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THE EFFECT OF RETIREMENT ON COGNITIVE FUNCTIONING

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SUMMARY

Cognitive impairment has emerged as a major driver of disability in old age, with profound effects on individual well-being and decision making at older ages. In the light of policies aimed at postponing retirement ages, an important question is whether continued labour supply helps to maintain high levels of cognition at older ages. We use data of older men from the US Health and Retirement Study to estimate the effect of continued labour market participation at older ages on later-life cognition. As retirement itself is likely to depend on cognitive functioning and may thus be endogenous, we use offers of early retirement windows as instruments for retirement in econometric models for later-life cognitive functioning. These offers of early retirement are legally required to be nondiscriminatory and thus, inter alia, unrelated to cognitive functioning. At the same time, these offers of early retirement options are significant predictors of retirement. Although the simple ordinary least squares estimates show a negative relationship between retirement duration and various measures of cognitive functioning, instrumental variable estimates suggest that these associations may not be causal effects. Specifically, we find no clear relationship between retirement duration and later-life cognition for white-collar workers and, if anything, a positive relationship for blue-collar workers. Copyright © 2011 John Wiley & Sons, Ltd.

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1. INTRODUCTION

Over the last century, longevity in the USA has increased from 47.3 years in 1900 to 77.8 years in 2005 (National Center for Health Statistics, 2009). These gains in life expectancy have been accompanied by large changes in morbidity patterns. The historically more important burden of infectious diseases has been largely replaced by degenerative diseases, which are mostly concentrated among older persons. Particularly, cognitive impairment has emerged as a major driver of disability in old age, and its relative share of the total disease burden is likely to increase further as longevity continues to increase. Estimates suggest that the number of people with dementia is likely to roughly double every 20 years, resulting in a projected number of 81.1 million persons with dementia by 2040 (Ferri *et al*., 2005).

Although some form of cognitive decline appears to be an inevitable affliction of old age, its progression can be relatively slow and might not result in any impairment of a person's well-being or ability to function on a daily basis. More serious forms of cognitive decline may, however, have profound adverse effects on various aspects of life including financial planning for retirement (Banks and Oldfield, 2007), medical treatment adherence and the planning of sequential activities (Fillenbaum *et al*., 1988). The list of potential risk factors

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for increased rates of memory loss is long and diverse, ranging from genetic factors over medical comorbidities to lifestyle and psychosocial factors (Institute for the Study of Aging, 2005). Identifying such risk factors and developing strategies to maintain high levels of cognition have thus emerged as key public health priorities associated with population ageing.

Among the lifestyle and psychosocial risk factors, continued intellectual stimulation is often seen as a key factor for retaining high levels of cognitive functioning at older ages (Small, 2002). Specifically, cognitive training and intellectual stimulation may help maintain brain plasticity and thus prevent accelerated memory loss at older ages. Suggested strategies aimed at delivering continued intellectual stimulation include formal training as well as informal training activities, such as crossword puzzles or cognitively challenging social interactions.

Continued professional activities have also been suggested as potentially protective strategies against cognitive decline. For example, using data on older men from the Twins Registry of World War II veterans, Potter *et al*. (2008) showed that intellectually demanding work is positively associated with cognitive performance in later life. Similarly, Adam *et al*. (2007) used data from the Survey of Health, Ageing and Retirement in Europe (SHARE), the English Longitudinal Survey on Ageing, and the US Health and Retirement Study (HRS) to show a strong negative association of retirement and cognition for both older European and Americans and that the strength of this association is monotonically increasing with length of retirement.

Although the aforementioned associations between continued employment and cognitive functioning are clearly suggestive, they have to be taken with a grain of salt, as potentially important endogeneity issues caution against a causal interpretation. The positive association between continued employment and cognitive function may, of course, at least in part be due to continued intellectual stimulation on the job. It may, however, be further exacerbated by potential reverse causation, as maintaining a certain level of cognition is likely to be a necessary condition for gainful employment, especially for intellectually demanding jobs. Identifying a causal effect of continued employment on cognitive functioning thus requires exogenous variation in job retention to rule out potentially confounding effects from cognition on employment.

In light of this criticism, Bonsang *et al*. (2010) have recently reconsidered the relationship between retirement and cognitive functioning in the SHARE and the HRS treating retirement as endogenous. Their study still indicates significant negative effects of retirement on cognitive functioning. For the USA, Bonsang *et al*. (2010) used eligibility ages for Social Security as instruments for retirement, which allows the authors to identify local effects of retirement on later-life cognition around those ages. However, the functional dependence between age and the thus constructed instruments for retirement does not allow the estimation of longer-run dose–response relationships between length of retirement and cognition at older ages, which seems at the heart of the argument that it is continued intellectual stimulation on the job that protects against cognitive decline. For Europe, Bonsang *et al*. (2010) exploited international differences in the age patterns of retirement as instruments. Rohwedder and Willis (2010) adopted a similar approach using data from all of the aforementioned studies, SHARE, the English Longitudinal Survey on Ageing, and the HRS, and also found a large and significant negative effect of retirement on later-life cognition. Although both of the latter approaches based on international comparisons break the functional dependence between age and the retirement instruments by using international variation in age eligibility rules, their econometric specifications still assume that retirement status has a constant additive effect on cognition. Specifically, by estimating coefficients for a simple dummy variable indicating ‘retirement,’ these authors implicitly assume an immediate shift in the level of cognitive functioning at the time of retirement, with no additional effect of retirement duration on the age trajectory of cognition. These approaches therefore also fall short of estimating a potential dose–response relationship between time spent in retirement and later-life cognition.

Our paper aims at estimating the causal dose–response relationship between retirement duration and later-life cognition, reflecting the idea that the impact of intellectual inactivity is likely to be cumulative over time. To achieve this goal, we require continuous exogenous variation in retirement that is not functionally dependent on age, which allows us to estimate the cumulative effects of retirement on cognitive functioning controlling for potentially confounding age patterns of cognitive decline. This focus on the dose–response relationship between continued labour supply and cognitive functioning also prevents us from using age-related

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discontinuities in within-country retirement incentives as instruments, as commonly carried out in the literature (see, for example, Charles (2002), Neuman (2008) or Bonsang *et al*. (2010)). Instead, we develop a stochastic model for the change in cognitive functioning and derive the exclusion restrictions required for a valid instrument in the context of this model. We argue that the offering of an early retirement window will satisfy these conditions. We then describe the results using various estimation strategies for several measures of cognitive functioning and discuss the findings at the end of the paper. We start out by describing the data we use.

