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ABSTRACT

The aim of this paper was to use a parametric stochastic frontier approach (coming from the economic literature) to explore the impact of the concept of activity (taken in a broad sense: i.e., including both professional and non-professional activities) on the constitution and the care of cognitive reserve among the European population aged 50 and up. For this purpose, we use individual data collected during the first wave of SHARE (Survey on Health, Ageing and Retirement in Europe) performed in 2004. The advantages of this survey were (1) it included a large population (n = 18,623) geographically distributed throughout Europe; and (2) it simultaneously analyzed several dimensions (physical and mental health, mobility, occupational activities, socioeconomic status, etc.). Our results confirm the positive impact of occupational activities on the cognitive functioning of elderly people. These results are discussed in terms of the prevention of cognitive aging and Alzheimer's disease, and more particularly of retirement policy issues.

1. INTRODUCTION

Over the past 25 years, a great deal of evidence has accumulated indicating that advancing age is accompanied by a systematic decline in performance on a wide variety of cognitive tasks, both in the laboratory and in everyday life (for a recent review, see Dixon, Bäckman, & Nilsson, 2004). For example, it is now widely accepted that age influences a number of general factors such as processing speed (Andrés & Van der Linden, 2000; Fisk & Warr, 1996; Salthouse, 1996), inhibition (Fisk & Sharp, 2004; Zacks & Hasher, 1994), and working memory (Van der Linden, Brédart, & Beerten, 1994), which in turn influence other cognitive functions such as episodic memory and language (Kwong See & Ryan, 1995; Park et al., 1996; Van der Linden et al., 1999).

Moreover, this decline in cognitive function with age is associated with structural changes in the brain (Raz, 2004). Therefore, even early in the aging process, global changes such as cerebral atrophy, ventricular enlargement, and hippocampal atrophy may be evident in some, but not all, individuals (Coffey et al., 1992; Meyer et al., 1999). The underlying pathological basis of cognitive decline must be loss of synapses, neurons, neurochemical inputs and neuronal networks (Hof, Cox, & Morrison, 1990; Honig & Rosenberg, 2000). However, although this cognitive decline with age has been defined (from both a functional and a neurological point of view) and may impair quality of life (Schaie, 1989, 1994), decline is not inevitable. Nature provides clear examples of elderly people who maintain their cognitive vitality, even in extreme old age (Berkman et al., 1993). Moreover, the idea that cognitive decline is inevitable is negated by the observation of centenarians who maintain a good intellectual level (Silver et al., 1998) and avoid dementia (Perls, 2004 a, b). Based on these findings, Fillit et al. (2002) suggested that individuals have varying degrees of "functional reserve" in their brains. Persons with a large functional reserve may have an increased ability to keep learning and adapting despite age-related changes (Baltes & Baltes, 1990).

This view has been formally developed by Stern (2002, 2003) and Scarmeas and Stern (2003) as the concept of "cognitive reserve." For Scarmeas and Stern (2003), cognitive reserve relates to the fact that innate intelligence or aspects of life experience such as educational or occupational attainments provide a reserve, represented by a set of skills or repertoires that allows some people to prevent the cognitive decline associated with normal aging or Alzheimer's disease. However, the processes leading up to the formation of this reserve remain relatively unclear. Two hypotheses have been put forward to explain the neurophysiological substrate of cognitive reserve (Scarmeas et al., 2003; Stern, 2002): the passive and active hypotheses. The passive hypothesis suggests that a larger cognitive reserve increases synaptic density and the number of neurons, resulting in an increased number of remaining available neurons when some them are altered by a pathological process. The active hypothesis suggests that cognitive reserve may take the form of using brain networks or cognitive paradigms that are more efficient or flexible, and thus less susceptible to disruption (Stern, 2003).

From a more functional point of view, recent studies have tried to identify parameters contributing to the development of a cognitive reserve. For example, education is widely recognized as having a significant impact on cognitive functioning, and is thought to support the cognitive reserve capacity (e.g., Le Carret et al., 2003). Some studies confirming this idea have suggested that people with a high educational level have a lower risk of developing dementia than people with a low educational level (Letenneur et al., 1999; Stern et al., 1994). Similarly, poorer linguistic ability in early life (Snowdon et al., 1996) and lower mental ability scores in childhood (Whalley et al., 2000) appear to be strong predictors of poor cognitive function and dementia in later life.

Factors other than IQ and education may also build up the reserve and influence the cognitive functioning of elderly people. Thus, several studies have suggested that differential susceptibility to age-related cognitive decline or to Alzheimer's disease is related to variables such as occupation (Evans et al., 1993; Letenneur, Commenges, Dartigues, & Barberger-Gateau, 1994; Schooler, Mulatu, & Oates, 1999; Stern et al., 1994), professional or leisure activities (Capurso et al., 2000; Scarmeas, Levy, Tang, Manly, & Stern, 2001; Wilson et al., 2002), and lifestyle (for a review, see Fillit et al., 2002; Fratiglioni, Paillard-Borg, & Winblad, 2004); all of these variables have therefore been considered to be associated with cognitive reserve.

