Economics Working Paper Series

2023/004

Gender Differences in the Effect of Retirement Duration on Cognitive Functioning

Yingying Zhang, Steve Bradley, Robert Crouchley

The Department of Economics
Lancaster University Management School
Lancaster LA1 4YX
UK

Gender Differences in the Effect of Retirement Duration on Cognitive Functioning

Yingying Zhang[1], Steve Bradley[2], Robert Crouchley[2]

Abstract

Mental health problems and severe cognitive decline can affect individual behaviours and physical health, cause adverse outcomes and generate significant economic costs for the society. In this paper we contribute to the existing literature by investigating long-term retirement effects on individual health outcomes for a developing country – China. Specifically, we examine the cumulative effect of years in retirement on cognitive functioning, measured by scores in cognitive tests such as word recall test and numeracy test, separately for men and women in China. Identifying such effects can be challenging due to endogeneity issues. To overcome this problem, we use different mandatory retirement ages as instruments for blue-collar and white-collar workers using three waves (2011-2015) of data from the national China Health and Retirement Longitudinal Study. Bivariate random-effect Tobit models are estimated, which also allows us to account for the left censored nature of retirement duration. We find that retirement duration is endogenous to men's scores in memory tests. After accounting for the observed and unobserved confounding factors, we find that one additional year in retirement reduces the number of words men recalled immediately and 10 minutes later by 0.9% and 1.7%, respectively. The effects for women are much smaller - only 25-35% of those for men. One more year in retirement reduces men' scores in numeracy test by 0.5%, and scores in mental intactness test by 0.3%, but the effect on women's scores are statistically insignificant. We also explore the underlying mechanisms for these effects by examining participation in various physical and social activities post-retirement.

Keywords: Retirement Duration, Cognitive Decline, Gender Differences.

[1] Centre for Health Economics, University of York, UK
[2] Department of Economics, Lancaster University, UK
Corresponding author:
Yingying Zhang, Centre for Health Economics, University of York, Heslington, York, YO10 5DD, UK.
Email: yingying.zhang@york.ac.uk

Gender Difference in the Effect of Retirement Duration on Cognitive Functioning

1 Introduction

Population aging has become a growing challenge for both developed and developing countries because of rising life expectancy and declining fertility. The consequential burdens on national pension systems and labour force shortages have induced countries to raise the pension-eligibility age. The retirement literature has focused on monetary outcomes of postponing retirement, including savings, private and public transfer. Non-monetary outcomes, such as individual physical health, health care use, and health behaviour, have also been widely studied (Johnston 2009, Charles 2004, Neuman 2008, Coe 2011, Grip 2012, Insler 2014, Eibich 2015). Less attention has been paid, however, to the mental health of retirees, including their cognitive decline process and depression symptoms.

There are several reasons why it is important to study cognitive decline and more generally the mental health of older workers. First, mental health problems and severe cognitive decline can affect individual behaviour and cause adverse outcomes, such as poor financial decision-making and a lack of retirement planning that will undermine an individual's support in later life and generate significant economic costs. The economic costs can come from public transfers, medical and health care expenditures, the opportunity costs for families and friends taking informal care responsibilities, and the forgone economic benefits of a healthy older population, for example, caring for grandchildren and volunteering. Serious forms of cognitive impairment can cause disability and dementia in old age (Coe 2012). Nonetheless, cognitive impairment is preventable if we have a better understanding of the risk factors.

Identifying the effect of retirement duration on cognitive levels can be challenging for several reasons. Firstly, individual retirement decisions and cognitive outcomes may depend on a common set of unobserved factors. Potential unobserved factors include differences in attitudes to labour market attachment, varying personality traits, unobserved characteristics of pre-retirement jobs, as well as those working conditions experienced throughout one's career (Garnaut 2006, Giles 2006). Secondly, reverse causality means that individuals in the worse cognitive conditions, or those suffering from more severe cognitive decline, may choose to retire earlier or later than those in a better cognitive condition. One solution is to find an instrumental variable (IV) that affects the retirement decision but not cognitive outcomes (see (Smith 2010, Wang 2007, Wang 2014)). Early research focusing on European countries have used cross-country variations in the eligibility ages for early and normal retirement benefits as IVs (Charles 2004, Neuan 2008, Coe 2011, de Grip 2012). Studies of the U.S. use within-country variation in early and normal pension-eligible ages as IVs (Johnston 2009, Insler 2014, Eibich 2015). Pension or Social Security reforms that generate exogenous variations in the retirement probability have also been exploited for identification in some studies (Insler 2014, Coe 2012, Rohwedder 2010, Bonsang 2012, Mazzonna 2012, Charles 2004, Batistin 2009). The pension arrangements in China provide a better opportunity to exploit this discontinuity in retirement incentives because retirement is mandatory for urban, formal, workers who reach retirement ages.

This paper examines the cumulative effect of years in retirement on cognitive test performance of formal retirees. We use three waves (2011-2015) of data from the China Health and Retirement Longitudinal Studies (CHARLS), a nation-wide, biannual household survey of people aged 45 or above. We restrict the sample to individuals who have urban residence permits (*hukous*) and live in urban areas, have formally retired, or work in the non-agricultural sectors.[1] To identify formal retirement, and to account for the potential endogeneity

[1] Because the data does not enable us to perfectly identify formal workers, there are informal workers who meet our sample criteria and are selected.

of retirement decision, we use the different mandatory retirement ages for blue-collar/ white-collar workers, and for men/ women as IVs. Cohort heterogeneity and attrition bias are tested for in our robustness checks.

We find that the number of years in formal retirement are endogenous to men's scores in memory tests. After accounting for the unobserved heterogeneity, we find that an additional year in retirement reduces the number of words men recalled immediately and recalled 10 minutes later by 0.9pp and 1.7pp, respectively. The magnitudes of these effects for women are only 25-35% of those for men. One more year in retirement reduces men' scores in numeracy tests by 0.5%, and scores in mental intactness test by 0.3%, but has no statistically significant effect on women's scores. We show that the gender-specific difference in the pattern of cognitive decline after retirement can be explained by the earlier retirement ages of women, the number of physical health problems and the types of social activities they take up after retirement.

The paper contributes to our understanding of the long-term retirement effects on individual health outcomes and adds to the limited evidence from a developing country of the cumulative retirement effect on cognitive functioning and subjective well-being. As such, this study adds to similar studies focusing on high-income countries where retirement ages tend to be older and retirement pensions more generous (Charles 2004, Neuman 2008, Coe 20011, de Grip 2012, Insler 2014, Eibich 2015, Rohwedder 10, Bonsang 2012, Charles 2004, de Grip 2011, Shai 2018, Atalay 2019, Gruber 2005, Celidoni 2017). From a methodological perspective, we contribute to the literature by adopting the bivariate random effects Tobit model. It accounts for the left-censored nature of the endogenous retirement duration, and tests for the presence of unobserved effects that affect both cognitive test scores and retirement duration.[2] Only a few of the previous studies consider the state dependence of health outcomes, and none of them use the dynamic model to solve the issue.[3]

The paper is organized as follows. Section 2 summarizes the relevant literature. Section 3 introduces the institutional background of mandatory retirement policy for formal workers in China, which is followed in Section 4 by a discussion of the data. Section 5 specifies the econometric model and is followed by a discussion of the statistical results in Section 6. Section 7 provides some robustness checks, and Section 8 concludes and discusses the policy implications of our findings.

2 A review of the literature

2.1 The Relationships Between Cognitive Ageing, Cognitive Decline and Retirement

Cognitive decline forms a fundamental aspect of the ageing process. Although cognitive-ageing is a natural, inevitable process, the progression of cognitive decline is not uniform or exogenous, but related to risk factors including genetics, medical comorbidities, lifestyle, psycho-social factors, and those yet to be identified (Coe 2012). If the progression is slow, it may not seriously affect individual well-being. The mechanisms underlying the retirement effect on cognition include changes in lifestyle and health behaviours (e.g. smoking, alcohol consumption, physical activity and dietary habits) (Charles 2004, Neuman 2008, de Grip 2012), the loss of intellectual stimulation in one's job (Bingley 2013, Lei 2018), less investment in cognitive repair activities (Charles 2004, de Grip 2012, Dave 2006, Salthouse 1996), and the loss of social interactions and networking available in a work environment (Hultsch 1999, Grossman 1972, Glass 1999).

[2] For comparison, we also estimate single random effects models that assume retirement duration is exogenous. For example, the Arellano and Bond model with an endogenous variable is estimated to account for the potential state dependence of the cognitive outcomes (see Appendix).

[3] Insler (2014) use health change instead of health level as the dependent variable to avoid the simultaneity problem. Dave et al. (2006) stratify the sample to include only individuals who have no major illnesses in waves before retirement, and no reported worsening of health between waves prior to retirement.

Specifically, an active and socially integrated lifestyle in later life in the social, mental, and physical dimensions has been found to benefit cognition and protect against dementia (Zantinge et al. 2013). Female retirees tend to spend more time on physical leisure activities and have healthier dietary habits compared to employed women. The recent psychiatry literature shows that depressive symptoms can be early manifestations of dementia. High blood pressure and its associated vascular damage and overt brain damage are well-known risk factors for cognitive impairment (Skoog 2006). The mental exercise hypothesis holds that continued intellectual stimulation is important in retaining a high level of cognitive functioning (Salthouse 1996, Hultsch 1999). Retirement from an intellectually demanding job without compensatory informal training or studying, or cognitively challenging social interactions, can lead to cognitive decline after retirement.

Grossman's (1972) health economics model predicts that retirees, or people approaching retirement may lack incentives to invest in cognitive repair activities, in the expectation of a declining return to further investments in work-related human capital. This can increase the rate of cognitive decline after retirement. Similar conclusions arise from the 'Dumbledore hypothesis' of cognitive ageing in psychology (Stine 2007), as well as from the 'on-the-job retirement hypothesis' (Rohwedder and Willis 2010, Mazzonna and Peracchi 2012). Empirically, the increasing rate of decline after retirement is captured by years in retirement (Bonsang 2012, Mazzonna 2012). The social capital literature suggests that social interactions and networking in the work environment can act as a buffer against health shocks and losing them after retirement may have a negative effect on health (Glass 1999, d'Hombres 2010, Börsch-Supan 2013).

Conversely, retirement can improve cognitive functioning and mental health for retirees if they are relieved from work-related strains, adopt a healthier lifestyle, and participate in leisure activities that are equally or more intellectually stimulating than their jobs. This is more likely for blue-collar workers who had worked in physically demanding jobs (See Ravesteijn et al. (2013) for a review).

2.2 Retirement and Health in China

Studies using cross-country variations in the pension-eligibility ages as instruments for retirement and using cross-sectional data are subject to the potential bias. This is because individuals from different countries can face different institutional settings and working cultures that are correlated with the retirement schemes.[4]

In the case of China, the relatively early retirement age of 50 for the majority of female workers and the retirement age of 60 for white-collar male workers means that with growing life expectancy, retirees now spend more time in retirement and in their home environment. The only evidence of a causal effect of retirement on cognitive decline is from Lei and Liu (2018), and their main analyses are based on cross-sectional data (although they do estimate fixed-effects models in the robustness checks). They do not look at the cumulative effect of retirement years, and do not study outcomes of subjective well-being and physical health.

