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## Abstract

**Does Retirement Affect Cognitive Functioning?**

This paper analyzes the effect of retirement on cognitive functioning using two large scale surveys. On the one hand the HRS, a longitudinal survey among individuals aged 50+ living in the United States, allows us to control for individual heterogeneity and endogeneity of the retirement decision by using the eligibility age for Social Security as an instrument. On the other hand, a comparable international European survey, SHARE, allows us to identify the causal effect of retirement on cognitive functioning by using the cross-country differences in the age-pattern of retirement. The results highlight in both cases a significant negative, and quantitatively comparable, effect of retirement on cognitive functioning. Our results suggest that promoting labor force participation of older workers is not only desirable to insure the viability of retirement schemes, but it could also delay cognitive decline, and thus the occurrence of associated impairments at older age.

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## 1. Introduction

In most developed countries, the proportion of older individuals has substantially increased over the last decades. This demographic shift has increased the focus on health in aging. At the same time, increased life expectancy combined with a decline in average retirement age have increased the proportion of an individual's life spent in retirement. This structural change imposes many challenges for the financial sustainability of social security systems. Moreover, this extended retirement spell raises questions about its potential consequences on the physical and mental health of the elderly, which may in turn affect long-term care expenditures (Dave et al., 2008).

Older individuals face many challenges associated with physical and mental deterioration. Among these, the decline in cognitive capacity with age has been well documented: a large amount of evidence suggests that aging is associated with a decline in the ability to perform several cognitive tasks (Dixon et al., 2004; Schaie, 1994). More particularly, aging has a salient effect on episodic memory tasks[2] (Petersen et al., 1992; Small, 2001), episodic memory deficits being also largely considered as a hallmark symptom of Alzheimer's disease (Adam et al., 2007; Dubois et al., 2007).

However, this decline is not homogenous across the population, with some people maintaining cognitive vitality even into extreme old age (Berkman et al., 1993; Silver et al., 1998; Silver et al., 2001). At the same time, age-related cerebral modifications that are at the root of Alzheimer's disease have been observed to have heterogeneous effects on cognitive functioning. For example, Katzman et al. (1989) described cases of cognitively normal elderly women who were discovered (by ways of post mortem analysis) to have advanced Alzheimer's disease pathology in their brains. Stern (2002, 2003) and Scarmeas and Stern (2003) propose the concept of cognitive reserve to explain this apparent absence of direct relationship between the severity of the factor that disrupts performance (such as the degree of brain modifications with age, or brain pathology associated with Alzheimer's disease) and the degree of disruption in performance or of dysfunction in daily life activities. This suggests that some individuals are able to more efficiently use their cognitive resources and thus are less susceptible to disruption. Individual heterogeneity may stem

[2] Episodic memory refers to memory of information about specific past events that involved the self (i.e. events personally lived) and occurred at a particular time and place (e.g., the last holidays).

from innate or genetic differences, or different life experiences, such as occupational attainment or leisure activities.

The degree of resilience to these biological changes, i.e., the cognitive reserve, has been found to depend on several factors. Among these, education undoubtedly plays an important role (Evans et al., 1993; Le Carret et al., 2003). Moreover, differential susceptibility to age-related cognitive decline or to Alzheimer's disease has also been shown to be related to occupation (Evans et al., 1993; Letenneur et al., 1994; Schooler et al., 1999; Stern et al., 1994), professional or leisure activities (Carpuso et al., 2000; Scarmeas et al., 2001; Wilson et al., 2002; Newson and Kemps, 2005), and lifestyle (for a review, see: Fillit et al., 2002; and Fratiglioni et al., 2004).

In summary, this literature suggests that individual heterogeneity in the level of cognitive functioning and the rate of age-related change in cognitive functioning is associated with an individual's lifestyle, such as his engagement in mentally stimulating activities (Salthouse, 2006). This hypothesis is quite appealing, as it suggests that individuals have some control over the evolution of their cognitive functioning, and that there is scope for policy interventions to affect the pattern of cognitive aging.

However, the way the causality runs between activities and the brain remains an open issue in neuropsychology. Do activities improve cognitive functioning or are brighter people more often engaged in cognitively demanding activities? One argument favoring the first hypothesis can be found in the neurobiological literature, where several experimental studies on animals have shown that rats bred in an enriched environment present a greater dendritic density in the hippocampus and an increased number of glial cells than animals bred in standard conditions (Rosenzweig and Bennett, 1972). Moreover, Winocur (1998) showed that these brain modifications affect the cognitive abilities of older rats. A second argument in favor of the causal effect of activities on cognitive functioning can also be found in studies such as that of Maguire et al. (2000), which shows that taxi drivers in London, who had developed an intensive practice of orientation in the city, had significantly posterior hippocampi than control subjects, and above all, that the amount of occupational experience is correlated with the size of the hippocampus. Those studies show that stimulating activities and environment are able to improve, or maintain, cognitive functioning and that this has a direct effect on the brain.

The aim of our study is to address the causal impact of lifestyle on cognitive functioning of older people by focusing on the relationship between cognitive functioning and retirement. Indeed, retirement implies major changes in individual lifestyle and is likely to affect involvement in activities that may contribute to maintaining, or improving, cognitive functioning at older age. If individuals have on average more cognitively stimulating activities at work than during retirement, we would expect a decline in cognitive functioning during retirement due to the decrease in stimulating activities, as suggested by the neuropsychological literature. From an economic point of view, cognitive functioning can be interpreted as a form of human capital, in particular health capital (Grossman, 1972), and its evolution will emerge from deliberate choices based on the perceived costs and benefits of investing in cognitive functioning. In the Grossman model, health capital is benefical as it reduces the time lost due to illness or injury, and thereby increases the time available to allocate to work, leisure, and health investments. The same reasoning may apply to cognitive functioning. Individuals with higher cognitive functioning may be more efficient in performing leisure and work activities, resulting in more effective time available to allocate to market and non-market activities. Eligibility for social security benefits corresponds to a drop in the relative wage rate in the Grossman model. It thus affects the marginal benefits and costs of effective time, and thus the investment in cognitive functioning. The marginal benefit is unambiguously lower, while the marginal cost may increase or decrease. This will depend on the relative marginal productivity of leisure and work. Due to social security benefits, work, as an investment in cognitive functioning, is more expensive. On the other hand, it decreases the cost of leisure, which also constitutes an input for cognitive functioning. The net impact of retirement on cognitive functioning can be positive, negative, or null. If the marginal productivity of work activities is always higher than the marginal productivity of leisure time, the eligibility for social security benefits will induce a decrease in cognitive functioning. In the case where labor has a low productivity and high non-labor productivity, the drop in the marginal cost may offset the decrease in marginal benefits and results in an increase in cognitive functioning when social security benefits become available.

In a recent study, Adam et al. (2007) found that retirees attain lower cognitive functioning than working individuals, using cross-sectional data from the United States and Europe.[3] Furthermore, they show that the longer the retirement spell, the lower the cognitive

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[3] The Health and Retirement Study 2004 (United States); the English Longitudinal Study on Ageing 2004 (United Kingdom); the Survey of Health, Ageing, and Retirement in Europe 2004 (Austria, Belgium, Denmark, France, Germany, Greece, Italy, the Netherlands, Spain, and Sweden).

score, which suggests an acceleration of cognitive decline during retirement. However, the difference observed across workers and retirees may have explanations other than a causal effect between retirement and cognition. First, impairments in cognitive functioning may prevent people from working, may increase disutility from work, or may lower productivity. Moreover, unobservable factors associated with cognitive functioning and retirement may be interrelated with both. Individuals with higher innate ability (and thus cognitive functioning) may invest more in human capital and retire at a later age than individuals with low innate ability.

Inspired by the research of Adam et al (2007), Coe and Zamarro (2008) and Rohwedder and Willis (2010) have also investigated the relationship between retirement and cognitive functioning by using cross-national data, the Survey of Health, Ageing, and Retirement in Europe (SHARE), and the difference in the legal age of retirement across countries as an instrument for retirement decision to avoid potential endogeneity bias. The results are mixed: while Rohwedder and Willis (2010) find a significant and quantitatively important (close to 40%) negative effect of retirement on cognitive functioning, Coe and Zamarro (2008) do not find a significant effect.