2. DATA

The data we used come from the US HRS, which is conducted by the Survey Research Center at the University of Michigan. The HRS is a longitudinal survey of people 50 years and older and their spouses (regardless of age) starting in 1992 with follow-up interviews every 2 years. Currently, nine waves of data are available (1992–2008). When weighted to account for initial oversampling of some population groups and for subsequent attrition, the HRS provides a representative sample of the relevant birth cohorts. We use the RAND HRS data files (St. Clair *et al*. 2010) for all background variables and construct the variables on cognitive functioning from the raw HRS files based on methods described in Ofstedal *et al*. (2005). Because these measures of cognitive functioning are only available from wave three onwards, we restrict our analysis to data collected between 1996 and 2008.

We further limit our analysis to respondents belonging to the original HRS or subsequent birth cohort (birth year 1931 or later) and who are younger than 80 years in a given wave. These age restrictions aim at focusing our analysis on age ranges for whom continued intellectual stimulation through work is most relevant and allows us to exclude many potential outliers whose low levels of cognition are likely to be pathological rather than a reflection of normal age-related cognitive decline.[1] We also restrict our analysis to male respondents to avoid potential confounding of our analysis related to cohort effects in lifetime female labour force participation. Finally, we distinguish between white-collar and blue-collar workers as defined by their job with the longest tenure to capture likely differences in the intellectual stimulation associated with different work environments. The samples include 22,114 person-year observations. Of these, 51% is for blue-collar workers. Table I reports basic descriptive statistics for our final samples of white-collar and blue-collar workers, respectively.

2.1. Cognitive functioning

Our analysis exploits a series of measures for cognitive function as outcome variables. Specifically, we consider measures of self-rated memory, immediate, delayed and total word recall, working memory and numeracy. These measures aim at covering different aspects of cognitive function within the framework of a large population-based general purpose survey. A more detailed description of these survey instruments as well as the rationale for their choice can be found in Ofstedal *et al*. (2005), on which this section draws.

Self-rated memory is assessed based on the survey instrument ‘How would you rate your memory at the present time? Would you say it is excellent, very good, good, fair, or poor?’ This survey instrument mainly characterises overall memory perceptions of respondents rather than ‘objective’ memory status. Yet, over and above being a useful measure of memory perceptions, this measure has also been shown to be correlated with more objective measures of memory performance (Maurer, 2009). We translated verbal responses to the self-rated memory question to a quantitative scale ranging from 1 (poor) to 5 (excellent).

We contrast our findings for self-rated memory with evidence from more objective test-based performance measures of cognitive functioning. Immediate and delayed word recall aim at assessing memory performance based on two word recall tasks. The respondents were read a list of 10 nouns and asked to recall as many words

[1]All results are robust to using age 70 years as a cutoff instead. Corresponding tables and figures are included in the online Appendix.

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Table I. Descriptive statistics by worker type

	Observation	Mean	Standard deviation	Minimum	Maximum
White-collar workers					
Immediate word recall	10 740	6.012	1.543	0.0	10.0
Delayed word recall	10 724	5.031	1.784	0.0	10.0
Total word recall	10 724	11.050	3.082	0.0	20.0
Serial 7 subtraction	10 743	4.335	1.103	0.0	5.0
Numeracy	2991	1.879	0.795	0.0	3.0
Self-rated memory	10 794	3.236	0.905	1.0	5.0
Whether retired	10 803	0.512	0.500	0.0	1.0
Retirement age	10 803	60.529	4.598	50.0	77.7
Time spent in retirement	10 803	2.950	4.280	0.0	23.2
Whether a window was offered before age 60 years	10 803	0.180	0.384	0.0	1.0
Time elapsed since first offer (if before age 60 years)	10 803	1.642	4.285	0.0	35.6
Age	10 803	63.479	5.554	50.0	78.0
GED	10 803	0.030	0.171	0.0	1.0
High school graduate	10 803	0.191	0.393	0.0	1.0
Some college	10 803	0.248	0.432	0.0	1.0
College and above	10 803	0.480	0.500	0.0	1.0
Black	10 803	0.075	0.264	0.0	1.0
Other than black or white	10 803	0.031	0.175	0.0	1.0
Hispanic	10 803	0.040	0.196	0.0	1.0
Blue-collar workers					
Immediate word recall	11 216	5.210	1.581	0.0	10.0
Delayed word recall	11 181	4.152	1.847	0.0	10.0
Total word recall	11 181	9.376	3.160	0.0	20.0
Serial 7 subtraction	11 057	3.529	1.641	0.0	5.0
Numeracy	2838	1.302	0.851	0.0	3.0
Self-rated memory	11 305	2.887	0.946	1.0	5.0
Whether retired	11 311	0.542	0.498	0.0	1.0
Retirement age	11 311	60.227	4.468	50.0	77.1
Time spent in retirement	11 311	3.161	4.434	0.0	25.4
Whether a window was offered before age 60 years	11 311	0.101	0.302	0.0	1.0
Time elapsed since first offer (if before age 60 years)	11 311	0.896	3.296	0.0	28.4
Age	11 311	63.388	5.518	50.0	77.9
GED	11 311	0.077	0.266	0.0	1.0
High school graduate	11 311	0.377	0.485	0.0	1.0
Some college	11 311	0.179	0.383	0.0	1.0
College and above	11 311	0.067	0.250	0.0	1.0
Black	11 308	0.170	0.376	0.0	1.0
Other than black or white	11 308	0.049	0.217	0.0	1.0
Hispanic	11 307	0.125	0.330	0.0	1.0

Descriptive statistics for all HRS waves between 1996 and 2008. The sample is restricted to men aged 50 to 80 years who were born between 1931 and 1955 and who were working at age 50 years.
GED, General Educational Development.

as possible from the list in any order. The score for immediate word recall counts the number of correct responses, leading to a test score between 0 and 10. Roughly 5 min later (after the administration of some additional survey instruments), the respondent is again asked to recall as many words from the previously read list of nouns. Again, corresponding test score is obtained as the sum of each correct answer (delayed word recall, range 0–10). We also combined the scores from both immediate and delayed word recall to obtain an overall summary measure for recall (total word recall), whose score ranges from 0 to 20.