For example, different studies have reported that there is a positive association between participation in intellectual, social and physical activities and performance on a wide range of cognitive tasks. In a longitudinal study over a six-year interval, Newson and Kemps (2005) obtained results suggesting that engaging in general lifestyle activities may promote successful cognitive aging (see also Hultsch, Hertzog, Small, & Dixon, 1999). Conversely, low-complexity occupations have been identified as risk factors for age-related cognitive decline (Capurso et al., 2000), and social isolation seems to accelerate this decline (Berkman, Glass, Brissette, & Seeman, 2000). Some other studies have focused on the effect of profession. Indeed, work can be seen as a rich activity contributing to the development of cognitive reserve. In a recent study, Schooler et al. (1999) showed that complex intellectual work increases the cognitive functioning of older workers. Work may also increase social interactions and a sense of self-efficacy, both of which are considered as important factors contributing to the maintenance of the cognitive reserve (Rowe & Kahn, 1998).

Taken together, these findings concerning cognitive reserve may have important implications for the structure of retirement in old age. Indeed, keeping up occupational activities (whether professional or otherwise) as long as possible in life plays a non-negligible role in maintaining cognitive reserve and vitality. Nevertheless, over the last two decades, retirement decisions have mainly been driven by institutions such as Social Security regulations that promote early retirement through financial incentives (Gruber & Wise, 1999, 2004) and tightly restrict professional activities after retirement. Therefore, in most European countries, an increasing number of workers leave the labor force before they reach 60 years of age, and even before age 55.

This background constitutes the starting point of this study, which aims to further explore the relationship between cognitive performances and occupational activities, defined in a broad sense (i.e., including professional, leisure, physical, and other activities), while simultaneously taking into account the influence of age and educational attainment, as well as factors related to social and economic status. For this purpose, we used individual data collected in the first wave of the Survey on Health, Ageing and Retirement in Europe (SHARE; Börsch-Supan et al., 2005), which includes modules covering most aspects of the European population aged 50 and over, including several cognitive tests.[1] The key strength of our study compared to the global literature in the field is that it has a very large population (around 18,000 people) and provides an international framework (ten countries) in which activity (professional) rates among people aged 50 and over vary dramatically as a consequence of national institutions and regulations (Blöndal & Scarpeta, 1998). Indeed, most studies include at most about two or three thousand participants limited to one region or one country with its specific policies in terms of employment. In addition, contrary to the majority of studies, which focus on only a few variables, the survey allows us to take into account a large number of dimensions simultaneously.

Moreover, for estimation purposes, we use a statistical approach coming from the economic literature, the parametric stochastic frontier approach (SFA), which was introduced by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). This approach, which was originally developed to measure firms' performance in an output-input setting, has been applied to measure individual performance in other fields of human behavior in which measurable outcomes are driven by observable factors.[2] In this study, an SFA frontier is estimated assuming that an individual's cognitive functions, represented by cognitive test scores, are potentially determined by age and education (in other words, age and years of education are the main variables entering in the analysis as explanatory factors of individuals' cognitive functions).[3]

Figure 1 illustrates these concepts in a simple output-input setting. Assuming that age is the driving factor (the input) and that the cognitive test score is the output, frontier analysis allows us to estimate the parametric function that envelopes all the observed individual performances. In this way, the ratio $\overline{AB}/\overline{AC}$ measures the distance to the boundary line that indicates poor individual cognitive reserve performance with respect to the "best practice," defined by the best performances in the sample.

INSERT FIGURE 1

In practice, SFA corresponds to a composed error term model estimated using econometric tools. On the one hand, we assume that a normally and symmetrically distributed error term catches random noise and, on the other hand, that an asymmetrically (truncated) normally distributed error term represents individuals' distance to the frontier, also known as technical inefficiency in the literature. The proposed model allows us to simultaneously test the effect of other factors that may potentially drive cognitive performance, with a particular interest in the impact of occupational activities and socioeconomic status on the constitution of individuals' cognitive reserves. More concretely, several variables are included in the analysis, but a distinction is made between control variables and factors explaining individual distances to the frontier.

2. METHODOLOGY

2.1. Sample

SHARE is a pan-European interdisciplinary panel data set including more than 22,000 persons aged 50 and over, and coming from 10 European countries ranging from Scandinavia to the Mediterranean.[4] The survey brings together many disciplines, including demography, economics, epidemiology, psychology, sociology and statistics. The data were collected using a computer-assisted personal interviewing (CAPI) program, supplemented by a self-completed paper-and-pencil questionnaire. For more details on the sampling procedure, questionnaire contents and fieldwork methodology, readers should refer to Börsch-Supan et al. (2005).

We applied certain selection criteria to the original sample. First, participants were excluded from the analysis if information from the survey showed that they had a history of psychiatric and/or cerebral pathology that could have an impact on their cognitive functions. More concretely, the exclusion criteria were (1) had sequelae of a cerebral vascular accident (827 participants), (2) had Parkinson's disease (137 participants) or brain cancer (26 participants), (3) were taking medication for a depression (1,076 participants), and (4) had been hospitalized in a psychiatric institution (455 participants). Missing or unreliable data for one of the variables retained in the analysis was another criterion for exclusion. In the end, of the initial 22,777 participants, 18,623 were selected for our analysis.

2.2. Cognitive tests

In SHARE, cognitive functioning was measured using short and simple tests of orientation, memory (learning and recall of a list of ten words), verbal fluency (a test of executive functioning) and numeracy (arithmetical calculations). Participants also had to subjectively rate their reading and writing skills. However, for the subsequent analysis, we decided to compute a global measure of cognitive functioning by focusing on two key cognitive domains: episodic memory (with the word list recall task) and executive functioning (with the semantic fluency task). The rationale underlying this choice was twofold: from a psychometric point of view, we selected sensitive cognitive scores that are not affected by ceiling or floor effects. From a more theoretical point of view, it is widely recognized that episodic memory and executive functioning are two cognitive domains that are particularly sensitive to cognitive aging. In fact, some authors consider that executive functions and episodic memory are the first cognitive functions to decline with age.[5]

The episodic memory task integrated in the survey was a test of verbal learning and recall, where the participants were required to learn a list of ten common words. At encoding, the words were presented automatically on a computer, and respondents were asked to read each word out loud. Then, immediate and delayed recall tasks were carried out. Immediate recall followed the encoding phase directly, while a short waiting period (about five minutes during which verbal fluency and numeracy questions were asked) was inserted before the delayed recall. During immediate and delayed recall, participants were asked to recall the ten words in any order. The memory score for this task was calculated by adding the number of target words recalled at the immediate recall phase to the number of target words recalled at the delayed recall phase (score ranging from 0 to 20).

