Household durables per capita	27,812	3,633.51	8,162.48	2.25	25.77	101,683.30
Hhsize	Household size	27,812	3.67	1.44	0.39	1.00	13.00
Gender	Dummy variable set to 1 if the gender of the household head is male	27,812	0.85	0.35	0.41	0.00	1.00
Age	Age of the household head	27,812	49.97	12.07	0.24	20.00	75.00
DtoGDP	Deposit to GDP	27,812	1.06	0.53	0.50	0.39	4.30
LtoGDP	Loan to GDP	27,812	0.90	0.25	0.28	0.59	1.96
DLtoGDP	Summation of deposit and loan to GDP	27,812	1.96	0.76	0.39	0.99	6.26
FI_Per_Thousand	Number of financial institutions per 1,000 people	27,812	0.05	0.04	0.74	0.00	0.17

One factor that equation (21) defines but neither the age nor the cohort effect accounts for is the presence of time effects (e.g., common macroeconomic shocks), which impinge on all cohorts to a greater or lesser degree, but they are located in real time and the cohort or age effect cannot account for them. The solution is to include fixed-year effects (θ_t); hence, the equation becomes:

$$(logI_{ict} - log\bar{I}_{ct})^2 = \sum_c \alpha_c Cohort_{ic} + \sum_n \beta_n Age_{ict} + \gamma X_{ict} + \theta_t + \varepsilon_{ct}. \quad (22)$$

However, an unrestricted estimation is not possible due to the dependency between age, cohort, and year. In particular, given that the cohort is the age minus the year plus a constant, the parameters of equation (22) are not identified. To overcome this difficulty, we apply the normalization method developed by Deaton and Paxson (1994b) for estimation.[11]

Considering that the age effect that equations (21) and (22) estimate might be linear,[12] and to assess the overall effect of population aging on inequality, we also estimate the restricted versions of (21) and (22) as follows:

$$(logI_{ict} - \overline{log}I_{ct})^2 = \beta Age_{ict} + \sum_c \alpha_c Cohort_{ic} + \gamma X_{ict} + \theta_t + \varepsilon_{ict}, \quad (23)$$

where parameter β represents the relationship between age and inequality. Regarding the importance of finance in smoothing consumption over the life cycle, we also include an interaction term between the age effect and the financial development to examine its role in moderating inequality triggered by the age effect in further analysis. Its sign and statistical significance will help us to identify the role of financial inclusion in attenuating the age effect on inequality.