Working memory, that is, the ability to process and store information simultaneously, is assessed based on a serial 7s subtraction test. In the serial 7s test, respondents are asked to subtract 7 from 100 and continue subtracting 7 from each subsequent number for a total of five trials. This test thus requires respondents to perform a basic arithmetic operation (subtracting 7) while memorising the result from the previous subtraction that is required as an input in this process. The serial 7s subtraction test score counts each correct subtraction, leading to scores between 0 and 5.

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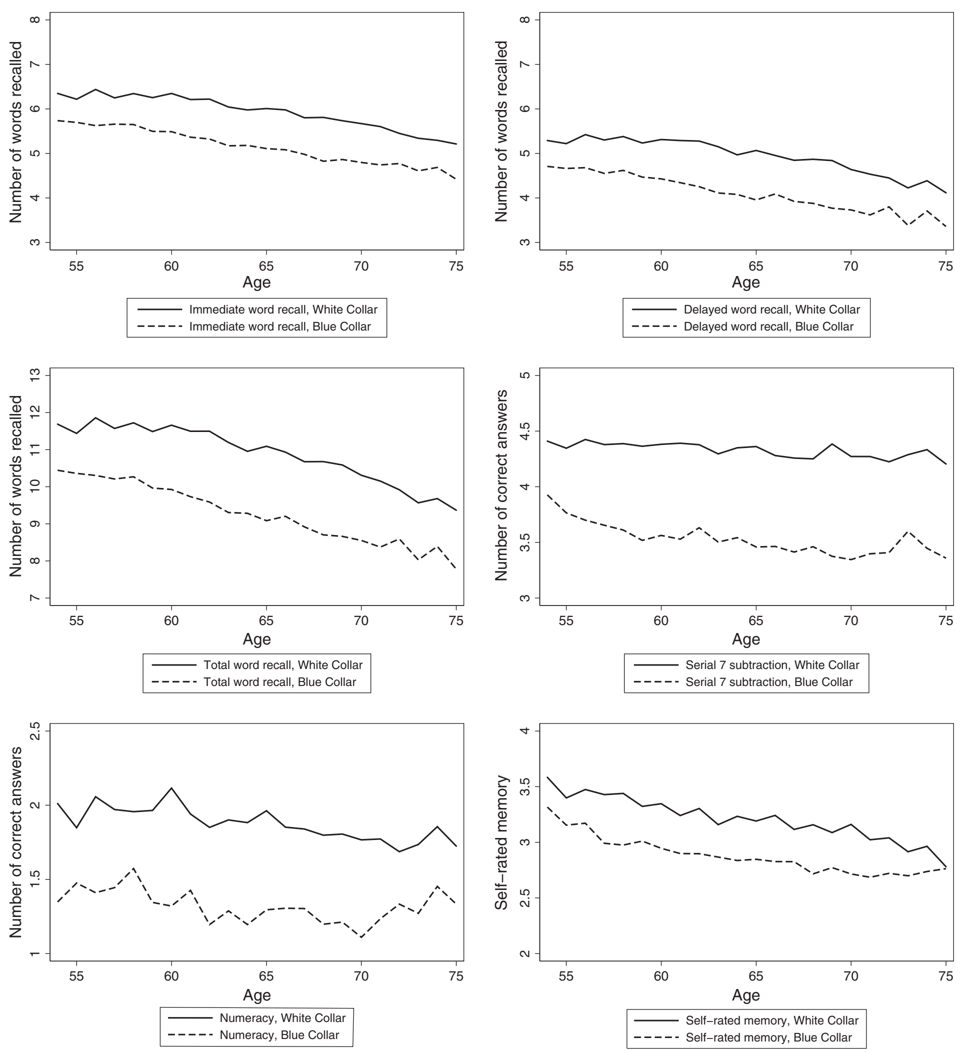
Finally, numeracy is measured as the number of correct responses to three numerical problems. The tasks involve three calculation tasks, that is, calculation of percentages, division and compound interest. Scoring correct solutions for each task yields a numeracy score ranging from 0 to 3. The numeracy questions have only been asked to all respondents in the 2002 and 2006 waves, which lead to a substantially reduced sample size.

We find substantial variation in all measures of cognitive function both by age and worker type (Figure 1). First, the graphs show generally lower levels of cognitive function for older ages. In addition, white-collar workers have substantially higher levels of cognitive functioning than blue-collar workers at all ages. With the exception of sample size-related fluctuations at the boundaries of the selected age groups, the decline in all measures is largely parallel for both worker types. It is most pronounced for immediate recall and self-rated memory and much smaller for the serial 7s subtraction test.



Source: HRS 1996-2008, own calculations.

Figure 1. Cognitive function by age and occupation group *Source*: HRS 1996–2008, own calculations

2.2. Explanatory variables

Our main explanatory variable of interest is retirement duration. We construct this variable as the elapsed time between the self-reported retirement date (as defined in the Research and Development HRS data, St. Clair *et al*. (2010)) and the interview date. We measure all temporal variables (including age) in full months and convert the scale to years by dividing the resulting number of months by 12 for ease of interpretation. Figure 2 plots the fraction of respondents in retirement for the two samples of blue-collar and white-collar workers. The strongest rise can be seen for blue-collar workers at age 62 years, when it is first possible to draw old age social security benefits. For white-collar workers, the increase is more steady but also strongest during individuals' early and mid 60s. By age 70 years, close to 90% of both types of workers are retired.

Beyond retirement duration, our econometric analyses will also include wave dummies, age and age squared and indicator variables for education (five categories for high school dropouts, General Educational Development (GED), high school, some college, college degree or more), race and ethnicity as additional controls.