Exploiting the changes in mandatory retirement ages, Che and Li (2018) find that the probability of reporting fair or poor health decreases by 34% after retirement among white-collar male workers. Increasing exercise, reduced smoking and drinking behaviours are possible channels behind the retirement effect. Using a similar identification strategy, Chen et al. (2020) find that retirement increases stress levels by 45% for women but reduces the level by 21% for men. Using a fuzzy regression discontinuity design at statutory retirement ages,

[4] Bonsang et al. (2012) point out that Northern-European countries having better health outcomes also set a higher eligibility age for retirement. Bingley and Martinello (2013) argue that cross-country variations in pension-eligibility ages are correlated with differences in years of schooling, which will affect cognitive functioning at old ages.

Zhang et al. (2018) find that retirement increases healthcare utilization as well as increasing the number of functional limitations and chronic diseases (e.g. hypertension, diabetes and stomach disease)[5] and increases in the Body Mass Index (BMI). They argue that the reduced opportunity cost of time after retirement drives the increase in in-patient care use, and hence more health problems are diagnosed. Finally, the likelihood of foregoing in-patient care increases by 20% for the low educated group, suggesting that the less-educated retirees face more severe health shocks due to a decrease in income after retirement. Using the same data and methods, Li (2017) also finds a 58.6% decline in the probability of reporting satisfactory health, and the depression index increases by 30.2%. Drinking behaviour also declines by 53% for male retirees, probably due to less work-related drinking that is common for male workers in China. There is no statistically significant retirement effect found for women. Feng and Zhang (2018, 2020) find that retirement increases provision of grandchild care for both genders, and weight and BMI index for low educated men.

Lei et al. (2015) find that social networks have ambiguous effects on subjective well-being (SWB). This could be because social networks reduce stress, by providing social support and information, however, social networks consume resources and are subject to relational constraints. Hence, the impact of social networks is ambiguous. The number of friends is more important than the number of relatives. Marriage, social activities, and participation in groups also matter. Meng and Xue (2020) find that one standard deviation increase in social networks reduces the measured mental health problem of rural migrant workers by 0.47 to 0.66 standard deviation.

3 The evolution of the pension system in China

In urban China, workers in the formal sector are subject to mandatory retirement ages and eligible to receive pensions afterwards. According to the official document issued by the State Council in 1978, the normal retirement ages are 60 for men, 55 for female civil servants or managers, and 50 for other female workers. Early retirement up to five years prior to the normal retirement age is allowed for people in physically-demanding jobs, civil servants working for 30 years or more, workers who have become disabled in work, and workers who were made redundant during the 1990s due to state sector restructuring.[6] Research shows that following these changes labour force participation rates fell by about 20% for men approaching retirement (aged 55-60), and about 15% for women aged 40 to 50 (Giles et al. 2006).

The normal retirement age for civil servants and urban workers in SOEs in China is one of the youngest around the world because of the low average life expectancy when it was introduced in the 1950s. However, from 1997 all employees in urban enterprises were subject to the mandatory retirement age. The enforcement is strict in the public sector but is more flexible in the private sector, and there is now an option for delayed retirement for some occupational groups.

The current social pension system in China was established during the pension reform in 1997 when the government aimed to lower the replacement ratio and extend the coverage to a wider group of workers. Specifically, the Basic Old Age Insurance (BOAI) covered workers formally employed in for-profit enterprises in the public or private sectors, and the Public Employee Pension (PEP) covered civil servants and employees in government institutions, such as schools and public hospitals. For the BOAI, the target replacement ratio

[5] 'These effects could reflect causal effects of retirement on genuine health, but it could also be that retirement makes it more likely that health problems are diagnosed'(Zhang et al. (2018) p172)

[6] Based on China Labour Statistical Yearbook in 2006 (available in http://www.stats.gov.cn/tjsj/ndsj/2006/indexeh.htm) from the Ministry of Labour and Social Security (MOLSS), 21 million workers, about 60% of the total SOEs workers, were laid-off from SOEs between 1994 and 2005, or 34 million if including collective enterprises. According to a survey by Garnaut et al. (2006) of 11 cities across China, redundant workers received compensation equivalent to three years' salary. However, in poorly performed enterprises more common in provinces with a high concentration of SOEs, such as Liaoning, Heilongjiang, Sichuan, Chongqing and Hebei, workers were laid-off without any compensation.

is 59.2% of the local average wage. The PEP was more generous than the other schemes and did not ask for any contribution from public employees. The average replacement ratio was 80-90% of pre-retirement wages.

The BOAI merged with PEP in 2015 and became a uniform programme for all formal employees in urban sectors and is still known as the BOAI. The pension schemes vary in their contribution and benefit rules, with significant inequality between formal and informal workers, and across regions as pensions are managed by provincial governments. From 2015, public employees are subject to the same contribution and benefit rules as formal employees in other sectors. Fang and Zhang (2018) provide a detailed introduction of the pension system in China.

Besides the compulsory BOAI, formal employees may also participate in Enterprise Annuity (EA), an employer-sponsored pension system introduced in 1991. EA remains small in coverage (by 2017 it had 23.3 million participants, about 5.8% of the coverage of BOAI) and is provided by large SOEs. In summary, the retirement pension programme has significant disparities in contributions and benefits between formal and informal workers, and across regions, with the average replacement ratio higher for formal workers.

4 Data, Variables and Summary Statistics

4.1 Data and variables

The China Health and Retirement Study (CHARLS) is a biannual, nation-wide longitudinal survey initiated to study the older workforce aged over 45 years, as well as their cohabiting spouses. It is equivalent to the Health and Retirement Study (HRS) in the United States. The 2011 baseline survey collects information on 17,708 respondents in 10,257 households residing in 150 counties in 28 provinces.[7] These respondents are followed-up in 2013, 2015, and 2018, although some dropped out in the middle of the surveys and new participants are included to replace them.

We use the CHARLS data because it contains the most detailed and comprehensive information on older people's health status and functioning. It also provides tests of cognitive functioning and depressive symptoms. The population of individuals aged over 45 years are ideal to study the relationship between health and retirement, as they are faced with more serious forms of cognitive declines and more severe mental or physical health problems compared with the younger population. This paper uses data from Version C of the Harmonized CHARLS dataset and supplements this with information from the main survey about job characteristics, for instance.

Cognitive ability tests conducted by CHARLS consist of a test of recalling words (referred to as memory tests for the rest of the paper) and a test of mental intactness. In the memory test, interviewers read a list of 10 common nouns to the respondents who were asked immediately to recall as many of the words as possible in any order, and to repeat this 10 minutes later. The number of words recalled immediately, and the number of words recalled 10 minutes later are used to measure memory. Previous research on cognitive outcomes have constructed measures of memory in different ways, such as taking an average of the words recalled immediately and 10 minutes later (Smith 2010, Lei 2018), or calculating the total number of words recalled (Rohwedder 2010). Some studies also look at the two memory test scores separately (Mazzonna 2012). The two memory tests measure different types of memory ability, as the number of words recalled immediately measures short-term memory and the number of words recalled 10 minutes later measures episodic memory. Episodic memory can be important for reasoning, and for both fluid and crystallised intelligence. However, it

[7] Tibet is not included in the survey, and two other provinces of Hainan and Ningxia are also not represented in the study due to their small population size.

should be noted that the two types of memory are closely related. We study changes in the two measures separately, as well as the total test scores.

In the test of mental intactness, respondents are asked to answer 10 questions which include successively subtracting 7 from 100 up to five times, naming the date, month, year and day of the week, and redrawing a picture of two overlapped pentagons. A mental intactness index is constructed by summing up the number of correct answers and has a range between 0 and 10. We calculate the numeracy test scores by counting the number of times that respondents successively subtract 7 from 100, and it has a range between 0 and 5. We also study the total scores of cognitive tests, which sum up the scores of the two memory tests and the scores of mental intactness test, and has a range between 0 and 30.

We define formal retirement based on the self-reported type of retirement, the type of employment, and the type of employers. In the Harmonized Survey, the individual's main labour force status is recorded as agricultural work [8], non-agricultural/employed, non-agricultural/self-employed, non-agricultural/unpaid family business, unemployed, retired, and never worked.[9] If respondents engage in more than one type of job, they are categorized into the job type that they spend the most time on, or as non-agricultural workers if they spend the same amount of time on both agricultural and non-agricultural work.

Few formal retirees who received retirement pensions go back to work after retirement and so they are excluded from the sample. We create an indicator of formal retirees that equals 1 for individuals self-reporting as having completed the formal retirement process and are not currently working or retired, and 0 for individuals self-reporting as not having completed formal retirement and working in the formal sector in China. This latter category includes government, SOEs, NGOs, and private firms. We restrict the sample to individuals who hold urban hukous and live in urban areas, who are either formally retired or working in the non-agricultural sector, and who do not have missing values on cognitive outcome variables. We exclude from our sample non-formal retirees, agricultural workers and the self-employed because they are not subject to compulsory retirement policy and their retirement decisions can be affected by many other factors other than compulsory retirement age.

The number of years that people have spent in formal retirement is calculated as the difference between the survey year and the year when they report to have completed their retirement process for formal retirees. It is set to 0 for people still in the labour force, and to 0.5 for people who retire in the survey year. We use 0.5 because we expect them to be different from people who have not retired when the survey started. We also try coding 1 for these individuals and the results do not differ.To account for potential confounding factors that predict both cognitive decline and retirement, we include a large set of controls. The demographic variables contain indicators for educational level (*rnprimary, rprimary, rsecondary, rhighabove*), and indicators for marital status (*rmarried*). Household-level controls include the number of children (*hchild*), the number of household members (*hhhres*), and the log of the value of household durable assets (*lnhhadurbl*). Finally, survey year dummies (*y2013, y2015*) are also included to account for aggregate health shocks, time-varying reporting changes, and effects of age. We do not control for age because the key variable of interest, years in retirement (*retdury*) is closely related to age as we expect people to retire at around retirement age. Including age variables will cause multicollinearity problem. We realize that the retirement duration effect might pick up some of the age effects, and we study that in Robustness check where we control for cohort effects. The size of sizes of the estimated retirement duration effects change only slightly, and remain significant. Table 1 shows short-forms and their detailed definitions of the dependent and explanatory variables in our empirical models.

[8] This includes individuals doing agricultural work for their own families or others in wage for at least 10 days

[9] Respondents who have worked for at least three months during their lifetime and have searched for a new job during the last month are categorized as unemployed, otherwise as retired if they have not searched for a new job during the last month.

Table 1: Definitions of the Dependent Variables and Covariates

rimrc	the number of words immediate recalled, ranging between 0 and 10
rdlrc	the number of words recalled 10 minutes later, ranging between 0 and 10
rmentalintact	the number of correct answers in mental intactness test, ranging between 0 and 10
rcesd10	the CES-D scores ranging between 0 and 30, a lower score indicating a better mental health condition
rdepress	an indicator of depression symptoms that equals 1 if an individual scored 10 or above in the CES-D test and equals 0 if an individual scored below 10.
rphyhealth	the sum of the number of chronic diseases or limitations ranging between 0 and 23, higher score indicating worse physical health
retire	an indicator for formal retirees that equals 1 for individuals having completed formal retirement process and are not currently working, equals 0 for those working in the formal sector
retdury	the number of years that people have spent in formal retirement, set to 0 for those still working, and to 0.5 for people retiring in the survey year
rabove50	1 if rage>=50, 0 otherwise
rabove55	1 if rage>=55, 0 otherwise
rabove60	1 if rage>=60, 0 otherwise
ragedif50	0 if aged 50 or below, positive and equal to the difference between individual age and 50 if above 50
ragedif55	0 if aged 55 or below, positive and equal to the difference between individual age and 55 if above 55
ragedif60	0 if aged 60 or below, positive and equal to the difference between individual age and 60 if above 60
rage	Age defined by birth year on ID, and reported age if missing ID information
rnprimary	1 if no primary school degree, including illiterate, not finishing primary school, only receiving private education (sishu), 0 otherwise (taken as reference group in the models)
rprimary	1 if highest educational attainment is finishing primary school, 0 otherwise
rsecondary	1 if highest educational attainment is finishing secondary school, 0 otherwise
rhighabove	1 if highest educational attainment is finishing high school or above (including vocational school, colleges, universities (bachelor, master or phd degree), 0 otherwise
rmarried	1 if married or partnered, 0 otherwise
Hchild	number of living children
Hhhres	number of people living in this household
lnhhadurbl	log (household durable assets' values)
y2013	1 if Wave 2 (2013)
y2015	1 if Wave 3 (2015)

In the appendix, we present the missing data patterns for male and female samples in Table A1. Over 50% of the sample remain in the survey for at least two waves.

