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Abstract

This paper investigates the effects of individual and environmental determinants on physical and cognitive impairment of Europeans aged 50 and older using data drawn from the Survey of Health Aging and Retirement in Europe (SHARE). The aim is to understand the different paths that need-related determinants of long-term care might take across individuals. As dependent variables, we consider several measures of physical and cognitive disability which are regressed on a list of covariates which includes biological, health, behavioural, socio-demographic and early-life conditions of individuals. We adopt a methodology that combines the structure of random effects models for longitudinal data with the flexibility of a tree regression method. We show the existence of clusters in the main determinants of functional decline (physical and cognitive). Our findings are in line with the existing literature, but, at the same time, we further characterize previous evidence: 1) cognitive impairment, measured by the results of a memory test, strongly depends on educational attainments, age and respondents' country of residence; 2) physical impairment, measured through the loss of handgrip strength, basic and instrumental activities of daily living (ADLs, IADLs) and mobility, strongly depends on health and behavioural factors.

Keywords: long-term care, physical impairment, cognitive impairment, health behaviour, early-life conditions, RE-EM tree analysis, SHARE

JEL codes: I12, J14, J26

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1. Introduction

According to most analyses and projections, an aging population will have a strong upward impact on demand and public spending for long-term care (LTC) (Mot et al., 2012; European Commission, 2012). Therefore, to predict and influence future trends in the demand of LTC, we need knowledge about the determinants of frailty and LTC needs among the elderly.

How do socioeconomic and health factors interact to determine the need of long-term care (LTC)? Are individual determinants more (or less) important than environmental characteristics in predicting LTC needs? By using a data-driven approach, this study aims at understanding the different paths that need-related determinants of LTC such as physical and cognitive impairment might take across individuals.

As explanatory framework, we consider a particular adaptation of the Andersen-Newman behavioural model (Andersen and Newman, 1973; Andersen, 1995).[1] Figure 1 shows the model we use to identify the main predictors of LTC utilization. Environmental (societal and institutional) determinants of LTC utilization are shown to affect the individual determinants. Two types of individual determinants (predisposing and enabling characteristics) then influence functional decline (physical and/or cognitive impairment) and the potential need of LTC. In the adaptation of the Andersen-Newman model reported in Figure 1, predisposing variables reflect the individual's propensity towards use of LTC services and pertain to socio-demographic (e.g. education, marital status), biological (age, sex, body mass index – BMI), health status, early-life, lifestyles conditions and belief characteristics (e.g. values concerning health and illnesses measurable in consequence such as smoking behaviour, alcohol consumption, or body mass index) while enabling factors are those that support or impede use of LTC services (e.g. income, type of health insurance, availability of formal and informal care).

[INSERT FIGURE 1 HERE]

Many empirical studies have found a socio-economic gradient in health and functional decline. For example, a large body of the literature suggests a negative correlation between individual's education level (a predisposing variable) or income level (an enabling variable) and physical and cognitive limitations (e.g., Avendano et al., 2005; Dewey and Prince, 2005; Kok et al., 2008). These results may be an effect of reduced incidence of chronic diseases and functional limitations due to healthy lifestyles and social involvement more concentrated among higher socio-economic status people (Avendano et al., 2005; Hairy et al., 2008; Mazzonna and Peracchi, 2013; Abuladze and Sakkeus, 2013). Moreover, both individual enabling variables (e.g., the availability of informal care at the household level) and institutional/environmental variables (e.g., the organization and funding of LTC systems) have a strong impact on both physical and cognitive decline (the LTC need related

[1] The Andersen-Newman model which has been discussed and continuously refined over the years assumes that individuals' use of health care services is a function of their predisposition to use services (predisposing factors), factors that support or impede use (enabling factors), as well as their need for health care (illness level). The model has been also applied to the analysis of health care demand by the elderly (e.g., Heider et al., 2014) and to investigate on the determinants of LTC use (eg. Bakx, 2010; Lou et al., 2011; Wu et al., 2014).

determinants). Under this respect, European countries are characterised by quite different models of LTC, ranging from countries with a strong public support to both formal and informal care (the Netherlands and Scandinavian countries) to countries where accessibility to formal services and government's support to informal family carers are rather scanty (Eastern European countries such as Poland and Czech Republic) (Kraus et al., 2010; Colombo et al., 2011; Colombo, 2012; Lipszyc et al., 2012; OECD, 2013).

This paper aims at analysing a part of the whole model represented in Figure 1. Using longitudinal data from the Survey of Health Aging and Retirement in Europe (SHARE), we investigate the relationship between individual and environmental factors (independent variables) and physical and cognitive functions which determines the need of LTC (dependent variables). In particular, we focus on the existence of clusters in the main determinants of functional decline (physical and cognitive impairment) of Europeans aged 50 and older.

Following Sela and Simonoff (2012) and Fu and Simonoff (2014), we adopt a hierarchical clustering method that combines the advantages of random effects models for longitudinal data with the flexibility of a nonparametric approach based on conditional inference trees. Our final output has the form of a binary tree, that is, a dendogram describing the patterns of LTC needs. Moving down the tree, we find clusters containing increasingly similar responses for the dependent variables. The term "binary" implies that each group of respondents, represented by a "node" in a regression tree, can only be split into two groups. Thus, each node can be split into two other nodes, and so on. The tree will end with a set of terminal nodes representing the final partition of the observations.

We show the existence of clusters in the main determinants of functional decline (physical and cognitive). According to our results, unobserved heterogeneity is clustered along some important dimensions: 1) cognitive impairment, measured by the results of a memory test, strongly depends on educational attainments, age and respondents' country of residence; 2) physical impairment, measured through the loss of handgrip strength, basic and instrumental activities of daily living (ADLs, IADLs) and mobility, strongly depends on health and behavioural factors. More specifically, in memory tests measuring cognitive ability, unobserved heterogeneity is strongly related to educational achievements. Immediately after educational achievements, respondent's age and country of residence are the best predictors of cognitive decline. Early-life conditions are important predictors for individuals aged seventy-two or less, while, for older respondents, cognitive decline is significantly associated with some measures of physical decline. The structure of clusters changes when we consider immediate and delayed recall tests separately. In contrast, groups heterogeneity in physical decline is more related to the health status, respondent's age, the number of chronic diseases and the level of physical activity. Interestingly, handgrip strength also depends on country of residence once we have opportunely clustered for respondents' sex and age.

Our analysis contributes to the existing literature in two ways. From a positive point of view, we order the main determinants of physical and cognitive impairment, revealing important interaction effects among predictors. This allows us to better characterize previous findings, showing that some results are due to specific subpopulations entering the analysis. For example, Jorm et al. (2004) found the existence of gender differences in verbal learning test, showing that women outperform men.[2] Our analysis confirms the validity of this finding, highlighting however the role of other

[2] According to Jorm et al. (2004), women perform better on recall and Symbol–Digit Modalities Test.

important factors - such as education, age and country of residence - in mediating this relationship. In fact our regression tree approach allows us to overcome some limitations of linear regression models, which do not provide any information either on the order of predictors or in their conditional effects. From a normative point of view, finding that a limited set of variables are crucial to shape the need for long-term care may suggest decision makers to give the priority to policy interventions affecting those variables. In this respect, our analysis may help institutions understand the level of intervention to delay or slow cognitive and physical decline and then the demand of long-term care.
The rest of the paper is organized as follows: Section 2 reviews the existing literature, Section 3 presents data and describes the methodology of empirical analysis, Section 4 comments the results and Section 5 concludes.

2. Literature Review

In the last decades several contributions have investigated on the individual and environmental determinants of the onset of cognitive and physical impairment among the elderly. This large body of literature can be divided into two branches. A first branch concerns the analysis of the determinants of the process of cognitive decline and cognitive reserve theory, while the second branch is more related to the relationship between demographic, socio-economic and behavioural variables and physical disabilities. In addition, several contributions have shown that both cognitive and physical decline in the elderly are partially related to individual's early-life conditions and may be influenced by institutional ("environmental") factors.

2.1 Cognitive Decline

Ageing is often associated with cognitive decline which is a likely factor in the development of functional impairment and disability. Cognition can be divided into different domains of ability, which can be tested separately; the most important of these are orientation, memory, executive function (planning, sequencing) and language (Dewey and Prince, 2005). Therefore, the cognitive measures adopted by existing surveys on the aged population (e.g., the English Longitudinal Survey on Ageing – ELSA, the US Health and Retirement Study – HRS and the Survey of Health, Ageing and Retirement in Europe - SHARE) are multidimensional, considering different domains of cognitive functioning. For example, in the SHARE cognitive ability is measured using simple tests of orientation, memory (registration and recall of a list of ten words), verbal fluency (a test of executive function) and numeracy (arithmetical calculations). These tests are partly based on the mini-mental-state-examination – MMSE (Folstein et al., 1975) or the Dementia Detection (DemTect) scale (Kalbe et al., 2004).
Cognitive impairment increases sharply after age 50, but cognitive functioning varies substantially across people at all ages (Schaie, 1989). In fact, recent research in neuroscience has questioned the idea that cognitive decline is inevitable and fixed (van Praag et al. 2000). According to the *cognitive reserve theory*, individuals are born with or can develop resources that help them resist normal and disease-related cognitive decline that occur in aging. Some studies suggest that people with a high educational level have a lower risk of developing cognitive impairment and dementia compared to people with a low educational level (Stern, 2002; Le Carret et al., 2010). In particular, Le Carret et al. (2010) show that the effect of education on cognitive reserve may be explained by an increase in

controlled processes and conceptualization abilities. Schneeweis et al. (2012) provide evidence of a causal link between SHARE respondents' education (measured by their number of years of schooling) and cognitive functioning in old-age, stronger in delayed memory, but weaker (or even null) on verbal fluency, numeracy, orientation to date and dementia. According to Mazzonna and Peracchi (2013), education and employment status are important predictors, not only of the level of cognitive scores, but also of their age-related decline. People with a high educational level not only maintain their cognitive function (see, e.g., Harum et al., 2003; Schneider et al., 2012) but seem also to show a lower risk of developing dementia (see, e.g., Letenneur et al., 1999; Stern et al., 1994).

2.2 Physical Disability

Physical functioning is an important dimension of health, as it reflects the ability of individuals to perform normally in a society. Limitations in physical functioning are measured by several instruments such as: self-reports on mobility sensory functioning and measurement of walking speed (Nicholas et al., 2003.); measurements of hand-grip strength, a strong predictor of functional limitations and disability (Rantanen et al. 1999)[3]; self-reports of basic activities of daily living (ADL; dressing, getting in/out bed, eating, etc.) and instrumental activities of daily living (IADL; preparing a meal, shopping, making telephone calls, etc.) (see Nicholas et al., 2003).[4]

Individuals' physical impairment shows a marked socio-economic gradient - lower levels of education and wealth are associated with more limitations in the ADL (Kok et al., 2008); positive wealth effects on grip strength were particularly evident in the old age particularly among the least wealthy (Hairi et al., 2010) - even though some authors have found that changes in functional capacity by socio-economic position remained the same or even narrowed with ageing (Sulander et al., 2012). Lower educated people are generally more likely to smoke, to be physically inactive and to be overweight and this may accelerate the decline in functional capacity (Cavelaars et al., 2000; Sulander et al., 2004, 2005; Aro et al., 2005; Tsubota-Utsugi et al., 2011). Both socio-demographic variables and regular physical exercise are usually related to different transitions patterns towards frailty (Young et al., 1995; Paterson and Warburton, 2010; Borrat-Besson et al., 2013). There is a general evidence of the importance of healthy life-styles to improve functional capacity also among the elderly (Adams et al., 1990; Davis et al., 1994).

2.3 Early-life circumstances

There is a growing literature on the long-lasting effects that circumstances in early-life and parental socio-economic status have on later life outcomes such as health, socio-economic status and cognitive ability. Deprived childhood economic conditions may lead to worse health conditions in the long-run (see, e.g., Schröder, 2013). Cognitive ability in later life seems partially related to some early-life conditions and particularly to the number of years of education (Banks and Mazzonna, 2012; Dal Bianco et al., 2013). The number of books at home at age 10 – a proxy for

[3] In a recent study, Taekema et al. (2010) show that "muscle wasting is associated with a detrimental outcome in older people". More specifically, the authors suggest to measure hand grip strength in order to identify those geriatric patients at risk of physical accelerated decline.

[4] Besides these instruments covering physical and sensory functional limitations and activity restrictions, a global activity limitation indicator (GALI) has also been developed (Robine and Jagger, 2003) and used within the SHARE (Jagger et al., 2010)

parental education and economic status - seems to have long-lasting beneficial effects on the individuals (e.g., higher earnings) and it is pushed by the reforms to increase the years of compulsory education (Brunello et al., 2012; Cavapozzi et al., 2011).