In this paper we estimate the causal impact of retirement on cognitive functioning using data from two large scale surveys and using novel identification strategies. First, we use panel data from the HRS, a longitudinal survey among individuals aged 50+ living in the United States, that allows us to control for individual heterogeneity and to circumvent the issue of endogenous retirement decision by using the eligibility age for Social Security as an instrument. Our identification approach follows that of Bound and Waidmann (2007), Charles (2002), and Neumann (2008), who analyze the effect of retirement on health. As a robustness check, we use workers' subjective beliefs about their retirement dates as an alternative instrumental variable for retirement. Second, we use cross-country data from SHARE, but unlike Coe and Zamarro (2008) and Rohwedder and Willis (2010) we identify the causal effect of retirement on cognitive functioning by using the cross-country differences in the age-pattern of retirement. The reason for that is that in European countries retirement eligibility depends not only on main Social security pension rules but also on eligibility rules, age is one among them, fixed by other social protection schemes, e.g. old-age unemployment, disability insurance, or early retirement schemes, in combination with labor market conditions (Gruber and Wise, 2004). The identification strategy will rely on the differences in the retirement age-patterns across countries and gender. Our results highlight in both cases a significant negative, and quantitatively comparable, effect of retirement on cognitive functioning, close to 10%.

The paper is organized as follows. Section 2 describes the econometric approach used to address the empirical issues and Section 3 presents the data, the measure of cognitive functioning, and the explanatory variables included in the empirical model. Section 4 details the results from the longitudinal analysis using HRS and the results from the cross-national analysis using SHARE. Finally, Section 5 concludes and draws out implications from the analysis.

## 2. Empirical model

The aim of the empirical analysis is to test the hypothesis that retirement affects cognitive functioning. In our model, we assume cognitive functioning ($c_{it}$), measured by the score obtained at a cognitive test (described below), depends on retirement status ($r_{it}$), along with a vector of exogenous variables ($x_{it}$) including age, socio-demographic and health characteristics, and an unobserved error term ($\varepsilon_{it}$):

$$c_{it} = f(x_{it}, r_{it}, \varepsilon_{it}) . \tag{1}$$

The error term can be decomposed into time-invariant individual heterogeneity ($\mu_i$) and an idiosyncratic error term ($\nu_{it}$):

$$\varepsilon_{it} = \mu_i + \nu_{it} . \tag{2}$$

Identification of the causal effect of retirement on cognitive functioning requires the error term and the retirement decision to be uncorrelated: $E(r_{it}\varepsilon_{it} | x_{it}) = 0$. This condition is unlikely to hold: first, retirement and cognitive functioning may be endogenous; low cognitive functioning may induce retirement. Second, unobserved individual heterogeneity may be correlated with both the retirement decision and cognitive functioning. Assuming linear separability, cognitive functioning and retirement are given by the following system of equations

$$c_{it} = x_{it}\beta_1 + r_{it}\beta_2 + \mu_i + \nu_{it} , \tag{3}$$

$$r_{it} = x_{it}\gamma_1 + c_{it}\gamma_2 + w_{it}\gamma_3 + \omega_i + \eta_{it} , \tag{4}$$

where equation (4) is the reduced-form equation of retirement decision, $w_{it}$ is a vector of variables directly related to the retirement decision, but is assumed to have no direct effect on cognitive functioning, $E(w_{it}v_{it}|x_{it})=0$, and $\eta_{it}$ is the idiosyncratic disturbance associated with retirement. From (3) and (4), the reduced-form model describing retirement decision is written as follows:

$$r_{it} = \frac{\gamma_1+\gamma_2\beta_1}{1-\beta_2\gamma_2}x_{it} + \frac{\gamma_3}{1-\beta_2\gamma_2}w_{it} + \frac{\gamma_2}{1-\beta_2\gamma_2}(\mu_i+\nu_{it}) + \frac{1}{1-\beta_2\gamma_2}(\omega_i+\eta_{it}), \tag{5}$$

$$r_{it} = \Pi_1 x_{it} + \Pi_2 w_{it} + \Pi_3(\mu_i+\nu_{it}) + \Pi_4(\omega_i+\eta_{it}), \tag{6}$$

where $\Pi_j$ represents the reduced-form parameters. If the retirement decision depends on cognitive functioning ($\gamma_2 \neq 0$), retirement will be correlated with the error term ($\varepsilon_{it}$) in equation (1) through $\mu_i$ and $\nu_{it}$. Moreover, retirement and the error term ($\varepsilon_{it}$) in equation (1) are likely to be correlated if the unobserved fixed individual heterogeneity from retirement decision and cognitive functioning are correlated ($E(\mu_i\omega_i|x_{it}) \neq 0$).

The fixed effects (FE) estimator allows measurement of the parameters of interest, controlling for unobserved individual heterogeneity. The effect of retirement on cognitive functioning ($\beta_2$) will be consistently estimated unless $\nu_{it}$ is correlated to the retirement decision (i.e. $\gamma_2 \neq 0$). Moreover, the FE estimates are also susceptible to attenuation bias from measurement error in the retirement variable (Griliches and Hausman, 1986). We deal with those issues by using Instrumental Variable (IV) methods. The instruments correspond to the vector $w_{it}$ in equation (4). To be valid instruments, the variables in the vector $w_{it}$ must be related to retirement decision ($\gamma_3 \neq 0$) and correlated to cognitive functioning only through the effect of retirement ($E(w_{it}v_{it}|x_{it},\mu_i)=0$). Large spikes in the retirement hazard at ages 62 and 65 have been well noted in the literature, and Social Security has been found to play a significant role in explaining such spikes (Burtless and Moffit, 1984; Gruber and Wise, 1999; Coile and Gruber, 2000). We thus use these key retirement ages in the United States as identifying instruments for the retirement decision. Age 62 represents the earliest age at which Social Security benefits can be claimed, while age 65 is the normal age of retirement in the US. Note that the normal retirement age is set to increase to age 67 over a

22-year period; this affects people born January 2, 1938, and later.[4] We thus compute two dummy variables equal to 1 if the individual belongs to the corresponding age-interval in the retirement equation, while the cognitive functioning equation includes age as a smooth function using low-order polynomials. While these specific age values are likely to have a direct effect on the decision to retire, it is less likely that they have a particular effect on cognitive functioning. The empirical strategy consists of estimating Equation (3) using the two-stage least-squares within estimator, with these age threshold dummies as instruments for retirement. As a robustness check, we also estimate the model by using an alternative instrument for retirement that corresponds to a dummy that is equal to one when the individual has reached her/his expected age of retirement.

The second part of the empirical analysis will use the cross-national difference in the pattern of retirement across European countries, which are mainly due to differences in institutional settings across countries, in order to identify the causal effect of retirement on cognitive functioning. We argue that the difference in the aggregate retirement profile across countries cannot be explained by differences in the profile of cognitive decline and can thus be used as an instrument for retirement decision.

## 3. Data

### *3.1. The Health and Retirement Study*

The empirical analysis uses five waves (1998–2006) from the Health and Retirement Study (HRS).[5] The HRS has been following a sample of Americans born between 1931 and 1941 and their partners since 1992. Since 1998, this survey has also included respondents from the Asset and Health Dynamics Among the Oldest Old (AHEAD) study (cohorts born between 1890 and 1923), and a representative sample of individuals born between 1924 and 1930 (the Children of the Depression Age) and between 1942 and 1947 (War Babies). An additional sample of individuals born between 1948 and 1953 (Early Baby Boomers) was added in 2004. Most interviews were done by telephone, although exceptions are made

[4] Table A1 in the Appendix shows the normal age of retirement for the different cohorts that we use for our empirical analysis.

[5] The HRS is sponsored by the National Institute of Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.

when the individual has health limitations or when the household has no telephone. The data contain a wide range of information about mental and physical health, labor status, financial situation, the family, and activities of the respondents.

In our study, we restrict the sample to respondents aged between 50 and 75. Moreover, all individuals are dropped from the study who report returning to work during the sampling period. This selection helps to temper measurement error issues in the FE models for the retirement variable. Finally, all observations are dropped where there are missing or unreliable values for the variables included in the model. The final sample includes 53,596 observations for 16,878 individuals.

### *3.2. The Survey of Health, Ageing and Retirement in Europe*

The cross-national analysis uses data from the Survey of Health, Ageing and Retirement in Europe (SHARE). SHARE is a European multi-disciplinary survey including more than 30,000 persons born in or before 1954, and coming from 14 European countries ranging from Scandinavia to the Mediterranean.[6] In this paper, we use release 2 of the first two waves of the survey, which were conducted in 2004 and 2006. The data were collected using a computer assisted personal interviewing (CAPI) program, supplemented by a self-completion paper and pencil questionnaire. For more details on the sampling procedure, questionnaire content and fieldwork methodology, we refer readers to Börsch-Supan and Jürges (2005).[7]

We restrict the sample to respondents aged between 50 and 65 years because it is during this age window that there are important differences in the employment rate across countries. All observations where there are missing or unreliable values for the variables included in the model are discarded from the analysis. The final sample includes 32,641 observations.