4. EMPIRICAL RESULTS

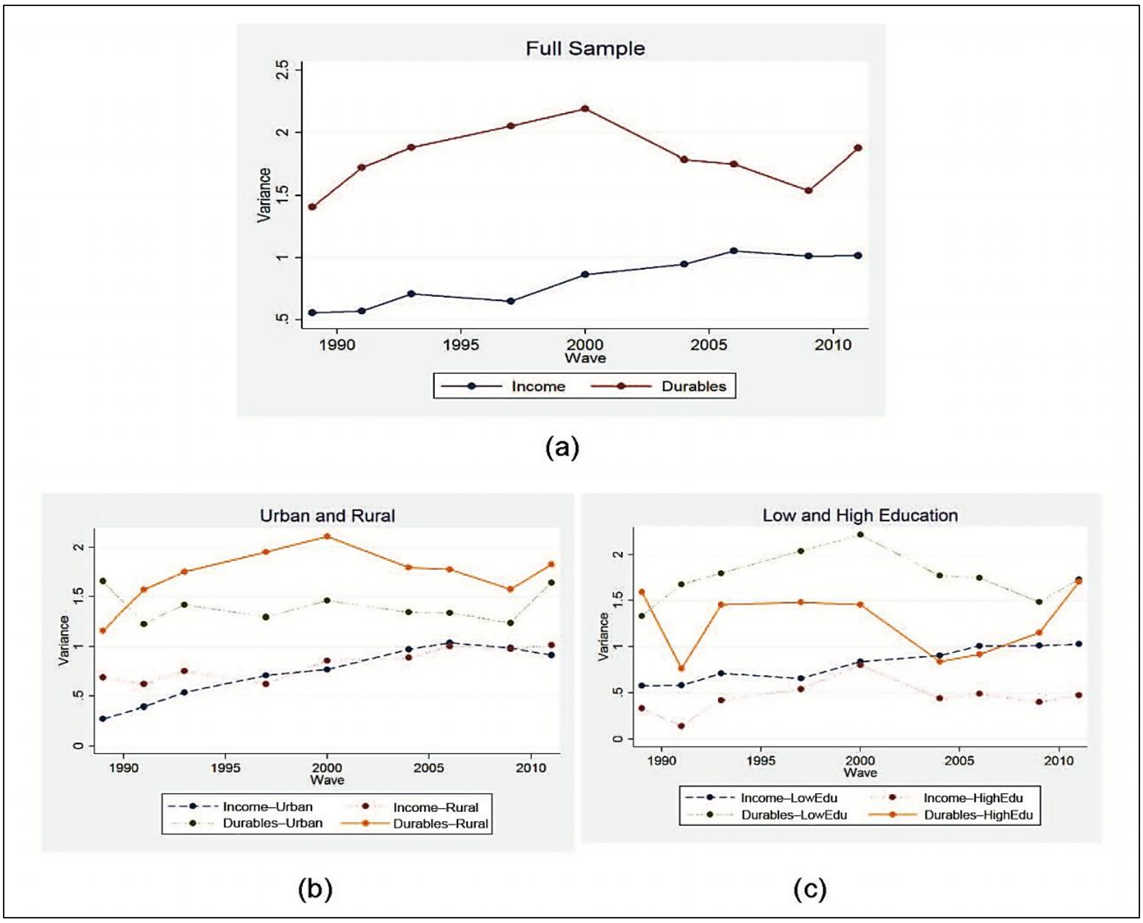
4.1 Evolution of Income and Consumption Inequality

Using CHNS data, the figures below demonstrate how income and consumption inequality have evolved in the PRC from 1989 to 2011. We computed the level of inequality as the variance of the logarithm values. Figure 3(a) suggests that consumption inequality is higher than income inequality in all the years, although they seem to converge over time. Figure 3(b) shows that consumption inequality in rural areas is higher than that in urban areas, while income inequality is largely the same in rural and urban areas. Figure 3(c) shows that cohorts with low educational attainment tend to experience greater consumption and income inequality than cohorts with high educational attainment. These facts are different from those observed in advanced economies, such as the US and the UK, where income inequality is higher than consumption inequality (Krueger and Perri 2006). According to the PIH, consumption inequality reflects idiosyncratic shocks that are insurable on the financial market while income inequality captures both insurable idiosyncratic shocks and uninsurable risks. Higher consumption inequality, especially for less-educated rural farmers in the PRC, indicates the limited access to financial and insurance services to hedge against adverse shocks that may put their livelihood at risk. This is not uncommon in developing countries (Fafchamps 2003; Dercon 2005), where it is difficult for poor households to smooth their consumption inter-temporally, and the credit markets in those countries often lag behind the economic development.

[11] In practice all the year dummies are constrained to be orthogonal to a time trend and add up to zero. The base year is set to be a timeless average of all years so that any time trend is attributed to the cohort and age and not to the time.

[12] Deaton and Paxson (1994a) find that the age effects in Taipei,China, Great Britain, and the United States are approximately linear.

Figure 3: Income and Durables' Consumption Inequality in the PRC, 1989–2011



4.2 Inequality and the Age Effect

We then test the lifetime profile of income and consumption inequality. Figures 4 and 5 plot the log variance of income and durables' consumption for the same cohort in different survey years. With the year of observation on the horizontal axis and the variances on the vertical axis, each panel shows the evolution of inequality of a single cohort specified by the age of the household head. The last panel of each figure shows the aggregate inequality for all households in each survey year as the sum of the weighted average of within-cohort inequality and inequality across cohorts. An increasing age effect on income inequality is observed for most cohorts, although it is not linear. The overall income inequality also displays an upward trend, particularly between the late 1990s and the mid-2000s, when a strong increase is apparent. However, the age effect on durables' consumption inequality for most cohorts, except the youngest cohort, assumes an inverse U-shaped pattern. The panel of the full sample suggests that the inequality in durables' consumption increases until 2000 and declines thereafter. Comparing these two types of inequality, we find that consumption inequality is higher than income inequality, especially in young ages.