2.3. Instruments: early retirement windows

Early retirement windows are a limited time offer, typically lasting 6 weeks to 3 months (Towers Perrin 1992). The HRS question starts with defining an early retirement window, stating the following:

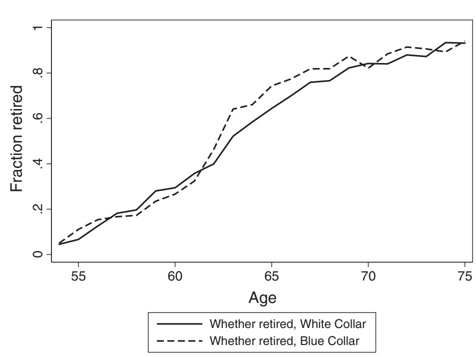
> *Employers sometimes encourage older workers to leave a firm at a particular time by offering a special financial incentive, like a cash bonus or improved pension benefits. These are often called 'early retirement windows'.*

The respondents are then asked the following:

> *Have you ever been offered such an early retirement window on any job?*

The survey then solicits information on how many offers the individual has received, when the offer(s) was received, which employer made it, what was offered in the plan and whether it was accepted. If the offer was accepted, they ask if the offer was influential in their decision to leave the job. If the offer was rejected, they ask whether the offer would have induced leaving the job if the offer were doubled. In total, 18% of white-collar workers and 10% of blue-collar workers were offered a retirement window before age 60 years (Table I). Coe and Lindeboom (2008) analysed several of these variables in detail and concluded that the offered windows are a major factor in determining retirement decisions.

Coe and Lindeboom (2008) also argued that conditional on observed characteristics, the offering of early retirement windows is exogenous to an individual's health because firms cannot limit eligibility to single individuals. Instead, firms can only select broad groups of workers to be eligible for early retirement windows, and



Source: HRS 1996-2008, own calculations.

Figure 2. Age trends in fraction retired by worker type *Source*: HRS 1996–2008, own calculations

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their power to limit eligibility is bounded tightly by the courts. This reasoning also holds for cognitive functioning—although it is in the firms' best interest to select individuals who experienced the greatest productivity decline, they may not legally target early retirement windows to workers with low levels of cognition. Statistical evidence suggests that this legal restriction was indeed binding. Exploring the panel nature of the data, Coe and Lindeboom (2008) did not find evidence that health status predicts offerings of retirement windows conditional on other observables. For a small subset of our data (those younger than 60 years who were working at baseline), we performed similar analyses. In particular, we checked whether cognitive functioning could predict the offering of an early retirement window in the next 2 years, conditioning on the remaining covariates. Based on these regressions, we find no evidence that offerings of early retirement windows are targeted to workers with low levels of cognition. We conclude from this that the exogeneity condition for the instrument—which we will make precise in the subsequent section—is likely to hold in our sample. To avoid repetition, we refer the interested reader to Coe and Lindeboom (2008) for additional background information on the institutional features, details of the statistical analyses and further references regarding the use of early retirement windows as instruments for retirement in econometric models for later-life health. To obtain reliable instruments for retirement duration, we use the time elapsed between the first time an early retirement window was offered to a respondent and the current interview date, if the window was offered before age 60 years. Particularly, by only considering retirement window offering before age 60 years, we focus directly on available options to retire 'early' relative to the usual retirement ages.

3. MODEL AND EMPIRICAL SPECIFICATION

We analyse the impact of retirement on later-life cognitive functioning within the framework of a dynamic statistical model that captures the dynamic interplay between continued cognitive stimulation on the one hand and changes in later-life cognitive function on the other. The literature in empirical labour economics has gained substantially in the past three decades from using these types of time series processes to model individual earnings dynamics (see MaCurdy (1982) for an early example and Meghir and Pistaferri (2004) for a recent extension and overview). Adda *et al.* (2009) applied this framework to a variety of health indicators, focussing on the decomposition of transitory and permanent shocks. Doing so is fruitful for cognitive functioning as well because the indicators we use are not immune to many short-term factors associated with concentration on a particular day and others—one may think about part of the transitory shocks in terms of measurement error.

3.1. Statistical model for the change in cognitive functioning

We denote the age t change in cognitive functioning by ΔCF_t and decompose it into a permanent (ρ_t) and a transitory (ε_t) component:

$$\Delta \text{CF}_t = \rho_t + \Delta \varepsilon_t \tag{1}$$

We focus on the permanent component and model its mean as a linear function of observed covariates:

$$\rho_t = \alpha_t + \text{RET}_t \cdot \gamma + X_t \beta + \psi_t \tag{2}$$

Our parameter of interest is γ, that is, the effect of being retired at age t on permanent innovations to cognitive functioning. This specification restricts γ to be the same across ages. Although this assumption is certainly debatable and could be relaxed in theory, doing so is infeasible empirically for us and will have to await better datasets to become available. One may also view γ to be the average of a set γ_t, $t \in \{0, 1, \ldots, T\}$ with possibly different elements. Because we focus on individuals who worked at age 50 years (indexed by 0, corresponding to the sampling frame for our data), the model is completed by the following initial conditions:

DOI: 10.1002/hec

$$\mathrm{CT}_0 = \alpha_0 + X\beta + \psi_0 \tag{3}$$

3.2. Empirical specification

Previous research using time series approaches to changes in wages or health has sought to estimate the entire dynamic structure of Equation (1). Because we do not have a sufficiently long panel available for such a formidable task, our aims are more modest. To develop an equation that we can estimate with our data, we first derive the cross-sectional implications of models (1)–(3):

$$\mathrm{CF}_t = \sum_{s=0}^{t} \alpha_s + \gamma \sum_{s=0}^{t} \mathrm{RET}_s + \sum_{s=0}^{t} X_s\beta + \sum_{s=0}^{t} \psi_s + \varepsilon_t - \varepsilon_0 \tag{4}$$

Equation (4) clearly highlights that later-life cognition should depend on cumulative exposures—including cumulative exposure to retirement—and not display large discontinuous changes in response to a simple change in labour market status. From Equation (4), it is also evident that it is *not* enough to have contemporaneous covariates in the model but that the entire history of life-course exposures is important. We therefore focus on covariates that are stable over time. To identify γ, we first assume ψ_t and ε_t to be independent across time and individuals, as is common in the literature. Furthermore, we need the following conditions to hold for instrumenting $\sum_{s=0}^{t}\mathrm{RET}_s$, the time spent in retirement until age t, with a variable Z_t:

1. $\theta \neq 0$ in $\sum_{s=0}^{t}\mathrm{RET}_s = a_t + Z_t\theta + \sum_{s=0}^{t} X_s \cdot b + u_t$
2. $\mathrm{cov}\left[Z_t, \sum_{s=0}^{t}\psi_s + \varepsilon_t - \varepsilon_0\right] = 0$

The first condition implies that conditional on age, there has to be nontrivial variation in the instrument. This rules out using ages 62 and 65 years—where retirement incentives induced by the social security system are strongest—as instruments, an approach taken by previous authors to estimate the impact that retirement has on health (Charles, 2002; Neuman, 2008). We hence use the offering of early retirement windows, similar to Coe and Lindeboom (2008). As we shall see later, the instruments will indeed be significant predictors of retirement duration, such that the first condition is satisfied. The second condition is the instrument exogeneity condition. This condition states that the time elapsed since the first offering of an early retirement window may not be correlated with the (overall sum of the) unexplained permanent innovations to cognitive functioning and the difference between the initial and contemporaneous transitory innovations, which should hold given the legally nondiscriminatory nature of offers of early retirement windows.

We estimate Equation (4) with data from the pooled cross sections of all waves between 1996 and 2008. Heteroskedasticity robust standard errors are adjusted for clustering at the individual level. The gains from using this approach instead of a single cross section come from reducing the impact of ε_t and from a modest increase in the clustering-adjusted sample size. Z_t is a vector of indicator variables containing the individual's age when the first retirement window was offered. We separate blue-collar and white-collar workers throughout the analysis because we expect the effects of retirement and of covariates to differ substantially. X_t furthermore includes education, race, ethnicity and wave dummies.

Unlike the previous studies of Adam *et al.* (2007), Bonsang *et al.* (2010) and Rohwedder and Willis (2010) mentioned previously, our model does not constrain the effect of retirement on later-life cognition to be a one-time discontinuous change in cognition in response to retirement. Instead, we operationalise the idea that continued intellectual exposure on the job (or lack thereof) affects later-life cognition by proposing a dose–response model in which the trajectory of cognitive ageing changes with the duration of retirement, that is, the cumulative amount of time spent out of the labour market. Although the linear model in Equation (4) is therefore well suited to capture the effects of cumulative exposures associated with retirement, one may still be concerned about potential nonlinearities in the effects of these exposures. In particular, time-varying coefficients on retirement (γ) in the permanent component of cognitive functioning (Equation (2)) could lead to nonlinearities in the cumulative effects of retirement duration.

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To assess the robustness of our benchmark estimations to potentially nonlinear effects of retirement duration on later-life cognition, we employ a semiparametric adaptation of the two-step approach for nonparametric estimation of additive models in the presence of continuous endogenous regressors proposed by Newey *et al*. (1999). Their estimation strategy is a generalisation of two-stage least squares (2SLS). The basic idea is to use estimated residuals from a first-stage nonparametric regression of the endogenous variable on all exogenous variables and the instruments to construct a control function for the estimation of the main equation of interest. Specifically, estimation of the main equation of interest is performed as a nonparametric regression of the main outcome of interest (here later-life cognition) on all exogenous controls, the endogenous variable and the first-stage residuals.

Although a full nonparametric implementation of this estimator can be challenging because of the curse of dimensionality, we follow the suggestion of Newey *et al*. (1999) and consider a semiparametric variant. In particular, we employ a partially linear model that treats all exogenous controls like in the previous 2SLS model but includes higher-order polynomial terms for both the endogenous variable (retirement duration) and the estimated residual from the first-stage regression. We selected a third-order polynomial for retirement duration and the control function for our baseline robustness check but obtained largely similar results when using second-order or fourth-order polynomials, respectively. We present those results in the online Appendix.

4. DESCRIPTION OF RESULTS

Table II presents our main results by contrasting estimates from standard ordinary least squares (OLS) regressions of later-life cognitive functioning on retirement duration and other sociodemographic controls with corresponding 2SLS estimations using the time elapsed between the first time an early retirement window was offered to a respondent (before age 60 years) and the current interview date as an instrumental variable for retirement duration. To begin with, consider the first rows in each panel, which contain the estimated OLS coefficients of time spent in retirement (measured in years but with monthly precision) on our measures for later-life cognitive functioning. Similar to Adam *et al*. (2007), we find the expected negative

Table II. The effect of retirement duration on cognitive functioning, where time spent in retirement is instrumented by time elapsed since first offer (if before age 60 years)

	Immediate word recall	Delayed word recall	Total word recall	Serial 7 subtraction	Numeracy	Self-rated memory
White collar						
OLS	−0.01881***	−0.02091***	−0.03927***	−0.00229	−0.00887***	−0.01305***
	0.00588	0.00745	0.01264	0.00440	0.00397	0.00414
2SLS	−0.01319	0.01663	0.00521	0.01010	−0.01354	−0.01249
	0.02877	0.03381	0.05966	0.02387	0.01608	0.01937
F (first stage)	63.09	62.76	62.76	63.56	62.57	64.44
N (total)	10 740	10 724	10 724	10 743	2991	10 794
N (clustered)	2542	2539	2539	2545	1988	2552
Blue collar						
OLS	−0.00680	−0.00355	−0.00974	−0.01138*	−0.00437	−0.01087***
	0.00594	0.00710	0.01226	0.00634	0.00431	0.00418
2SLS	0.19319***	0.19592*	0.37845***	0.13882*	0.10463	0.03025
	0.08684	0.10012	0.17580	0.07951	0.06703	0.04642
F (first stage)	13.06	13.18	13.18	13.41	7.45	13.12
N (total)	11 209	11 174	11 174	11 050	2837	11 298
N (clustered)	2894	2892	2892	2877	2008	2901

Separate regressions by worker type using pooled cross sections of all HRS waves between 1996 and 2008, standard errors clustered at the individual level. Stars denote significance at the 10%, 5% and 1% levels. The sample is restricted to men aged 50 to 80 years who were born between 1931 and 1955 and who were working at age 50 years. Further controls include a quadratic age trend, education in five categories, race, ethnicity and wave dummies.
OLS, ordinary least squares; 2SLS, two-stage least squares.