Executive functioning was assessed using a fluency task, which is a test of how quickly participants can think of words from a particular category; in this case, they had to name as many different animals as possible in one minute. The timing of this test was controlled by computer. Performance is defined as the total number of different animal names given by the participant. Repetitions and redundancies (e.g., *white cow, brown cow*) were not counted, and nor were proper nouns (e.g., *Spot, Bambi*). However, different breeds (e.g., *dog, terrier, poodle*) and different gender- or generation-specific names (e.g., *bull, cow, steer, heifer, calf*) were counted as correct.

From the total memory and fluency scores, we created a general cognitive score by averaging the standardized memory and fluency scores. In this way, we obtained one value representing a more global and more sensitive assessment of cognitive functioning to be used in the subsequent analysis.

2.3. Statistics: The stochastic frontier approach and description of variables included for the analysis

In order to identify the main factors driving individuals' cognitive functions, we propose the following stochastic frontier model: [$r_i = f(X_i, D_i) + \varepsilon_i$] *(1)*; where r_i is the cognitive test score of individual *i*, X_i is a vector containing the two main determinants of cognitive functions (i.e., age and education), along with a vector, D_i, of control variables and ε_i is a composed error term of the form: [$\varepsilon_i = v_i - u_i$] *(2)*; where the v_i term is assumed to be a two-sided random (stochastic) disturbance designated to account for statistical noise and distributed iid $N(0, \sigma_v^2)$, and u_i a random term assumed to be independently distributed as truncations at zero of the $N(\varphi_i, \sigma_u^2)$ distribution.[6]

The u_i term has a key interpretation in the frontier analysis literature: it corresponds to the distance to the best practice represented by the stochastic frontier $[f(X_i, D_i) + v_i]$, which is the segment $\overline{B}\overline{C}$ in Figure 1. In the case analyzed here, the best practice would correspond to the maximum cognitive functions each individual is expected to achieve given his/her age and years of education. In other words, the estimated frontier must be seen as an extended benchmark setting, corresponding in this case to all the individuals who participated in the first wave of SHARE.

We chose a translogarithmic specification for the relation between the cognitive functions and the age and education explanatory factors in equation (1). The proposed function corresponds to a second-order approximation on these two variables aside from the $d_{m,i}$ *(m= 1, 2…,M)* control variables. The estimated function is as follows:

$$ln\, r_i = \beta_0 + \beta_1 \, ln\, x_{1,i} + \beta_2 \, ln\, x_{2,i} + 0.5\beta_3 (ln\, x_{1,i})^2 + 0.5\beta_4 (ln\, x_{2,i})^2 \beta_5 (ln\, x_{1,i})(ln\, x_{2,i})$$

$+ \sum_{m=1}^{M} \lambda_m d_{m,i} + v_i - u_i$ *(3)*, where β_k (*k* = 0,1,…,5) and λ_m (*m* = 1,2,…,M) are parameters to be estimated.[7] The main advantage of the translog specification is its great flexibility. Other than the logarithmic transformation of variables, second-order terms allow for non-linear relations and interactions among age and education.

Moreover, we introduce here the SFA model specification proposed by Battese and Coelli (1995) that allows one to simultaneously test the influence of other individual characteristics, denoted by $z_{j,i}$ variables (j=1,…,J), on cognitive performance u_i, through the truncation parameter φ_i, as follows: [$\varphi_i = \delta_0 + \sum_{j=1}^{J} \delta_j z_{j,i}$] *(4)*. δ_0 and δ_j are parameters to be estimated jointly with the β_k and λ_m parameters in equation (3) using a maximum likelihood optimization algorithm.[8] In addition, two other parameters are simultaneously estimated: $\sigma_\varepsilon^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / \sigma_\varepsilon^2$, with the last term corresponding to the share of inefficiency on total error term variance.

2.4. Survey variables included in the analysis[9]

As mentioned in the previous subsection, the two main variables assumed to determine cognitive performance are *age* (x_1) and *years of education* (x_2). Years of education are constructed for the different countries according to the 1997 *International Standard Classification of Education* (ISCED-97) (OECD, 1999).

Next, we selected from among the SHARE variables several indicators that may potentially explain poor individual cognitive performance (these indicators correspond to z_j variables). Different categories can be distinguished among them.

First, occupational activities are represented by three variables: z_1 is a binary variable indicating that the person is engaged in a *professional activity*, more specifically that she/he is employed or self-employed. z_2 is a discrete variable corresponding to the number (1 to 7) of *non-professional activities* engaged in during the last month, including did voluntary or charity work, cared for a sick or disabled adult; provided help to family, friends or neighbors; attended an educational or training course; went to a sports, social or other kind of club; or took part in a religious, or a political or community-related organization. z_3 is the *frequency* (1 to 3 where 1 corresponds to *less than weekly,* 2 corresponds to *almost every week*, and 3 corresponds to *almost daily*) at which these *non-professional activities* were exercised.