2.4 The impact of environmental determinants

Jagger et al. (2011) show that European countries are characterized by a substantial inequality in all health expectancies (LE-50 and Healthy Life Years measures). Moreover, they show that the patterns of progression from disease to disability were not the same across countries. According to these authors, the differences in patterns of health expectancies between countries may indicate environmental, technological, healthcare or other factors that could potentially delay progression from disease to disability: a phenomenon to be explored.

3. Data and methods

3.1 Data

To investigate and characterize the existence of clusters in the main determinants of physical and cognitive impairment, we use data drawn from the Survey of Health, Ageing and Retirement in Europe (SHARE). This is a multidisciplinary survey which collects information on health, socio-economic status and family networks for individuals aged fifty or over who speak the official language of their country, plus their partner regardless of age. The first wave of SHARE took place in 2004 and involved eleven European countries: Austria (A), Belgium (B), Switzerland (C), Germany (D), Spain (E), France (F), Greece (G), Italy (I), Denmark (K), the Netherlands (N) and Sweden (S). Other countries have been added in the following waves. Since clustering analysis generally requires a relatively large dataset, in this paper we select Waves 2 and 4 to include also Poland (P) and the Czech Republic (Z).[5]
Table 1 describes our variables (dependent and independent) and provides some summary statistics.

[INSERT TABLE 1 HERE]

3.1.1 Dependent variables

On the basis of Figure 1, we consider different outcome variables to measure the need-related determinants of LTC demand. In particular, we are interested in those variables associated with cognitive and physical impairment of SHARE respondents.

Cognitive ability measures

In each of the SHARE waves, a series of brief tests on the individual cognitive abilities is collected, even though the features of some of them have been changed between Wave 2 and Wave 4. In this work we focus on one of these measures: the number of Worlds Recalled (WR), i.e. the number of words that a person can recall (one immediate and one delayed recall) from a list of ten. The ten word-list-learning test is a standardized modified version of the Rey's Auditory Verbal Learning

[5] We use release 2.6.0 for wave 2 (November 29th, 2013, DOI: 10.6103/SHARE.w2.260) and release 1.1.1 for wave 4 (March 28th, 2013, DOI: 10.6103/SHARE.w4.111).

Test (RAVLT), a test of verbal learning and memory, where the respondent is asked to learn a list of ten common words. The respondent may hear the list only once and then will be asked to recall the words immediately (immediate recall) and again later on (delayed recall), after an interference period.[6] The SHARE version of the RAVLT differs as in each wave the collected test consists of only one immediate recall trial and one delayed recall (the lists of ten words used in Wave 4 are however different with respect to those used in the previous waves) (Dal Bianco et al., 2013). Besides the total number of words recalled, as robustness check, we also consider the instant and delayed recall test separately. Table 1 shows that the average number of WR is 8.89, with 5.14 words recalled on the instant trial and 3.75 words recalled on the delayed trial. By using a short-term verbal memory test, Singh-Manoux et al. (2008) define a critical minimum value of 4 out of 20 words (20% of the list) to identify individuals with memory deficit. This value coincides with the value observed in the worst quintile. In our case, the worst quantile recall a maximum of 5 out of 10 words (50%).

Physical (dis)ability measures

A first measure of physical (dis)ability that we consider is the maximum handgrip strength. According to the test instructions, two grip strength measurements on each hand were recorded with a dynamometer at the interview. The maximum grip strength is defined as the maximum measurement of both hands or of one hand. In the SHARE sample, it ranges from a minimum value of 2 kg to a maximum value of 84 kg, with an average value of 34.24 kg; for men and women this value is 43.12 kg and 26.6 kg, respectively. Diagnostic measures for sarcopenia in patients aged 50 and over are 39.6 kg for men and 26.2 kg for women (see Bijlsma et al., 2013).

A second measure of physical impairment is given by the number of basic activities of daily living (ADL) that one can perform alone. This measure is used to access the need for supportive services for physically impaired individuals. The considered ADL index is based on six activities: dressing, walking across a room, bathing or showering, eating, getting in and out of bed, and toileting. On average, our population can perform 5.84 activities. This suggests that our dependent variable is right-censored at six, with a small portion of respondents characterized by the lack of at least one ADL. To measure respondents' functional status, we also consider the number of instrumental activities of daily living (IADL) that one can perform alone. The IADL index takes into account the following activities: using a map to get around in a unknown place; preparing a hot meal; shopping for groceries; making telephone calls; taking medications; doing work around the house or garden; managing money, such as paying bills and keeping track of expenses. On average, respondents can perform 6.75 out of 7 instrumental activities.

Finally, we use an indicator of physical mobility. This variable is the number of everyday activities that individuals can do with no difficulty, excluding those difficulties that they expect to last less than three months. These activities refer to mobility, arm function and fine motor functioning reported by respondents.[7] The average number of everyday activities that individuals can do with no difficulty is 8.52, with values ranging from 0 to 10. However, 50 percent of respondents are able to perform all activities and another 17% of them report only one difficulty. Those individuals with three or more difficulties constitute the 22.72% of the sample.

[6] The original RAVLT consists of five consecutive trials each followed by an immediate recall and one delayed recall, which enables to compute several indices from the outcomes (Estévez-González et al. 2003).

[7] The term fine motor function refers to those movements of small muscle in coordination with the eyes.

3.1.2 Independent variables

Physical and cognitive disabilities depend on both short- and long-term determinants. We divide these determinants into five categories: health and medical variables, biological measures, behavioural factors, socio-economic and demographic determinants, early-life conditions.

Health conditions are proxied by two variables: a self-reported health (SRH) status and the number of chronic diseases declared by respondents. By looking at Table 1, we can see that, although the majority of respondents suffer from some chronic diseases, the 91% of them report a good health status. Many epidemiological studies have shown that SRH is a good predictor of future morbidity and mortality as well as functional abilities (see, e.g., Idler and Kasl, 1995; Idler and Benyamini, 1997; Benyamini and Idler, 1999; Kawachi et al., 1999; Subramanian et al., 2001). Similarly, other studies have shown that physical and cognitive disabilities are an adverse outcome of different chronic diseases (see, e.g., Svedberg et al., 2009; Kim, 2011). We also include six dummy variables indicating whether respondents take some specific drugs at least once a week. In particular, we consider drugs for: (1) high blood cholesterol; (2) high blood pressure; (3) coronary or cerebrovascular diseases; (4) other heart diseases; (5) diabetes; (6) anxiety or depression. This set of dummies should capture the effects of important medical conditions on functional decline. According to Table 1, one out of two respondents take drugs for high blood pressure, while one out of three respondents are treated for high blood cholesterol. In contrast, only a 7% of respondents take drugs for anxiety or depression.

To account for biological aspects, we use information on the subjects' age, gender and Body Mass Index (BMI). The average respondent is 66 years old, and women constitute 54% of respondents. BMI is calculated by dividing a person's weight (in kilograms) by their height (in meters) squared and signals overweight for values in a range 25.0-29.9 and obesity for values above 30.0. The BMI is an important indicator, since it captures several dimensions. First of all, the BMI can indicate some biological factors predisposing to chronic diseases and then functional disabilities. Secondly, the BMI is also associated with nutritional, behavioural and environmental factors that can increase the probability of physical and cognitive decline. In our sample, the average value of BMI is 27.01 (27.18 for men and 26.87 for women).

Also current and past habits may affect the probability of functional and cognitive decline. Therefore, we control for important behavioural factors (daily drinking, performed physical activities, and smoking). Table 1 shows that 80% of respondents consume less than 2 drinks in a day. Current smokers represent a 27% of the sample, while almost half of the sample declares to do vigorous activities (activities or sports requiring a more than moderate level of energy). We have also included two dummy variables indicating whether a respondent has ever changed her level of physical activity or diet. These changes concerned a 27-28% of the sample.

As socio-economic and demographic factors, we included: having a partner, the educational attainment, the working status and the income level. The fraction of respondents living with a spouse or a partner is 75%. The average education is below ISCED (*International Standard Classification of Education*) 3-4.[8] Most of respondents are still working and, on average, their equivalized annual household income is € 23,872.

[8] ISCED 3 corresponds to a lower secondary education level, while ISCED 4 corresponds to an upper secondary education level.

To control for very long-term determinants of functional and cognitive decline, we also consider several variables related to long-term habits and early-life conditions (vaccinations, regular checks of blood pressure, regular dental care, parents' life-styles, having few books[9], math and language skills in the childhood, living in a rural area during childhood). Almost all respondents have been vaccinated during childhood (99% of the sample). Moreover, practically all of them had their blood pressure checked regularly over the curse of several years. This means that these two variables exhibit a too low variability to explain our dependent variables. On the contrary, only the 62% of the sample reported a period of regular dental checks. In addition, the 41% of respondents had less than 25 books in the house when they were ten. This fraction is comparable with the percentage of individuals that had a first residence located in rural areas (44%). We have also included two dummy variables indicating the presence of math and language skills when the subject was ten. These measures are self-reported and indicate that more than one-third of the population recall good math and language performances in their preadolescence. Both measures may be related to unobservable characteristics such as individual capacities but also to the quality of the educational environment at which respondents were exposed during their childhood. Here, the term educational environment refers to the entire context influencing and forming a child. Finally, the majority of respondents grew up with parents used to smoke, while the incidence of parents used to drink heavily is about 9%.

In the next section, we will explain the empirical strategy adopted to ascertain the existence of clustering in the determinants of functional decline (physical and cognitive impairment) of Europeans over 50s.

3.2 Methodology

We are interested in understanding a part of the whole model represented in Figure 1, i.e., the relationship between the environmental and individual variables and physical and cognitive impairment which determines the need of LTC. In order to discover the real data-generation process, we adopt a data-driven approach, without assuming a priori any parametric form to model this relationship.

Longitudinal analyses are extremely rewarding when one wants to fit complex or highly structured data. Traditional panel data analyses are based on point estimates that lead to a single value of a statistic. They assume a constant relationship between a certain explanatory variable and the outcome. This assumption is often too restrictive for data on health in which important interactions and nonlinear effects take place. Therefore, to identify the best predictors we adopt a flexible data-driven approach derived from Fu and Simonoff (2014). In particular, we use a conditional inference tree method to estimate a Random Effects Expectation Maximization (RE-EM) model. This approach allows us to combine the structure of random effects (RE) models for longitudinal data with the flexibility of a tree regression method (Sela and Simonoff, 2012).[10] The latter is a

[9] This is a zero-one dummy that captures the presence of less than 25 books at the parental home at age ten, information collected during the third wave of SHARE, SHARELIFE, as proxy for parental education and economic status.

[10] In theory, when a sample comes from a very large population, as in our case, RE models are more appropriate than FE models. This happens because the vector of fixed effects cannot be extended to the rest of the population and then

nonparametric method for estimating a regression function. As shown by Fu and Simonoff (2014), with respect to recursive partitioning analyses based on some pruning criteria, a conditional inference tree provides estimates that are unbiased. This approach provides improved predictive power compared to linear models with RE and regression trees without RE. Moreover, results are less sensitive to parametric assumptions.[11]

Following Sela and Simonoff (2012) and Fu and Simonoff (2014), we start from a very general effects model with additive error:

$$y_{it} = b_i + f(X_{it}, Z_i) + \varepsilon_{it}, \qquad t = 1,2 \tag{1}$$

$$\begin{pmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \end{pmatrix} \sim N(0, R_i),$$

where y_{it} is the observed outcome for individual i at time t, $b_i \sim N(0, D)$ is the vector of random effects, X_{it} is a matrix of time-varying regressors, Z_i is a matrix of time-invariant regressors, $f(.)$ is an a priori unknown function, and ε_{it} is an error term. The error terms are independent across observations and uncorrelated with the random effects. Finally, R_i is a diagonal matrix, assuming that errors are not autocorrelated.[12]

Since both b_i and $f(.)$ are unknown, Sela and Simonoff (2012) and Fu and Simonoff (2014) propose the following estimation algorithm:

1. Initialize the estimated random effects, $\hat{b}_i$, to zero
2. Iterate through the following steps until the change in the restricted likelihood function is less than a certain tolerance value:
   (a) Estimate a regression tree approximating $f(.)$, based on the target variable, $y_{it} - b_i$, and covariates, x_{it}. Use this regression tree to create a set of indicator variables, $I(x_{it} \in g_p)$, where g_p is the p-th group and ranges over all of the terminal nodes in the tree.
   (b) Fit the linear random effects model, $y_{it} = b_i + I(x_{it} \in g_p)\mu_p + \varepsilon_{it}$, where μ_p is the expected level of the outcome for group p.
   Extract $\hat{b}_i$ from the estimated model.
3 Replace the predicted response at each terminal node of the tree with the estimated population level predicted outcome $\hat{\mu}_p$ from the linear model fit in 2b.