[6]SHARE data includes fourteen European countries: Austria, Belgium, Czech Republic, Germany, Denmark, France, Greece, Ireland, Italy, the Netherlands, Poland, Spain, Sweden, and Switzerland.

[7] More information can be found on the SHARE website: http://www.share-project.org/.

*3.3. The measure of cognitive functioning*

The HRS contains measures of cognitive functioning based on simple tests. The empirical analysis using the HRS focuses on one key cognitive domain: episodic memory, which is assessed through a test of verbal learning and recall. The motivation for analyzing this particular cognitive domain is twofold: first, this cognitive aspect is particularly affected by aging; some studies even argue that this cognitive function is among the first to decline with aging (Souchay et al., 2000; Anderson and Craik, 2000; Prull et al., 2000). Second, the related measure used to assess episodic memory, i.e., the score obtained in a test of word learning and recall, does not suffer from floor or ceiling effects (excess of maximum or minimum values), which thus provides a more sensitive measure than other measures of cognitive functioning that only allow for limited variability in scores. In the HRS, the episodic memory task consists of learning a list of ten common words.[8] The interviewer reads a list of 10 words (e.g., book, child, hotel, etc.) to the respondent, and asks the respondent to recall as many words as possible from the list in any order. Then, immediate and delayed recall phases are carried out. Immediate recall follows directly, while a short interval is inserted before the delayed recall. Memory score for this task is calculated by the sum of the number of target words recalled at the immediate recall phase and the number of target words recalled at the delayed recall phase (score ranging from 0 to 20). The memory score has a distribution close to the normal distribution with a sample mean of 10.5 and a standard deviation of 3.4.

In the SHARE data, cognitive functioning is measured using a similar test of verbal learning and recall of ten common words, as for the HRS. The sample mean is 9.4 with a standard deviation of 3.3. Figure 1a and 1b display the distirbution of the memory score for HRS and SHARE, respectively.

[Figure 1a and Figure 1b about here]

[8] Note that the HRS in fact uses four different lists of common words and that respondents are asked a different list of words from the lists that they, and their spouse, had to answer during the previous wave. This is done in order to avoid the respondent remembering the words from that previous list. There is, in fact, evidence of such a learning effect with the first two waves of the HRS, where individuals were asked the same list of words.

Moreover, SHARE data also include a word fluency test score based on the task of naming as many animals as possible in 60 seconds. This task is aimed at measuring the executive functioning of the individual. The fluency score has a sample mean of 20.5 with standard deviation of 7.2.

To ease the interpretation of our results, we use standardized measures of the test scores as dependent variable in our analysis.

### *3.4. The retirement variable*

There are many definitions of retirement. For the purpose of our analysis, we follow Lazear (1986) and define an individual as being retired if he is definitively out of the labor force with the intention of staying out permanently. In the model assuming exogeneity of retirement (i.e., without using IV techniques), we use a categorical variable describing retirement status and time spent in retirement for retired individuals. Retirement duration is measured using information about the month and year of interview and the month and year when the individual left his/her last job. The reference categories include "Working", "Retired for 0 to 4 years", "Retired for 5 to 9 years", and "Retired for 10 years or more".

For the model using IV methods with eligibility rules as instruments, we use a dummy variable related to retirement status: an individual is defined as "Working" if he claims to be currently working for pay and "Retired" if he reports not working. The analysis using SHARE data uses the same definition.

### *3.5. The explanatory variables*

In addition to the retirement variable, we include several other explanatory variables that are likely to be related to cognitive functioning. The effect of education is measured using a second-order polynomial of years of education.[9] Second-order polynomials of age are included in order to account for the "normal" cognitive aging process. The effect of age is assumed to be quadratic, allowing cognitive functioning to decline at an increasing rate with aging. We control for health by including a variable equal to 1 if a doctor has ever told the

[9] Note that this variable is truncated at 17 years of education in the HRS.

respondent that he has had a stroke (or a transient ischemic attack), a heart related disease[10], or high blood pressure. Finally, we include a dummy variable for single-living households, and a categorical variable for ethnicity (White/Caucasian, Black/African American, or Other) for HRS data. The cross-national analysis using SHARE includes a dummy variable equal to one if the individual is interviewed for the second time to account for the test-retest effect (contrary to the HRS, the list of words used for the word recall test is the same for both waves; it is thus possible that individuals who do the test for the second time attain a better score than those doing the test for the first time).

## 4. Results

### *4.1. Evidence from the United States*

#### *4.1.1. Baseline results*

Column (i) of Table 1 presents the parameters of Equation (3) estimated by Ordinary Least Squares (OLS).[11] Almost all coefficients are highly significant. These results are in accordance with the results obtained by Adam et al. (2007), who use data from Europe (SHARE and ELSA) and the United States (HRS). The coefficients on education and age have the expected signs and are highly significant.

Education is positively related to cognitive functioning, while age has a negative effect. Living in a single household may have two opposite effects on cognitive functioning. First, it may induce lower cognitive functioning due to the lack of social interaction (Ybarra et al., 2008). Second, it may stimulate cognitive functioning, as single-living individuals must deal alone with all tasks associated with management of the household. The empirical results show that individuals living alone have a lower cognitive score. Consistent with the findings of Patel et al. (2002), suffering from a stroke has a large and significant negative impact on the dependent variable. The coefficients of the other health-related variables, i.e.

[10] Heart-related diseases include heart attack, coronary heart disease, angina, congestive heart failure, and other heart problems.

[11] The standard errors of the estimates are corrected for autocorrelation among the observations corresponding to the same individuals over time.

having high blood pressure or a heart-related disease, are also negative and significant. All the coefficients related to retirement spell are negative and highly significant.

[Table 1 about here]

### 4.1.2. The within estimator

The OLS estimator does not take into account the unobserved individual heterogeneity that might be correlated to the explanatory variables in the equation, and it thus may lead to inconsistent estimates of the effects of the covariates on cognitive functioning. Column (ii) of Table 1 displays the parameters of Equation (3) estimated with the fixed effects model.

The effect of aging is more pronounced when we control for individual heterogeneity. This suggests that older individuals have unobserved characteristics that are positively related to their cognitive functioning. This may be due to cohort effects or a selection process where individuals with higher endowment in health, and cognitive ability, live longer than individuals with lower endowments.[12] Regarding the health related variables, only the coefficients related to stroke and to heart-related disease remain negative and highly significant.

The parameters associated with retirement and retirement spell remain negative and highly significant, but their magnitude is lower as compared to the OLS estimates. This is what we can expect from the within estimator, as this controls for individual heterogeneity, which is likely to be negatively correlated to retirement. Moreover, the within estimator is more prone to attenuation bias due to measurement error in the retirement variable (Griliches and Hausman, 1986).

### 4.1.3. The IV estimator

The previous section showed that the negative effect of retirement on cognitive score remains, even when individual heterogeneity is controlled for. However, the transitory shocks in cognitive functioning may induce older workers to leave the labor force. Moreover, the within estimator exacerbates measurement error and is likely to suffer from attenuation bias. To solve those potential issues, we employ IV methods, using the

[12] This result might also be due to attrition where individuals with lower cognitive performance are more likely to leave the panel.

eligibility rules as instruments for retirement in the same spirit of Bound and Waidmann (2007), Charles (2002), and Neumann (2008). We use age-threshold dummy variables for reaching the minimum age for being eligible for Social Security benefits (62 years) and the normal age of retirement as defined in Table A1 in the Appendix, as instruments for retirement. While these specific age values are likely to have a direct effect on the decision to retire, it is unlikely that they have a particular effect on cognitive functioning. The IV estimator uses only work/retirement status as an endogenous variable and thus does not take into account retirement duration. Table 2 presents the parameter estimates of the model estimated by the two-stage least-squares within estimator.[13]

The parameters of the first-stage equation describing the retirement decision are displayed in column (i). The instruments, i.e., the eligibility ages for Social Security, have large and highly significant effects on the probability of retirement. The probability of retirement increases by nine percentage points at age 62. The F-test of joint significance of the instruments proposed by Bound et al. (1995) confirms that they are significant predictors of retirement ($F(2, 36710) = 250.75$). The Sargan-Hansen test of overidentifying restrictions does not reject the hypothesis that our instruments are valid.