Table 2: Summary Statistics by Wave and Gender

	Men			Women		
	2011	2013	2015	2011	2013	2015
rimrc	4.77	4.80	4.77	5.03	5.04	5.11
	(1.74)	(1.77)	(1.73)	(1.62)	(1.76)	(1.80)
rdlrc	3.70	3.84	3.75	4.14	4.16	4.07
	(1.94)	(2.00)	(2.00)	(2.11)	(2.16)	(2.05)
rser7	3.74	3.73	3.67	3.48	3.48	3.45
	(1.70)	(1.67)	(1.72)	(1.81)	(1.76)	(1.83)
rmentalintact	8.31	8.34	8.31	8.05	8.13	8.03
	(2.07)	(1.95)	(2.03)	(2.21)	(2.15)	(2.20)
rcesd10	5.20	5.38	5.11	6.54	6.36	6.13
	(4.61)	(4.29)	(4.70)	(5.37)	(4.80)	(5.39)
rdepress	0.17	0.15	0.15	0.26	0.22	0.21
rphyhealth	2.67	3.15	3.45	2.88	3.49	3.78
	(2.99)	(3.30)	(3.40)	(2.89)	(3.19)	(3.24)
retire	0.61	0.61	0.59	0.76	0.76	0.73
retdury	3.28	3.45	3.72	6.91	7.05	7.56
	(4.78)	(4.85)	(5.19)	(6.52)	(6.57)	(6.97)
rage	62.07	62.87	62.50	59.48	59.92	60.23
	(10.35)	(10.53)	(11.04)	(10.11)	(10.36)	(10.51)
rnoprimary	0.10	0.10	0.08	0.15	0.14	0.12
rprimary	0.16	0.15	0.24	0.14	0.15	0.23
rsecondary	0.27	0.27	0.25	0.30	0.29	0.28
rhighabove	0.47	0.48	0.43	0.42	0.42	0.37
rmarried	0.94	0.92	0.93	0.83	0.81	0.83
hchild	2.06	2.00	2.00	1.88	1.89	1.90
	(1.28)	(1.30)	(1.29)	(1.18)	(1.22)	(1.21)
hhhres	3.03	3.05	2.77	2.81	2.94	2.74
	(1.38)	(1.34)	(0.98)	(1.33)	(1.29)	(1.04)
lnhhadurbl	7.82	7.98	8.08	7.87	7.96	8.04
	(1.73)	(1.84)	(1.87)	(1.81)	(1.95)	(1.94)
N	1,159	1,174	1,210	1,052	1,051	1,066

Table 2 reports summary statistics of our study sample by gender and survey year. There is no clear time trend in cognitive test performance for either men or women. Women tend to report better subjective well-being conditions over time, as represented by the lower CES-D scores which measures the depressive symptoms and has a range of 0 to 30 (the lower, the better). Both men and women report slightly lower risk of depression, which is defined based on whether individuals score 10 or more in the CES-D test. The number of physical health problems increases for both men and women. The proportion of formal retirees (*retire*) is stable between waves, whereas the number of years retirees have spent in retirement increases. The value of household durable assets increases with time, which can be a result of inflation or increasing wealth levels

5 Modelling the effect of retirement on health

To investigate the cumulative effect of retirement years on cognitive functioning, mental health condition, and the physical health of formal retirees in China, we estimate a bivariate random effects model with an endogenous predicting variable – see Equation 1. We also estimate single random effects (RE) models that do not account for the endogeneity of the retirement decision for comparison.

We estimate the following RE model for cognitive outcomes:

$$Y_{it} = \beta_0 + \beta_1 RetYrs_{it} + \beta_2 X_{it} + \eta_{i1} + v_{it1} \tag{1}$$

For $i = 1, \dots, N$, and $t = 2, \dots, T$. where X_{it} are individual and household-level controls and are strictly exogenous covariates. η_{i1} are unobserved individual-level effects and v_{it1} are idiosyncratic errors. Y_{it} includes cognitive outcomes: (1) total number of words recalled (0-20); (2) the number of words recalled immediately (0-10); (3) the number of words recalled after 10 minutes (0-10); (4) the numeracy test score that is part of the mental intactness test score (0-5); (5) the mental intactness test score (0-10); and (6) the total cognitive test score (0-25).

$RetYrs_{it}$ denotes the years that retirees have spent in retirement and is 0 for those still in the labour force. Equation (1) is estimated using a linear random effects estimator. As $RetYrs_{it}$ might be endogenous to the current health condition Y_{it}, we estimate the following random effects Tobit model for individuals making the transition into retirement. The model has a left censored limit of zero and a random effect and takes the following forms:

$$RetYrs^*_{it} = \theta_0 + \theta_1 d(Age_{it} \geq 55) + \theta_2 d(Age_{it} \geq 60) + \theta_3 X_{it} + \theta_4 \bar{X}_i + \eta_{i2} + v_{it2} \quad (for\ men) \text{ or}$$

$$RetYrs^*_{it} = \theta_0 + \theta_1 d(Age_{it} \geq 50) + \theta_2 d(Age_{it} \geq 55) + \theta_3 X_{it} + \theta_4 \bar{X}_i + \eta_{i2} + v_{it2} \quad (for\ women)$$

$$\begin{gathered} RetYrs_{it} = RetYrs^*_{it} \ \ if \ \ RetYrs^*_{it} > 0 \\ RetYrs_{it} = 0 \ \ if \ \ RetYrs^*_{it} \leq 0 \end{gathered} \tag{2}$$

where η_{i2} are unobserved individual-level effects and v_{it2} are idiosyncratic errors.

In the model for females, the IVs for $RetYrs_{it}$ include an indicator of passing the normal retirement age of 50 for female workers, $d(Age_{it} \geq 50)$, and an indicator of passing the normal retirement age of 55 for female civil servants, $d(Age_{it} \geq 55)$. Similarly, an indicator of passing the early retirement age of 55, $d(Age_{it} \geq 55)$, and an indicator of passing the normal retirement age of 60, $d(Age_{it} \geq 60)$, are used as IVs in the model for men.

We estimate equation (1) and (2) jointly in a bivariate model, and assume that individual heterogeneities (η_{i1}, η_{i2}) share a zero-mean bivariate joint normal distribution. The model can be estimated using the '***gsem***' command in Stata. We report the covariance between the unobserved individual heterogeneities, $cov(\eta_{i1}, \eta_{i2})$ at the bottom of the tables, in addition to the variances of η_{i1} and η_{i2}. The correlation can only be estimated from the non-missing data. A non-zero correlation between η_{i1} and η_{i2} indicates a significant correlation between the unobservables that predict years in retirement and cognitive test scores, conditioning on the observable characteristics.

6 Results

Table 3 shows the results of estimating the Random Effects Tobit models of retirement duration as a function of the mandatory retirement ages, separately for men and women. It shows that the mandatory retirement ages are valid IVs as they are statistically significant, and they positively predict the years men and women spent in formal retirement. We also report the variances of individual heterogeneity, $\sigma^2_{\eta i2}$, and of idiosyncratic errors, σ^2_{vit2}. $\sigma^2_{\eta i2}$ tells us the level of variability between individuals across all treatment groups. The results show that the variability is about 9-10 years for men and women. The residual variance σ^2_{vit2} tells us the level of variability within a treatment group. If we calculate its square root, we obtain an estimate of 4-5 years for men and women. The fact that individual heterogeneity is significant means we should use RE models instead of pooled OLS to estimate the retirement duration for men and women in our sample.

Table 3: Determinants of Retirement Duration

	(1)	(2)
	Men	Women
rabove50		7.241***
		(0.499)
rabove55	8.570***	7.529***
	(0.630)	(0.419)
rabove60	10.000***	
	(0.483)	
rprimary	-1.412*	1.264
	(0.838)	(0.832)
rsecondary	-1.543*	2.743***
	(0.810)	(0.782)
rhighabove	-0.484	1.645**
	(0.784)	(0.770)
rmarried	-3.923***	-3.518***
	(0.674)	(0.516)
hchild	1.575***	1.436***
	(0.158)	(0.166)
hhhres	-0.605***	-0.347***
	(0.121)	(0.115)
lnhhadurbl	-0.088	-0.068
	(0.073)	(0.062)
y2013	0.278	0.081
	(0.242)	(0.213)
y2015	0.863***	1.063***
	(0.258)	(0.231)
_cons	-9.740***	-8.677***
	(1.262)	(1.091)
$\sigma^2_{\eta i2}$	85.108***	104.367***
	(4.427)	(5.347)
σ^2_{vit2}	20.999***	17.010***
	(0.997)	(0.757)
N	4776	4214
log likelihood	-8323	-9121

Notes: * p < 0:10, ** p < 0:05, *** p < 0:01. The sample is restricted to urban-hukou holders living in the urban areas, having formally retired or working in the non-agricultural sectors.

Table 4 shows the variance of individual heterogeneity in models which predicting men's cognitive functioning, that is, $\sigma^2_{\eta i1}$. The variance of individual heterogeneity in predicting men's retirement duration is again $\sigma^2_{\eta i2}$, which is similar to the finding in Table 3. Both $\sigma^2_{\eta i1}$ and $\sigma^2_{\eta i2}$ are statistically significant, justifying the use of RE models instead of pooled models. $cov(\eta_{i1}, \eta_{i2})$ represents the covariance between individual heterogeneity in predicting men's cognitive functioning (η_{i1}) and individual heterogeneity in predicting men's years in retirement (η_{i2}). A significant $cov(\eta_{i1}, \eta_{i2})$ suggests that retirement duration is endogenous to cognitive functioning, so we need to take account of this endogeneity if we are to identify the causal effect of retirement duration on cognitive outcomes. Table 4 shows that $cov(\eta_{i1}, \eta_{i2})$ are statistically significant in outcomes related to memory tests (column 1-3, 6), meaning retirement duration is endogenous to men's memory test scores. The positive signs of $cov(\eta_{i1}, \eta_{i2})$ suggest that there exist unobserved confounding factors that predict both more years in retirement and higher memory test scores for men. Our sample selection criteria are not perfect insofar as we only include formal workers, however, informal, non-agricultural workers do not have a permanent contract with a company, hence retirement behaviour amongst this group is likely to be very different. Given informal workers tend to work beyond the mandatory retirement ages and so report less years in retirement, the unobserved factors that predict formal workers behaviour possibly reflect higher initial cognitive levels, as well as the intellectually stimulating activities and social activities that are undertaken by formal retirees. These factors can delay or help preserve cognitive decline, but do not affect the numeracy test scores.

For comparison, we re-estimate the models using single RE models, which do not account for the endogeneity of retirement duration. The results are reported on the top two rows in Table 4. The effects of retirement duration decline in magnitude in the RE models, although they are still negative. The relative decline in the number of words recalled immediately and after 10 minutes are 0.7% and 1.1% respectively. Not accounting for the unobserved effects downwardly biases the effect of retirement duration.