Figure 4: Variance of Log Income by Age Group

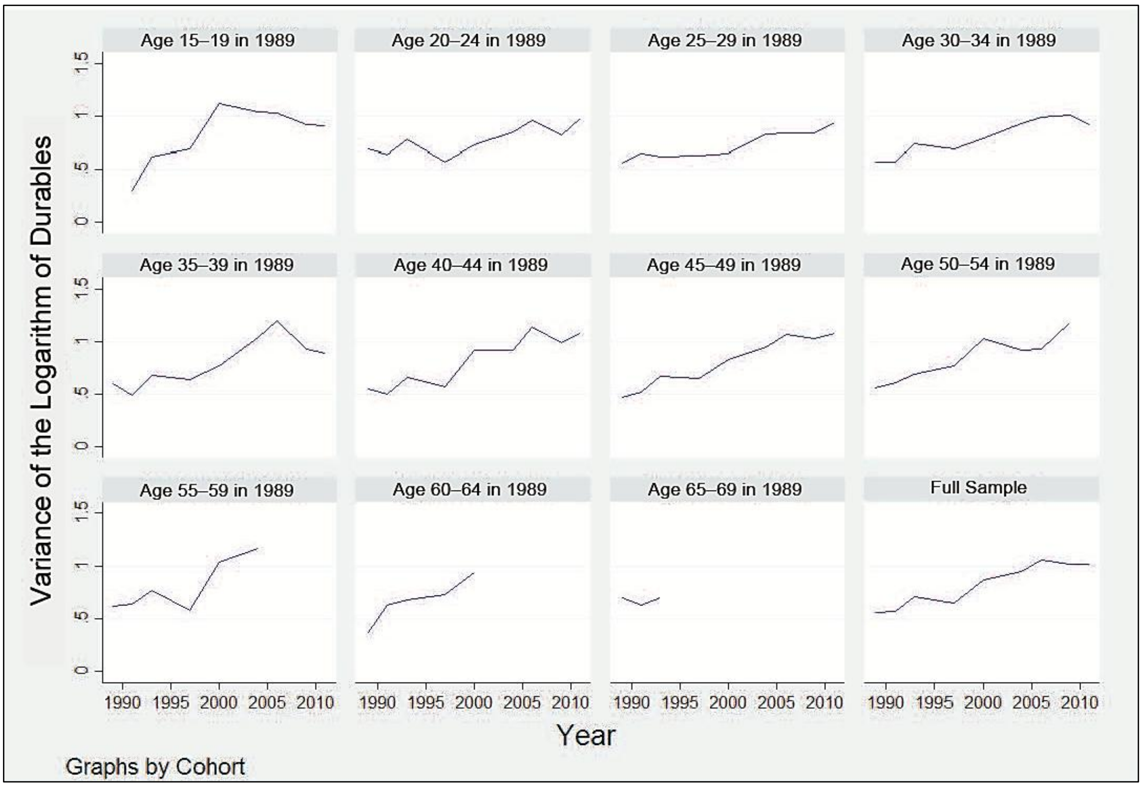
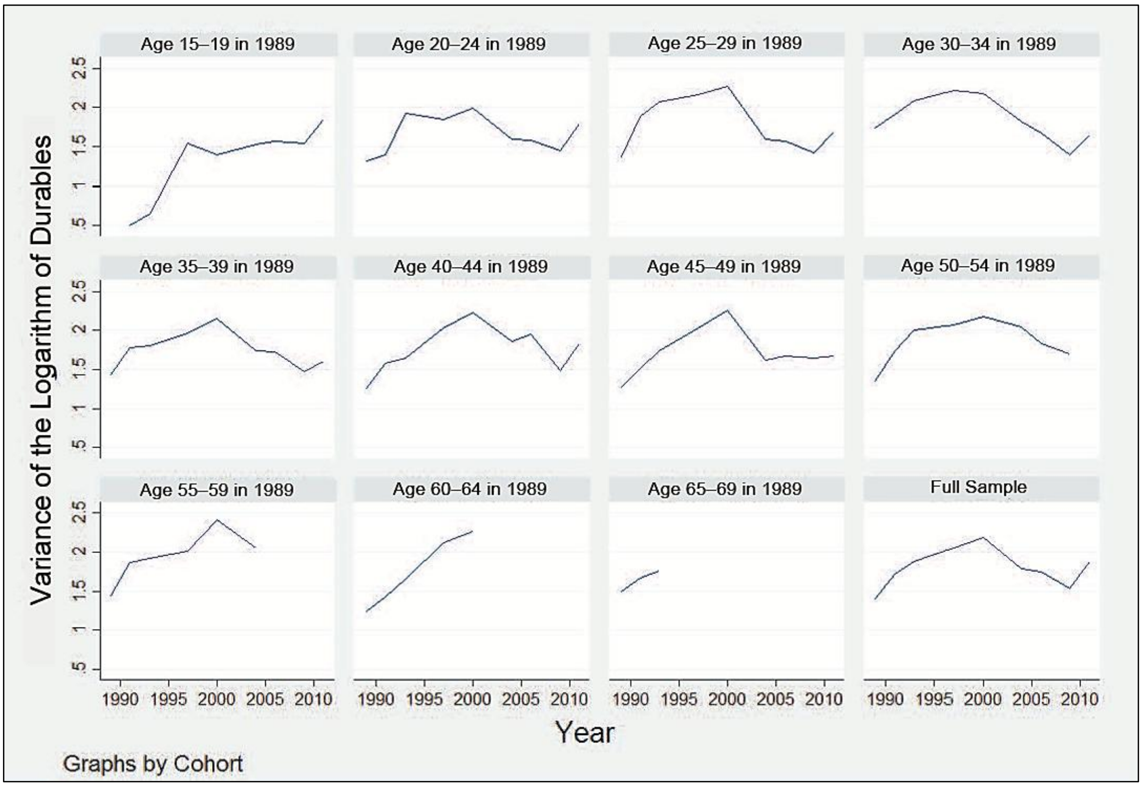
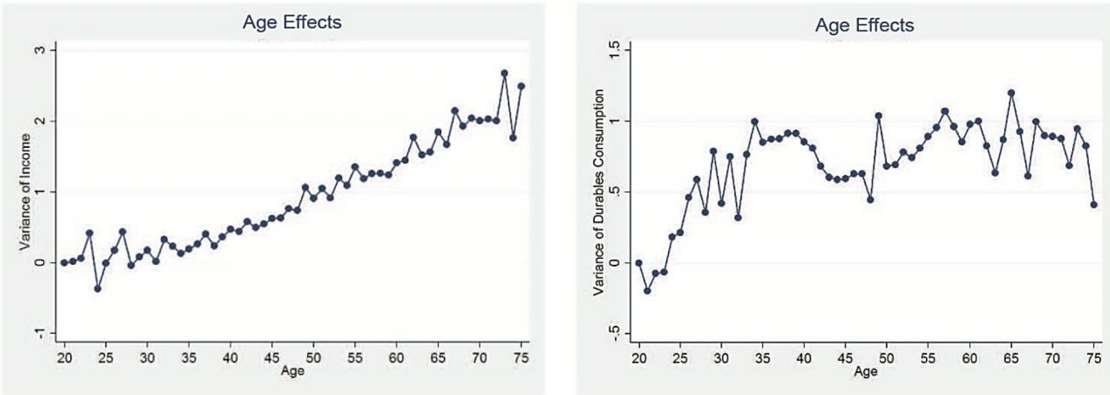


Figure 5: Variance of Log Durables' Consumption by Age Group



The estimation results of equation (21) are not presented in numerical form, since there are multiple cohort and age effects. Following the method by Deaton and Paxson (1994a), we plot the age effect after controlling the cohort and year effect in Figure 6. Inequality in income increases with age throughout the whole life cycle, while inequality in durables' consumption increases with age only during young periods and then remains stable.