Second, physical activities are summarized by three variables: z_4 indicates the *frequency* (1 to 4) *of vigorous physical activity*. z_5 is the *frequency* (1 to 4) *of physical activities* that require a low or *moderate* level of energy such as gardening, cleaning the car, or going for a walk. Finally, z_6 is a dummy variable indicating whether the individual suffers from at least one *mobility limitation* in doing everyday activities such as walking 100 meters, sitting for about two hours, climbing several flights of stairs without resting, etc. (the full list contains 10 activities).

Third, a binary variable, z_7, is built on the basis of the *EURO-D scale of depression,* which takes into account depression symptoms such as pessimism, suicidal tendencies, guilt, sleeping disorders, interest, irritability, and so on (Prince et al., 1999a, 1999b). As indicated above, persons who suffered or had suffered in the past from severe neurological and psychiatric diseases were not retained in the analysis. A binary variable for *single-person households*, z_8, is expected to capture the effect of social isolation on cognitive reserve preservation. We also include a series of dummy variables, z_9, z_{10} and z_{11}, corresponding to the individual's position in *wealth distribution*: second, third and fourth quartiles, respectively (first quartile as reference group). Finally, the *number of living children* and its square, z_{12} and z_{13}, are included in the model. These variables are proxies for individuals' socioeconomic characteristics and must be considered as representative of their lifestyle.

Moreover, several dummy variables are integrated into the model as controls. First, we include country dummies (d_1 to d_9). They are expected to catch differences across countries that, particularly in the case of cognitive tests, may be the result of language and cultural differences. Other controls are dummy variables corresponding to *women* (d_{10}) and to individuals *born outside the country* (d_{11}). Differences in cognitive test scores due to sex and origin cannot be considered to be representative of cognitive reserve differences but are the consequence of particular life circumstances. A dummy variable indicates that the person suffers from at least two *chronic diseases* (d_{12}) among a list of 15 diseases including high blood pressure or cholesterol, diabetes, asthma, osteoporosis, arthritis, etc. Finally, we include three dummy variables (d_{13} to d_{15}) corresponding to the respondent's observed willingness to answer, as assessed by the interviewer (the reference group corresponds to those who were very willing to answer).

3. RESULTS

Table 1 presents the mean fluency, memory and global assessment scores by country, age group and years of education. Significant differences can be observed among countries. Scores tend to be higher in northern countries (Denmark and Sweden) and lower in southern countries (Greece, Italy and Spain). However, age and educational level are, as expected, two main factors driving cognitive performance.

INSERT TABLE 1

Table 2 presents the results of three stochastic frontier estimations corresponding to alternative cognitive test indicators. The first and second columns have as dependent variables the fluency and memory tests and the third column the global assessment indicator corresponding to the average for the standardized fluency and memory tests (see Section 2.2). As expected, the third column parameters are, in most cases and for nearly all variables, contained in the range of those estimated for the two first models.

INSERT TABLE 2

Not surprisingly, the age and education coefficients have the expected signs, negative for increasing age and positive for increasing years of education, for both the first- and the second-order variables. Moreover, in all cases these coefficients are highly significant, with the only exception being the age and education cross-effect under the fluency model. The results are slightly different between models; in particular, memory test scores seem to be more negatively affected by aging, and less sensitive to increasing education.

In most cases, the control variables present significant parameters indicating that, as expected, they are important. However, we will not pay further attention to them, other than to say that if we had not controlled for them, the other parameters would be severely biased.

Summing up, we consider that the cognitive reserve frontier estimated here is statistically well defined, as a function of age and years of education, and can be considered as a good benchmark with respect to which individual cognitive performance can be assessed.

Therefore, most of our attention will focus on the parameters presented at the bottom of Table 2. These correspond to the z_j variables considered as potential factors affecting individuals' poor performance or, in other words, distances to the estimated frontier. Note that negative amounts indicate less distance to the frontier or better cognitive functions, while positive signs indicate worse cognitive performance.

All the δ_j parameters are statistically significant and their signs correspond to our expectations, with the sole exception of δ_6, which corresponds to mobility limitations, in the fluency model. Clearly, all types of occupational activities, professional or otherwise, have a positive effect on the constitution of a cognitive reserve, as does the frequency with which non-professional activities are engaged in. In addition, vigorous or moderate physical activity appears to favor cognitive performance.

The case of mobility limitations is less clear. The estimated parameters indicate that fluency and memory are affected differently: fluency positively and memory negatively. This controversial result can probably be seen as confirmation that these cognitive tests tap into different skills. A similar conclusion can be drawn from the coefficients associated with the depression scale (EURO-D). In both cases, the effect of depression on cognitive function inefficiency is positive, but it is higher for the memory test (1.210) than for the fluency test (0.219).

Moreover, the results indicate that living in a single-person household has negative effects on the cognitive measures. This confirms the assumption that social isolation is bad for the preservation of cognitive reserve. Moreover, if an individual belongs to the richest wealth quartiles of the society, which we interpret as indicators of "lifestyle," her/his cognitive performance is better, as indicated by the negative parameters associated with the second, third and fourth wealth distribution quartiles. Finally, the impact of the number of children on cognitive reserve is U-shaped: the minimum inefficiency is reached when the number of children is 4, 2, and 3 for fluency, memory and global assessment scores, respectively.