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associations between length of retirement and the measures of cognitive functioning for both white-collar and blue-collar workers. Moreover, these negative associations between retirement duration and later-life cognition are typically strongly significant for white-collar workers but tend to be smaller and only occasionally statistically significant for men who worked most of their life in blue-collar jobs. Overall, the estimated associations are relatively small. Taking the estimations for immediate word recall among white-collar workers as an example, our coefficient estimates suggest that an additional year spent in retirement is associated with an average reduction of .0188 correctly recalled words (out of 10), holding everything else (age, in particular) constant.

Treating retirement duration as endogenous changes the picture considerably. The effects of retirement duration on later-life cognition of white-collar workers vary across the different measures of cognitive function and are statistically insignificant throughout. Specifically, although the estimated 2SLS coefficients for immediate word recall, numeracy and self-rated memory remain negative; we obtain sign reversals for the cognitive function measures based on delayed and total word recall as well as the serial 7s subtraction test. Overall, our evidence on potential effects of retirement duration on later-life cognition of white-collar workers is rather mixed and inconclusive. Importantly, this mixed evidence does not seem to be due to weak instruments, as all first-stage F-statistics for the excluded instruments are larger than 10 and thus above the rule-of-thumb cutoff suggested by Staiger and Stock (1997).

The differences between the OLS and 2SLS estimates are even more striking for blue-collar workers. Although the OLS estimates indicated a negative—albeit insignificant—association between retirement duration and cognitive function for all cognition measures, the 2SLS estimates of the causal effect of retirement duration on later-life cognition display a complete sign reversal. Retirement duration appears to have positive effects on later-life cognition of blue-collar workers, and these effects are often statistically significant. In the case of numeracy, the substantially smaller sample size (Section 2.1) reduces the precision of the estimates. The estimated effects are not only often significant but also fairly substantial in magnitude. For example, other things equal, five additional years in retirement for a blue-collar worker yield improved memory corresponding to roughly one correctly recalled word in both the immediate and delayed word recall tasks. Again, the first-stage F-statistics show no sign of weak instruments other than for the smaller numeracy sample.

To provide additional intuition on the meaning of these 2SLS results, Figure 3 plots estimated age trajectories for our cognitive functioning measures comparing retirement at age 55 years with retirement at age 62 years. These plots highlight both the effects of cognitive ageing and how retirement duration affects cognitive decline. The plots also contain kernel density estimates for the age distribution in our samples to clarify the support of the data with regard to age. As can be seen from the figure, retirement duration has mixed effects on later-life cognition of white-collar workers, and the size of these effects is very small. For blue-collar workers on the other hand, earlier retirement appears to have a strong protective effect on later-life cognition with actual cognitive increases following retirement.

The general picture of an unclear effect of retirement on cognitive functioning for white-collar workers and a positive effect for blue-collar workers also emerges in our nonlinear specifications. Table III and Figure 4 present corresponding estimates based on a model with a third-order polynomial for retirement duration and a third-order polynomial of the first-stage residual as a control function for the endogeneity of retirement duration. As can be seen from the figure, the estimated effects are largely identical to those from the linear 2SLS model, noting that the tails of the figures largely reflect invalid out-of-support predictions implied by the use of global polynomials.

Finally, our findings are also robust to alternative nonlinear specifications in retirement duration using second-order or fourth-order polynomials as well as the inclusion of a large number of interaction terms between age and education and restricting the sample to only include respondents 70 years or younger. Tables and figures containing the results of these additional robustness checks are presented in the online Appendix.

Figure 3. The effect of retirement duration on cognitive functioning based on a two-stage least squares strategy. Note: The graphs are an illustration of the point estimates in Table II, setting education to high school graduate and all other covariates besides age to zero. Please refer to Table II for the statistical significance of the retirement duration coefficient

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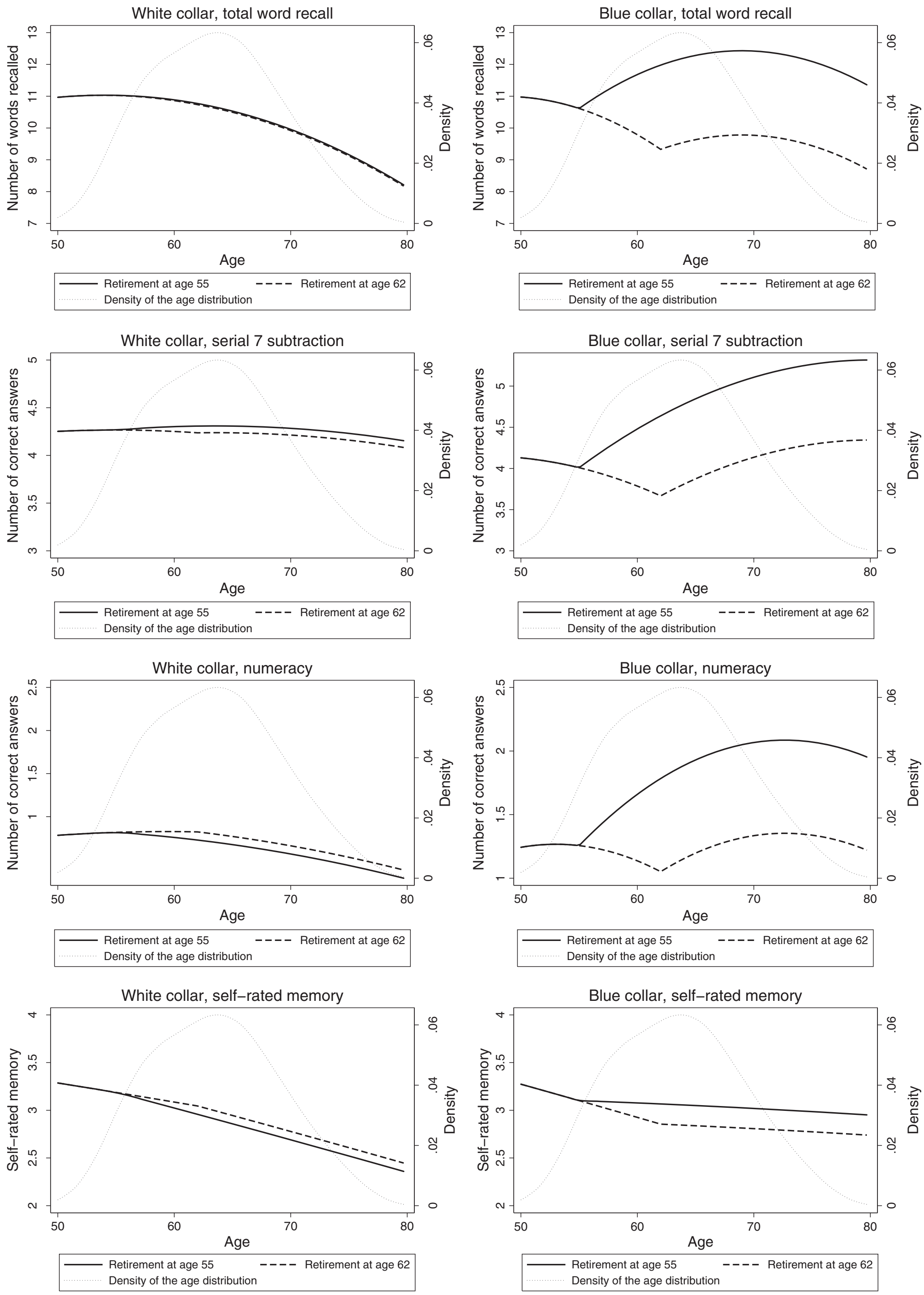