Coefficients of *retdury* suggest that retirement duration significantly reduces scores in all cognitive tests for men, especially memory tests scores (columns 1-3). One more year in retirement reduces the number of words recalled by 0.04-0.06 or 0.9%-1.7% (the total score is 10 and the average score is 4.73 for *rimrc*; it is 3.72 for *rdlrc*). One more year in retirement also reduces the scores in the numeracy test by 0.02 or 0.5% (the total score is 7 and the average score is 3.71), and the scores in mental intactness test by 0.02 or 0.3% (the total score is 10 and the average score is 8.23). The underlying mechanisms behind the effects of retirement years are investigated in section 8.

Table 4: Bivariate Effect of Years in Retirement on Male Retirees' Cognitive Functioning

	(1)	(2)	(3)	(4)	(5)	(6)
	rwordrecalls	rimrc	rdlrc	rser7	rmentalintact	rcognitive
RE						
retdury	-0.073***	-0.031***	-0.042***	-0.015***	-0.018***	-0.087***
	(0.008)	(0.004)	(0.005)	(0.004)	(0.005)	(0.010)
N	4210	4224	4226	4307	4275	4203
log likelihood	-10631	-7821	-8472	-8197	-8836	-11370
Bivariate						
retdury	-0.108***	-0.043***	-0.064***	-0.016***	-0.023***	-0.120***
	(0.013)	(0.006)	(0.007)	(0.006)	(0.007)	(0.015)
rprimary	1.301***	0.525***	0.771***	0.617***	1.121***	1.971***
	(0.214)	(0.108)	(0.123)	(0.108)	(0.132)	(0.259)
rsecondary	1.779***	0.766***	1.036***	0.741***	1.413***	2.556***
	(0.208)	(0.106)	(0.119)	(0.105)	(0.129)	(0.252)
rhighabove	2.393***	1.126***	1.260***	0.959***	1.707***	3.396***
	(0.202)	(0.102)	(0.116)	(0.102)	(0.125)	(0.244)
rmarried	-0.096	0.010	-0.098	0.240**	0.244*	0.176
	(0.229)	(0.116)	(0.133)	(0.118)	(0.142)	(0.275)
hchild	-0.251***	-0.134***	-0.115***	0.047*	-0.018	-0.228***
	(0.053)	(0.027)	(0.031)	(0.027)	(0.032)	(0.064)
hhhres	-0.077*	-0.031	-0.051**	0.000	0.008	-0.079
	(0.041)	(0.021)	(0.024)	(0.021)	(0.025)	(0.049)
lnhhadurbl	0.148***	0.071***	0.082***	0.082***	0.124***	0.206***
	(0.028)	(0.014)	(0.017)	(0.015)	(0.018)	(0.034)
y2013	0.174*	0.009	0.135**	-0.045	-0.032	0.113
	(0.104)	(0.053)	(0.063)	(0.057)	(0.066)	(0.124)
y2015	-0.082	-0.054	-0.033	-0.124**	-0.166**	-0.226*
	(0.106)	(0.054)	(0.064)	(0.058)	(0.067)	(0.126)
_cons	6.914***	3.982***	2.880***	2.171***	5.908***	9.287***
	(0.372)	(0.189)	(0.217)	(0.193)	(0.232)	(0.448)
$\sigma^2_{\eta i1}$	3.392***	0.861***	0.936***	0.671***	1.211***	5.153***
	(0.242)	(0.062)	(0.081)	(0.061)	(0.092)	(0.349)
$\sigma^2_{\eta i2}$	84.497***	84.837***	84.286***	85.114***	85.118***	84.760***
	(4.332)	(4.379)	(4.305)	(4.427)	(4.426)	(4.371)
$cov(\eta_{i1}, \eta_{i2})$	3.646***	1.323**	2.253***	0.120	0.529	3.484***
	(1.039)	(0.516)	(0.612)	(0.477)	(0.584)	(1.229)
N	4776	4776	4776	4776	4776	4776
log likelihood	-18947	-16140	-16787	-16519	-17158	-19688

Notes: * p < 0:10, ** p < 0:05, *** p < 0:01. Indicators for the mandatory retirement ages, which are 55 or 60 for men and 50 or 55 for women, are used as instruments for years in retirement. The sample is restricted to urban-hukou holders living in the urban areas, having formally retired or working in the non-agricultural sectors. Column (1) total number of words recalled (0-20); (2) number of words recalled immediately (0-10); (3) number of words recalled after 10 minutes (0-10); (4) numeracy test score that is part of the mental intactness test score (0-5); (5) mental intactness test score (0-10); (6) the sum of total number of words recalled and numeracy test score (0-25).

Table 5: Bivariate Effect of Years in Retirement on Female Retirees' Cognitive Functioning

	(1)	(2)	(3)	(4)	(5)	(6)
	rwordrecalls	rimrc	rdlrc	rser7	rmentalintact	rcognitive
RE						
retdury	-0.036***	-0.012***	-0.024***	-0.007*	-0.004	-0.044***
	(0.007)	(0.003)	(0.004)	(0.004)	(0.005)	(0.009)
N	3862	3874	3869	3952	3900	3857
log likelihood	-9768	-7086	-7843	-7654	-8259	-10445
Bivariate						
retdury	-0.052***	-0.018***	-0.032***	-0.005	-0.011	-0.056***
	(0.012)	(0.006)	(0.007)	(0.006)	(0.008)	(0.014)
rprimary	1.732***	0.790***	0.909***	0.757***	1.425***	2.502***
	(0.203)	(0.098)	(0.120)	(0.108)	(0.135)	(0.253)
rsecondary	2.395***	1.099***	1.293***	1.023***	1.944***	3.400***
	(0.194)	(0.093)	(0.114)	(0.103)	(0.129)	(0.242)
rhighabove	3.377***	1.625***	1.742***	1.263***	2.250***	4.639***
	(0.192)	(0.092)	(0.113)	(0.102)	(0.127)	(0.239)
rmarried	0.625***	0.297***	0.338***	0.151*	0.202*	0.788***
	(0.168)	(0.081)	(0.100)	(0.090)	(0.111)	(0.206)
hchild	-0.333***	-0.159***	-0.171***	-0.082***	-0.172***	-0.417***
	(0.057)	(0.028)	(0.034)	(0.031)	(0.038)	(0.070)
hhhres	-0.027	-0.007	-0.022	0.011	0.000	-0.012
	(0.043)	(0.021)	(0.026)	(0.023)	(0.028)	(0.052)
lnhhadurbl	0.170***	0.082***	0.096***	0.056***	0.081***	0.219***
	(0.028)	(0.014)	(0.017)	(0.015)	(0.018)	(0.034)
y2013	0.137	0.056	0.077	-0.007	0.033	0.112
	(0.107)	(0.054)	(0.066)	(0.059)	(0.070)	(0.124)
y2015	0.041	0.079	-0.026	-0.066	-0.081	-0.055
	(0.111)	(0.056)	(0.068)	(0.061)	(0.072)	(0.130)
_cons	5.952***	3.437***	2.433***	2.195***	5.857***	8.205***
	(0.339)	(0.165)	(0.202)	(0.182)	(0.223)	(0.413)
$\sigma^2_{\eta i1}$	3.582***	0.719***	1.121***	0.915***	1.644***	6.364***
	(0.254)	(0.059)	(0.088)	(0.073)	(0.116)	(0.385)
$\sigma^2_{\eta i2}$	103.854***	104.037***	103.926***	104.325***	104.320***	104.123***
	(5.315)	(5.327)	(5.325)	(5.345)	(5.338)	(5.331)
$cov(\eta_{i1}, \eta_{i2})$	1.789*	0.669	0.875	-0.254	0.817	1.485
	(1.079)	(0.504)	(0.620)	(0.545)	(0.708)	(1.329)
N	4214	4214	4214	4214	4214	4214
log likelihood	-18888	-16207	-16963	-16775	-17380	-19565

Note: ibid.

Table 5 reports the estimates of the bivariate model for women. $\sigma^2_{\eta i1}$ and $\sigma^2_{\eta i2}$ are again statistically significant, justifying the use of RE models. $cov(\eta_{i1}, \eta_{i2})$ is not significant across models of different outcomes, suggesting that endogeneity is not a concern in predicting women's cognitive test scores. Estimation of the single RE models shows that an additional year in retirement reduces the number of words recalled immediately by 0.02 or 0.4% (the total score is 10 and the average score is 5.00), and the number of words recalled after 10 minutes by 0.03 or 0.8% (the total score is 10 and the average score is 4.07). The magnitudes of these effects are only 25-35% of those for men.

One more year in retirement also reduces the scores in the numeracy test by 0.01 or 0.2% (the total score is 7 and the average score is 3.47), though this variable is marginally statistically significant. The effect is also not significant for women's mental intactness scores, in contrast to the negative and significant effect for men (about 0.5% for every additional year in retirement). The gender difference in the effect of retirement duration could be due to the fact that women retire earlier at around 50 while men retire at 60. Given the same number of years in retirement, female retirees are generally younger than male retirees, and thus perform better in cognitive tests. It might also be that females have different social activities and physical activities, or other mentally stimulating activities, that men and women take up after retirement. These activities compensate for the loss of intellectual stimulation and human capital investment and social network in the working environment and can slow down the cognitive decline process for retirees. Atalay et al. (2019) find a greater cognitive decline shortly after retirement for men than for women, and find evidence that women spent more time in mental and household activities after retirement. We explore these mechanisms in greater detail in the section 8.

There are other explanatory variables that have a statistically significant effect on cognitive decline, which include educational level and household asset values. Empirical evidence has shown that education is an important factor that affects the process of cognitive ageing (Bank 2012), and education achievement is highly related to wealth and income levels. A child's early environment is also strongly predictive of cognitive ability (Case 2008), reflecting better nutrition and childhood health. Being married improves women's performance in memory tests but not men.

In summary, we find that retirement duration significantly reduces scores in memory tests for both men and women, with the magnitude of these effects for women being 25-35% of those for men.

7 Robustness Checks

Cohort effects can be a concern in identifying the true effects of retirement duration on cognitive outcomes as initial cognitive endowment, early life environment, and especially differences in schooling can cause cohort heterogeneity in cognitive abilities (Mazzonna 2012, Richards 2004, Cunha 2007, Case 2009, Currie 2009). Cohort differences in initial conditions can generate a negative bias and over-estimate the negative effect of retirement duration, while cohort differences in mortality generate a positive bias and underestimate the age effect (Coe 2011). Cohort-specific macroeconomic events can have a lasting effect on health, causing nonlinear relationships between cognitive decline and age, hence cognitive ageing cannot be fully controlled by age (Mazzonna 2012).

If cohort heterogeneity is a fixed effect that reflects different initial conditions, then Mazzonna and Peracchi (2012) suggest one solution which is to difference it out by using panel dimension of the data. But this approach does not work if the cohort effect is due to differences in mortality, which might only be a concern for the very oldest cohort. Given that the birth years of our sample fall between 1941 and 1971, the relevant macroeconomic event that can have lifelong effects on health and cognitive abilities might be the Second World War (WWII 1939-1945) and the Great Famine (1959-1961). The Great Famine has been used as an IV for educational achievement in Huang and Zhou (2013)'s study of the effect of education on cognition at older ages.