The linear random effects model in 2b is estimated using a restricted maximum likelihood (REML) technique. While for point 2a, Fu and Simonoff (2014) suggest to use a conditional inference tree.

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estimates lack of external validity. In addition, when the time dimension is small and cross-section dimension is large, RE are more efficient than FE, since the number of parameters estimated in a FE model increases with the number of individuals. Another important advantage of RE is that they allow for the inclusion of time-invariant regressors. Moreover, RE are often appropriate when data are collected hierarchically or observations are taken on related individuals (e.g., spouses, partners, siblings, etc). Finally, another reason to adopt a RE approach is based on the fact that our data change relatively slowly over time and, therefore, FE estimates absorb most of the variability contained in the data.

[11] All computations are made using R version 3.1.1 and Stata 13.1. The R code has been kindly provided by Wei Fu and Jeffrey S. Simonoff.

[12] Note that, if $f(.)$ is a linear function and effects b_i are fixed or correlated with covariates, then model (1) becomes a linear fixed effects model. Vice versa, if $f(.)$ is a linear function and effects b_i are random or uncorrelated with x_{it}, then model (1) becomes a linear random effects model.

The estimation of a conditional inference tree follows three steps: 1) test the global null hypothesis of independence between any of the input variables and the output. If this hypothesis is rejected, select the input variable with the strongest association to the dependent variable. This association is measured by a p-value corresponding to a test for the partial null hypothesis of a single input variable and the outcome; 2) implement a binary split in the selected input variable; 3) recursively repeat the previous steps. With respect to other partitioning techniques and classification methods, the main advantage of this approach is that it takes into account the *distributional* properties of the variables.[13] This leads to results that are robust to the structure of the dataset.[14]

This algorithm recalls, although they differ, the Expectation-Maximization (EM) algorithm provided by Laird and Ware (1982). For this reason, Sela and Simonoff (2012) call the resulting estimator a Random Effects-EM (RE-EM) tree. The resulting models can be represented as a binary tree. In general, a binary tree starts with a "root node" partitioning the entire sample into two subgroups based on the value of an explanatory variable. The variable selected for the first split represents the most important explanatory variable. Each subgroup corresponds to a "child node" which may be further partitioned, again based on the value of an explanatory variable. The final output is a dendogram describing the patterns of sequential splits. Moving down the hierarchy, we find groups containing increasingly similar responses for the dependent variable (see Breiman et al. 1984).

4. Results and discussion

4.1 Linear random effects estimates

4.1.1 Determinants of cognitive (dis)ability

By using a linear random effects model, Table 2 reports the impacts of our covariates on our three measures of cognitive impairment.[15] The number of recalled words increases with the health status. Individuals reporting a good health status perform better than those reporting a poor health status in all recall tests. Overall, the former recall 0.34 words more than the latter. In contrast, the number of words recalled is negatively associated with the number of chronic diseases reported by respondents. The average loss of recall capacity is equal to 0.03 words for every additional disease; nonetheless, when we distinguish between immediate and delayed recall, the statistical association between the presence of chronic diseases and cognitive impairment is significant only for the delayed recall test. The correlation between the BMI and our recall measures is negative and statistically significant for both the overall test and the delayed recall test. We also included a squared term for the BMI in order to capture possible nonlinearities due to the effects of under- and over-weight conditions. This second term captures some nonlinear effects of BMI on delayed recall. With respect to sedentary individuals, respondents conducting an active life tend to recall a higher number of words, and this is true for both immediate and delayed recall. Likewise, increasing the

[13] For a general description of the methodology see Hothorn et al. (2006) and Strobl et al. (2009).
[14] See Fu and Simonoff (2014) for further details on the statistical method.
[15] We also estimated a fixed effects regression model. However, within estimators are never significant. This means that only the cross-sectional information is relevant to explain cognitive abilities. This result is likely to depend on the fact that we consider only two waves. FE estimates are available upon request from the authors.

level of physical activity or passing to a healthier diet may have positive effects on memory performances. By looking at Table 2, we can say that conducting an active life is particularly important to maintain cognitive function. Note however that the number of words recalled is higher for smokers than for non smokers. Peeke and Peeke (1984) found that high-nicotine cigarettes resulted in improved recall for both immediate- and delayed-recall tests. In this regard, Mondadori (1981) argues that many drugs that are self-administered (and potentially reinforcing) can have memory-facilitating effects. However, these effects cease during abstinence periods. Interestingly, a regular dental care since the childhood – a proxy of early-life prevention attitudes and habits - is positively associated with our memory measures. With an average value of 0.5 words recalled, the impact of regular dental care on the three outcome variables is comparable with the impact of other important explanatory variables such as language abilities and the health status.

Among socio-economic and demographic variables, education and having a partner are those with the largest impact on recall capacity. Yet, the association between the income level and the number of words recalled is small. An increase of one thousand Euros in the average income level leads to only 0.005 additional words.

In contrast, memory performances are strongly correlated with early life conditions such as the area in which respondents had their first residence and the number of books available when they were ten. Individuals who spent their early life in rural areas tend to recall a smaller number of words with respect to those grew up in non-rural areas. The average gap is about 0.18 words, with a larger fraction of words forgotten in the delayed trial. The number of books available during the childhood is positively associated with the number of words recalled. As expected, we found that math skills and language skills at the age of ten correlate with memory performances. The coefficient of language skills is slightly greater than the coefficient of math skills.

In line with the existing literature, women perform better than men in recall tests (e.g. see Jorm et al., 2004). On average, women recall 1.27 out of 20 words more than men, with 0.59 additional words recalled immediately and 0.69 additional words recalled afterward. Obviously, the number of words recalled decreases with respondent's age. The average loss of recall capacity is equal to 0.07 words for every additional year. This loss is almost equally divided between instant and delayed recall. Finally, there is a positive association between physical capacities and cognitive capacities. In particular, the number of IADL that respondents can perform alone and their handgrip strength positively correlate with our cognitive measures.

[INSERT TABLE 2 HERE]

4.1.2 Determinants of physical (dis)ability

The effects of our covariates on the four physical impairment measures are reported in Table 3.[16] The general health status is positively associated with all physical ability measures. Together with the evidence reported in Table 2, this means that physical and cognitive measures reflect the self-perceived health status. Vice versa, the number of chronic diseases is negatively associated with all physical ability measures.

[16] In this case, both within and between estimators are statistically significant. This means that physical functions are more sensitive to changes in time-variant regressors than cognitive functions even when the time horizon is limited.

Table 3 shows a hump-shaped relationship between BMI and physical ability measures. The maximum handgrip strength is low for both underweight and obese (second class obesity, i.e., BMI>35.9) respondents. ADL an IADL reach a maximum for lower levels of the BMI (27 and 34, respectively), whereas mobility is always decreasing in the BMI. In this case, Column 1 captures the idea that, for a wide range of the BMI, the muscle strength is positively related to the body mass. On the other hand, above the normal weight threshold, ADL and IADL tend to be negatively associated with the BMI. A positive correlation emerges between the level of activity and our physical ability measures. The same conclusion holds for those who passed from a low activity level to a higher activity level. [17]

Regular dental care and the number of books available during childhood show a positive association with both handgrip strength and mobility. Therefore, early-life conditions are related to adults' physical abilities. With respect to non-workers, workers show better performances in all outcomes, except the number of ADL. The handgrip strength increases with the presence of math skills, whereas the mobility index is higher for those having language skills or a partner. Moreover, respondents with a family history of alcoholism show lower physical abilities.

The area of residence during childhood explains part of the variability observed in the maximum handgrip strength and IADL. In particular, individuals who grew up in rural areas are stronger in terms of handgrip than those in urban or suburban areas but also more exposed to IADL problems. Comparing Column 2 with Column 3, we can see that the number of IADL is more sensitive to socio-economic factors than the number of ADL.

Naturally, women have less handgrip strength than men, but, more interestingly, also their mobility is lower. Age is an important explanatory variable for all measures of physical ability. That is, physical capacities decrease with respondents' age.

Quite interestingly, the use of drugs for anxiety and depression is strongly associated with lower physical performances.

[INSERT TABLE 3 HERE]

4.2 Clustering the determinants of functional decline

The rest of the analysis aims to determine the relative importance of different explanatory variables on physical and cognitive decay. By using the unbiased RE-EM tree approach described in section 3.2.2, we better characterize previous results identifying the true hierarchical structure of data. In addition, regression trees allow selecting those variables that may mediate the impact of a covariate on the outcome.

4.2.1 Determinants of cognitive (dis)ability

[17] A positive relationship seems to emerge also between the number of drinks and IADL as well as the mobility index. However, considering that 80% of respondents drink less than two glasses of alcohol per day, we cannot say anything about the effects of alcohol abuse on physical capacities.

Figures 2-4 show the regression trees for words recalled, instant recall and delayed recall, respectively. Starting from Figure 2, we can see that the main stratification variable for the number of words recalled is the educational level. Significant differences in memory capacities emerge between individuals with less than a secondary education level and individuals with at least a secondary degree. This means that education is the principal explanatory variable in all studies attempting to explain the cognitive performance measured by the number of words recalled. This evidence is confirmed by Figure 3 that considers the number of words immediately recalled and Figure 4 that accounts for the number of words recalled afterward. By using a quasi-experimental design, Harum et al. (2003) found a significant difference in word recall tests when comparing those subjects completing elementary school to those subjects completing high school and college. Similarly, Schneider et al. (2012) found that the effect on performance of a less than high school education is equivalent to the effect of as much as 22 years of cognitive aging. This evidence drives our second level of splitting. The second best predictor, which is mediated by the educational level, is the respondent's age. In other words, age interacts with the educational level to explain memory performances. The existence of these interaction effects can be well explained with the cognitive reserve theory. According to this theory, formal education provides an additional cognitive reserve mitigating the effects of aging on memory loss. Once educational and age heterogeneity is taken into account, then one should distinguish among the countries they are investigating. In particular, looking at figures 2-4, one should pay a particular attention to three countries, namely Spain, Italy and Poland, with the inclusion of Greece if we are considering educated individuals aged seventy-one or less. These countries show lower performances than other European countries. Using SHARE data, Brothers et al. (2014) show that respondents in Southern and Eastern Europe have lower mean test scores than those in Northern and Western Europe. Moreover, participants' scores do not differ by country of birth group. After this aggregation level, figures 2-4 show that results change across subgroups and memory tests. In Southern and Eastern Europe, age is particularly important for low educated individuals, while, for high educated respondents, the presence of language skills at early ages is associated with better cognitive performance. Other countries, such as Belgium, Germany, France, and Czech Republic, show a positive effect of language skills on the number of words recalled by low educated respondents. The fact that weak language skills may result in a lower memory performance is not new in the medical literature. For instance, Kennedy (2012) argues that words recognition remains unchanged or increases as vocabulary expands. However, our results suggest that this finding is particularly relevant for a subset of European countries.

In general, women living in Central and Northern European countries perform better than men in memory tests. A wide body of literature demonstrated the existence of a female advantage in language capacities (see, e.g., Jorm et al., 2004). Interestingly, for educated respondents, the tree generated for immediate recall test corresponds to the tree characterizing the overall recall performance. Since the largest fraction of our sample is composed by educated individuals aged seventy-one or less, we can say that the level of education, language capacities and gender are crucial to predict the number of words recalled. Among less educated individuals, women living in Central and Northern European countries and aged seventy-two or less are those with the highest number of words recalled, and this evidence is driven by the delayed recall test. The same is true for educated individuals, where women with a tertiary education living in Central and Northern European countries perform better than anyone else.

Compared to Figure 3, Figure 4 shows that, after the first three levels of splitting, variables affecting the delayed recall differ from those affecting the immediate recall. In particular, each subgroup presents a specific path. At the fifth level of clustering, the main determinant of subgroups formation is the number of IADL. This means that physical disabilities are correlated with cognitive ones. Using a random effects model, Farias et al. (2009) showed that changes in memory performance were associated with changes in the number of IADLs, even after controlling for age, education, and gender. Again educated women aged seventy-one or less, living in Central and Northern European countries, are those remembering the highest number of words (immediately and at a later time).

[INSERT FIGURES 2-4 HERE]

4.2.2 Determinants of physical (dis)ability

Figures 5-8 show the unbiased RE-EM trees for the maximum handgrip strength, ADL, IADL and mobility, respectively. According to Figure 5, as expected, respondents' gender is the main splitting variable for the maximum handgrip strength.[18] After having distinguished between men and women, at the second and third level of clustering, age becomes the most important variable to predict the maximum handgrip strength. Muscle strength naturally declines with age. However, the combined effect of gender and age on the maximum grip strength confirms those studies showing that this natural decline occurs at a different age in women compared with men (see, e.g., Vianna et al. 2007).