The effect of retirement on memory score is negative and significant. It suggests that individuals retiring experience a drop in cognitive score by about 0.3 of a standard deviation (95% confidence interval -.56 to -.05). It corresponds to about one word less, or a 10% decrease in cognitive score. The estimate is larger than in the model that assumes exogeneity of retirement (See column (ii)), possibly due to measurement errors in the retirement variables that are likely to bias downward the within estimates. The Durbin-Wu-Hausman test rejects the null hypothesis of exogeneity of retirement. This result suggests that the endogeneity bias, if any, tends to underestimate the impact of retirement on cognitive score. Nevertheless, these results reinforce our previous findings showing the negative relationship between retirement and cognitive functioning.

[Table 2 about here]

[13] Table 2A in Appendix presents the results of the two-stage least-squares estimator that does not control for unobserved time invariant heterogeneity. Those results are consistent with those presented in Table 2.

*4.1.4. Alternative instruments: expected age of retirement*

This section presents results of the IV model using an alternative instrument for retirement: expected age of retirement. This measure has been found to be a good predictor of actual date of retirement (Bernheim, 1989; Disney and Tanner, 1999). The HRS includes questions on whether and when the respondent plans to retire, and if there is currently no planned retirement date, when he thinks he will stop work or retire.[14] For this purpose, we select all individuals who are working at the first interview year and who have reported the year they expect to retire. The instrument is defined as a dummy variable equal to 1 when the respondent has reached her/his expected retirement age. Table 3 displays the results of the model estimated by two-stage least-squares within estimator.[15] The first stage equation shows that this instrument has a large and significant impact on the retirement decision. The probability of retirement increases by about 19 percentage points when individuals reach their expected retirement age. The F-test on the instrument shows that it has strong predictive power on actual retirement ($F(1,\ 16190) = 690.85$). The estimated effect of retirement on memory score is again negative and significant and close to the previous within-IV estimator. The magnitude of the effect is estimated to be -0.24 of a standard deviation of the memory score (95% confidence interval -0.43 to -0.06).

[Table 3 about here]

*4.1.5. Does cognitive functioning affect retirement expectations?*

Further evidence that causality runs from retirement to cognitive functioning comes from an analysis of the effect of cognitive functioning on retirement expectations. We estimate a model of retirement decision that includes cognitive score as an explanatory variable to check whether a drop in cognitive capacity may affect the propensity to work of older workers. For this purpose, we estimate Equation (4) and test the hypothesis that the coefficient of cognitive functioning ($\gamma_2$) is equal to zero. To avoid the issue of simultaneity, we use retirement expectations of older workers as a proxy for labor force attachment, rather than actual labor force status. Our test analyzes whether cognitive functioning affects

[14] We use the measure available in the RAND HRS Data File (See Saint Clair et al., 2007).

[15] Table 3A in Appendix presents the results of the two-stage least-squares estimator that does not control for unobserved time invariant heterogeneity. Those results are consistent with those presented in Table 3.

expectation of retirement at age 65. The validity of subjective expectation measures has been shown to provide strong predictive power of actual behavior (Manski, 2004; Disney and Tanner, 1999; Benitez-Silva and Dwyer, 2005). This proxy for labor force attachment allows measurement of the effect of a change in cognitive functioning on retirement expectations of older individuals, while avoiding the issue of simultaneity of cognitive functioning and labor force status. Table 4 presents the results of the fixed effects model on workers less than 65 years old. The coefficient of memory score is not significant, suggesting that changes in cognitive functioning do not affect the retirement expectations of older workers. These results are in accordance with Haardt (2008), who found no evidence that changes in cognition affect retirement decision, using the English Longitudinal Survey on Ageing (ELSA). These findings support our previous results that the negative relationship between cognitive functioning and retirement is unlikely to be due to reverse causality.

[Table 4 about here]

### *4.2. Evidence based on cross-country comparisons*

In this section, we provide further evidence on the relationship between retirement and cognitive functioning from an international perspective. Gruber and Wise (1999, 2004) have highlighted the strong relationship between financial disincentives to work and the participation rate of older individuals across countries. As a result, a suitable instrument for retirement to analyze the causal effect of retirement on cognitive functioning would be the differences in financial incentives that older workers face across countries. However, those incentives are quite difficult to calculate in practice due to the complexity and the multitude of social security programs that exist across European countries.[16] Contrary to the United States, where the major pathway to retirement is Social Security, many European countries have different pathways to retirement, including old-age unemployment, disability, early retirement schemes, and of course, legal retirement schemes.

Since our data set lack information that allows us to correctly calculate financial incentives for retirement (e.g. due to the absence of information on life-cycle contributions to retirement schemes), we use the differences in the aggregate employment rate by country,

[16] Other than the complexity of computations, the main limitation is unavailability of complete data on professional life, to perform retirement incentives' computations.

gender and age, which capture financial incentives and institutional rules, but are unlikely to be caused by differences in cognitive decline across countries. The heterogeneity in the age-profile of retirement across countries can thus be used as an instrument to analyze the causal effect of retirement on cognitive functioning.

The micro-analysis includes the same controls as for the empirical analysis on HRS data: a second-order polynomial in age, gender, country dummies, years of education[17], three dummies equal to 1 if a doctor has ever told the respondent that he has had a stroke (or a transient ischemic attack), a heart related disease, or high blood pressure.

### *4.2.1. Country-level analysis*

Adam et al. (2007) found a relationship between the differences in cognitive scores between 50-54 and 60-64 year-old men relative to the score of the 50-54 year-old men across European countries and the US. They found that the relative decrease in cognitive score was higher in countries where the drop in employment was also higher. Figure 4 replicates the figure of Adam et al. (2007) with the updated data of SHARE using the pooled sample from the two first waves and HRS 2004 where cognitive functioning is measured by the word recall test, while Figure 4b uses the fluency score as a measure of cognitive functioning (and thus where the United States is lacking). As in Adam et al. (2007), these figures highlight a strong relationship between the relative decrease in cognitive score and the relative decrease in employment rate across those two age categories. If we compare those figures with Figure 3 from Gruber and Wise (1999), which highlight the strong relationship between the tax force to retire and the unused labor force capacity among older workers, we see that the greatest drops in the employment rate occur in countries where financial disincentives to work are the highest. The coefficient of the regression line fitting the relationship between the relative drop in employment rate and the relative drop in cognitive functioning suggests that retirement decreases cognitive functioning by about 10%. This result is consistent with those obtained by the individual-level analysis that uses the longitudinal dimension of the HRS and the eligibility age for Social Security, or the expected age of retirement, as an instrument for retirement.

[Figure 2, Figure 3a and Figure 4b about here]

[17] Years of education are constructed for the different SHARE-participating countries according to the 1997 International Standard Classification of Education (OECD, 1999).

*4.2.2. Individual-level analysis*

SHARE also allows the estimation of the causal effect of retirement on cognitive functioning at the individual level. We use the aggregate employment rate by country, gender and age as an instrument for retirement to estimate the causal effect of retirement on cognitive functioning. The aggregate employment rates are directly calculated from SHARE data as the average employment rate by country, gender and age.[18] This measure is then used as an instrument for individual retirement.

[Table 5 about here]

Table 5 presents the results of the OLS and the IV model using the normalized fluency score and the normalized word recall test score as the dependent variable.[19] The results for both cognitive tests are very similar, especially regarding the retirement status. Moreover, the effect of being retired on cognitive score estimated by OLS is also similar to the OLS estimates obtained using the HRS data. By construction, the instrument in the first-stage equation is highly significant. The IV estimates of the effect of being retired on both cognitive scores are also very similar and close to the results using the HRS data. The magnitude of the effect is estimated to be -0.2 of a standard deviation of the memory score (95% confidence interval -0.28 to -0.09) and -0.18 of a standard deviation of the fluency score (95% confidence interval -0.28 to -0.09).As for the model using longitudinal data from the HRS, the IV estimator confirms the negative effect of retirement on cognitive functioning for both cognitive tests.[20] The magnitude of effect of retirement on cognitive functioning is lower than the estimates obtained by Rohwedder and Willis (2010). This may be due to the fact that, contrary to their specification, our model also controls for country differences and individual characteristics. Omitting those variables is likely to violate the independence assumption between the instruments and the error term. Indeed, we observe

[18] As a robustness check, we also calculated those aggregate employment rates by using data from the Labour Force Survey and obtained the same results.