In order to illustrate the effect of the *z* variables on cognitive capacity, we present in Table 3 the results of a simulation performed on the base of the 60-year-old individuals interviewed in the first wave of SHARE. The outcome of this simulation is estimated in terms of cognitive aging, in other words, in years of cognitive decline. These estimates were calculated in two steps using the parameters presented in Table 2. In the first step, we calculated for each individual his/her cognitive performance change, corresponding to a change in a specific *z* characteristic, all other characteristics being equal. In the second step, we computed the equivalent change in cognitive aging due to the *z* factors. For this purpose, we assume that the slope of the cognitive frontier is at 60 years of age, and for a given education level, remains invariant (see Figure 1).

INSERT TABLE 3

More concretely, this table quantifies the positive impact on cognitive functioning of variables directly associated with the notion of activities. For example, a 60-year-old individual delays his/her cognitive aging by 1.91 years if she/he continues to work, and 1.96 years if she/he performs one activity almost daily. Our analyses also show that the impact of non-professional activities varies as a function of the number and frequency of these activities. Thus, the estimated benefit in terms of years of cognitive aging for a 60-year-old individual changes: (1) from 1.40 to 1.96 years when one activity is performed daily instead of less than weekly; and, even more strikingly, (2) from 1.96 to 3.03 years when two activities are performed almost daily instead of one activity. However, the involvement of other variables (such as physical activity, mobility limitation, etc.) is weaker (i.e., less than one year of cognitive aging delay), except for depression: individuals without depressive symptoms defer their cognitive decline by 1.28 years.

4. DISCUSSION

In this paper, we propose the use of a parametric stochastic frontier approach (Aigner et al., 1977; Meeusen & Van den Broeck, 1977) to study the impact of potential factors (and more specifically of occupational activities, defined in a broad sense) on cognitive functions among the European population aged 50 and over. For this purpose, we used individual data collected during the first wave of SHARE (Börsch-Supan et al., 2005), performed in 2004. Compared to the majority of studies in the cognitive reserve literature, the advantage of this survey is that it includes a large population distributed geographically throughout Europe. Moreover, the multidisciplinary nature of SHARE allows us to simultaneously analyze several dimensions of participants' lives: physical and mental health, mobility, occupational activities, and socioeconomic status, in addition to cognitive performances, whereas most of the studies focus on only a few of these parameters.

As expected, our results show that cognitive performance is mainly driven by age (negatively, which refers to cognitive aging; for a review, see Buckner, 2004) and by years of education (positively). This second result is clearly in accordance with studies suggesting that education is one of the major factors contributing to the development of the cognitive reserve (Le Carret et al., 2003, 2005; Liao et al., 2005; Scarmeas, Albert, Manly, & Stern, 2006). Taking into account these effects of age and education, we use the SFA (Kumbhakar & Knox Lovell, 2002) to create a "frontier" corresponding to the optimum cognitive functioning that each individual is expected to achieve given his/her age and education level. This model then allows us to test simultaneously the effect of different factors (associated directly or indirectly with the notion of "general activity") that potentially drive cognitive performance and therefore contribute to the formation of individuals' cognitive reserve. Our results show that, after controlling the side effects of some factors not associated with the notion of "activity" (such as sex, being born inside or outside the country, and suffering from a chronic disease), all types of occupational activities (professional or not) clearly have a positive effect on cognitive reserve constitution. More specifically, individuals who continue to work or who engage in a non-professional activity have better cognitive performance. So a 60-year-old individual who continues to work delays his/her cognitive aging by 1.91 years. In the same vein, this individual delays cognitive aging by 1.96 years if he/she performs one activity almost daily.

Globally, these results confirm similar observations such as Menec's six-year longitudinal study (Menec, 2003) that show a relation between everyday activities and successful aging. Our data did not allow us to distinguish between cognitively stimulating (or non-stimulating) professional or occupational activities. However, in light of studies showing that the level of complexity of an occupation positively influences the level of intellectual functioning (e.g., Schooler et al., 1999, for professional activities; Hultsch et al., 1999, for social and new-information-processing activities), the protective effect of professional activities on cognitive aging should be all the greater the more these activities tend to mobilize cognitive resources.

Moreover, our analyses show that this positive effect is not restricted to professional activities but is also observed for non-professional activities, depending on their number and frequency. Recollect that our analyses show that the estimated benefit in terms of years of cognitive aging for a 60-year-old individual changes from 1.40 to 1.96 years when one activity is performed daily instead of less than weekly, and from 1.96 to 3.03 years when two activities are performed almost daily instead of one activity. The contribution of non-professional activities can be considered as equivalent to (or even slightly greater than) the impact of professional activities. This can be explained by the fact that non-professional occupational activities are mostly voluntary while professional activity are imposed for some people, and this constraint may generate depression and anxiety (factors that have negative effects on cognitive functioning). In that sense, it should be remembered that some studies show that retirement can lead to a reduction in depressive symptomatology (Gall, Evans, & Howard, 1997; Reitzes, Mutran, & Fernandez, 1996).

In addition to the effect of professional or non-professional activities, a significant protective effect of the practice of physical activities is highlighted in our study, and this applies to both strenuous and moderate physical activity. These results are consistent with the literature in the field (for similar conclusions about the role of physical activities, see Albert et al., 1995, for strenuous physical activity; Carmelli, Swan, LaRue, & Eslinger, 1997, for low-level physical activity). In a recent meta-analysis including studies conducted from 1966 through 2001, Colcombe and Kramer (2003) showed that, aggregating across studies, fitness training has a positive effect on the cognitive functions of older people, and thus on the development and maintenance of a cognitive reserve. Our data, however, show that this significant effect of physical activity is slighter, and in any case weaker, than the effects of professional and non-professional activities: a 60-year-old individual acquires only 0.68 years of cognitive aging benefits as a result of physical activities. This slighter effect of physical activities may be what explains our inconsistent results concerning the mobility limitation variable (with the observation of a lower fluency score but a higher memory score for people with mobility limitations compared to people without such limitations). Nevertheless, this variable is suspected to have a negative impact on the possibility of both physical activities and non-physical activities.