Men aged sixty-two to seventy-nine, living in Spain, France, Greece, Italy and Poland, show lower levels of handgrip strength than men living in Central and Northern European countries. The same is true form women aged sixty-nine or less. As suggested by Andersen-Ranberg et al. (2009), this evidence contrasts with the fact that life expectancy is higher in Southern European countries than in Northern European ones. According to them, gene–environment interactions may explain country-specific differences. By looking at Figure 5, we cannot reject their hypothesis, since the country of residence significantly interacts with environmental factors, such as the activity level, and variables capturing the product of genetic and environmental factors, such as IR, IADL and the number of chronic diseases. In addition, men's strength is particularly sensitive to the activity level, whereas women's strength depends on health variables such as the self-perceived status, the number of chronic diseases and the number of words instantaneously recalled.

The RE-EM tree referring to the ADL measure is presented in Figure 6. Following this tree, we can see that a first division must be made between who declared an adequate health status and who did not. For the former, a second important determinant is having more or less than 3 chronic diseases. If the respondent declared to suffer from less than three chronic diseases, then age is more important than the activity level; vice versa, if the respondent declared to suffer from, at least, three chronic diseases, then the activity level is more important than the respondent's age. In contrast, among who declared to suffer from poor health, the second most important splitting variable is the respondent's age. The activity level is an important splitting variables for respondents aged seventy-

[18] Cheung et al. (2013) found different association patterns of handgrip strength with chronic diseases in men and women. This evidence can be explained with the intrinsic differences between men and women. Baumgartner et al. (1999) argue that sex hormones crucially affect the handgrip strength.

six or less, while the number of chronic diseases is crucial for older individuals. Interestingly, the unbiased RE-EM tree selected only 4 covariates to predict the number of ADL. Concerning the correlation between the number of ADL and the number of chronic diseases, Malhotra et al. (2012) found that heart diseases, diabetes, osteoporosis, chronic respiratory illness and renal/urinary tract illness were significantly associated with ADL limitations. In addition, according to Paterson and Warburton (2010), regular aerobic activity and short-term exercise programmes confer a reduced risk of functional limitations and disability in older age. Paterson and Warburton also infer the existence of a threshold in the activity level to maintain functional independence. Comparing high- and low-active individuals, Young et al. (1995) found that the activity level was associated with optimal function for basic ADL. Moreover, in subjects with a chronic disease, at least a moderate physical activity was sufficient to maintain physical functioning.

The health status represents the most important splitting variable also for the number of IADL (see Figure 7). The respondent's age moderates the relationship between the activity level, the health status and the number of IADL. For individuals aged eighty-two or less, this relationship is also mediated by the number of chronic diseases. By looking at the last two levels of the tree, we can notice that some clusters depend on the consumption of antidepressants and anxiolytics, while other clusters depend on immediate and delayed recall performance. We can conclude that the effect of mental conditions on the number of IADL is mediated by the level of physical activity and the number of chronic diseases.

Figure 8 provides the RE-EM tree results for the mobility index. The first three levels of clustering give a clear picture of what determines the most important differences in the mobility index. The average number of chronic diseases is the primary splitting variable, with a threshold value of 2 chronic diseases. Subsequently, it is important to distinguish between who always declared an adequate health status and who declared a poor health status. After this distinction, the average level of activity becomes relevant to identify further subgroups. The hierarchical structure of the data generation process explains why some studies failed to find a significant relationship between the activity level and mobility measures. Indeed, the interaction between chronic diseases and physical activity is rather complex. For example, Hirvensalo et al. (2000) showed that, for those with intact mobility, the risk of dependency did not differ between active and sedentary individuals. Similarly, Wannamethee et al. (2005) noted that the trend between physical activity and mobility capacity becomes statistically insignificant once the activity level is adjusted for the existence of chronic diseases.

[INSERT FIGURES 5-8 HERE]

4.3 Comparing the results of the linear random effects model and the unbiased RE-EM tree

We conclude the analysis comparing the fit of the unbiased RE-EM tree with the fit of a linear random effects model. Table 4 contains the sum of squared errors (SSEs) of these two models. The first row of Table 4 contains the sum of squared errors (SSEs) of our RE-EM trees (stopped at the fifth level of clustering) for all dependent variables. The second row presents the SSEs for the whole RE-EM trees. The SSEs of the linear models are reported in the third and fourth rows.

Finally, the last row simply reports the number of variables selected by the unbiased RE-EM tree analysis (stopped at the fifth level of clustering). The whole tree always outperforms the random effects model, while the RE-EM trees arrested at the fifth level of clustering already capture the largest fraction of the variance explained by the linear model. In particular, when we consider the measures of physical disabilities as dependent variables, the arrested trees already outperform the linear models. This means that combining few explanatory variables in the correct way, we can increase the fraction of explained variability.

[INSERT TABLE 4 HERE]

5. Conclusions

In this paper, we performed a hierarchical cluster analysis to discover the association between individual and environmental characteristics and cognitive and physical disabilities influencing long-term care needs of the over-fifties. Using a panel data approach, we classified the principal determinants of physical and cognitive disabilities going beyond the limitations of traditional linear regression models. In fact, if linear models measure the *marginal effects* of the predictor variables on the outcome variables, they are absolutely inappropriate to identify complex patterns in the data. On the contrary, our analysis shed some light on the true data generation process. Moreover, a cluster analysis may help decision makers understand which data aggregation level is needed for policy interventions.

Both analyses, linear and nonlinear, lead to sensible results. However, the RE-EM tree analysis showed that some variables are more important than others in predicting cognitive and physical performance of European over-fifties.

As measures of cognitive abilities, we employed standard world recall tests indicators. In particular, we considered both an immediate and a delayed recall test. The most important variable in explaining both cognitive outcomes is the educational level. Once we distinguish between high and low educated respondents, their age becomes the second most important splitting variable for our cognitive measures. Subsequently, the formation of clusters of explanatory variables depends on the respondent's country of residence. Early-life conditions are important predictors for individuals aged seventy-two or less, while, for older respondents, cognitive decline is significantly associated with some measures of physical decline. After this level of clustering, immediate and delayed recall performance differ in some explanatory variables.

Concerning physical disabilities, we explored the effects of individual covariates on three different measures: the maximum handgrip strength, the number of ADL, the number of IADL and a mobility index. The handgrip strength obviously differs between men and women. Men's handgrip strength depends on the activity levels and their country of residence, while women's strength is a nonlinear function of their health status. Moving towards the number of ADL that individuals can perform alone, we found that the health status is the principal explanatory variable. Other important splitting variables are the number of chronic diseases, the age, and the activity level. The analysis on the number of IADL provides similar results, although the regression tree is richer than the tree depicted for the number of ADL. Finally, the best predictor of the mobility outcome is the number of chronic diseases. Adults with a higher number of chronic diseases face several mobility, arm and fine motor problems. Immediately after the number of chronic diseases, the self-perception of health is a good indicator of mobility impairment. The third splitting variable is the activity level, while after this, we found that biological, environmental and health indicators complete the picture. Overall, physical conditions correlate especially with age, health status and the dummy variable indicating whether the respondent lives an active life or not.

It is worth mentioning that some covariates, usually considered as key predictors, never enter the first five levels of our trees. These variables are the income level, having a partner, being a current smoker, the number of daily drinks and the area of residence when the respondent was child. This means that their effects are mediated by the variables mentioned above.

From a policy point of view, if few important variables are able to shape the long-term care risk, then decision makers should give the priority to policy interventions affecting those variables. From our analysis, public health programs to detect those at high risk or to improve modifiable risk factors, such as sedentary habits, seem particularly effective to prevent or delay cognitive and physical decline among the elderly. Since the educational level and some early-life conditions are important predictors of age-related functional decline (especially of cognitive impairment), health promotion through risk factor prevention should be tailored towards the lower education and socio-economic groups. In addition, some policy interventions are more urgent in some countries than in others.

References

Abuladze L., Sakkeus L. (2013). Social networks and everyday activity limitations. In Börsch-Supan, A., Brandt, M. Litwin, H., Weber, G. (Eds.), *Active ageing and solidarity between generations in Europe. First results from SHARE after the economic crisis*, de Gruyter, Berlin, 311-321.

Adams W.L., Garry P.J., Rhyne R., Hunt W. C, Goodwin J.S. (1990). Alcohol intake in the healthy elderly. Changes with age in a cross-sectional and longitudinal study. *Journal of American Geriatrics Society*, 38, 211-6.

Andersen R.M. (1995). Revisiting the behavioral model and access to medical care: does it matter?. *Journal of Health and Social Behavior*, 36 (1), 1-10.

Andersen R.M., Newman, J.F. (1973). Societal and individual determinants of medical care utilization in the United States. *Milbank Fund Quarterly*. 51 (1), 95–124.

Andersen-Ranberg K., Petersen I., Frederiksen H., Mackenbach J., Christensen K. (2009). Cross-national differences in grip strength among 50+ year old Europeans: Results from the SHARE study. *European Journal of Ageing*, 6(3), 227-236.

Aro A.R., Avendano M., Mackenbach J. (2005), *Health Behaviour*, in Börsch-Supan, A., Brugiavini, A., Jürges, H., Mackenbach, J., Siegrist, J., Weber, G. (Eds.): *Health Ageing and Retirement in Europe: First results from the Survey of Health, Ageing and Retirement in Europe.* Mannheim: Mannheim Research Institute for the Economics of Aging (MEA), 102-107.

Avendano M., Aro A.J., Mackenbach J. (2005). Socio-economic disparities in physical health in 10 European countries. In Börsch-Supan, A., Brugiavini, A., Jürges, H., Mackenbach, J., Siegrist, J., Weber, G. (Eds.): *Health Ageing and Retirement in Europe: First results from the Survey of Health, Ageing and Retirement in Europe.* Mannheim: Mannheim Research Institute for the Economics of Aging (MEA), 89-94.

Bakx P. (2010). *Determinants of long-term care use*. Netspar Theses, Master in Health Economics, Policy, and Law Erasmus University Rotterdam.

Banks J., Mazzonna, F. (2012). The effect of childhood education on old age cognitive abilities: evidence from a Regression Discontinuity design. *The Economic Journal*, 122(560), 418-448.

Baumgartner R.N., Waters D.L., Gallagher D., Morley J.E., Garry P.J. (1999). Predictors of skeletal muscle mass in elderly men and women. Mech Ageing Dev 107,123–136.

Benyamini Y., Idler E.L. (1999). Community studies reporting association between self-rated health and mortality: Additional studies, 1995-1998. Res Aging, 21, 392-401.

Bijlsma A.Y., Meskers M.C.G., Molendijk M., Westendorp R.G.J., Sipilä S., Stenroth L., Sillanpää E., McPhee J.S., Jones D.A., Narici M., Gapeyeva H., Pääsuke M., Seppet E., Voit T., Barnouin Y., Hogrel J.Y., Butler-Browne G., Maier V. (2013). Diagnostic measures for sarcopenia and bone mineral density. *Osteoporos Int*, 24, 2681–2691.

Borrat-Besson C., Ryser V-A., Wernli B. (2013). Transitions between frailty states – a European comparison. In Börsch-Supan, A., Brandt, M. Litwin, H., Weber, G. (Eds.), *Active ageing and solidarity between generations in Europe. First results from SHARE after the economic crisis*, de Gruyter, Berlin, 175-185.

Boris K. (2014). RHAUSMAN: Stata module to perform Robust Hausman Specification Test. Statistical Software Components S457909, Boston College Department of Economics.

Breiman L., Friedman J.H., Olshen R.A., Stone C.J. (1984). Classification and regression trees. Monterey, Calif., U.S.A.: Wadsworth, Inc.

Brothers T.D., Theou O., Rockwood K. (2014). Do Performance-based Health Measures Reflect Differences in Frailty Among Immigrants Age 50+ in Europe?. Can Geriatr J., 17(3), 103–107.

Brunello G., Weber G., Weiss C.T. (2012). Books Are Forever: Early Life Conditions, Education and Lifetime Income, IZA Discussion Paper No. 6386, February.

Cameron A.C., Trivedi, P.K. (2005). *Microeconometrics: methods and applications*. Cambridge university press.

Cavapozzi D., Garrouste C., Paccagnella O. (2011). Childhood schooling and income inequality. In A. Börsch-Supan et al. (Eds.), *The individual and the welfare state. Life histories in Europe*. Heidelberg: Springer.