[19] Table 4A in Appendix presents the results of the estimations made on the sample including both SHARE and HRS data (from 2004). Results do not differ significantly from those presented in Table 5.

[20] As a robustness check, we have also estimate the model that include interaction terms between country dummies and age (age age squared) and we found the same results. See Table A5 in Appendix.

large differences in memory score across countries; even among workers in their fifties (the observed gaps before retirement cannot be explained by differences in retirement pattern across countries).[21] For instance, we observe a clear North-South gradient in memory score across European countries. At the same time, the eligibility age for retirement benefits tends to be higher in Northern countries than in Southern countries. We thus argue that the larger impact they find is mainly due to the omission of country dummies that leads to overestimate the parameter of interest.

## 5. Conclusion

This paper has analyzed the effects of retirement on cognitive functioning, measured by a test of word learning and recall, using longitudinal data on older Americans from 1998 to 2006 (HRS) and a cross-national survey on older individuals from 14 European countries (SHARE). The empirical results highlight a significant negative causal impact of retirement on cognitive functioning. This negative effect remains even when controlling for individual heterogeneity and the endogeneity of the retirement decision. We show that this relationship is unlikely to be due to reverse causality by using eligibility for Social Security and expected age of retirement as instruments for retirement. Furthermore, we find no evidence that changes in cognitive functioning affect retirement expectations. This is in accordance with results from Haardt (2008), who found no significant effect of cognitive decline on the labor force supply of older workers in England using data from the English Longitudinal Study on Ageing. The empirical analysis using the cross-national differences in age-pattern of retirement (as a result of differences in institutional settings and labor market conditions) as an instrument for retirement provides results that are in accordance with those found using the longitudinal American data. In both cases we found a significant negative, and comparable, effect of retirement on cognitive functioning, close to 10%.

Those results demonstrate a causal effect of activity (here professional activity) on cognition using different large survey data and different identification strategies. Before that, arguments in favor of an effect of activities on cognition were relatively indirect coming from: (1) several experimental studies on animals (Rosenzweig and Bennett, 1972; Winocur, 1998); and (2) studies showing the presence of brain plasticity even in adults

[21] As previously mentioned, note also that HRS does not use the same list of words as SHARE.

(Nudo, 1996), and that the stimulation of the environment can modulate this brain plasticity (Döbrössy and Dunnett, 2001).

On a theoretical point of view, all these results support the disuse perspective (Salthouse, 1991), which assumes that decreases in activity patterns result in atrophy of cognitive skills, while stimulating mental activities increase them (the “use-it or lose it” hypothesis), and suggest that retirement plays a significant role in explaining cognitive decline at older age. However, further studies will be necessary to specify the role of professional activities on cognition (and more particularly on the memory functioning). Indeed, a first question is to investigate whether the impact of the retirement on cognitive functioning depends on the type of professional activity: physical versus intellectual work; weak versus important workload; stressful work or not... For example, some studies have shown that intellectually demanding jobs during adulthood are associated with better cognitive functioning in later life, whereas manual labor are associated with worse cognitive functioning (Jorm et al., 1998; Potter, Helms, and Plassman, 2008). A second important question is to determine whether the relation between retirement and cognition is direct and/or whether there are some intermediate variables between retirement and cognition. Indeed, work is known to increase social interactions and a sense of self-efficacy, both variables being considered as important factors contributing to the maintenance of the cognitive reserve (Rowe and Kahn, 1998).

Finally, it can be underlined that memory loss and dementia among the elderly represent a major public health burden, especially in the current context of population aging. Cognitive impairments, even those not reaching the threshold of dementia diagnosis, are associated with a loss of quality of life, increased disability, and higher health-related expenditures (Albert et al., 2002; Ernst and Hay, 1997; Lyketsos et al., 2002; Tabert et al., 2002). Our findings suggest that reforms aimed at promoting labor force participation at an older age may not only insure the sustainability of social security systems but may also create positive health externalities that may in turn affect expenditures on long-term care.

The interest of future research will be to determine the long term benefit of variables like retirement on the cost of cognitive aging and dementia; cost in terms of, for example, number of days of delaying institutionalization (institutionalization being considered as the largest component of cost, accounting 84% of the costs for people with severe dementia; Hux et al., 1998).

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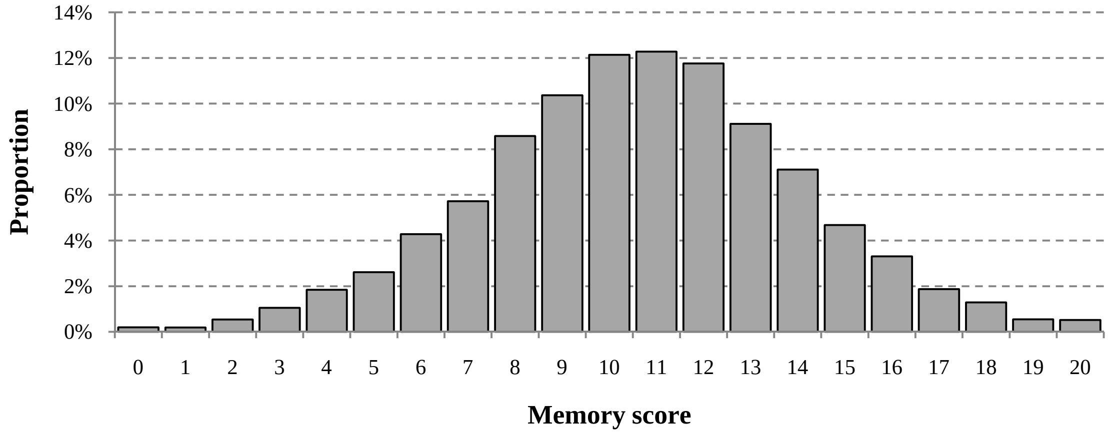
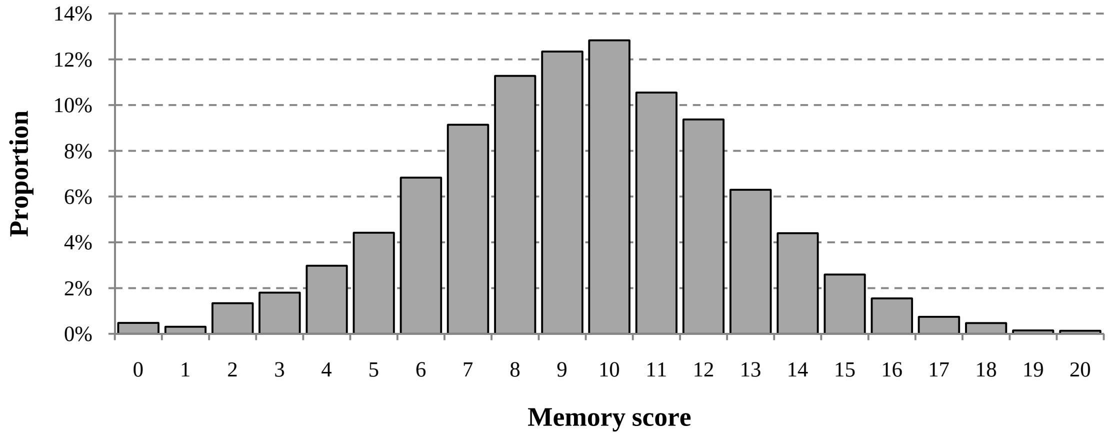
## Tables and Figures

### Figure 1a: Distribution of memory score in US



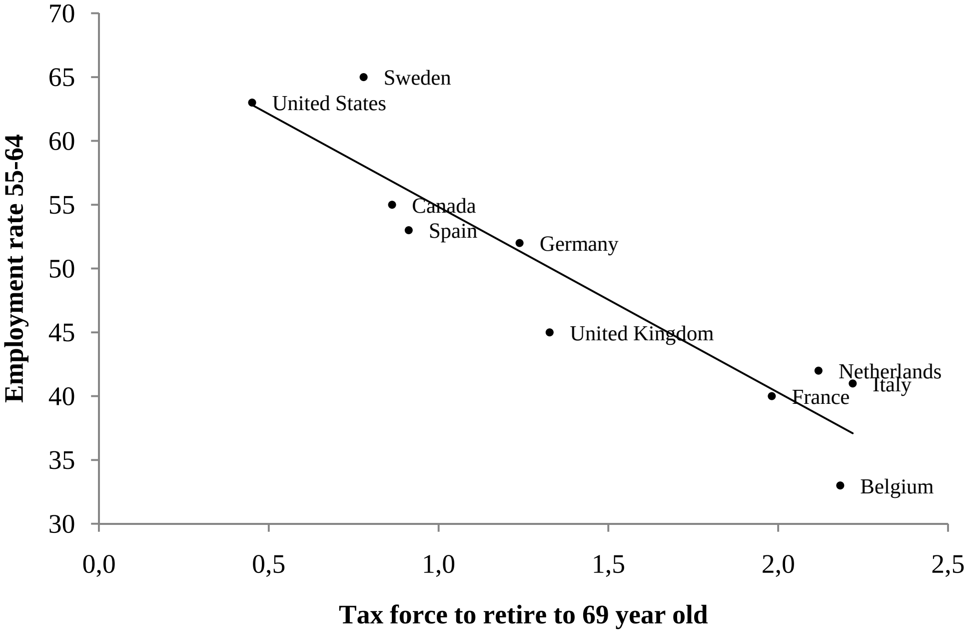

Note: Health and Retirement Study 1998-2006. All were 50-75 year-old individuals. The memory score is the sum of the number of words recalled from a list of ten words during immediate and delayed recall tasks.