Finally, our results show that (1) belonging to the less wealthy quartile of the population, and (2) living alone (variables indirectly associated with the notion of activity) have a negative impact on the preservation of cognitive reserve; the latter result is consistent with studies showing that social isolation or social disengagement is a risk factor for cognitive impairment among elderly persons (Bassuk, Glass, & Berkman, 1999; for a recent review of this question, see also Fratiglioni et al., 2004).

Although our results clearly confirm the relationship between activity and cognitive functioning, the important and thorny problem of the "causal relation," which is not always addressed in studies, remains to be considered. Indeed, the question is whether the decrease in cognitive functioning is the consequence of the reduction in activity or vice versa. As suggested by Schooler and Mulatu (2001), there is probably a reciprocal relation between cognitive functioning and cognitive stimulation. The impact of cognitive deficits on daily life activities has been clearly demonstrated at both a clinical and an empirical level. However, the effect of activity on cognitive functioning is less evident. Our data do not allow us to respond directly to this question. Nevertheless, two arguments from the literature can be advanced in favor of the second hypothesis (see Fratiglioni et al., 2004). The first can be found in the literature on animal studies. For example, several experimental studies in rats suggest that animals bred in enriched environments present a greater dendritic density in the hippocampus and an increased number of glial cells than animals bred in standard conditions (Rosenzweig & Bennett, 1972). In addition, Winocur (1998) showed more recently that these brain modifications affect the cognitive abilities of old rats (i.e., rats bred in an enriched environment performed better on a memory test than those bred in a standard environment; see also Pham, Winblad, Granholm, & Mohammed, 2002). A second argument can be found in studies showing (1) the presence of brain plasticity even in adults (Nudo, 1996), and (2) that the stimulation of the environment can modulate this brain plasticity (for a review, see Döbrössy & Dunnett, 2001; Robertson & Murre, 1999). The Maguire et al. (2000) study is a well-known example, examining taxi drivers in London who had developed an intensive practice of orientation in the city. The authors showed that these taxi drivers had significantly larger posterior hippocampi than control subjects, and above all, that the amount of occupational experience correlated with the size of the hippocampus.

Taking into account the fact that activities (professional or otherwise) in old age have a direct impact on the formation and preservation of the cognitive reserve, the data from our study and from other work in the field have several implications for the prevention of cognitive aging and Alzheimer's disease. Very concretely, these data showing the positive impact of professional activity suggest that if an individual would like to continue with his/her professional activities, and insofar as there is no contraindication (e.g., health risk or danger for others as with a bus or truck driver), there is no reason to prevent that person from doing his/her job but, in fact, every reason to promote this. On the other hand, in light of studies showing the increased risk of depression in people who continue to work (in all likelihood, because they are forced to continue), there is no reason to prevent an elderly individual from stopping his/her professional activities insofar as (1) this is his/her choice, and (2) this is institutionally possible. However, in this case, it appears necessary for our institutions to undertake a wide-ranging reflection process on how to develop and propose constructive activities for retired people (e.g., voluntary participation in charitable organizations, leisure activities, etc.), and also about how to promote participation in these activities from the perspective of maintenance of cognitive vitality and prevention of cognitive aging and dementia.

In conclusion, our study confirms (by means of a promising statistical method from the economic literature: SFA) the significant impact of professional and other activities on the cognitive functioning of elderly people. Moreover, we must emphasize that our data were obtained in a cross-sectional, instantaneous framework. SHARE is a longitudinal project and the same respondents will be interviewed again at the end of 2006. When the data from the second wave of SHARE become available, a more complete study will be possible. More specifically, particular attention will be paid to the problem of causality by directly relating retirement decisions to individuals' cognitive performance.

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FOOTNOTES

1 For a complete description of SHARE, see the dedicated website: www.share-project.org. This paper uses data from the early Release 1 of SHARE 2004. This release is preliminary and may contain errors that will be corrected in later releases. The SHARE data collection has been primarily funded by the European Commission through the 5th framework programme (project QLK6-CT-2001-00360 in the thematic programme Quality of Life). Additional funding came from the US National Institute on Aging (U01 AG09740-13S2, P01 AG005842, P01 AG08291, P30 AG12815, Y1-AG-4553-01 and OGHA 04-064). Data collection in Austria (through the Austrian Science Fund, FWF), Belgium (through the Belgian Science Policy Office) and Switzerland (through BBW/OFES/UFES) was nationally funded. The SHARE data set is introduced in Börsch-Supan et al. (2005); methodological details are contained in Börsch-Supan and Jürges (2005).

2 See, for instance, its application to households' wellbeing in Lovell, Richardson, Travers, and Wood (1994) and to students' performance in Perelman and Santin (2005).

3 For a complete survey, see Kumbhakar and Knox Lovell (2002) and Coelli, Rao, O'Donnell, and Battese (2005).

4 Release 1 of SHARE data includes 10 countries: Austria (AU), Denmark (DK), France (FR), Germany (DE), Greece (GR), Italy (IT), Netherlands (NL), Spain (ES), Sweden (SE) and Switzerland (CH).