Figure 6: Age Effects and Inequality



Panel A: Income Inequality Panel B: Consumption Inequality

Tables 2 and 3 present the estimation results of equation (23) regarding the overall effect of an aging population on inequality. The coefficients for age, our main variable of interest, are significantly positive, indicating that an aging population enlarges inequality in both income and durables' consumption. The comparison of the magnitude of coefficients indicates that the age effect is larger for consumption than for income. This finding is consistent with our theoretical prediction. To test the impact of financial development on the age effect, we expand our estimation by including an interaction term of *age effect* × *financial development*. The idea is that, as the financial development advances, it is more likely for households to leverage financial tools to smooth their consumption over their life cycle and hence to attenuate the age effect on inequality. A statistically significant coefficient for the interaction term with a sign opposite to that of the coefficient for the age effect would suggest that financial development helps to moderate the size of the age effect on inequality. We measure financial development with four indicators: loan to GDP, deposit to GDP, sum of loan and deposit to GDP, and number of financial institutions per 1000 residents. Tables 2 and 3 show that the coefficients for the interaction terms are negative and statistically significant for consumption inequality but insignificant for income inequality in most cases. These findings confirm the positive role of the financial sector in moderating the age effect on consumption inequality.

Considering the widely acknowledged urban–rural disparity in the PRC, we divide households into urban and rural groups by their *hukou* status and compare the age effects on income and consumption inequality across the two groups. The results shown in Tables 4 and 5 indicate that the age effects on both income and consumption inequality are stronger in urban areas than in rural areas. The statistically insignificant coefficient for the interaction term between age and financial indicators shown in Table 4 implies that financial development hardly moderates the age effect on income inequality in either rural or urban areas. However, the coefficients for all the interaction terms are significantly negative in Table 5, suggesting the important role of financial development in attenuating the age effect on consumption inequality. Moreover, the impact of financial development is larger in rural areas than in urban areas.

Table 2: Aging and Income Inequality

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	0.0285***	0.00356	0.0240***	0.0284***	0.0267***	0.0251***	0.0179***
	(18.05)	(0.505)	(5.305)	(4.678)	(5.664)	(4.573)	(2.971)
AgeSquare		5.86e-05					
		(0.841)					
Gender			0.0358	0.0372	0.0370	0.0366	0.0334
			(1.124)	(1.168)	(1.160)	(1.147)	(1.048)
Hhsize			0.101***	0.101***	0.101***	0.101***	0.104***
			(12.35)	(12.32)	(12.35)	(12.34)	(12.67)
LtoGDP				0.114			
				(0.495)			
Age*LtoGDP				–0.00558			
				(–1.340)			
DtoGDP					–0.0386		
					(–0.378)		
Age*DtoGDP					–0.00318		
					(–1.411)		
DLtoGDP						–0.0789	
						(–0.900)	
Age*DLtoGDP						–0.000145	
						(–0.0990)	
FI_Per_Thousand							–5.834***
							(–3.031)
Age*FI_Per_Thousand							0.110***
							(3.671)
Constant	–1.233***	0.614***	–1.570***	–1.443***	–1.222***	–1.116**	–1.116**
	(–8.118)	(3.569)	(–3.864)	(–2.800)	(–2.586)	(–2.189)	(–2.475)
Observations	27,812	27,812	27,812	27,812	27,812	27,812	27,812
R–squared	0.013	0.004	0.036	0.036	0.036	0.036	0.037
Wave Effect	No	No	Yes	Yes	Yes	Yes	Yes
Cohort FE	Yes	No	Yes	Yes	Yes	Yes	Yes
Province FE	No	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes	Yes	Yes	Yes

Notes: 1) Authors' estimation based on the data from the China Health and Nutrition Survey, 1989–2011. t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2) LtoGDP – loan to GDP; DtoGDP – deposit to GDP; DLtoGDP – (deposit + loan)/GDP; FI_Per_Thousand: number of financial institutions per 1000 people.