### Figure 1b: Distribution of memory score in Europe



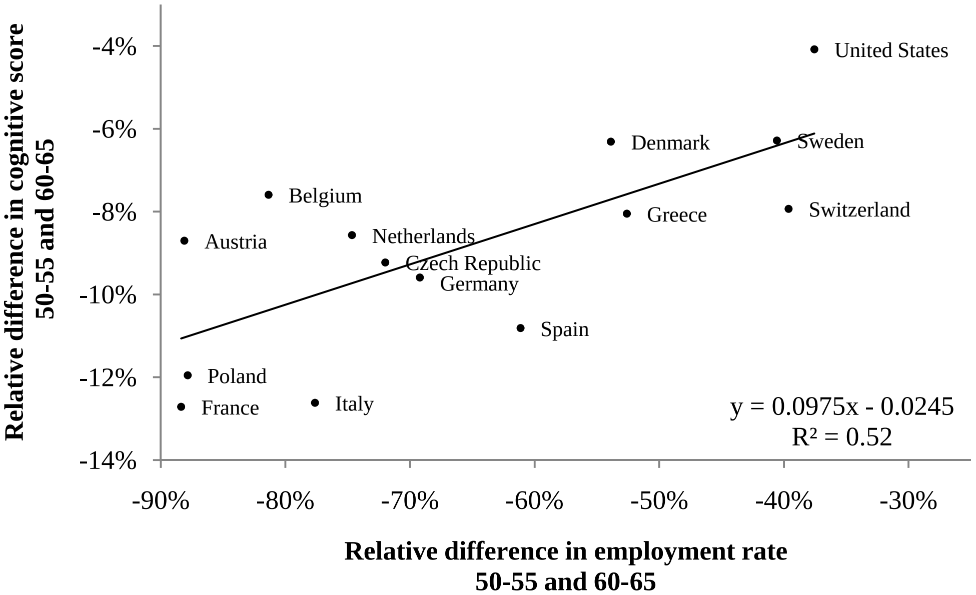

Note: The Surveey of Health, Ageing, and Retirement in Europe 2004-2006.. All were 50-65 year-old individuals. The memory score is the sum of the number of words recalled from a list of ten words during immediate and delayed recall tasks.

## Figure 2: Unused labor force capacity versus tax force to retire



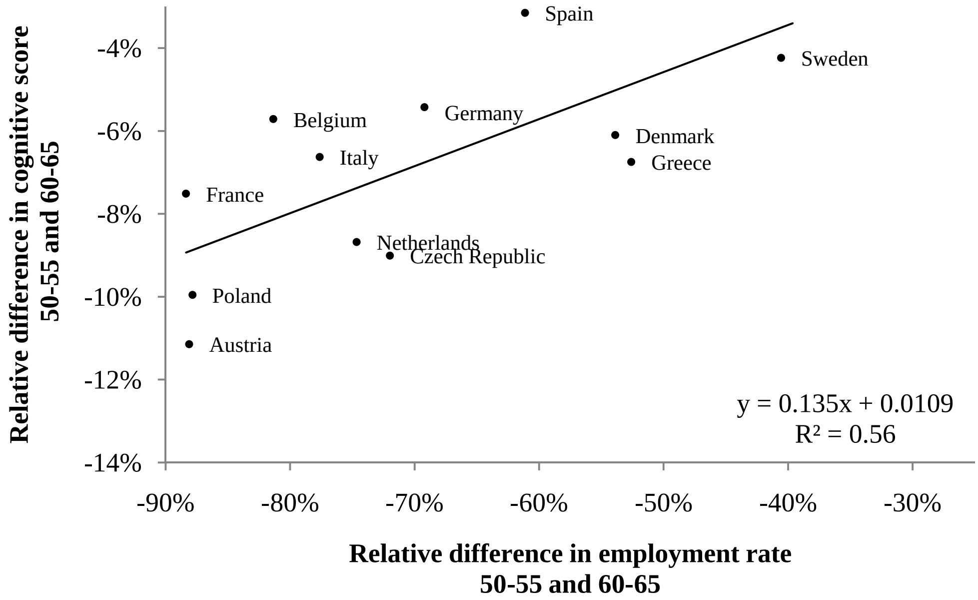

Source: Adapted from *"Social Security and Retirement Around the World,"* Jonathan Gruber and David A. Wise, eds., Chicago: University of Chicago Press, 1999. The tax force to retire is the log of the sum of the implicit tax rates over the period from the early retirement age (when a person is first eligible for social security benefits) to age 69.

## Figure 3a: Employment rate and memory score. Relative difference between 60-65 and 50-55 year-old men




Note: Survey of Health, Ageing and Retirement in Europe 2004-2006.
Health Retirement Study 2004 for the US. The relative difference in employment rate/cognitive score is defined as $(Y_{60-65} - Y_{50-55}) / Y_{50-55}$ for $Y_i$= the average employment rate/cognitive score for the age category i.

**Figure 3b: Employment rate and fluency score. Relative difference between 60-65 and 50-55 year-old men**




Note: Survey of Health, Ageing and Retirement in Europe 2004-2006. The relative difference in employment rate/cognitive score is defined as $(Y_{60-65} – Y_{50-55}) / Y_{50-55}$ for $Y_i$= the average employment rate/cognitive score for the age category i.

**Table 1: Determinants of cognitive functioning at older age**

| Dependent variable: | Memory score | |
|---|---|---|
| | OLS (i) | FE model (ii) |
| Constant | -0.090*** | -0.092*** |
| | (0.014) | (0.021) |
| Work and Retirement: | | |
| Working | - | - |
| Retired for 0 to 4 years | -0.119*** | -0.039** |
| | (0.013) | (0.015) |
| Retired for 5 to 9 years | -0.164*** | -0.047** |
| | (0.016) | (0.023) |
| Retired for 10 years or more | -0.205*** | -0.089*** |
| | (0.018) | (0.032) |
| Age | -0.032*** | -0.051*** |
| | (0.001) | (0.002) |
| $(Age^2)/10$ | -0.015*** | -0.012*** |
| | (0.001) | (0.001) |
| Single household | -0.032** | -0.008 |
| | (0.014) | (0.019) |
| High blood pressure | -0.051*** | -0.016 |
| | (0.011) | (0.017) |
| Heart-related disease | -0.035** | -0.043** |
| | (0.014) | (0.022) |
| Stroke | -0.260*** | -0.205*** |
| | (0.028) | (0.040) |
| Years of education | 0.101*** | - |
| | (0.002) | |
| Years of education$^2$ | 0.001*** | - |
| | (0.000) | |
| Woman | 0.348*** | - |
| | (0.011) | |
| Ethnicity: | | |
| Caucasian | - | - |
| African American | -0.377*** | - |
| | (0.017) | |
| Other | -0.268*** | - |
| | (0.028) | |
| (Within-)$R^2$ | 0.223 | 0.042 |
| Number of observations | 53,596 | 53,596 |
| Number of individuals | 16,878 | 16,878 |

Note: Health and Retirement Study 1998-2006. All respondents were aged between 50 and 75 years. The dependent variable is the Z-score of the word recall test. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