5 For executive functioning, see, for instance, Souchay, Isingrini, and Espagnet (2000), and for episodic memory, Anderson and Craik (2000) and Prull, Gabrieli, and Bunge (2000).

6 Both terms are independently distributed $(\sigma_{uv} = 0)$.

7 Note that the random terms v_i and u_i are added in equation (3), as in equation (1), independently of the logarithmic transformation. Therefore, u_i corresponds to the performance ratio $(0 \le u_i \le 1)$.

8 For estimations, we used FRONTIER Version 4.1, a program developed by Coelli (1994).

9 More detailed information on the SHARE questionnaire and data are available at www.share-project.org.

TABLES

Table 1

Cognitive performance by country, age group and education (Mean scores)

	Observations	Fluency	Memory	Global assessment
Country				
AU	1687	21.7	9.0	0.26
CH	843	20.1	9.4	0.21
DE	2565	20.3	9.3	0.21
DK	1337	22.0	9.7	0.37
ES	1888	14.8	6.0	–0.64
FR	1282	19.7	7.9	–0.04
GR	1756	14.6	8.0	–0.37
IT	2137	14.2	6.7	–0.58
NL	2350	19.9	9.2	0.16
SE	2554	23.4	9.4	0.44
Age group				
50–54	3387	21.2	9.9	0.35
55–59	3457	20.6	9.4	0.24
60–64	3277	20.0	8.9	0.13
65–69	2914	19.0	8.3	–0.03
70–74	2281	17.3	7.3	–0.28
75–79	1640	16.3	6.9	–0.42
80–84	931	15.2	6.0	–0.62
85–99	512	13.5	5.0	–0.88
Years of education				
0–2	1046	12.3	5.0	–0.96
3–5	2313	14.5	6.2	–0.64
6–9	4111	17.6	7.7	–0.20
10–12	4489	20.2	9.1	0.17
13–15	4345	21.8	9.6	0.36
16+	2095	22.1	10.3	0.47
Total	18399	19.1	8.5	0.00

Table 2
Stochastic frontier parameters

Variables and coefficients		Fluency		Memory		Global assessment	
		Parameter	(t-ratio)	Parameter	(t-ratio)	Parameter	(t-ratio)
Age and years of education							
Intercept [a]	β_0	0.394*	(41.2)	0.439*	(46.6)	0.400*	(46.6)
ln x_1 (Age)	β_1	–0.362*	(–19.4)	–0.505*	(–27.2)	–0.477*	(–28.8)
ln x_2 (Years of education)	β_2	0.218*	(28.7)	0.208*	(27.6)	0.239*	(36.2)
$(\ln x_1)^2$	β_3	–0.980*	(–9.5)	–1.157*	(–11.1)	–1.175*	(–12.9)
$(\ln x_2)^2$	β_4	0.059*	(14.6)	0.055*	(13.0)	0.063*	(17.6)
$(\ln x_1)(\ln x_2)$	β_5	–0.008	(–0.3)	0.134*	(4.5)	0.090*	(3.5)
Control variables (dummies)							
d_1 (CH)	λ_6	–0.100*	(–7.8)	–0.003	(–0.2)	–0.066*	(–5.8)
d_2 (DE)	λ_7	–0.091*	(–9.2)	–0.026	(–2.5)	–0.071*	(–7.9)
d_3 (DK)	λ_8	–0.046*	(–4.1)	–0.011	(–1.0)	–0.035*	(–3.5)
d_{64}(ES)	λ_9	–0.218*	(–19.1)	–0.194*	(–16.5)	–0.241*	(–23.6)
d_{75}(FR)	λ_{10}	–0.012	(–1.0)	–0.063*	(–5.2)	–0.042*	(–4.0)
d_{86}(GR)	λ_{11}	–0.359*	(–32.9)	–0.089*	(–8.0)	–0.246*	(–25.5)
d_{97}(IT)	λ_{12}	–0.295*	(–27.4)	–0.167*	(–15.0)	–0.270*	(–27.8)
d_8 (NL)	λ_{13}	–0.115*	(–11.7)	–0.023	(–2.2)	–0.085*	(–9.7)
d_9 (SE)	λ_{14}	0.068*	(7.0)	0.013	(1.3)	0.043*	(4.9)
d_{10} (Women)	λ_{15}	–0.006	(–1.4)	0.082*	(17.2)	0.043*	(10.8)
d_{11} (Born outside the country)	λ_{16}	–0.106*	(–12.0)	–0.053*	(–5.9)	–0.085*	(–11.0)
d_{12} (Chronic disease)	λ_{19}	0.001	(0.3)	–0.002	(–0.3)	0.001	(0.3)
d_{13} (High willingness to answer)	λ_{20}	–0.050*	(–9.4)	–0.047*	(–8.8)	–0.051*	(–10.9)
d_{14} (Average willingness to answer)	λ_{21}	–0.091*	(–11.0)	–0.105*	(–12.5)	–0.097*	(–13.2)
d_{15} (Low willingness to answer)	λ_{22}	–0.173*	(–6.8)	–0.104*	(–4.0)	–0.127*	(–5.6)
Factors explaining the distance							
Intercept [b]	δ_0	–0.640*	(–5.3)	–4.115*	(–6.1)	–1.205*	(–7.7)
z_1 (Professional activity)	δ_1	–0.513*	(–13.0)	–1.689*	(–7.8)	–0.915*	(–18.3)
z_2 (Non-professional activities)	δ_2	–0.500*	(–17.7)	–0.625*	(–8.3)	–0.525*	(–17.3)
z_3 (Frequency of non-prof. activities)	δ_3	–0.185*	(–5.5)	–0.184*	(–4.3)	–0.135*	(–3.7)
z_4 (Vigorous physical activity)	δ_4	–0.260*	(–12.8)	–0.355*	(–7.1)	–0.306*	(–16.2)
z_5 (Moderate physical activity)	δ_5	–0.411*	(–15.6)	–0.322*	(–8.1)	–0.313*	(–15.6)
z_6 (Mobility limitations)	δ_6	–0.061	(–1.6)	0.416*	(6.4)	0.222*	(7.7)
z_7 (EURO-D depression scale)	δ_7	0.219*	(5.5)	1.210*	(6.4)	0.607*	(14.0)
z_8 (Single-person household)	δ_8	0.066	(1.9)	0.620*	(8.8)	0.317*	(7.1)
z_9 (2nd wealth quartile)	δ_9	–0.313*	(–10.0)	–0.143*	(–3.5)	–0.216*	(–7.8)
z_{10} (3rd wealth quartile)	δ_{10}	–0.423*	(–10.1)	–0.568*	(–5.2)	–0.358*	(–11.1)
z_{11} (4th wealth quartile)	δ_{11}	–0.458*	(–12.0)	–0.413*	(–7.9)	–0.401*	(–10.4)
z_{12} (Number of children)	δ_{12}	–0.328*	(–14.2)	–0.239*	(–5.4)	–0.277*	(–11.3)
z_{13} (Number of children²)	δ_{13}	0.041*	(12.9)	0.056*	(6.1)	0.044*	(11.9)
Other parameters	σ	0.964*	(16.7)	2.741*	(7.6)	1.120*	(14.6)
	γ	0.945*	(261.1)	0.986*	(536.6)	0.968*	(402.9)