Cavelaars A.E., Kunst A.E., Geurts J.J., Crialesi R., Grotvedt L., Helmert U., Lahelma E., Lundberg O., Matheson J., Mielck A., Rasmussen N.K., Regidor E., do Rosario-Giraldes M., Spuhler T., Mackenbach J.P. (2000). Educational differences in smoking: international comparison. *British Medical Journal* 320,1102-1127.

Cerhan J.R., Folsom A.R., Mortimer J.A., Shahar E., Knopman D.S., McGovern P.G., Hays M.A., Crum L.D., Heiss G. (1998). Correlates of cognitive function in middle-aged adults. Atherosclerosis Risk in Communities (ARIC) Study Investigators. Gerontology, 44(2), 95-105.

Cheung C-L, Nguyen U-S D.T., Au E., Tan K.C.B., Kung A.W.C. (2013). Association of handgrip strength with chronic diseases and multimorbidity. Age (Dordr), 35(3), 929–941.

Colombo C. (2012). Typology of public coverage for Long-term care in OECD countries. In Costa-Font J. And Courbage C. (eds.), *Financing Long-term care in Europe*, Palgrave, Macmillan.

Colombo F., Llena-Nozal A., Mercier J., Tjadens F. (2011), *Help Wanted? Providing and Paying for Long-Term Care*, OECD Health Policy. Studies, OECD Publishing. http://dx.doi.org/10.1787/9789264097759-en

Dal Bianco C., Garrouste C., Paccagnella O. (2013). Early-life circumstances and cognitive functioning dynamics in later life. In Börsch-Supan, A., Brandt, M. Litwin, H., Weber, G. (Eds.), *Active ageing and solidarity between generations in Europe. First results from SHARE after the economic crisis*, de Gruyter, Berlin, 209-223.

Davis M.A., Neuhaus J. M., Moritz D.J., Lein D., Barclay J.D., Murphy S.P. (1994). Health behaviours and survival among middle-aged and older men and women in the NHANES Follow-up Study. *Preventive Medicine*, 23,369-76.

Dewey M..E., Prince M.J. (2005). Cognitive Function, in Börsch-Supan, A., Brugiavini, A., Jürges, H., Mackenbach, J., Siegrist, J., Weber, G. (Eds.): *Health Ageing and Retirement in Europe: First results from the Survey of Health, Ageing and Retirement in Europe.* Mannheim: Mannheim Research Institute for the Economics of Aging (MEA), 118-125.

Estévez-González A., Kulisevsky J., Boltes A., Otermín P., García-Sánchez C. (2003). Rey verbal learning test is a useful tool for differential diagnosis in the preclinical phase of Alzheimer's disease: comparison with mild cognitive impairment and normal aging. *International Journal of Geriatric Psychiatry*, 18(11), 1021–1028.

European Commission - Directorate-General for Economic and Financial Affairs (2012), *The 2012 Ageing Report: Economic and budgetary projections for the EU27 Member States (2010-*

2060), Joint Report prepared by the European Commission (DG ECFIN) and the Economic Policy Committee (AWG), European Economy 2/2012, European Union, Brussels, 2012.

Farias S.T., Cahn-Weiner D.A., Harvey D.J., Reed B.R., Mungas D., Kramer J.H., Helena Chui H. (2009). Longitudinal Changes in Memory and Executive Functioning are Associated with longitudinal change in instrumental activities of daily living in older Adults, 23(3), 446-461.

Folstein M.F., Folstein S., McHugh P.R. (1975). "Mini-mental state": A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research*, 12(3), 189-198.

Fu W., Simonoff J.S. (2014). Unbiased Regression Trees for Longitudinal Data. Available at SSRN: http://ssrn.com/abstract=2399976 or http://dx.doi.org/10.2139/ssrn.2399976.

Hairi F.M., Avendano M., Mackenbach J. (2008). Changes in health-behaviour related determinants, in Börsch-Supan, A., Brugiavini, A., Jürges, H., Kapteyn, A., Mackenbach, J., Siegrist, J., Weber, G. (Eds.), *Health, Ageing and Retirement in Europe (2004-2007): Starting the Longitudinal Dimension*, Mannheim Research Institute for the Economics of Aging (MEA), 129-134.

Hairi F.M., Mackenbach J., Andersen-Ranberg K., Avendano M., (2010). Does socio-economic status predict grip strength in older Europeans? Results from the SHARE study in non-institutionalised men and women aged 50+. Journal of *Epidemiology and Community Health*, 64, 829-837.

Harum P., Galvez O., Mayol L.G., Blanchard R. (2003). Immediate and delayed memory recall patterns of chronic hemodialysis adult hispanic patients, Journal of Renal Nutrition, 13(2), 98-104.

Hausman, J. A. (1978). Specification Tests in Econometrics. Econometrica, 46(6), 1251–1271.

Heider, D., Matschinger, H., Müller, H., Saum, K., Quinzler, R., Haefeli, W.E., Wild, B., Lehnert, T., Brenner, H., König H-H. (2014), Health care costs in the elderly in Germany: an analysis applying Andersen's behavioral model of health care utilization, *BMC Health Services Research*, 14, 71.

Hirvensalo M., Rantanen T., Heikkinen E. (2000). Mobility difficulties and physical activity as predictors of mortality and loss of independence in the community-living older population. J Am Geriatr Soc, 48, 493-498.

Honoré B.E. (1992). Trimmed Lad and Least Squares Estimation of Truncated and Censored Regression Models with Fixed Effects. *Econometrica*, 60(3), 533-565.

Hothorn T., Hornik K., Zeileis A. (2006). Unbiased recursive partitioning: A conditional inference framework. Journal of Computational and Graphical Statistics, 15, 651-674.

Idler E.L., Kasl S. (1995). Self-ratings of health: Do they also predict change in functional ability? J Gerontol Soc Sci, 50, S344-S353.

Idler E.L., Benyamini Y. (1997). Self-rated health and mortality: A review of twenty-seven community studies. J Health Soc Behav, 38, 21-37.

Jagger C., Gillies C., Cambois E., Van Oyen H., Nusselder W., Robine J-M., the EHLEIS Team (2010). The Global Activity Limitation Index measured function and disability similarly across European countries. *Journal of Clinical Epidemiology*, 63, 892-899

Jagger C., Weston C., Cambois E., Van Oyen H., Nusselder W., Doblhammer G., Rychtarikova J., Robine, J.M., the EHLEIS team (2011). Inequalities in health expectancies at older ages in the

European Union: findings from the Survey of Health and Retirement in Europe (SHARE) *J Epidemiol Community Health,* 65, 1030-1035.

Jorm A.F., Anstey K.J., Christensen H., Rodgers B. (2004). Gender differences in cognitive abilities: The mediating role of health state and health habits. *Intelligence*, 32, 7–23.

Kalbe E., Kessler J., Calabrese P. et al. (2004). DemTect: a new, sensitive cognitive screening test to support the diagnosis of mild cognitive impairment and early dementia. *Int J Geriatr Psychiatry*; 19, 136 – 43

Kawachi I., Kennedy B.P., Glass R. (1999). Social capital and selfrated health: A contextual analysis. Am J Public Health, 89, 1187-1193.

Kennedy G.J. (2012). Geriatric Mental Health Care: A Treatment Guide for Health Professionals. Guilford Press, New York.

Kim I.H. (2011). Age and gender differences in the relation of chronic diseases to activity of daily living (ADL) disability for elderly South Koreans: based on representative data. J Prev Med Public Health., 44(1), 32-40. doi: 10.3961/jpmph.2011.44.1.32.

Kok R., Avendano M., Mackenback J. (2008). The association between socioeconomic status and changes in health in Europe. In Börsch-Supan, A., Brugiavini, A., Jürges, H., Kapteyn, A., Mackenbach, J., Siegrist, J., Weber, G. (Eds.), *Health, Ageing and Retirement in Europe (2004-2007): Starting the Longitudinal Dimension*, Mannheim Research Institute for the Economics of Aging (MEA).

Kraus M., Riedel M., Mot E., Willemè P., Röhrling G., Czypionka, T. (2010). *A Typology of Long-Term Care Systems in Europe*, ENEPRI Research Report No. 91/August 2010.

Laird N.M., Ware J.H. (1982). Random-effects models for longitudinal data. Biometrics, 38, 963-974.

Le Carret N., Lafont S., Letenneur L., Dartigues J.F., Mayo W., Fabrigoule C. (2010). The Effect of Education on Cognitive Performances and Its Implication for the Constitution of the Cognitive Reserve. *Developmental Neuropsychology*, *23*(3), 317–337.

Letenneur L., Gilleron V., Commenges D., Helmer C., Orgogozo J.M., Dartigues J.F. (1999). Are sex and educational level independent predictors of dementia and Alzheimer’s disease ? Incidence data from the PAQUID project. *Journal of Neurology, Neurosurgery & Psychiatry,* 66(2), 177–183.

Lipszyc B., Sail E., Xavier A. (2012). *Long-term care: Need, use and expenditure in the EU-27*. European Commission, Directorate-General for Economic and Financial Affairs, Economic Papers 469 | November 2012.

Lou V.W.Q., Chui E.W.T., Leung A.Y.M., Tang K.L., Chi I., Leung Wong E.K.S., Kwan C.W. (2011), Factors affecting long-term care use in Hong Kong, *Hong Kong Medical Journal*, 17 (3), 8-12.

Malhotra C., Chan A., Malhotra R., Østbye T. (2012). Prevalence, correlates and perceived causes of limitations in activities of daily living among older Singaporeans. Aging Clinical and Experimental Research, 24(1), 56-61.

Mazzonna F., Peracchi F. (2013). Patterns of cognitive ageing. In Börsch-Supan, A., Brandt, M. Litwin, H., Weber, G. (Eds.), *Active ageing and solidarity between generations in Europe. First results from SHARE after the economic crisis*, de Gruyter, Berlin, 199-208.

Mondadori C. (1981). Pharmacological modulation of memory: trends and problems. Acta Neurol Scand Suppl, 89, 129-43.

Mot E., Faber R., Geerts J., Willemé P. (eds.). Performance of long-term care systems in Europe. ENEPRI Research Report No. 117, December.

Nicholas S., Huppert F.A., McWilliams B., Melzer D. (2003). Physical and cognitive function. In *Health, wealth and lifestyles of the older population in England: The 2002 English Longitudinal Study of Ageing*, ed. M. Marmot, J. Banks, R. Blundell, C. Lessof, and J. Nazroo, 249-271. London: IFS.

OECD (2013), *Health at a Glance 2013: OECD Indicators*, *Chapter 8: Ageing and long-term care*. OECD Publishing. http://dx.doi.org/10.1787/health_glance-2013-en

Paterson D.H., Warburton D.E.R. (2010). Physical activity and functional limitations in older adults: a systematic review related to Canada's Physical Activity Guidelines. *International Journal of Behavioral Nutrition and Physical Activity*, 7-38.

Peeke S.C., Peeke H.V.S. (1984). Attention, memory, and cigarette smoking. Psychopharmacology, 84, 205-216.

Rantanen T., Guralnik J.M., Foley D., Masaki K., Leveille S., Curb J.D., White L., (1999). Midlife handgrip strength as a predictor of old age disability. *Journal of the American Medical Association* 281, 558-560.

Robine J-M., Jagger C., the Euro-Reves Group (2003). Creating a coherent set of indicators to monitor health across Europe, *European Journal of Public Health*, 13(3), 6-14.

Schaie W. (1989). The hazards of cognitive aging. *The Gerontologist* 29, 484–493.

Schneeweis N., Skirbekk V., Winter-Ebmer R. (2012). Does schooling improve cognitive functioning at older ages?. IZA Discussion Paper 6958.

Schneider A.L.C., Sharrett R. A., Patel M.D., Alonso A., Coresh J., Mosley T., Selnes O., Selvin E., Gottesman R.F. (2012). Education and Cognitive Change over 15 Years: The Atherosclerosis Risk in Communities Study. *J Am Geriatr Soc*., 60(10), 1847–1853.

Schröder M. (2013). Jobless now, sick later? Investigating the long-term consequences of involuntary job loss on health. *Advances in Life Course Research*, 18, 5–15.

Sela R.J., Simonoff J.S. (2012). RE-EM Trees: A Data Mining Approach for Longitudinal and Clustered Data. Machine Learning, 86, 169-207.

Singh-Manoux A., Gimeno D., Kivimaki M., Brunner E., Marmot M.G. (2008). *Arterioscler Thromb Vasc Biol*., 28(8), 1556–1562. doi: 10.1161/ATVBAHA.108.163998

Stern Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*, 8, 448-460.