Note: The graphs are an illustration of the point estimates in Table 2, setting education to high school graduate and all other covariates besides age to zero. Please refer to Table 2 for the statistical significance of the retirement duration coefficient.

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Table III. The effect of retirement duration on cognitive functioning, adjusting for endogeneity of time spent in retirement as the endogenous variable by means of a nonlinear control function based on time elapsed since first offer (if before age 60 years)

	Immediate word recall	Delayed word recall	Total word recall	Serial 7 subtraction	Numeracy	Self-rated memory
White collar						
Time in retirement	−0.03187	−0.03775	−0.07253	0.00960	−0.03920	−0.03697
	0.03654	0.04319	0.07529	0.03163	0.02553	0.02407
Time in retirement^2	−0.00041	0.00395	0.00421	−0.00054	0.00120	0.00139
	0.00294	0.00347	0.00596	0.00260	0.00295	0.00186
Time in retirement^3	0.00011	−0.00001	0.00008	0.00002	0.00004	−0.00000
	0.00011	0.00013	0.00023	0.00011	0.00012	0.00007
First-stage residual	0.01157	−0.00925	0.00175	−0.00373	0.01715	0.01627
	0.03315	0.03913	0.06888	0.02907	0.02023	0.02171
First-stage residual^2	−0.00107	−0.00195	−0.00304	0.00074	−0.00158*	0.00076
	0.00108	0.00143	0.00237	0.00089	0.00091	0.00082
First-stage residual^3	−0.00021	−0.00038***	−0.00060*	−0.00013	−0.00013	−0.00021*
	0.00015	0.00019	0.00032	0.00014	0.00012	0.00012
F (first stage)	63.09	62.76	62.76	63.56	62.57	64.44
p (endogenous variable)	.078	.02	.026	.992	.053	.246
p (control function)	.31	.052	.083	.637	.139	.307
N (total)	10 740	10 724	10 724	10 743	2991	10 794
N (clustered)	2542	2539	2539	2545	1988	2552
Blue collar						
Time in retirement	0.15491***	0.15084*	0.29830***	0.13248***	0.05327	0.01505
	0.07068	0.09148	0.15112	0.06580	0.06485	0.04510
Time in retirement^2	0.00440*	0.00482	0.00897*	0.00089	0.00440*	0.00121
	0.00261	0.00309	0.00528	0.00277	0.00251	0.00170
Time in retirement^3	−0.00012	−0.00012	−0.00024	−0.00004	−0.00007	−0.00003
	0.00009	0.00011	0.00019	0.00010	0.00009	0.00006
First-stage residual	−0.19070***	−0.18996***	− 0.37007***	−0.15205***	−0.08935	−0.03290
	0.06928	0.08948	0.14808	0.06417	0.06283	0.04442
First-stage residual^2	−0.00007	−0.00019	−0.00017	0.00126	−0.00100	0.00192***
	0.00109	0.00136	0.00228	0.00114	0.00084	0.00078
First-stage residual^3	−0.00013	−0.00013	−0.00025	−0.00003	−0.00022	−0.00015
	0.00016	0.00021	0.00035	0.00017	0.00013	0.00012
F (first stage)	13.06	13.18	13.18	13.41	7.45	13.12
p (endogenous variable)	.01	.025	.012	.174	.008	.799
p (control function)	.019	.098	.037	.07	.037	.037
N (total)	11 209	11 174	11 174	11 050	2837	11 298
N (clustered)	2894	2892	2892	2877	2008	

Separate regressions by worker type using pooled cross sections of all HRS waves between 1996 and 2008, standard errors clustered at the individual level. Stars denote significance at the 10%, 5% and 1% levels. The sample is restricted to men aged 50 to 80 years who were born between 1931 and 1955 and who were working at age 50 years. Further controls include a quadratic age trend, education in five categories, race, ethnicity and wave dummies.

5. DISCUSSION

In line with previous evidence presented in Adam *et al*. (2007), we document negative associations between retirement duration and many measures of later-life cognitive functioning of older American men. These associations are especially strong for retirees who used to work in white-collar occupations but also obtain for former blue-collar workers. Taken at face value, these associations suggest a potential negative relationship between time spent in retirement and cognition in later life.