Table 6: Bivariate Effect of Years in Retirement on Male Retirees (With or Without Cohort Effects)

	(1)	(2)	(3)	(4)	(5)	(6)
	rimrc	rdlrc	rmentalintact	CESD	Physical	Depression
Without Cohort Effects						
retdury	0.043***	0.064***	-0.023***	-0.026	0.067***	-0.002*
	(0.006)	(0.007)	(0.007)	(0.017)	(0.008)	(0.001)
N	4776	4776	4776	4776	4776	4776
Log likelihood	-16140	-16787	-17158	-20717	-18165	-9949
With Cohort Effects						
retdury	0.044***	0.061***	-0.024***	-0.028	0.049***	-0.003**
	(0.007)	(0.008)	(0.008)	(0.019)	(0.009)	(0.001)
WWII	0.001	-0.098	0.102	0.103	0.304	0.008
	(0.101)	(0.114)	(0.121)	(0.307)	(0.187)	(0.023)
the Great Famine	-0.109	-0.069	-0.325**	0.106	-0.419*	-0.009
	(0.123)	(0.139)	(0.149)	(0.377)	(0.235)	(0.028)
N	4240	4240	4240	4240	4240	4240
Log likelihood	-14332	-14936	-15229	-18463	-15845	-8764

Notes: * p < 0:10, ** p < 0:05, *** p < 0:01. Indicators for the mandatory retirement ages, which are 55 or 60 for men and 50 or 55 for women, are used as instruments for years in retirement. The sample is restricted to urban-hukou holders living in the urban areas, having formally retired or working in the non-agricultural sectors. We also control for educational levels, marital status, number of children and of household members, values of household durable assets, survey year dummies. Column (1) number of words recalled immediately (0-10); (2) number of words recalled after 10 minutes (0-10); (3) mental intactness test score (0-10); (4) total scores in CES-D test (0-30, the higher the worse in mental health conditions); (5) number of physical health problems; (6) probability of being depressed (1 if scoring 10 or above in the CES-D test).

We re-estimate the bivariate random effects Tobit models, above, but include extra control variables of being born during the WWII and being born during the Great Famine. We compare the estimates with those from earlier models without cohort effects in Tables 6 and 7.

Table 6 shows that the WWII cohort or the Great Famine cohort are not significantly different from the rest of the sample in most of the outcomes we study. However, men born during the Great Famine do score significantly lower in mental intactness tests. The magnitude is 0.325 or 3.9%. The level of statistical significance and the magnitude of the estimated effects of retirement duration do not change much after controlling for the two cohorts.

Table 7 shows that women born during the Great Femine score 0.23 or 4.8% lower in words recalled immediately and score 0.28 or 7.4% lower in words recalled 10 minutes later, and score 0.38 or 4.8% lower in mental intactness test, compared to women not born during the Great Femine. Effects of an additional year in retirement decline in size (0.2% vs. 0.4% for *rimrc* and 0.6% vs. 0.8% for *rdlrc*) after controlling for cohort effect, but they remain statistically significant.

Women born during the WWII cohort score higher in CES-D test, have a higher probability of being depressed, and report more physical health problems than women who were not born during the WWII. After accounting for the cohort effects, the negative effect of an additional year in retirement on physical health problems reduces by about 9% in size.

Table 7: Bivariate Effect of Years in Retirement on Female Retirees (With or Without Cohort Effects)

	(1) rimrc	(2) rdlrc	(3) rmentalintact	(4) CESD	(5) Physical	(6) Depression
Without Cohort Effects						
retdury	-0.018***	-0.032***	-0.011	-0.013	0.051***	-0.002
	(0.006)	(0.007)	(0.008)	(0.019)	(0.009)	(0.001)
N	4214	4214	4214	4214	4214	4214
Log likelihood	-16207	-16963	-17380	-21068	-17879	-11212
With Cohort Effects						
retdury	-0.012**	-0.026***	-0.006	-0.030	0.034***	-0.003
	(0.006)	(0.007)	(0.008)	(0.021)	(0.009)	(0.002)
WWII	-0.108	-0.113	0.034	0.833**	0.997***	0.070**
	(0.114)	(0.140)	(0.159)	(0.414)	(0.227)	(0.031)
the Great Famine	-0.233**	-0.285**	-0.377**	0.629	-0.027	0.043
	(0.118)	(0.145)	(0.163)	(0.428)	(0.247)	(0.032)
N	3776	3776	3776	3776	3776	3776
Log likelihood	-14407	-15071	-15460	-18782	-15738	-9884

Notes: ibid.

The problem of panel attrition bias occurs if people in poor cognitive abilities are more likely to drop out of the survey or die during the survey (Behncke 2012, Coe 2011, Mazzonna 2012, Atalay 2019). If non-response is systemically related to cognitive declines, estimated effects of retirement duration would be biased.

To test for potential attrition bias, we re-estimate the bivariate RE Tobit models but restrict the sample further to people who stay for at least 2 consecutive waves. The sample sizes decrease, but the effects of retirement duration do not change in terms of significant levels (results not reported here). The negative effects of an additional year in retirement on men's or women's cognitive test scores reduce after we restrict to a longitudinal sample, probably because retirees staying for more than 1 wave tend to score better in cognitive tests than retirees who stay for only 1 wave (which can be due to attrition effect). The negative effect of an additional year in retirement on men's or women's physical health also declines in magnitude, likely because those suffering from more physical health problems are more likely to leave after 1 wave of survey.

Another way to test for attrition effect is to include longitudinal sample dummies in the models. We create three dummies: staying for both wave 1 and 2 but not wave 3, staying for both wave 2 and 3 but not wave 1, and staying for waves 1, 2 and 3. The reference group is individuals who stay for only 1 wave (only 101 men and 96 women stayed in the survey for wave 1 and 3 but not wave 2, and we treat them the same as those staying for only 1 wave). We find that most of the longitudinal sample dummies are not significant. Women staying for 3 waves do score lower in mental intactness test and report more physical health problems, but this is likely due to age effects rather than attrition effect, which should see them score better in cognitive tests and report fewer physical problems.

8 The Underlying Mechanisms between Mental Health and Retirement

To understand the underlying mechanisms between retirement duration and cognitive functioning, we study mental and physical health outcomes that are closely related to cognitive decline.[10] Specifically, mental health is measured by total scores in the CES-D test (0-30, the higher the scores, the worse the subjective well-being and the more depressive symptoms people show), and the probability of being depressed (equal to 1 if scoring 10 or above in the CES-D test, zero otherwise). Physical health is measured by the total number of self-reported chronic diseases and functional limitations.

As shown in Table 8, the statistically significant and positive $cov(\eta_{i1}, \eta_{i2})$ indicates that retirement duration is endogenous to the subjective and physical well-being of men. The confounding factors predict both earlier retirement (more years in retirement) and worse physical and mental well-being. There might also be reverse causality where people in worse mental and physical health conditions retire earlier. We focus on the local average treatment effects produced by the bivariate random effects Tobit model. What these estimates show is that an additional year in retirement reduces the CES-D scores for men by around 0.03 or 0.6% (the sample average score is 5.39) insignificantly, and reduces their risk of depression by 0.002 or 1.2% (the sample average is 0.17), and increases the number of physical health problems by 0.07 or 2.4% (the sample average is 2.88).

As for women, both $\sigma^2_{\eta i1}$ and $\sigma^2_{\eta i2}$ are statistically significant, justifying the use of RE models instead of pooled models. Again, $cov(\eta_{i1}, \eta_{i2})$ is not significant for women's subjective well-being but is significant for physical health. An additional year in retirement does not significantly affect the probability of depression or CESD, but increases and the number of physical health problems by 0.05 or 1.6% (the sample average is 3.20) for women.

In summary, retirement duration improves subjective well-being of men and reduces the risk of depression for men. It also significantly increases the number of physical health problems for both men and women. Subjective well-being, as measured by depressive symptoms, might not be related to individual performance in cognitive tests, because men's depressive symptoms improve while women's do not, and men's cognitive functioning declines more than women' after retirement. Physical health problems can be associated with cognitive test scores as physical health conditions deteriorate more after retirement for men than for women.

[10] Medical comorbidities and psycho-social factors have been identified as risk factors of cognitive decline (1). The recent psychiatry literature shows that depressive symptoms can be an early manifestation of dementia (35).

Table 8: Bivariate RE Estimation of Retirement Duration Effect on Subjective and Physical Well-Being

	CES-D (0-30)		Depression (0,1)		Physical Problems	
	Men	Women	Men	Women	Men	Women
	(1)	(2)	(3)	(4)	(5)	(6)
RE						
retdury	-0.002	-0.019	-0.000	-0.002	0.090***	0.067***
	(0.012)	(0.012)	(0.001)	(0.001)	(0.006)	(0.006)
N	4312	3954	4312	3954	4423	3907
Log Likelihood	-12396	-11946	-1630	-2091	-9844	-8759
Bivariate						
retdury	-0.026	-0.013	-0.002*	-0.002	0.067***	0.051***
	(0.017)	(0.019)	(0.001)	(0.001)	(0.008)	(0.009)
$\sigma^2_{\eta i1}$	10.595***	13.012***	0.047***	0.055***	5.735***	5.818***
	(0.527)	(0.727)	(0.003)	(0.004)	(0.214)	(0.230)
$\sigma^2_{\eta i2}$	85.025***	104.316***	85.034***	104.391***	85.480***	105.455***
	(4.409)	(5.346)	(4.402)	(5.350)	(4.424)	(5.444)
$cov(\eta_{i1}, \eta_{i2})$	2.790**	-0.628	0.243**	0.028	3.293***	2.366**
	(1.405)	(1.820)	(0.108)	(0.132)	(0.761)	(0.945)
N	4776	4214	4776	4214	4776	4214
Log Likelihood	-20717	-21068	-9949	-11212	-18165	-17879

Note: * p < 0:10, ** p < 0:05, *** p < 0:01. Indicators for the mandatory retirement ages, which are 55 or 60 for men and 50 or 55 for women, are used as instruments for years in retirement. The sample is restricted to urban-hukou holders living in the urban areas, having formally retired or still working in the non-agricultural sectors. Column (1)(2): total scores in CES-D test (0-30, the higher the worse in mental health conditions); (3)(4): number of physical health problems

In Table 9 we report the estimates of the effect of retirement duration on the probability of participating in various social activities (columns 1-9), the probability of participating in none of these activities (column 10), as well as on the total number of these social activities they participate in (column 11). We report only coefficients of the retirement duration to save space. Both $\sigma^2_{\eta i1}$ and $\sigma^2_{\eta i2}$ are statistically significant, justifying the use of random effects models instead of pooled models. $cov(\eta_{i1}, \eta_{i2})$ is not significant in most of the models for men except for predicting interaction with friends (column 1) and predicting the probability of using the internet (column 8). Unobserved factors related to probability of working can predict both interactions with friends in work environment and Internet use, and retirement duration. Estimates for retirement duration suggest that an additional year in formal retirement significantly reduces the probability of men interacting with friends (column 1) by 0.008 or 2.0%, of helping family, friends, or neighbours (column 3) by 0.007 or 4.4%, possibly because they lose some interpersonal relationships in work or related to their jobs. An additional year in retirement also reduces men's probability of taking voluntary work (column 6), caring for a sick or disabled adult (column 7), use of internet (column 8) and the number of social activities (column 11). The relative sizes of these effects are reported in Table 9.

These findings help to explain the deteriorating mental health conditions after retirement because isolation and lack of social activities is a driver of mental health problems and depression. An additional year in formal retirement increases the probability of men joining a sports or social club (column 4) by 0.004 (or 2.0%), but this is not the same as saying that men increase physical activities, which we study in Table 10. For women, an additional year in formal retirement reduces the probability of interacting with friends (column 1), providing help to family, friends, or neighbours (column 3), internet use (column 8) and total number of social activities (column 11).