## Table 2: Determinants of cognitive functioning at older age: IV-FE estimators

| Dependent variable: | Retired | Memory score | |
|---|---|---|---|
| | LPM | FE model | IV-FE model |
| | (i) | (ii) | (iii) |
| Constant | 0.579*** | -0.111*** | 0.078 |
| | (0.009) | (0.018) | (0.088) |
| Work and Retirement: | | | |
| Working | - | - | - |
| Retired | - | -0.033** | -0.305** |
| | | (0.015) | (0.131) |
| Instruments: | | | |
| Eligibility I (62+) | 0.088*** | - | - |
| | (0.007) | | |
| Eligibility II (normal retirement age+) | 0.142*** | - | - |
| | (0.009) | | |
| Age | 0.028*** | -0.053*** | -0.043*** |
| | (0.001) | (0.002) | (0.005) |
| $(Age^2)/10$ | -0.002*** | -0.013*** | -0.013*** |
| | (0.001) | (0.001) | (0.001) |
| Single household | -0.020*** | -0.008 | -0.014 |
| | (0.008) | (0.019) | (0.019) |
| High blood pressure | 0.020** | -0.015 | -0.009 |
| | (0.008) | (0.017) | (0.017) |
| Heart-related disease | 0.047*** | -0.043** | -0.031 |
| | (0.010) | (0.022) | (0.022) |
| Stroke | 0.110*** | -0.206*** | -0.177*** |
| | (0.019) | (0.040) | (0.042) |
| Within-$R^2$ | 0.201 | 0.042 | 0.033 |
| Test of overidentifying restriction (*p*-value) | | | 0.480 |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.028 |
| Number of observations | 53,596 | 53,596 | 53,596 |
| Number of individuals | 16,878 | 16,878 | 16,878 |

Note: Health and Retirement Study 1998-2006. All respondents were aged between 50 and 75 years. The dependent variable is the Z-score of the word recall test. Robust standard errors are in parentheses. Age is expressed in deviation from the sample mean. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 3: Determinants of cognitive functioning at older age: IV-FE estimators**

| Dependent variable: | Retired | Memory score |
|---|---|---|
| | LPM | IV-FE model |
| | (i) | (ii) |
| Constant | 0.434*** | 0.092 |
| | (0.013) | (0.060) |
| Work and Retirement: | | |
| Working | - | - |
| Retired | - | -0.244** |
| | | (0.097) |
| Instruments: | | |
| Reaching the expected age of retirement | 0.193*** | - |
| | (0.010) | |
| Age | 0.058*** | -0.031*** |
| | (0.002) | (0.008) |
| $(Age^2)/10$ | 0.012*** | -0.007*** |
| | (0.001) | (0.003) |
| Single household | -0.027** | -0.057* |
| | (0.013) | (0.029) |
| High blood pressure | 0.012 | -0.017 |
| | (0.012) | (0.026) |
| Heart-related disease | 0.062*** | -0.028 |
| | (0.018) | (0.033) |
| Stroke | 0.221*** | -0.170** |
| | (0.035) | (0.073) |
| Within-$R^2$ | 0.340 | 0.027 |
| Durbin-Wu-Hausman test (*p*-value) | | 0.048 |
| Number of observations | 22,450 | 22,450 |
| Number of individuals | 6,253 | 6,253 |

Note: Health and Retirement Study 1998-2006. All respondents were aged between 50 and 75 years, were working during the first wave of interview and had reported their expected age of retirement. The dependent variable is the Z-score of the word recall test. Age is expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 4: Determinants of expectation about working at 65 years old. Fixed-effects linear model**

| Dependent variable: | Self-reported probability of working at 65 years old |
|---|---|
| | FE model |
| Constant | 0.480*** |
| | (0.025) |
| Cognitive Z-score | 0.002 |
| | (0.004) |
| Age | 0.023*** |
| | (0.004) |
| $(Age^2)/10$ | 0.006*** |
| | (0.002) |
| Single household | 0.039*** |
| | (0.013) |
| High blood pressure | 0.018 |
| | (0.013) |
| Heart-related disease | -0.042** |
| | (0.020) |
| Stroke | -0.067 |
| | (0.046) |
| Within-$R^2$ | 0.015 |
| Number of observations | 17,774 |
| Number of individuals | 7,372 |

Note: Health and Retirement Study 1998-2006. All workers were aged between 50 and 64 years. Age is expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 5: Determinants of memory/fluency score at older age. IV estimator**

| | Retired | Memory score | | Fluency score | |
|---|---|---|---|---|---|
| | LPM | OLS | IV | OLS | IV |
| | (i) | (ii) | (iii) | (iv) | (v) |
| Constant | 1.003*** | 0.075** | 0.109*** | 0.408*** | 0.428*** |
| | (0.014) | (0.032) | (0.042) | (0.032) | (0.042) |
| Work and Retirement: | | | | | |
| Working | - | - | - | - | - |
| Retired | - | -0.132*** | -0.191*** | -0.149*** | -0.185*** |
| | | (0.013) | (0.050) | (0.013) | (0.049) |
| Instrument: | | | | | |
| Country/gender-specific employment rate by age | -0.994*** | - | - | - | - |
| | (0.023) | | | | |
| Age | -0.002* | -0.012*** | -0.010*** | -0.004*** | -0.003 |
| | (0.001) | (0.001) | (0.003) | (0.001) | (0.003) |
| $(Age^2)/10$ | -0.001 | 0.004 | 0.005 | 0.005* | 0.006** |
| | (0.001) | (0.003) | (0.003) | (0.003) | (0.003) |
| Single household | 0.012 | -0.107*** | -0.107*** | -0.069*** | -0.069*** |
| | (0.008) | (0.016) | (0.016) | (0.016) | (0.016) |
| High blood pressure | 0.017*** | -0.030** | -0.029** | -0.026** | -0.025** |
| | (0.006) | (0.012) | (0.012) | (0.012) | (0.012) |
| Heart-related disease | 0.102*** | -0.083*** | -0.077*** | -0.076*** | -0.072*** |
| | (0.009) | (0.021) | (0.022) | (0.019) | (0.020) |
| Stroke | 0.176*** | -0.288*** | -0.277*** | -0.254*** | -0.248*** |
| | (0.016) | (0.041) | (0.042) | (0.037) | (0.038) |
| Years of education | -0.018*** | 0.065*** | 0.064*** | 0.063*** | 0.062*** |
| | (0.001) | (0.002) | (0.002) | (0.001) | (0.002) |
| Years of education$^2$ | -0.006*** | -0.008*** | -0.008*** | -0.010*** | -0.011*** |
| | (0.001) | (0.003) | (0.003) | (0.002) | (0.002) |
| Woman | -0.009 | 0.285*** | 0.295*** | 0.047*** | 0.053*** |
| | (0.006) | (0.011) | (0.014) | (0.011) | (0.014) |
| Second time interview | -0.019*** | 0.137*** | 0.135*** | 0.063*** | 0.062*** |
| | (0.004) | (0.010) | (0.010) | (0.010) | (0.010) |
| Country fixed effects | Yes | Yes | Yes | Yes | Yes |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.210 | | 0.358 |
| $R^2$ | 0.359 | 0.192 | 0.191 | 0.258 | 0.258 |
| Number of observations | 32,641 | 32,641 | 32,641 | 32,641 | 32,641 |

Note: Survey of Health, Ageing, and Retirement in Europe 2004-2006. All respondents were aged between 50 and 65 years. The dependent variables are the Z-score of the score obtained at the word recall test and the fluency test. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

## Appendix

**Table 1A: Normal retirement age in the US**

| Cohorts: Birth date | Normal age of retirement |
|---|---|
| Before 1/2/1938 | 65 |
| 1/2/1938 - 1/1/1939 | 65 and 2 months |
| 1/2/1939 - 1/1/1940 | 65 and 4 months |
| 1/2/1940 - 1/1/1941 | 65 and 6 months |
| 1/2/1941 - 1/1/1942 | 65 and 8 months |
| 1/2/1942 - 1/1/1943 | 65 and 10 months |
| 1/2/1943 - 1/1/1955 | 66 |
| 1/2/1955 - 1/1/1956 | 66 and 2 months |
| 1/2/1956 - 1/1/1957 | 66 and 4 months |
| 1/2/1957 - 1/1/1958 | 66 and 6 months |
| 1/2/1958 - 1/1/1959 | 66 and 8 months |
| 1/2/1959 - 1/1/1960 | 66 and 10 months |
| 1/2/1960 and later | 67 |