Yet, robust empirical evidence for a negative gradient of cognitive functioning in retirement needs to account for potential reverse causation, which may stem from differential selection into retirement based on

Figure 4. The effect of retirement duration on cognitive functioning, based on the approach of Newey *et al*. (1999). Note: The graphs are an illustration of the point estimates in Table III, that is, the control function uses a third-order polynomial. Education is set to high school graduate and all other covariates besides age are set to zero. Please refer to Table III for the statistical significance of the retirement duration coefficients

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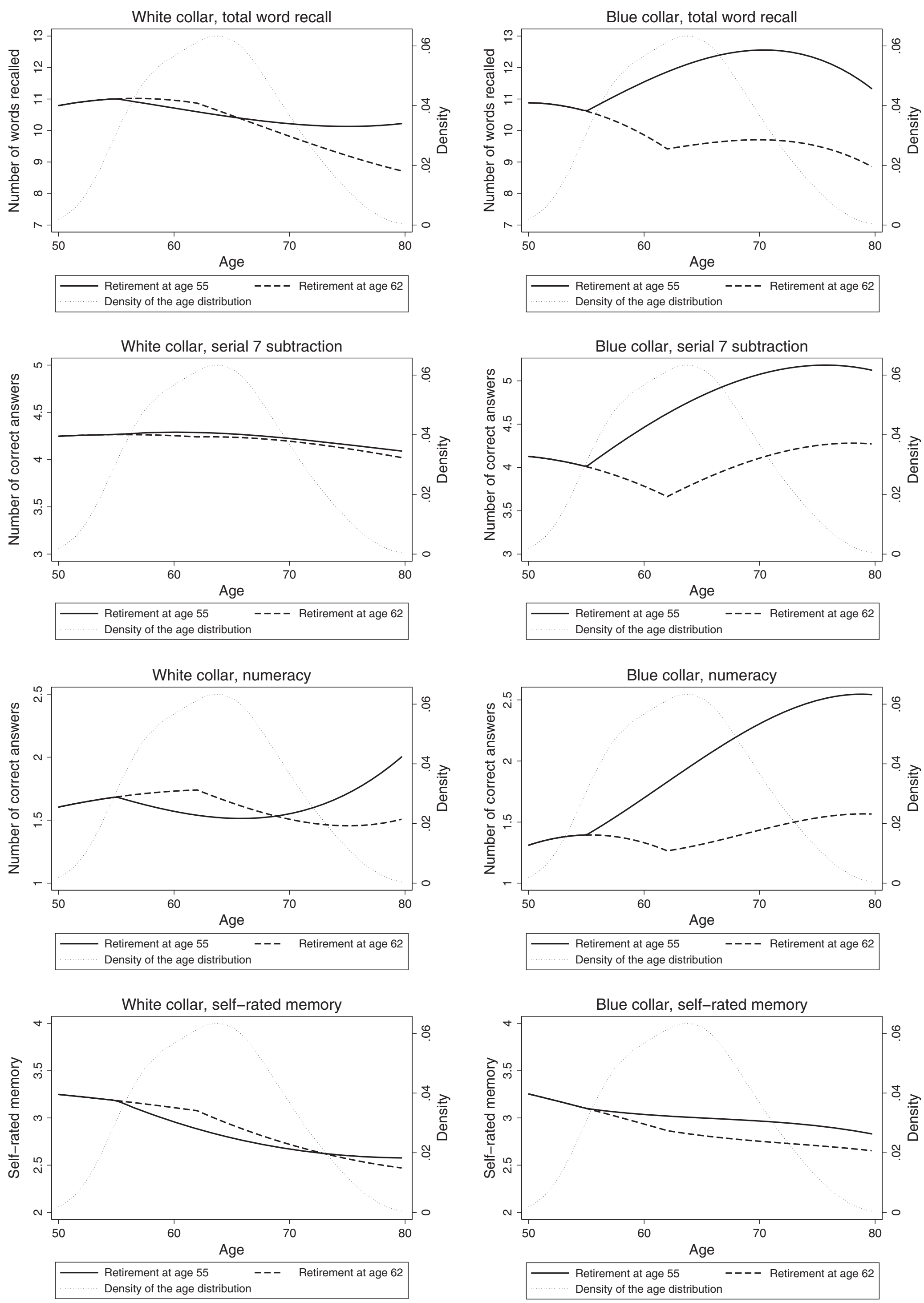

Note: The graphs are an illustration of the point estimates in Table 3, i.e. the control function uses a 3^{rd} order polynomial. Education is set to high school graduate and all other covariates besides age are set to zero. Please refer to Table 3 for the statistical significance of the retirement duration coefficients.

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cognitive ability. To this end, we advanced an instrumental variables strategy that isolates exogenous variation in the length of retirement based on the nondiscriminatory offering of early retirement windows by employers.

Our instrumental variables estimates caution against a causal interpretation of the negative association between retirement duration and cognitive function. Specifically, we find no evidence for such a negative relationship between retirement and later-life cognition once we instrument retirement duration. Although we find no systematic relationship between retirement length and cognition for white-collar workers, our evidence further suggests that retirement may even be beneficial for later-life cognition of blue-collar workers, indicating interesting heterogeneity in the likely effects of retirement for different occupations and work environments. Importantly, despite this mixed evidence, our results may still be consistent with the 'use it or lose it' hypothesis. Specifically, depending on the type of job and alternative activities during retirement, continued intellectual stimulation may be easier to obtain on or off the job. For example, it may be easier for some blue-collar workers to engage in intellectually stimulating activities outside their formal work settings, whereas the change in intellectual stimulation associated with retirement may be smaller for white-collar workers. A more in-depth exploration of the relationship between continued labour supply, activity patterns during retirement and cognitive performance at older ages may further clarify these issues and will be explored in future research.

The finding that much of the negative association between retirement and health is due to the endogeneity of retirement is not new and has been extensively documented in the literature for health aspects other than cognitive function. For example, Charles (2002), Neuman (2008), Bound and Waidmann (2007) and Coe and Lindeboom (2008) also found that the strong and significant negative associations between retirement and various measures of health disappeared in instrumental variables models that account for the endogeneity of retirement. At the same time, our findings are at odds with the evidence presented in Bonsang *et al.* (2010) and Rohwedder and Willis (2010), who also studied the response of later-life cognitive function to retirement using instrumental variables. Potential explanations for the diverging finding are differences in the type of exogenous variation used to identify the model (international differences in retirement ages versus the nondiscriminatory offering of early retirement windows), differences in model specification (analysis of a discontinuous effect of retirement status versus a dose–response relationship based in retirement duration) and differences in the exact samples used for the analysis. Although it appears challenging to reconcile the different findings at this point, we hope that future research based on alternative identifying assumptions and additional data may help to further clarify the relationship between retirement and later-life cognitive function and the relative roles of the work environment versus alternative uses of time during retirement for maintaining high levels of cognition in later life. Based on the evidence presented here, extended work lives are unlikely to produce sizeable gains in later-life cognitive function, especially for blue-collar workers.

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