Table 3: Aging and Durables' Inequality

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Age	0.108***	0.174***	0.0281**	0.0499***	0.0389***	0.0652***	0.0827***
	(22.27)	(6.099)	(2.083)	(2.756)	(2.772)	(3.986)	(4.616)
AgeSquare		–0.00183***					
		(–7.383)					
Gender			1.413***	1.422***	1.420***	1.423***	1.427***
			(14.88)	(14.98)	(14.97)	(14.99)	(15.04)
Hhsize			0.453***	0.453***	0.453***	0.448***	0.437***
			(18.53)	(18.53)	(18.56)	(18.30)	(17.80)
LtoGDP				0.170			
				(0.248)			
AgeLtoGDP				–0.0314**			
				(–2.529)			
DtoGDP					1.391***		
					(4.583)		
AgeDtoGDP					–0.0477***		
					(–7.102)		
DLtoGDP						0.497*	
						(1.905)	
AgeDLtoGDP						–0.0163***	
						(–3.741)	
FI_Per_Thousand							19.90***
							(3.473)
AgeFI_Per_Thousand							–0.514***
							(–5.758)
Constant	–4.173***	1.978	–2.638**	–0.765	–3.334**	–2.704*	–5.858***
	(–8.903)	(1.528)	(–2.178)	(–0.499)	(–2.369)	(–1.780)	(–4.362)
Observations	27,812	27,812	27,812	27,812	27,812	27,812	27,812
R-squared	0.021	0.046	0.109	0.110	0.111	0.110	0.110
Wave Effect	No	Yes	Yes	Yes	Yes	Yes	Yes
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	No	No	Yes	Yes	Yes	Yes	Yes
Controls	No	No	Yes	Yes	Yes	Yes	Yes

Note: 1) Authors' estimation based on the data from the China Health and Nutrition Survey, 1989–2011. t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2) LtoGDP – loan to GDP; DtoGDP – deposit to GDP; DLtoGDP – (deposit + loan)/GDP; FI_Per_Thousand: number of financial institutions per 1000 people.

Table 4: Aging and Income Inequality, Urban vs Rural

	(1)	(2)	(3)	(4)	(5)	(6)
Variables		**Urban**			**Rural**	
Age	0.0364***	0.0299***	0.0301***	0.0226***	0.0207***	0.0243***
	(11.30)	(3.302)	(3.187)	(12.74)	(4.021)	(4.533)
Gender		–0.132**	–0.131**		0.0447	0.0458
		(–2.487)	(–2.467)		(1.052)	(1.078)
Hhsize		0.0731***	0.0731***		0.0871***	0.0872***
		(3.968)	(3.965)		(9.611)	(9.618)
DtoGDP			0.122			–0.150
			(0.588)			(–1.300)
Age*DtoGDP			–0.00315			–0.00206
			(–0.760)			(–0.760)
Constant	–1.999***	–2.165***	–2.295**	–0.546***	–0.530	0.0783
	(–7.254)	(–2.759)	(–2.469)	(–2.789)	(–1.054)	(0.137)
Observations	9,480	9,480	9,480	18,332	18,332	18,332
R-squared	0.016	0.043	0.043	0.010	0.033	0.033
Wave Effect	No	Yes	Yes	No	Yes	Yes
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	No	Yes	Yes	No	Yes	Yes
Controls	No	Yes	Yes	No	Yes	Yes