Stern Y., Gurland B., Tatemichi T.K., Tang M.X., Wilder D., Mayeux R. (1994). Influence of education and occupation on the incidence of Alzheimer’s disease. *Journal of the American Medical Association, 271,* 1004–1010.

Stott D.J., Falconer A., Kerr G.D., Murray H.M., Trompet S., Westendorp R.G.J., Buckley B., de Craen A.J.M., Sattar N., Ford I. (2008). Does Low to Moderate Alcohol Intake Protect Against Cognitive Decline in Older People?. *Journal of the American Geriatrics Society*, 56(12), 2217-2224.

Strobl C., Malley J., Tutz G. (2009). An Introduction to Recursive Partitioning: Rationale, Application, and Characteristics of Classification and Regression Trees, Bagging, and Random forests. Psychological Methods, 14(4), 323–348.

Subramanian S.V., Kawachi I., Kennedy B.P. (2001). Does the state you live in make a difference? Multilevel analysis of self-rated health in the US. Soc Sci Med, 53, 9-19.

Sulander T., Helakorpi S., Rahkonen O., Nissinen A., Uutela A. (2004). Smoking and alcohol consumption among the elderdly: trends and associations, 1985-2001. *Preventive Medicine* 39,413-418.

Sulander T., Martelin T., Rahkonen O., Nissinen A., Uutela A. (2005). Associations of functional ability with health-related behavior and body mass index among the elderly. *Archives of Gerontology and Geriatrics*, 40, 185–199.

Sulander T., Heinonen H., Pajunen T., Karisto A., Pohjolainen P., Fogelholm M. (2012). Longitudinal changes in functional capacity: effects of socio-economic position among ageing adults, *International Journal for Equity in Health*, 11, 78.

Svedberg P., Gatz M., Pedersen N.L. (2009). Genetic and environmental mediation of the associations between self-rated health and cognitive abilities. Exp Aging Res., 35(2), 178-201. Doi 10.1080/03610730902720372.

Taekema D.G., Gussekloo J., Maier A.B., Westendorp R.G., de Craen A.J. (2010).Handgrip strength as a predictor of functional, psychological and social health. A prospective population-based study among the oldest old. *Aging*, 39(3), 331-7. doi: 10.1093/ageing/afq022.

Tsubota-Utsugi M., Ito-Sato R., Ohkubo T., Kikuya M., Asayama K., Metoki H., Fukushima N., Kurimoto A., Tsubono Y., Imai Y. (2011). Health Behaviors as Predictors for Declines in Higher-Level Functional Capacity in Older Adults: The Ohasama Study, *JAGS – Journal of American Geriatrics Society*, 59, 1993-2000.

van Praag H., Kempermann G. Gage F. (2000). Neural consequences of environmental enrichment. *Nature Review Neuroscience* 1, 191–198.

Vianna L.C., Oliveira R.B., Araùjo C.G. (2007). Age-related decline in handgrip strength differs according to gender. Journal of Strength and Conditioning Research, 21(4), 1310–1314.

Wannamethee S.G., Ebrahim S., Papacosta O., Shaper A.G. (2005). From a postal questionnaire of older men, healthy lifestyle factors reduced the onset of and may have increased recovery from mobility limitation. J.Clin.Epidemiol., 58(8), 831-40.

Wu C.-Y., Hu H.J., Huang N., Fang Y.T., Chou Y.-J., Li C.-P. (2014). Determinants of Long-Term Care Services among the Elderly: A Study in Taiwan, *PLoS ONE*, 9(2), e89213. doi:10.1371/journal.pone.0089213

Young D., Masaki K., Curb J. (1995). Associations of physical activity with performance-based and self-reported physical functioning in older men: The Honolulu Heart Programme. J Am Geriatr Soc, 43, 845-854.

TABLES

Table 1: Description of Variables and Summary Statistics (15,105 Obs.)

Variable	Description	Mean	SD	Min	Max
Dependent Variables					
WR	Number of words that a person can recall (10 words for immediate and 10 words for delayed recall).	8.90	3.41	0	20
IR	Number of words recalled on the instant trial (from a list of 10).	5.14	1.68	0	10
DR	Number of words recalled on the delayed trial (from a list of 10).	3.75	2.00	0	10
handgrip	Maximum handgrip strength in kg.	34.24	11.78	2	84
ADL	Number of basic activities of daily living that one can perform alone.	5.84	0.60	0	6
IADL	Number of instrumental activities of daily living that one can perform alone	6.75	0.77	0	7
mobility	Number of everyday activities that individuals can do with no difficulty (mobility, arm function and fine motor function).	8.52	2.11	0	10
Health and medical variables					
health	Self-perceived health status (1=good)	0.91	0.28	0	1
chronic	Number of chronic diseases (from a list of 19).	1.85	1.48	0	10
DBC	Drugs for high blood cholesterol.	0.28	0.45	0	1
DBP	Drugs for high blood pressure.	0.49	0.50	0	1
DCD	Drugs for coronary diseases.	0.10	0.31	0	1
DHD	Drugs for other heart diseases.	0.12	0.32	0	1
DD	Drugs for diabetes.	0.13	0.33	0	1
DAD	Drugs for anxiety or depression.	0.07	0.25	0	1
Biological measures					
age	age	66.40	9.11	50	102
Gender	1=female	0.54	0.50	0	1
BMI	Body max index, BMI = weight in kg/(height in cm)^2.	27.01	4.16	15.06	40
Behavioral factors					
drinks	Dummy variable indicating whether a respondent drinks more than 2 drinks in a day (1=yes).	0.20	0.40	0	1
smoking	Current smoking (1=yes).	0.27	0.44	0	1
active	Vigorous activities? (1=yes).	0.55	0.50	0	1
ch. activity	During your life, have you ever increased your physical activity? (1=yes).	0.27	0.44	0	1
ch. diet	During your life, have you ever changed your diet to improve your health? (1=yes).	0.28	0.45	0	1
Socio-economic and demographic determinants					
partner	Living with spouse/partner (1=yes)	0.75	0.43	0	1
education	Educational attainment based on the International Standard Classification of Education (1= ISCED 0-2, 2= ISCED 3-4, 3=ISCED 5-6).	1.73	0.77	1	3
working	Working status (1=not working).	0.81	0.39	0	1
income	Household income divided by the number of equivalent adults (thousands of Euros).	23.872	31.539	0	1100
Early-life conditions					
dental	Regular dental care started in childhood (1=yes).	0.62	0.48	0	1
books	Number of books in the house when ten (1=less than 25)	0.59	0.49	0	1
math	Math skills: relative position to others mathematically when ten (1=good).	0.35	0.48	0	1
language	Language skills: relative position to others language when ten (1=good).	0.37	0.48	0	1
vaccinations	During your childhood, that is, from when you were born up to and including age 15, have you received any vaccinations? (1=yes).	0.99	0.09	0	1
blood pressure	Have you ever had your blood pressure checked regularly over the course of several years? (1=yes)	1.00	0.02	0	1
parents smoke	Did parents smoke during childhood? (1=yes).	0.63	0.48	0	1
parents drink	Did parents drink heavily during childhood? (1=yes).	0.09	0.28	0	1
rural area	Area of residence during childhood was rural or a village (1=yes).	0.44	0.50	0	1

Table 2: Cognitive Abilities

	WR	IR	DR		WR	IR	DR
	(1)	(2)	(3)		(1')	(2')	(3')
Constant	11.257***	5.473***	5.806***	books	0.616***	0.311***	0.305***
	(2.293)	(0.946)	(1.585)		(0.064)	(0.031)	(0.038)
chronic	-0.034*	-0.007	-0.025**	math	0.398***	0.174***	0.223***
	(0.020)	(0.010)	(0.013)		(0.061)	(0.030)	(0.037)
age	-0.072***	-0.034***	-0.039***	language	0.443***	0.218***	0.229***
	(0.004)	(0.002)	(0.002)		(0.063)	(0.031)	(0.038)
BMI	-0.153**	-0.043	-0.112***	parents	0.063	0.037	0.024
	(0.064)	(0.032)	(0.038)		(0.055)	(0.027)	(0.033)
BMI sq.	0.002**	0.001	0.002***	parents	0.012	-0.013	0.025
	(0.001)	(0.001)	(0.001)		(0.098)	(0.048)	(0.058)
drinks	-0.001	-0.001	-5.2e-4	rural area	-0.177***	-0.069**	-0.109***
	(0.003)	(0.002)	(0.002)		(0.055)	(0.027)	(0.033)
health	0.335***	0.168***	0.173***	dental	0.504***	0.255***	0.248***
	(0.093)	(0.049)	(0.056)		(0.062)	(0.031)	(0.037)
active	0.140***	0.057**	0.085***	DBC	0.116**	0.033	0.083**
	(0.052)	(0.026)	(0.032)		(0.057)	(0.029)	(0.035)
partner	0.170***	0.110***	0.061	DBP	0.105**	0.023	0.081**
	(0.063)	(0.031)	(0.038)		(0.053)	(0.027)	(0.032)
income	0.005***	0.002***	0.003***	DCD	-0.004	-0.003	0.001
	(0.001)	(3.8e-4)	(4.9e-4)		(0.075)	(0.038)	(0.046)
gender	1.270***	0.588***	0.693***	DHD	-0.031	-0.019	-0.015
	(0.084)	(0.042)	(0.050)		(0.069)	(0.035)	(0.042)
education	0.752***	0.351***	0.398***	DD	-0.133*	-0.052	-0.081*
	(0.041)	(0.020)	(0.025)		(0.073)	(0.037)	(0.044)
working	0.041	0.014	0.030	DAD	-0.187**	-0.108**	-0.078
	(0.069)	(0.035)	(0.041)		(0.086)	(0.042)	(0.053)
vaccinations	0.263	0.134	0.122	mobility	0.021	0.006	0.015
	(0.286)	(0.139)	(0.171)		(0.017)	(0.009)	(0.010)
blood	-0.489	0.221	-0.681	ADL	-0.008	-0.021	0.012
	(2.043)	(0.806)	(1.449)		(0.052)	(0.027)	(0.031)
ch. activity	0.383***	0.174***	0.206***	IADL	-0.341***	-0.182***	-0.161***
	(0.063)	(0.031)	(0.039)		(0.044)	(0.025)	(0.024)
ch. diet	0.229***	0.073**	0.152***	handgrip	0.031***	0.016***	0.015***
	(0.061)	(0.030)	(0.037)		(0.004)	(0.002)	(0.002)
smoking	0.242***	0.087***	0.155***				
	(0.062)	(0.031)	(0.038)				
Observation	15,105	15,105	15,105				
Number of	9,404	9,404	9,404				

Notes: This table reports the coefficients of three linear random effects models for three different measures of cognitive abilities. For space reasons, results are reported in two columns. In Columns 1 and 1', the dependent variable is the total number of words recalled (WR). In Columns 2 and 2', we consider only the number of words instantaneously recalled (IR). Finally, in Columns 3 and 3', we consider the delayed recall performance. Robust standard errors in parentheses. Significance levels: *10%, **5%, ***1%.