Note. * Significant at the 1% level; [a] Reference group: AU, Men, Born in the same country, no Activities of Daily Living limitations, no Instrumental Activities of Daily Living limitations, less than 2 chronic diseases; [b] Reference group: No paid work, no other activities, no mobility limitations, no depression, not single, first quartile of wealth.

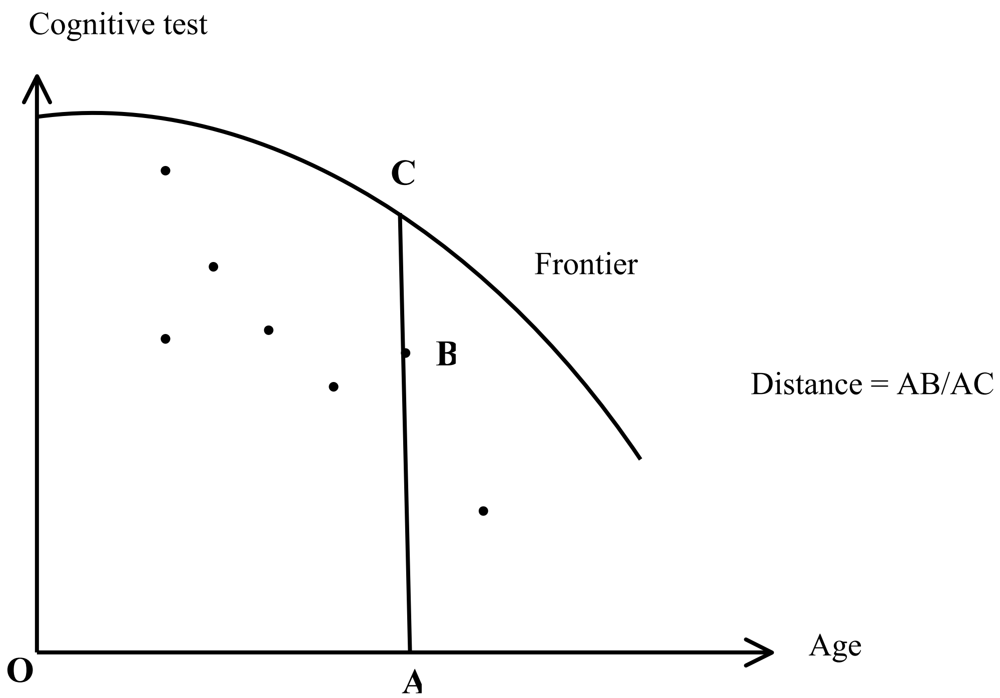
Table 3

The impact of *z* variables on cognitive performance
(Equivalent years of cognitive aging for 60-year-old individuals)

	Memory	Fluency	Global assessment
• Professional activity	–1.61	–1.92	–1.91
Other activity:			
• One activity performed less than weekly	–0.78	–2.65	–1.40
• One activity performed almost weekly	–0.96	–3.34	–1.68
• One activity performed almost daily	–1.13	–4.01	–1.96
• Two activities performed less than weekly	–1.38	–4.49	–2.48
• Two activities performed almost weekly	–1.55	–5.15	–2.76
• Two activities performed almost daily	–1.72	–5.80	–3.03
• Moderate physical activity	–0.31	–1.66	–0.68
• Vigorous physical activity	–0.34	–1.00	–0.65
• Mobility limitation	0.40	–0.23	0.46
• Depression	1.16	0.83	1.28
• Single-person household	0.60	0.25	0.66
Wealth:			
• 1st quartile	–	–	–
• 2nd quartile	–0.14	–1.19	–0.45
• 3rd quartile	–0.54	–1.60	–0.75
• 4th quartile	–0.40	–1.73	–0.84

FIGURE CAPTION

Figure 1. The distance concept



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