To study the mechanisms underlying changes in physical health, we also look at participation and time spent in physical activities. Specially, individuals were asked whether they did any vigorous, moderately energetic or mildly energetic physical activities for at least 10 minutes every week. Then they were asked about the number of days each week they did these three types of physical activities.

Table 10 shows the estimated effect of retirement duration on the probability of participating in various physical activities and on the amount of time people spent on these activities. Both men and women are less likely to take up any vigorous or moderate physical activities as years in retirement rises, but men extract from vigorous physical activities more than women do. Men take up more light exercises as a compensation. Given that men report lightly more physical problems than women do, our findings suggest that maintaining certain levels of vigorous physical activities is more beneficial for retaining physical health conditions of retirees compared to light activities.

Table 9: Effect of Retirement Years on Participation in Social Activities

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Men											
Mean (Y)	0.409	0.308	0.158	0.200	0.060	0.028	0.029	0.202	0.023	0.301	1.478
SD	(0.492)	(0.462)	(0.365)	(0.400)	(0.237)	(0.166)	(0.168)	(0.401)	(0.150)	(0.459)	(1.464)
retdury	-0.008***	-0.001	-0.007***	0.004***	-0.001	-0.001**	-0.002***	-0.012***	0.000	0.002	-0.032***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.000)	(0.002)	(0.006)
Relative effect (%)	-2.0	-0.3	-4.4	2.0	1.7	-3.6	-6.9	-5.9	0.0	0.7	-2.2
$\sigma^2_{\eta i1}$	0.061***	0.113***	0.019***	0.033***	0.011***	0.004***	0.003***	0.073***	0.001*	0.056***	0.806***
	(0.005)	(0.005)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.004)	(0.001)	(0.004)	(0.048)
$\sigma^2_{\eta i2}$	84.676***	85.166***	84.827***	85.093***	85.127***	84.939***	84.604***	83.708***	85.064***	85.167***	84.561***
	(4.381)	(4.429)	(4.423)	(4.433)	(4.427)	(4.406)	(4.413)	(4.251)	(4.427)	(4.430)	(4.334)
$cov(\eta_{i1}, \eta_{i2})$	0.327**	0.127	0.104	-0.007	0.024	0.069	0.075	0.648***	0.012	-0.069	1.754***
	(0.151)	(0.146)	(0.109)	(0.107)	(0.066)	(0.045)	(0.051)	(0.151)	(0.029)	(0.129)	(0.515)
N	4776	4776	4776	4776	4776	4776	4776	4776	4776	4776	4776
Log likelihood	-11252	-10738	-10028	-10423	-8142	-6662	-6701	-9877	-6194	-10851	-15707

Women											
Mean (Y)	0.419	0.253	0.160	0.287	0.063	0.034	0.035	0.188	0.017	0.311	1.514
SD	(0.493)	(0.435)	(0.366)	(0.452)	(0.243)	(0.182)	(0.184)	(0.391)	(0.130)	(0.463)	(1.526)
retdury	-0.006***	0.002	-0.003***	0.001	0.001	-0.000	-0.001	-0.008***	-0.000	0.004**	-0.019***
	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.002)	(0.005)
Relative effect (%)	-1.4	0.8	-1.9	0.3	1.6	0.0	2.9	-4.3	0.0	1.3	-1.3
$\sigma^2_{\eta i1}$	0.049***	0.102***	0.015***	0.069***	0.013***	0.008***	0.004***	0.062***	0.000	0.061***	0.928***
	(0.006)	(0.005)	(0.003)	(0.005)	(0.001)	(0.001)	(0.001)	(0.003)	(0.000)	(0.005)	(0.054)
$\sigma^2_{\eta i2}$	103.768***	104.335***	104.349***	104.836***	104.324***	104.336***	104.372***	102.650***	104.359***	103.961***	103.919***
	(5.281)	(5.350)	(5.348)	(5.363)	(5.345)	(5.347)	(5.346)	(5.237)	(5.347)	(5.274)	(5.286)
$cov(\eta_{i1}, \eta_{i2})$	0.436***	-0.022	0.013	0.340**	-0.029	0.014	-0.025	0.382***	0.000	-0.524***	1.560***
	(0.162)	(0.148)	(0.087)	(0.145)	(0.069)	(0.052)	(0.046)	(0.135)	(0.000)	(0.159)	(0.518)
N	4214	4214	4214	4214	4214	4214	4214	4214	4214	4214	4214
Log Likelihood	-11884	-11068	-10712	-11397	-9047	-7879	-7972	-10435	-6650	-11516	-16058

Notes: * p < 0:10, ** p < 0:05, *** p < 0:01. Indicators for the mandatory retirement ages, which are 55 or 60 for men and 50 or 55 for women, are used as instruments for years in retirement. The sample is restricted to urban-hukou holders living in the urban areas, having formally retired or working in the non-agricultural sectors. We also control for marital status, education level, household size, number of children, durable assets' values, survey year dummies. (1) Interacted with friends (2) Played Ma-jong, played chess, played cards, or went to community club (3) Provided help to family, friends, or neighbours (4) Went to a sport, social, or other kind of club (5) Took part in a community-related organization (6) Done voluntary or charity work (7) Cared for a sick or disabled adult (8) Used the Internet(9) Other (10) None of these (11) Total number of activities.

Table 10: Effect of Retirement Years on Participation in Physical Activities

	(1) vgact	(2) vgactx	(3) mdact	(4) mdactx	(5) ltact	(6) ltactx
Men						
retdury	-0.013***	-0.071***	-0.008**	-0.042**	0.004**	0.041***
	(0.002)	(0.013)	(0.003)	(0.020)	(0.002)	(0.014)
$\sigma^2_{\eta i1}$	0.039***	1.436***	0.044***	1.858***	0.028***	1.479***
	(0.007)	(0.223)	(0.010)	(0.405)	(0.005)	(0.285)
$\sigma^2_{\eta i2}$	84.954***	84.865***	84.540***	84.433***	85.059***	84.837***
	(4.428)	(4.428)	(4.372)	(4.375)	(4.428)	(4.427)
$cov(\eta_{i1}, \eta_{i2})$	0.111	0.863	-0.471*	-3.061*	-0.045	-0.924
	(0.167)	(1.019)	(0.244)	(1.620)	(0.130)	(0.995)
N	4914	4914	4914	4914	4914	4914
Log Likelihood	-9565	-12754	-10004	-13362	-9363	-13008
Women						
retdury	-0.007***	-0.029***	-0.011***	-0.066***	0.001	0.024**
	(0.001)	(0.008)	(0.002)	(0.012)	(0.001)	(0.011)
$\sigma^2_{\eta i1}$	0.021***	0.532***	0.019**	0.832**	0.019***	1.143***
	(0.005)	(0.145)	(0.009)	(0.408)	(0.005)	(0.283)
$\sigma^2_{\eta i1}$	104.297***	104.164***	104.328***	104.315***	104.364***	104.324***
	(5.343)	(5.343)	(5.346)	(5.346)	(5.347)	(5.346)
$cov(\eta_{i1}, \eta_{i2})$	-0.108	-0.769	-0.063	-0.443	0.051	-0.288
	(0.113)	(0.630)	(0.111)	(0.742)	(0.104)	(0.793)
N	4334	4334	4334	4334	4334	4334
Log Likelihood	-9990	-13031	-10717	-14021	-10121	-13615

Notes: * p < 0:10, ** p < 0:05, *** p < 0:01. (1):Any Vigorous Activities At Least 10 Minutes Continuously; (2) Days of Vigorous Activities; (3) Any Moderate Activities At Least 10 Minutes Continuously; (4) Days of Moderate Activities; (5) Any Light Activities At Least 10 Minutes Continuously; (6) Days of Light Activities.

9 Conclusion

This paper examines the effect of retirement duration on cognitive functioning, separately for men and women. To identify formal retirement and to account for potential endogeneity of retirement decision, we use the different mandatory retirement ages for blue-collar and white-collar workers, and for men and women as IVs. The bivariate random effects Tobit model accounts for the left-censored nature of retirement duration and indicates the presence of unobserved factors that predict both cognitive test performance and retirement duration. A statistically significant correlation between the two random effects suggests that retirement years is endogenous to cognitive test scores. For comparison, we also estimate single random effects models that assume retirement duration is exogenous.

We find that retirement duration is endogenous to men's scores in memory tests but not scores in numeracy tests. An additional year in retirement reduces the number of words men recalled immediately by 0.9% and words recalled 10 minutes later by 1.7%. It also reduces men' scores in numeracy tests by 0.5%, and scores in mental intactness test by 0.3%. Retirement duration is exogenous to women's cognitive test scores. An additional year in retirement reduces the number of words recalled immediately by 0.4% and words recalled after 10 minutes by 0.8%. It does not affect women's scores in numeracy test or mental intactness test. The magnitudes of these effects for women are only 25-35% of those for men.

The gender difference in effects of retirement duration can be due to the fact that women retire earlier at around 50 when they are in better physical health. One more year in formal retirement increases the number of physical health problems by 3.1% for men and by 1.8% for women. It can also be explained by the different social activities and physical activities that men and women take up after retirement. Men reduce their interaction with friends and use of the Internet more than women do, and men take less vigorous physical activities after retirement. The lack of compensating social or intellectual activities after retirement may also explain the decline in men's cognitive scores after retirement. The lack of vigorous physical activities may explain the worse physical health conditions of male retirees. We explore cohort effects and find that after accounting for cohort heterogeneity in initial cognitive endowment, the effects of retirement duration are still statistically significant and the changes in sizes are small. We do not find evidence of severe cognition-related attrition effects that undermine our estimates.

Findings of this paper suggest that when making decisions on raising retirement ages, policy makers should also consider the cumulative effect of retirement. Policies should also be introduced that provide incentives for retirees to adopt a healthier lifestyle, support cognitive maintenance activities, or remove barriers that prevent retirees from taking part-time or informal work. Occupational training programmes targeted at older workers may also help them maintain cognitive abilities and feel meaningful and useful. Active ageing programmes such as the Active, Connected, Engaged (Beedie 2014) in the UK provide a lost-cost, yet sustainable physical intervention that relies on peer education may significantly reduce cognitive decline and promote a healthier and rewarding retirement.

References

[1] David W Johnston and Wang-Sheng Lee. Retiring to the good life? the short-term effects of retirement on health. *Economics Letters*, 103(1):8–11, 2009.

[2] Kerwin Kofi Charles. Is retirement depressing? Labour force inactivity and psychological well-being in later life. *Research in Labor Economics*, 23(2004):269–299, 2004.

[3] Kevin Neuman. Quit your job and get healthier? the effect of retirement on health. *Journal of Labor Research*, 29(2):177–201, 2008.

[4] Norma B Coe and Gema Zamarro. Retirement effects on health in Europe. *Journal of health economics*, 30(1):77–86, 2011.

[5] Andries de Grip, Maarten Lindeboom, and Raymond Montizaan. Shattered dreams: the effects of changing the pension system late in the game. *The Economic Journal*, 122(559):1–25, 2012.

[6] Michael Insler. The health consequences of retirement. *Journal of Human Resources*, 49(1): 195–233, 2014.

[7] Peter Eibich. Understanding the effect of retirement on health: Mechanisms and heterogeneity. *Journal of health economics*, 43:1–12, 2015.

[8] Norma B Coe, Hans-Martin von Gaudecker, Maarten Lindeboom, and Jürgen Maurer. The effect of retirement on cognitive functioning. *Health economics*, 21(8):913–927, 2012.