Table 3: Physical Abilities

	handgrip	ADL	IADL	mobility		handgrip	ADL	IADL	mobility
	(1)	(2)	(3)	(4)		(1')	(2')	(3')	(4')
Constant	42.100***	5.317***	-0.709**	7.845***	smoking	0.208	-0.003	0.018	0.027
	(3.861)	(0.263)	(0.318)	(0.824)		(0.168)	(0.011)	(0.013)	(0.033)
chronic	-0.536***	-0.062***	-0.089***	-0.389***	books	0.789***	-0.009	-0.011	0.075**
	(0.047)	(0.006)	(0.007)	(0.013)		(0.160)	(0.012)	(0.015)	(0.036)
age	-0.370***	-0.007***	-0.013***	-0.037***	math	0.434***	-0.022*	-0.004	0.006
	(0.008)	(0.001)	(0.001)	(0.002)		(0.159)	(0.011)	(0.013)	(0.034)
BMI	1.078***	0.054***	0.068***	0.170***	language	-0.186	0.017	0.009	0.076**
	(0.167)	(0.017)	(0.019)	(0.040)		(0.159)	(0.011)	(0.014)	(0.034)
BMI sq.	-0.015***	-0.001***	-0.001***	-0.004***	parents smoke	0.362**	0.002	-0.014	-0.018
	(0.003)	(3.1e-4)	(3.4e-4)	(0.001)		(0.142)	(0.010)	(0.013)	(0.031)
drinks	0.011	4.2e-4	0.001*	0.005***	parents drink	-0.405*	-0.033	-0.062**	-0.181***
	(0.008)	(3.5e-4)	(0.001)	(0.002)		(0.242)	(0.021)	(0.027)	(0.057)
health	1.844***	0.451***	0.473***	1.712***	ruralarea	1.036***	-0.003	-0.042***	-0.016
	(0.228)	(0.036)	(0.039)	(0.075)		(0.139)	(0.011)	(0.013)	(0.031)
active	1.290***	0.087***	0.153***	0.572***	dental	0.978***	-0.001	0.014	0.148***
	(0.115)	(0.008)	(0.010)	(0.029)		(0.158)	(0.012)	(0.014)	(0.036)
partner	0.077	0.011	0.062***	0.066*	DBC	0.918***	0.072***	0.109***	0.327***
	(0.148)	(0.013)	(0.016)	(0.037)		(0.136)	(0.013)	(0.016)	(0.035)
income	0.002	-3.5e-4**	-2.2e-4	0.001	DBP	0.479***	0.064***	0.091***	0.203***
	(0.002)	(1.6e-4)	(1.8e-4)	(4.5e-4)		(0.132)	(0.012)	(0.014)	(0.032)
gender	-15.743***	-0.009	-0.080***	-0.513***	DCD	-0.034	-0.033	-0.071**	-0.193***
	(0.160)	(0.012)	(0.014)	(0.033)		(0.169)	(0.022)	(0.028)	(0.053)
education	0.260**	-0.008	-0.006	0.025	DHD	-0.063	-0.004	-0.005	-0.202***
	(0.103)	(0.007)	(0.008)	(0.022)		(0.159)	(0.020)	(0.024)	(0.049)
working	1.097***	0.017	0.038**	0.286***	DD	-0.431**	0.034*	0.085***	0.242***
	(0.167)	(0.014)	(0.018)	(0.041)		(0.178)	(0.019)	(0.022)	(0.048)
vaccinations	-0.094	-0.014	-0.009	0.213	DAD	-1.109***	-0.087***	-0.201***	-0.379***
	(0.677)	(0.060)	(0.090)	(0.167)		(0.207)	(0.029)	(0.034)	(0.062)
blood pressure	0.690	-0.084*	-0.206*	-0.532	IR	0.218***	0.008**	0.032***	0.027**
	(3.024)	(0.045)	(0.123)	(0.573)		(0.046)	(0.004)	(0.006)	(0.011)
ch. activity	0.744***	0.026***	0.021*	0.145***	DR	0.104***	0.010***	0.013***	0.029***
	(0.160)	(0.010)	(0.012)	(0.033)		(0.038)	(0.003)	(0.004)	(0.009)
ch. diet	-0.445***	-0.014	-0.006	-0.091***					
	(0.157)	(0.012)	(0.014)	(0.035)					
Observations	15,105	15,105	15,105	15,105					
Number of id	9,404	9,404	9,404	9,404					

Notes: This table reports the coefficients of three linear random effects models for three different measures of physical abilities. For space reasons, results are reported in two columns. In Columns 1 and 1', the dependent variable is the handgrip strength. In Columns 2 and 2', we consider the number of Activities of Daily Living (ADL) that an individual can perform alone. Columns 3 and 3' present the results for the number of Instrumental Activities of Daily Living (IADL) that an individual can perform alone. Finally, in Columns 4 and 4', we use the mobility index as dependent variable. Robust standard errors in parentheses. Significance levels: *10%, **5%, ***1%.

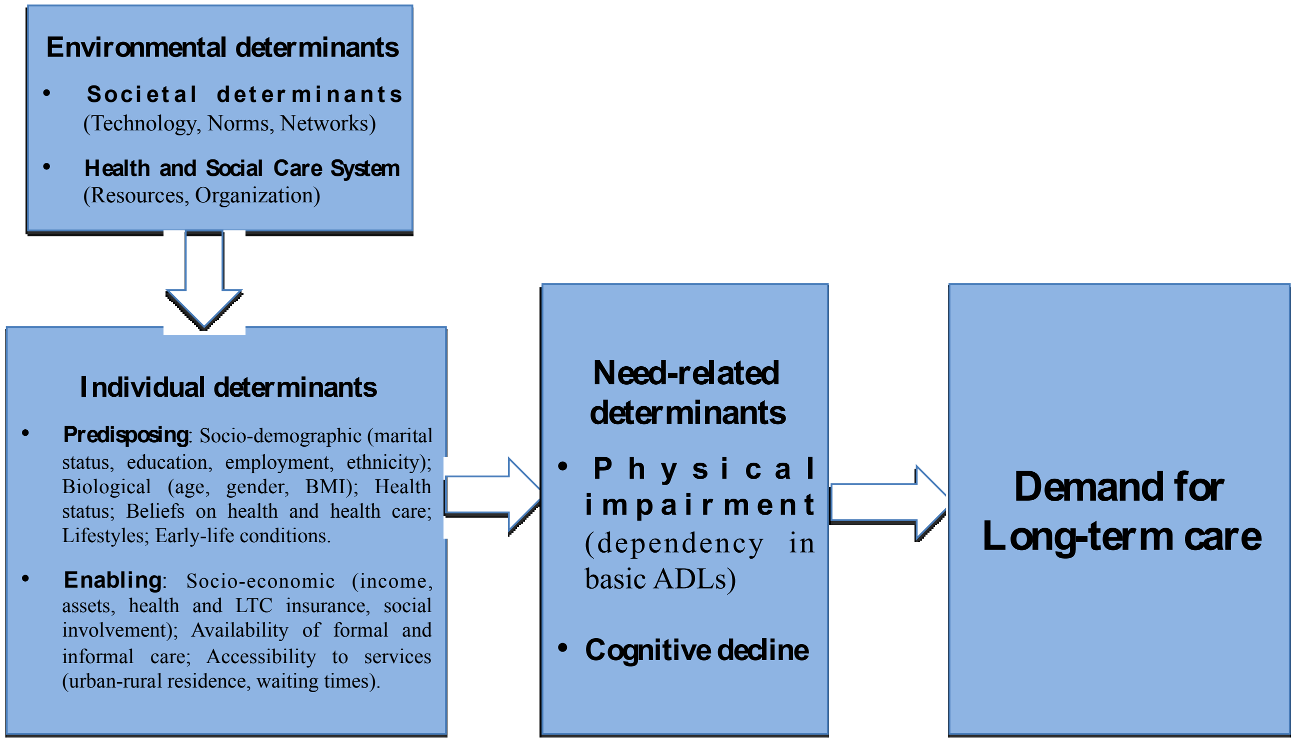
Table 4: Sum of Squared Errors

	WR	**IR**	**DR**	**ADL**	**IADL**	**mobility**	**handgrip**
REEM (five levels)	130011	32802	47237	**4541**	**6539**	**41450**	**754782**
REEM (whole)	**125035**	**31624**	**45729**	**4507**	**6267**	**38569**	**697768**
RE (with n. vars)	127028	32631	47213	4696	7119	41769	765147
RE	125528	31860	46166	4611	6963	39223	732413
Number of variables for five levels.	12	10	8	4	10	6	8

Notes: This table presents the sum of squared errors of both REEM tree estimates and RE estimates.

FIGURES

Figure 1: Determinants of demand for LTC: an adaptation of the Andersen-Newman model



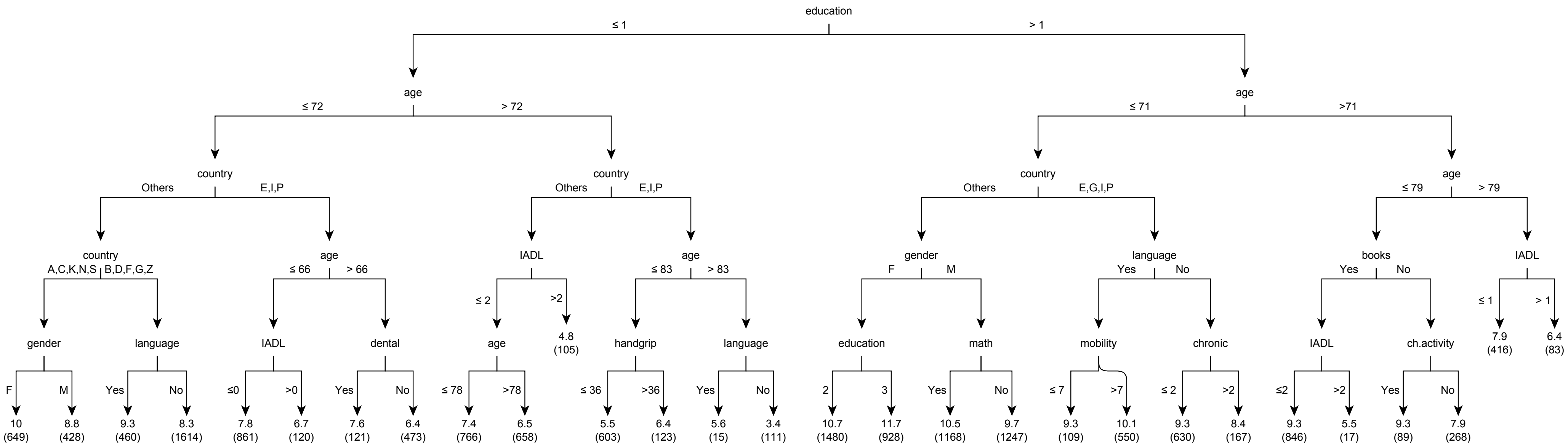


Figure 2: Words Recalled (RE-EM tree)

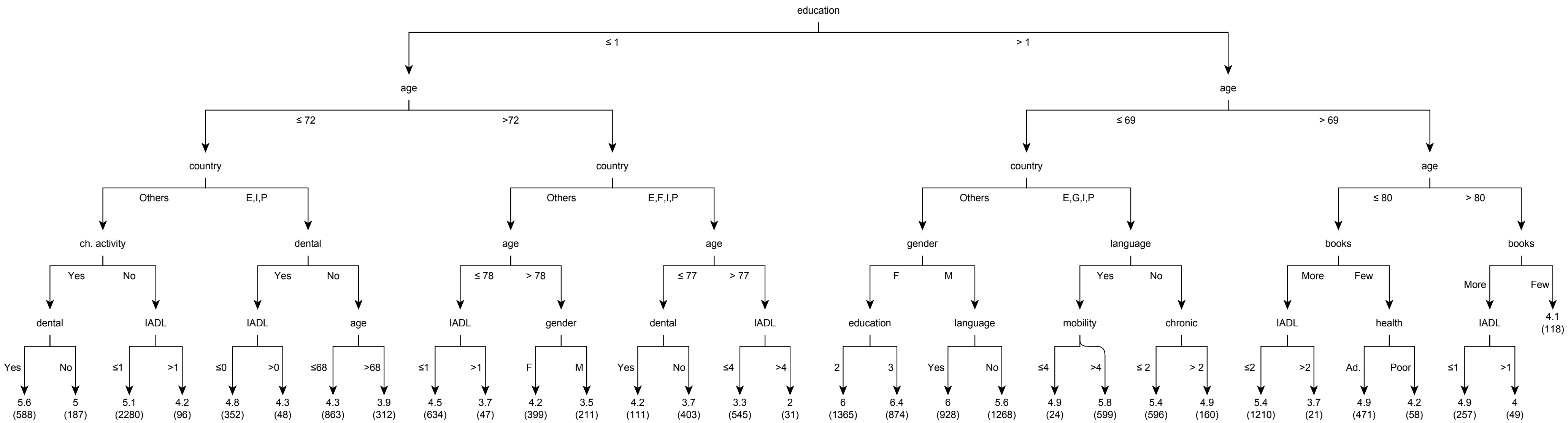


Figure 3: Immediate Recall (RE-EM tree)