**Table 2A: Determinants of cognitive functioning at older age: IV estimator**

| Dependent variable: | Retired | Memory score | |
|---|---|---|---|
| | LPM | OLS | IV |
| | (i) | (ii) | (iii) |
| Constant | 0.439*** | -0.092*** | -0.054 |
| | (0.010) | (0.014) | (0.068) |
| Work and Retirement: | | | |
| Working | - | - | - |
| Retired | - | -0.155*** | -0.221* |
| | | (0.012) | (0.117) |
| Instruments: | | | |
| Eligibility I (62+) | 0.101*** | - | - |
| | (0.008) | | |
| Eligibility II (normal retirement age+) | 0.172*** | - | - |
| | (0.011) | | |
| Age | 0.021*** | -0.034*** | -0.032*** |
| | (0.001) | (0.001) | (0.004) |
| $(Age^2)/10$ | -0.000 | -0.016*** | -0.016*** |
| | (0.001) | (0.001) | (0.001) |
| Single household | -0.017** | -0.032** | -0.033** |
| | (0.008) | (0.014) | (0.014) |
| High blood pressure | 0.045*** | -0.052*** | -0.049*** |
| | (0.006) | (0.011) | (0.012) |
| Heart-related disease | 0.095*** | -0.037** | -0.030* |
| | (0.008) | (0.014) | (0.018) |
| Stroke | 0.170*** | -0.262*** | -0.251*** |
| | (0.013) | (0.028) | (0.034) |
| Years of education | -0.021*** | 0.101*** | 0.100*** |
| | (0.001) | (0.002) | (0.003) |
| Years of education$^2$ | -0.001*** | 0.001*** | 0.001*** |
| | (0.000) | (0.000) | (0.000) |
| Woman | 0.123*** | 0.342*** | 0.351*** |
| | (0.007) | (0.011) | (0.019) |
| Ethnicity: | | | |
| Caucasian | - | - | - |
| African American | 0.001 | -0.375*** | -0.375*** |
| | (0.009) | (0.017) | (0.017) |
| Other | 0.011 | -0.268*** | -0.267*** |
| | (0.015) | (0.028) | (0.028) |
| $R^2$ | 0.272 | 0.222 | 0.222 |
| Test of overidentifying restriction (*p*-value) | | | 0.792 |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.556 |
| Number of observations | 53,596 | 53,596 | 53,596 |
| Number of individuals | 16,878 | 16,878 | 16,878 |

Note: Health and Retirement Study 1998-2006. All respondents were aged between 50 and 75 years. The dependent variable is the Z-score of the word recall test. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 3A: Determinants of cognitive functioning at older age: IV estimator**

| Dependent variable: | Retired | Memory score | |
|---|---|---|---|
| | LPM | OLS | IV |
| | (i) | (ii) | (iii) |
| Constant | 0.115*** | -0.091*** | -0.070*** |
| | (0.008) | (0.021) | (0.025) |
| Work and Retirement: | | | |
| Working | - | - | - |
| Retired | - | -0.131*** | -0.202*** |
| | | (0.019) | (0.047) |
| Instruments: | | | |
| Reaching the expected age of retirement | 0.378*** | - | - |
| | (0.009) | | |
| Age | 0.009*** | -0.030*** | -0.029*** |
| | (0.001) | (0.003) | (0.003) |
| $(Age^2)/10$ | 0.000 | -0.014*** | -0.014*** |
| | (0.001) | (0.002) | (0.002) |
| Single household | 0.000 | -0.004 | -0.004 |
| | (0.009) | (0.022) | (0.022) |
| High blood pressure | 0.020*** | -0.044*** | -0.041** |
| | (0.006) | (0.016) | (0.016) |
| Heart-related disease | 0.052*** | -0.020 | -0.015 |
| | (0.011) | (0.024) | (0.024) |
| Stroke | 0.151*** | -0.207*** | -0.195*** |
| | (0.028) | (0.061) | (0.061) |
| Years of education | -0.008*** | 0.100*** | 0.099*** |
| | (0.001) | (0.003) | (0.003) |
| Years of education$^2$ | -0.000 | 0.001** | 0.001** |
| | (0.000) | (0.001) | (0.001) |
| Woman | 0.035*** | 0.332*** | 0.336*** |
| | (0.006) | (0.017) | (0.017) |
| Ethnicity: | | | |
| Caucasian | - | - | - |
| African American | -0.024*** | -0.337*** | -0.337*** |
| | (0.009) | (0.024) | (0.024) |
| Other | -0.004 | -0.275*** | -0.276*** |
| | (0.013) | (0.045) | (0.045) |
| $R^2$ | 0.287 | 0.178 | 0.177 |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.084 |
| Number of observations | 22,450 | 22,450 | 22,450 |
| Number of individuals | 6,253 | 6,253 | 6,253 |

Note: Health and Retirement Study 1998-2006. All respondents were aged between 50 and 75 years, were working during the first wave of interview and had reported their expected age of retirement. The dependent variable is the Z-score of the word recall test. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 4A: Determinants of memory score at older age. IV estimator**

| | Retired | Memory score | |
|---|---|---|---|
| | LPM | OLS | IV |
| | (i) | (ii) | (iii) |
| Constant | 0.998*** | 0.014 | 0.069* |
| | (0.014) | (0.031) | (0.040) |
| Work and Retirement: | | | |
| Working | - | - | - |
| Retired | - | -0.142*** | -0.239*** |
| | | (0.011) | (0.047) |
| Instrument: | | | |
| Country/gender-specific employment rate by age | -0.993*** | - | - |
| | (0.021) | | |
| Age | -0.003** | -0.008*** | -0.004* |
| | (0.001) | (0.001) | (0.002) |
| $(Age^2)/10$ | -0.001 | -0.001 | 0.000 |
| | (0.001) | (0.003) | (0.003) |
| Single household | 0.010 | -0.101*** | -0.100*** |
| | (0.007) | (0.014) | (0.014) |
| High blood pressure | 0.023*** | -0.050*** | -0.048*** |
| | (0.005) | (0.011) | (0.011) |
| Heart-related disease | 0.117*** | -0.062*** | -0.051*** |
| | (0.008) | (0.017) | (0.018) |
| Stroke | 0.207*** | -0.305*** | -0.285*** |
| | (0.014) | (0.034) | (0.035) |
| Years of education | -0.007 | 0.296*** | 0.311*** |
| | (0.006) | (0.010) | (0.012) |
| Years of education$^2$ | -0.019*** | 0.069*** | 0.068*** |
| | (0.001) | (0.001) | (0.002) |
| Woman | -0.006*** | -0.009*** | -0.010*** |
| | (0.001) | (0.002) | (0.002) |
| Second time interview | -0.018*** | 0.126*** | 0.125*** |
| | (0.004) | (0.010) | (0.010) |
| Country fixed effects | Yes | Yes | Yes |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.033 |
| $R^2$ | 0.342 | 0.212 | 0.210 |
| Number of observations | 39,564 | 39,564 | 39,564 |

Note: Survey of Health, Ageing, and Retirement in Europe 2004-2006 and Health and Retirement Study 2004. All respondents were aged between 50 and 65 years. The dependent variables are the Z-score of the score obtained at the word recall test. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.

**Table 5A: Determinants of memory/fluency score at older age. IV estimator**

| | Retired | Memory score | | Fluency score | |
|---|---|---|---|---|---|
| | LPM | OLS | IV | OLS | IV |
| | (i) | (ii) | (iii) | (iv) | (v) |
| Retired | - | -0.135*** | -0.288*** | -0.145*** | -0.130** |
| | | (0.013) | (0.060) | (0.013) | (0.058) |
| Instrument: | | | | | |
| Country/gender-specific employment rate by age | -0.986*** | - | - | - | - |
| | (0.027) | | | | |
| Country fixed effects | Yes | Yes | Yes | Yes | Yes |
| Durbin-Wu-Hausman test (*p*-value) | | | 0.009 | | 0.795 |
| $R^2$ | 0.359 | 0.193 | 0.190 | 0.259 | 0.259 |
| Number of observations | 32,641 | 32,641 | 32,641 | 32,641 | 32,641 |

Note: Survey of Health, Ageing, and Retirement in Europe 2004-2006. All respondents were aged between 50 and 65 years. The dependent variables are the Z-score of the score obtained at the word recall test and the fluency test. The model also includes the control variables used in Table 5 with interaction terms between age, age squared and country dummies. Age and years of education are expressed in deviation from the sample mean. Robust standard errors are in parentheses. (*), (**), (***) mean that the coefficient estimate is significantly different from zero at the 10%, 5%, 1% levels, respectively.