[9] Susann Rohwedder and Robert J Willis. Mental retirement. *Journal of Economic Perspectives*, 24(1):119–38, 2010.

[10] Eric Bonsang, Stéphane Adam, and Sergio Perelman. Does retirement affect cognitive functioning? *Journal of health economics*, 31(3):490–501, 2012.

[11] Fabrizio Mazzonna and Franco Peracchi. Ageing, cognitive abilities and retirement. *European Economic Review*, 56(4):691–710, 2012.

[12] Kerwin Kofi Charles. Is retirement depressing? Labour force inactivity and psychological wellbeing in later life. In *Accounting for worker well-being*, pages 269–299. Emerald Group Publishing Limited, 2004.

[13] Erich Battistin, Agar Brugiavini, Enrico Rettore, and Guglielmo Weber. The retirement consumption puzzle: Evidence from a regression discontinuity approach. *American Economic Review*, 99 (5):2209–26, 2009.

[14] Andries de Grip, Maarten Lindeboom, and Raymond Montizaan. Shattered dreams: The effects of changing the pension system late in the game. *The Economic Journal*, 122(559):1–25, 2011.

[15] Ori Shai. Is retirement good for men's health? evidence using a change in the retirement age in Israel. *Journal of Health Economics*, 57:15–30, 2018.

[16] Kadir Atalay, Garry F Barrett, and Anita Staneva. The effect of retirement on elderly cognitive functioning. *Journal of Health Economics*, 66:37–53, 2019.

[17] Jonathan Gruber and David Wise. Social security programs and retirement around the world: Fiscal implications, introduction and summary. Technical report, National Bureau of Economic Research, 2005.

[18] Martina Celidoni, Chiara Dal Bianco, and Guglielmo Weber. Retirement and cognitive decline. a longitudinal analysis using share data. *Journal of Health Economics*, 56:113–125, 2017.

[19] Pierre-Jean Messe and François-Charles Wolff. Healthier when retiring earlier? Evidence from France. *Applied Economics*, pages 1–22, 2019.

[20] John Bound and Timothy Waidmann. Estimating the health effects of retirement. *Michigan Retirement Research Centre Research Paper No. UM WP*, 168, 2007.

[21] Ingo WK Kolodziej and Pilar García-Gómez. Saved by retirement: Beyond the mean effect on mental health. *Social Science & Medicine*, 225:85–97, 2019.

[22] Paul Bingley and Alessandro Martinello. Mental retirement and schooling. *European Economic Review*, 63:292–298, 2013.

[23] Xiaoyan Lei and Hong Liu. Gender difference in the impact of retirement on cognitive abilities: Evidence from urban China. *Journal of Comparative Economics*, 46(4):1425–1446, 2018.

[24] Dhaval Dave, Inas Rashad, and Jasmina Spasojevic. The effects of retirement on physical and mental health outcomes. Technical report, National Bureau of Economic Research, 2006.

[25] Timothy A Salthouse. The processing-speed theory of adult age differences in cognition. *Psychological review*, 103(3):403, 1996.

[26] David F Hultsch, Christopher Hertzog, Brent J Small, and Roger A Dixon. Use it or lose it: Engaged lifestyle as a buffer of cognitive decline in aging? *Psychology and aging*, 14(2):245, 1999.

[27] Michael Grossman. On the concept of health capital and the demand for health. *Journal of Political Economy*, 80(2):223–255, 1972.

[28] Elizabeth A. L. Stine-Morrow. The dumbledore hypothesis of cognitive aging. *Current Directions in Psychological Science*, 16(6):295–299, 2007.

[29] Thomas A Glass, Carlos Mendes De Leon, Richard A Marottoli, and Lisa F Berkman. Population based study of social and productive activities as predictors of survival among elderly Americans. *BMJ*, 319(7208):478–483, 1999.

[30] Béatrice d'Hombres, Lorenzo Rocco, Marc Suhrcke, and Martin McKee. Does social capital determine health? Evidence from eight transition countries. *Health Economics*, 19(1):56–74, 2010.

[31] Axel Börsch-Supan and Morten Schuth. Early retirement, mental health and social networks. *Active ageing and solidarity between generations in Europe: First results from SHARE after the economic crisis*, page 337, 2013.

[32] James Banks and Fabrizio Mazzonna. The effect of education on old age cognitive abilities: Evidence from a regression discontinuity design. *The Economic Journal*, 122(560):418–448, 2012.

[33] Flavio Cunha and James Heckman. The technology of skill formation. *American Economic Review*, 97(2):31–47, 2007.

[34] Anne Case and Christina Paxson. Height, health, and cognitive function at older ages. *American Economic Review*, 98(2):463–67, 2008.

[35] Anne Case and Christina Paxson. Early life health and cognitive function in old age. *American Economic Review*, 99(2):104–09, 2009.

[36] Yaakov Stern. What is cognitive reserve? theory and research application of the reserve concept. 2002.

[37] Else M Zantinge, Matthijs van den Berg, Henriette A Smit, and H Susan J Picavet. Retirement and a healthy lifestyle: opportunity or pitfall? a narrative review of the literature. *The European Journal of Public Health*, 24(3):433–439, 2013.

[38] Ingmar Skoog and Deborah Gustafson. Update on hypertension and Alzheimer's disease. *Neurological Research*, 28(6):605–611, 2006.

[39] Bastian Ravesteijn, Hans van Kippersluis, and Eddy van Doorslaer. The contribution of occupation to health inequality. In *Health and Inequality*, pages 311–332. Emerald Group Publishing Limited, 2013.

[40] Yi Che and Xin Li. Retirement and health: Evidence from China. *China Economic Review*, 49: 84–95, 2018.

[41] Simiao Chen, Pascal Geldsetzer, and Till Bärnighausen. The causal effect of retirement on stress in older adults in China: A regression discontinuity study. *SSM-population health*, 10:100462, 2020.

[42] Yi Zhang, Martin Salm, and Arthur van Soest. The effect of retirement on healthcare utilization: Evidence from China. *Journal of Health Economics*, 62:165–177, 2018.

[43] Wentian Li. An empirical study on the health of retirement to the working population—based on China health and retirement longitudinal study. *American Journal of Industrial and Business Management*, 7(4):429–443, 2017.

[44] Jin Feng and Xiaohan Zhang. Retirement and grandchild care in urban China. *Feminist Economics*, 24(2):240–264, 2018.

[45] Jin Feng, Qin Li, and James P Smith. Retirement effect on health status and health behaviours in urban China. *World Development*, 126:104702, 2020.

[46] Xiaoyan Lei, Yan Shen, James P Smith, and Guangsu Zhou. Do social networks improve Chinese adults' subjective well-being? *The Journal of the Economics of Ageing*, 6:57–67, 2015.

[47] Xin Meng and Sen Xue. Social networks and mental health outcomes: Chinese rural–urban migrant experience. *Journal of Population Economics*, 33(1):155–195, 2020.

[48] Ross Garnaut, Ligang Song, and Yang Yao. Impact and significance of state-owned enterprise restructuring in China. *The China Journal*, (55):35–63, 2006.

[49] John Giles, Albert Park, and Fang Cai. How has economic restructuring affected China's urban workers? *The China Quarterly*, 185:61–95, 2006.

[50] James P Smith, John J McArdle, and Robert Willis. Financial decision making and cognition in a family context. *The Economic Journal*, 120(548): F363–F380, 2010.

[51] Mo Wang. Profiling retirees in the retirement transition and adjustment process: Examining the longitudinal change patterns of retirees' psychological well-being. *Journal of Applied Psychology*, 92(2):455, 2007.

[52] Mo Wang and Junqi Shi. Psychological research on retirement. *Annual review of psychology*, 65:209–233, 2014.

[53] Eric French and John Jones. Public pensions and labour supply over the life cycle. *International Tax and Public Finance*, 19(2):268–287, 2012.

[54] John Rust and Christopher Phelan. How social security and medicare affect retirement behaviour in a world of incomplete markets. *Econometrica*, pages 781–831, 1997.

[55] Eric French and John Bailey Jones. The effects of health insurance and self-insurance on retirement behaviour. *Econometrica*, 79(3):693–732, 2011.

[56] Eric French. The effects of health, wealth, and wages on labour supply and retirement behaviour. *The Review of Economic Studies*, 72(2):395–427, 2005.

[57] Marcus Richards, Beverly Shipley, Rebecca Fuhrer, and Michael EJ Wadsworth. Cognitive ability in childhood and cognitive decline in mid-life: longitudinal birth cohort study. *BMJ*, 328(7439): 552, 2004.

[58] Janet Currie. Healthy, wealthy, and wise: Socioeconomic status, poor health in childhood, and human capital development. *Journal of Economic Literature*, 47(1):87–122, 2009.

[59] Wei Huang and Yi Zhou. Effects of education on cognition at older ages: Evidence from China's great famine. *Social Science & Medicine*, 98:54–62, 2013.

[60] Cheng Huang, Michael R Phillips, Yali Zhang, Jingxuan Zhang, Qichang Shi, Zhiqiang Song, Zhijie Ding, Shutao Pang, and Reynaldo Martorell. Malnutrition in early life and adult mental health: evidence from a natural experiment. *Social Science & Medicine*, 97:259–266, 2013.

[61] Stefanie Behncke. Does retirement trigger ill health? *Health Economics*, 21(3):282–300, 2012.

[62] Stephen Nickell. Biases in dynamic models with fixed effects. *Econometrica*, pages 1417–1426, 1981.

[63] Badi Baltagi. *Econometric Analysis of Panel Data*. John Wiley & Sons, 2008.

[64] Manuel Arellano and Stephen Bond. Some tests of specification for panel data: Monte carlo evidence and an application to employment equations. *The Review of Economic Studies*, 58(2): 277–297, 1991.

[65] Jeffrey M Wooldridge. Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity. *Journal of Applied Econometrics*, 20(1):39–54, 2005.

[66] Richard Blundell and Stephen Bond. Initial conditions and moment restrictions in dynamic panel data models. *Journal of Econometrics*, 87(1):115–143, 1998.

[67] Frank Windmeijer. A finite sample correction for the variance of linear efficient two-step GMM estimators. *Journal of Econometrics*, 126(1):25–51, 2005.

[68] Nikolaos Scarmeas and Yaakov Stern. Cognitive reserve and lifestyle. *Journal of Clinical and Experimental Neuropsychology*, 25(5):625–633, 2003.

[69] Chris Beedie, Steven Mann, Robert Copeland, and Sarah Domone. Identifying what works for local physical inactivity interventions. 2014.