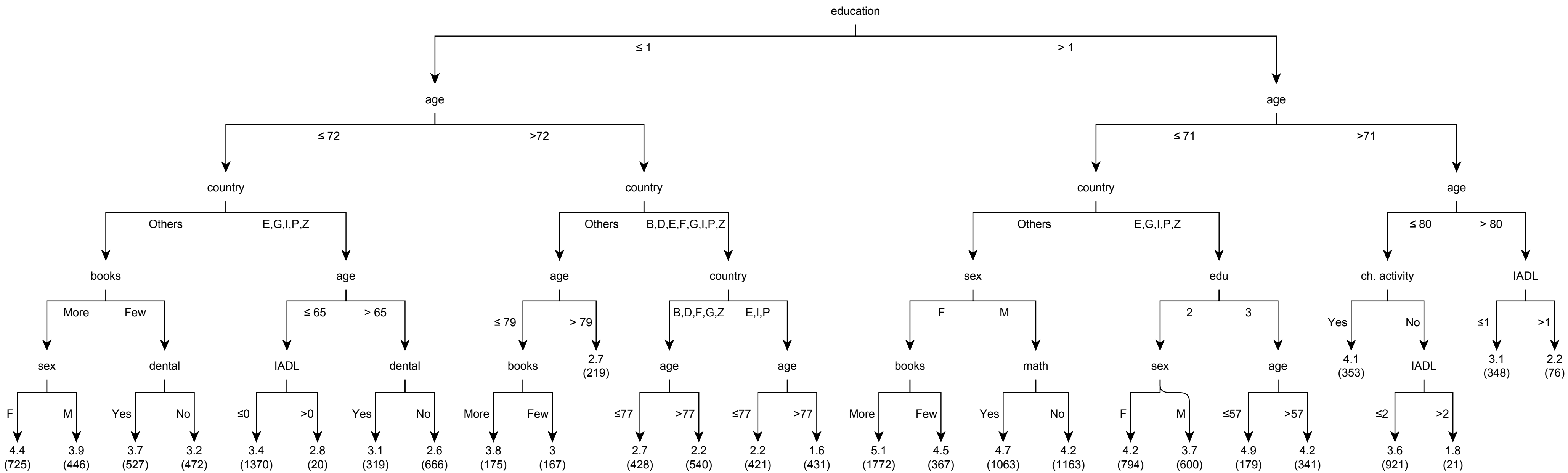


Figure 4: Delayed Recall (RE-EM tree)

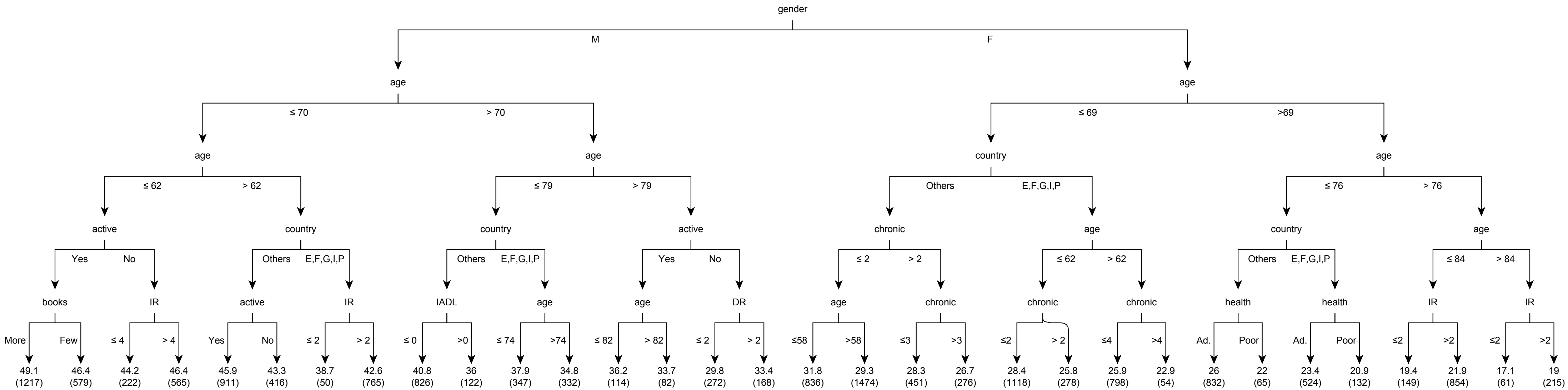


Figure 5: Maximum Handgrip Strength (RE-EM tree)

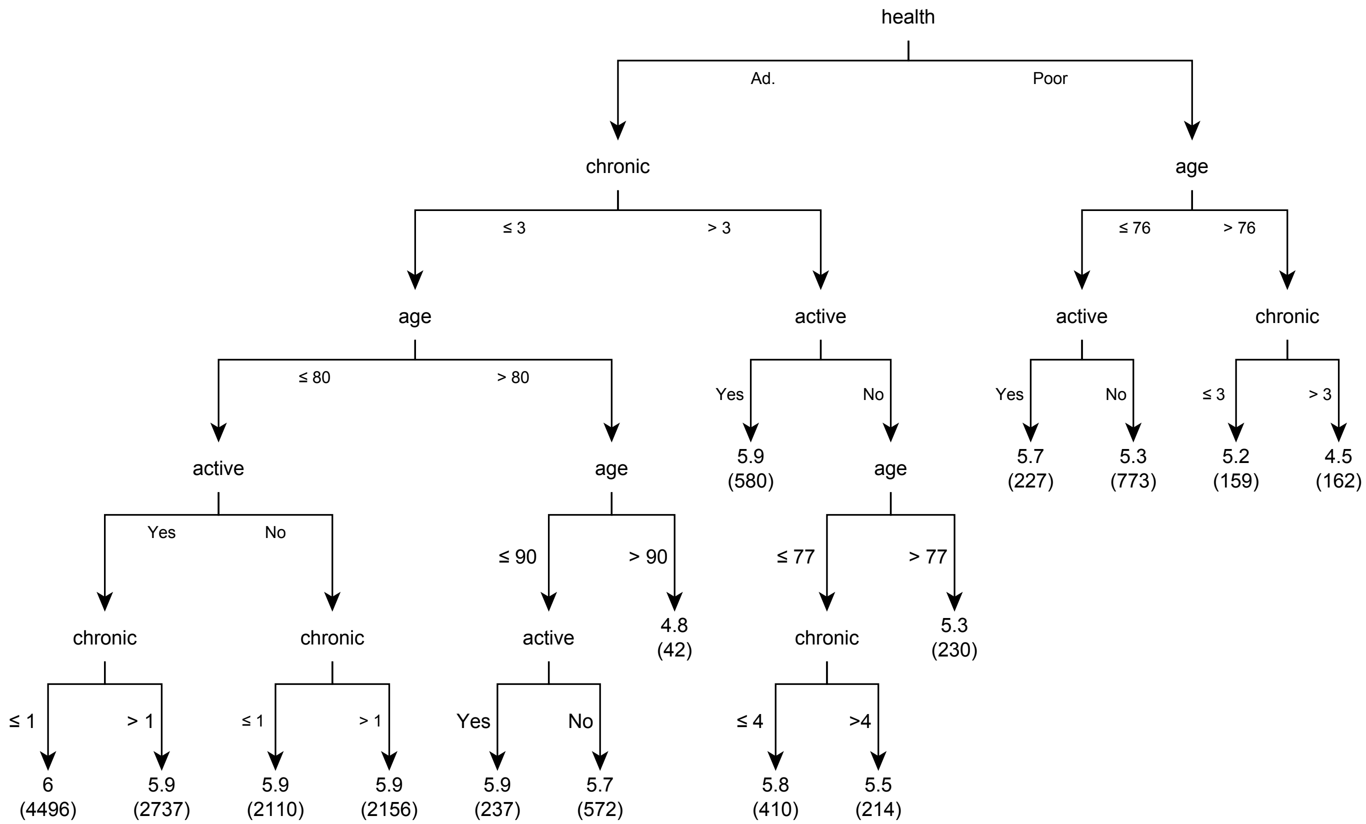


Figure 6: ADL (RE-EM tree)

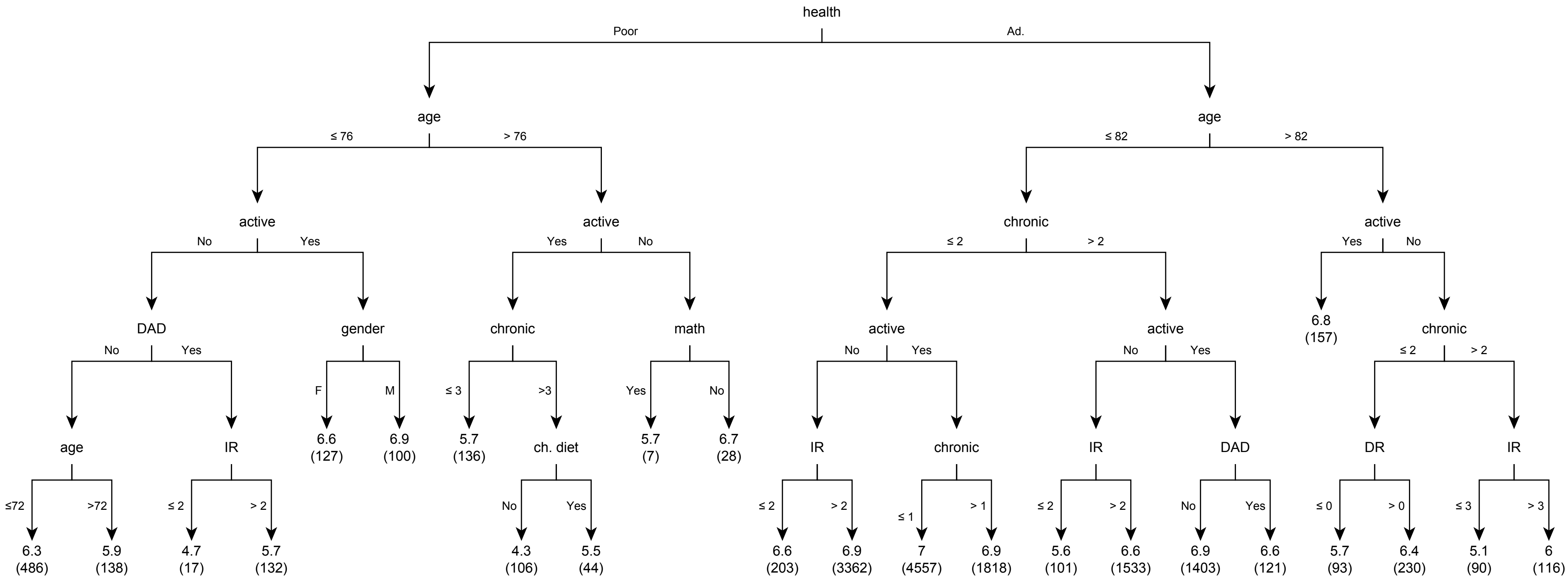


Figure 7: IADL (RE-EM tree)

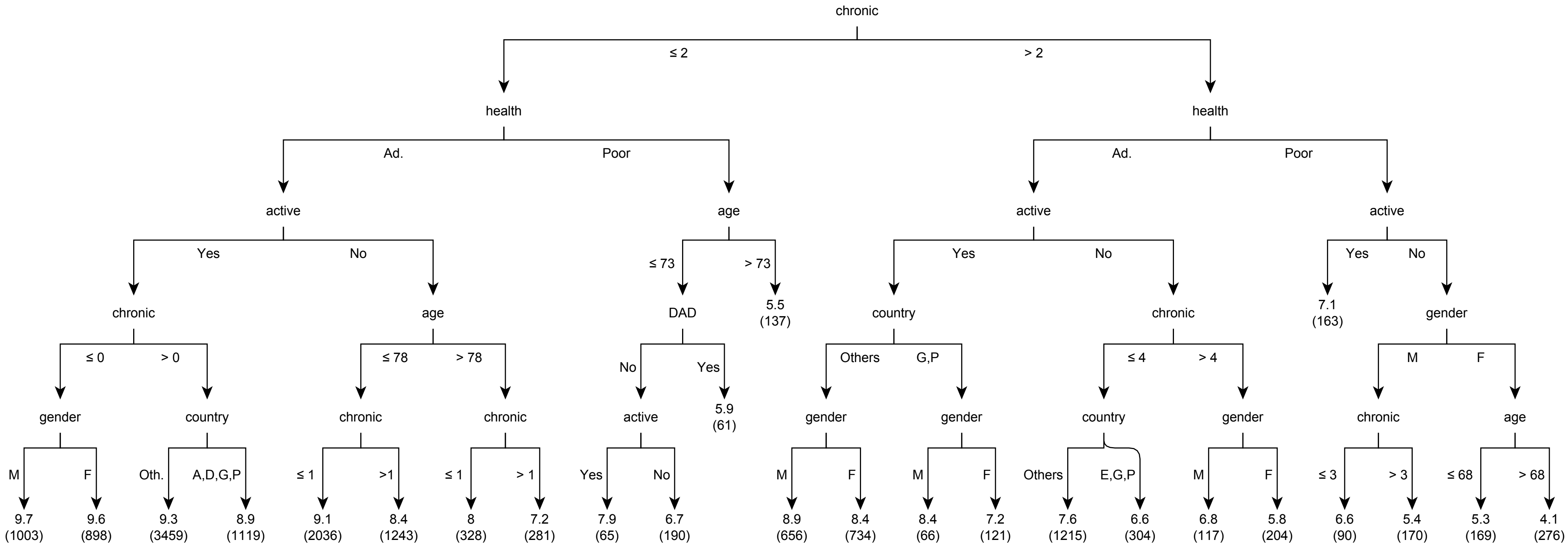


Figure 8: Mobility (RE-EM tree)