Table 5: Aging and Durables' Inequality, Urban vs Rural

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
		Urban			**Rural**	
Age	0.156***	0.161***	0.158***	0.0247	0.0263	0.0993***
	(7.121)	(8.838)	(6.764)	(1.030)	(1.532)	(4.541)
Gender	–0.123	–0.114	–0.117	1.603***	1.599***	1.601***
	(–1.194)	(–1.115)	(–1.138)	(11.77)	(11.75)	(11.77)
Hhsize	0.365***	0.362***	0.341***	0.213***	0.214***	0.192***
	(10.25)	(10.20)	(9.529)	(7.344)	(7.357)	(6.583)
LtoGDP	–1.017			–0.391		
	(–1.271)			(–0.411)		
Age*LtoGDP	–0.00536			–0.0212		
	(–0.404)			(–1.172)		
DtoGDP		1.437***			1.144***	
		(3.582)			(3.088)	
Age*DtoGDP		–0.0369***			–0.0455***	
		(–4.617)			(–5.236)	
FI_Per_Thousand			41.72***			19.67***
			(5.677)			(2.736)
Age*FI_Per_Thousand			–0.582***			–0.647***
			(–5.308)			(–5.628)
Constant	–9.912***	–14.31***	–13.76***	2.540	–0.204	–4.867***
	(–5.134)	(–7.979)	(–8.118)	(1.244)	(–0.111)	(–2.754)
Observations	9,480	9,480	9,480	18,332	18,332	18,332
R-squared	0.095	0.097	0.098	0.138	0.138	0.139
Wave Effect	Yes	Yes	Yes	Yes	Yes	Yes
Cohort FE	Yes	Yes	Yes	Yes	Yes	Yes
Province FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Note: 1) Authors' estimation based on the data from the China Health and Nutrition Survey, 1989–2011. t-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

2) LtoGDP – loan to GDP; DtoGDP – Deposit to GDP; DLtoGDP – (deposit + loan)/GDP; FI_Per_Thousand: number of financial institutions per 1000 people.

5. CONCLUSION

This paper studies the distributional effects of population aging. For the theoretical analysis, we build a two-period overlapping-generation (OLG) model with an uncertain lifetime to assess the impacts of population aging on income and consumption inequality. We find that population aging has the overall effect of aggravating inequality. We also identify a pattern whereby consumption inequality is higher than income inequality within the young cohort. For the empirical analysis, we use the household data from the China Health and Nutrition Survey (CHNS) to evaluate the age effect on income and consumption inequality, and our findings are largely in alignment with the results predicted in the theoretical model. In addition, we find that the age effect is larger for consumption inequality than for income inequality and that the age effect on inequality is larger in urban areas than in rural areas. We also empirically investigate the role of the financial sector in smoothing consumption over the lifetime. Our conclusion is that financial inclusion helps to attenuate the age effect on inequality, implying the importance of promoting financial access among citizens in a rapidly aging society.

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APPENDIX

$$\frac{\partial k^*}{\partial x} = \frac{A(1+e)\alpha^2\beta(1+e-x^2\beta\lambda)\left(\frac{A(1+e)x(1-\alpha)\alpha\beta}{(1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda}\right)^{\frac{\alpha}{1-\alpha}}}{((1+e)\alpha(1+x\beta)+\lambda x(1+x\alpha\beta))^2};$$

$$\frac{\partial k^*}{\partial e} = \frac{Ax^2\alpha\beta(1+x\alpha\beta)\lambda\left(\frac{A(1+e)x(1-\alpha)\alpha\beta}{(1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda}\right)^{\frac{\alpha}{1-\alpha}}}{((1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda)^2};$$

$$\frac{\partial k^*}{\partial \beta} = \frac{A(1+e)x\alpha(\alpha+e\alpha+x\lambda)\left(\frac{A(1+e)x(1-\alpha)\alpha\beta}{(1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda}\right)^{\frac{\alpha}{1-\alpha}}}{((1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda)^2};$$

$$\frac{\partial k^*}{\partial \lambda} = -\frac{(1+x\alpha\beta)\left(\frac{A(1+e)x(1-\alpha)\alpha\beta}{(1+e)\alpha(1+x\beta)+x(1+x\alpha\beta)\lambda}\right)^{\frac{2-\alpha}{1-\alpha}}}{A(1+e)(1-\alpha)^2\alpha\beta}.$$

Because that > 1, $0 < x, \beta, \lambda < 1$, it is easy to see that $1 + e - x^2\beta\lambda > 0$; hence, we have $\frac{\partial k^*}{\partial x} > 0$. The other three results are straightforward.