Appendix

A.1 Years of Retirement by Age and Gender

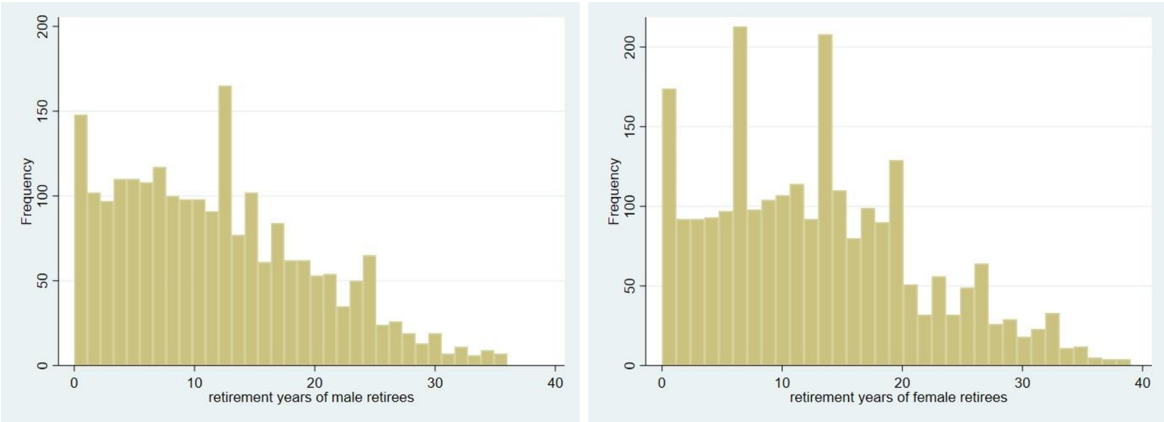

Figure A1: Retirement Years by Gender

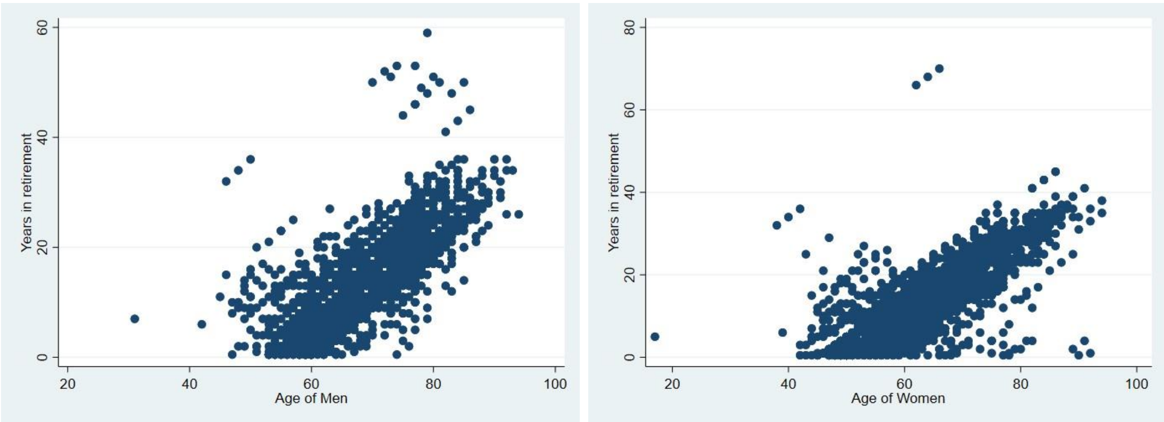

Figure A2: Retirement Years by Age and Gender

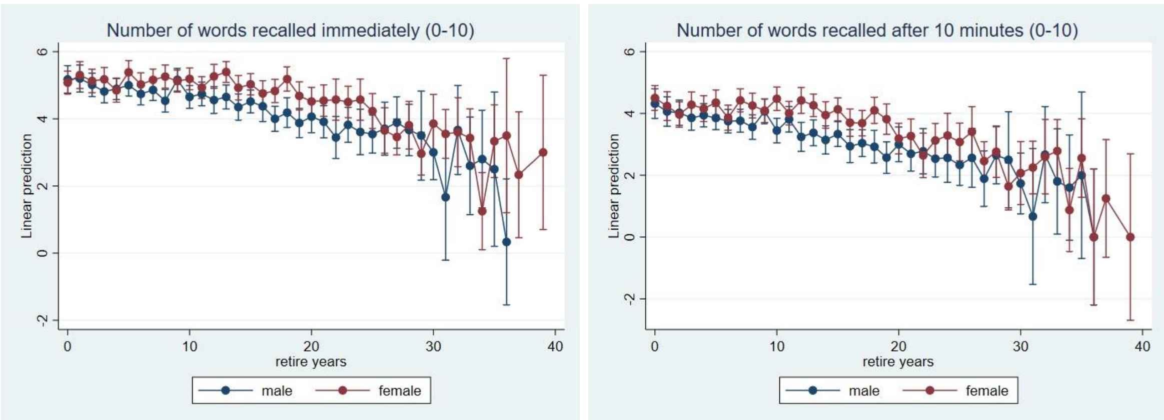

Figure A3: Memory test scores by retirement years and gender

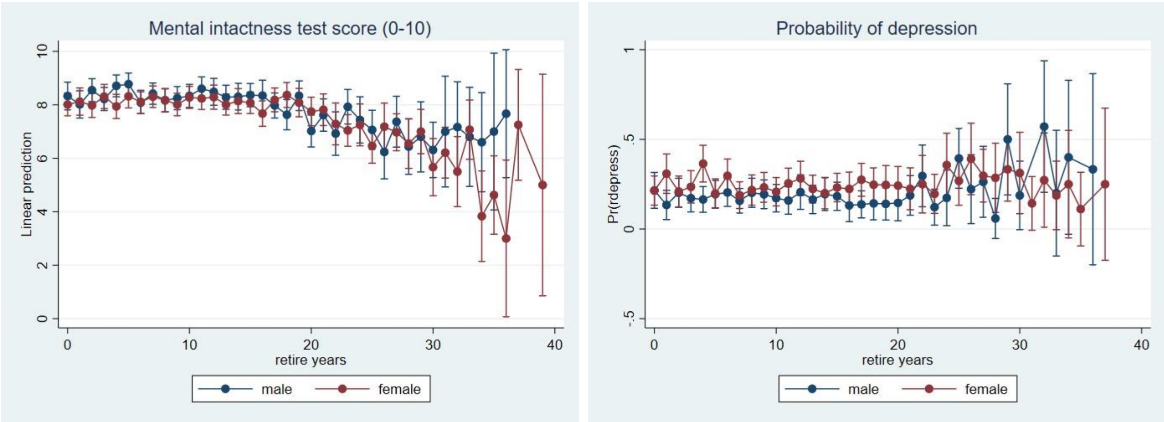

Figure A4: Mental intactness scores and depression risk by retirement years and gender

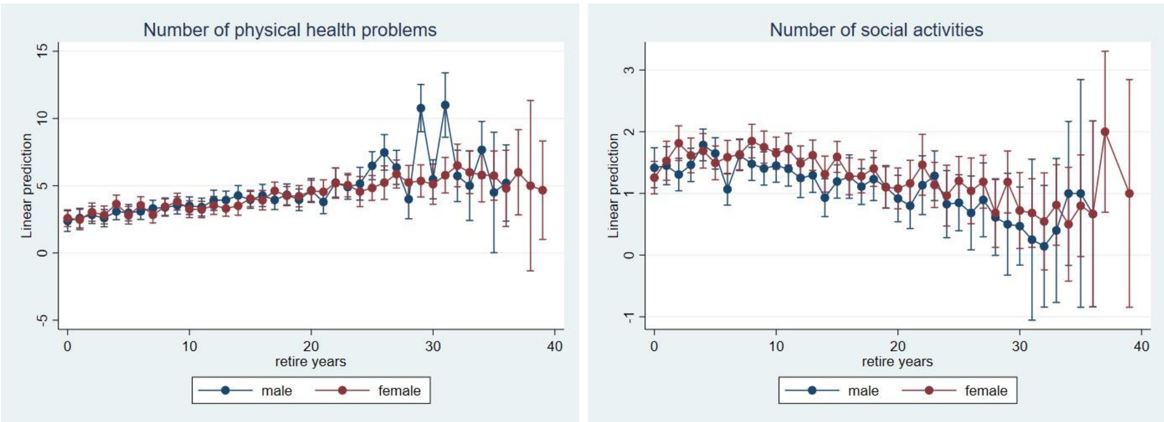

Figure A5: Physical problems and number of social activities by retirement years and gender

A.2 Distribution of Retirement Ages by Gender

Table A1: Retirement Ages by Gender

	Men			Women		
retire age	Freq.	Percent	Cum.	Freq.	Percent	Cum.
40	8	0.31	0.31	31	1.2	1.2
41	17	0.66	0.97	32	1.24	2.44
42	21	0.82	1.79	17	0.66	3.1
43	20	0.78	2.57	26	1.01	4.11
44	15	0.58	3.15	35	1.36	5.46
45	28	1.09	4.24	153	5.93	11.39
46	38	1.48	5.72	104	4.03	15.41
47	37	1.44	7.16	100	3.87	19.29
48	69	2.68	9.84	104	4.03	23.32
49	42	1.63	11.48	147	5.69	29.01
50	79	3.07	14.55	926	35.86	64.87
51	60	2.33	16.89	193	7.47	72.35
52	65	2.53	19.42	112	4.34	76.68
53	64	2.49	21.91	43	1.67	78.35
54	83	3.23	25.14	58	2.25	80.6
55	308	11.98	37.12	240	9.3	89.89
56	156	6.07	43.19	75	2.9	92.8
57	88	3.42	46.61	43	1.67	94.46
58	81	3.15	49.77	35	1.36	95.82
59	131	5.1	54.86	29	1.12	96.94
60	885	34.44	89.3	25	0.97	97.91
61	143	5.56	94.86	8	0.31	98.22
62	46	1.79	96.65	8	0.31	98.53
63	27	1.05	97.7	6	0.23	98.76
64	14	0.54	98.25	8	0.31	99.07
65	25	0.97	99.22	9	0.35	99.42
66	5	0.19	99.42	3	0.12	99.54
67	6	0.23	99.65	6	0.23	99.77
68	3	0.12	99.77	4	0.15	99.92
70	6	0.23	100	2	0.08	100
Total	2,570	100		2,582	100	

Table A2: Years in Retirement by Gender

	Men			Women		
Number of Years	Freq.	Percent	Cum.	Freq.	Percent	Cum.
0	2,725	55.44	55.44	1,893	43.68	43.68
0.5	70	1.42	56.87	103	2.38	46.05
1	78	1.59	58.45	71	1.64	47.69
2	102	2.08	60.53	92	2.12	49.82
3	97	1.97	62.5	92	2.12	51.94
4	110	2.24	64.74	93	2.15	54.08
5	110	2.24	66.98	97	2.24	56.32
6	108	2.2	69.18	98	2.26	58.58
7	117	2.38	71.56	115	2.65	61.24
8	100	2.03	73.59	98	2.26	63.5
9	98	1.99	75.58	104	2.4	65.9
10	98	1.99	77.58	107	2.47	68.37
11	91	1.85	79.43	114	2.63	71
12	73	1.49	80.92	92	2.12	73.12
13	92	1.87	82.79	124	2.86	75.98
14	77	1.57	84.35	84	1.94	77.92
15	102	2.08	86.43	110	2.54	80.46
16	61	1.24	87.67	80	1.85	82.3
17	84	1.71	89.38	99	2.28	84.59
18	62	1.26	90.64	90	2.08	86.66
19	62	1.26	91.9	64	1.48	88.14
20	53	1.08	92.98	65	1.5	89.64
21	54	1.1	94.08	51	1.18	90.82
22	35	0.71	94.79	32	0.74	91.56
23	50	1.02	95.81	56	1.29	92.85
24	27	0.55	96.36	32	0.74	93.59
25	38	0.77	97.13	49	1.13	94.72
26	24	0.49	97.62	26	0.6	95.32
27	26	0.53	98.15	38	0.88	96.19
28	19	0.39	98.54	26	0.6	96.79
29	13	0.26	98.8	29	0.67	97.46
30	19	0.39	99.19	18	0.42	97.88
31	7	0.14	99.33	23	0.53	98.41
32	11	0.22	99.55	16	0.37	98.78
33	6	0.12	99.67	17	0.39	99.17
34	9	0.18	99.86	11	0.25	99.42
35	2	0.04	99.9	12	0.28	99.7
36	5	0.1	100	5	0.12	99.82
37				4	0.09	99.91
38				1	0.02	99.93
39				3	0.07	100
Total	4,915	100		4,334	100	