Working Paper no.: 2017/04

Michaël Boissonneault and Antoine Vilotitch

The link between age, work and health among older people: Visual examination by the use of heat maps

NiDi
netherlands interdisciplinary demographic institute

The link between age, work and health among older people: Visual examination by the use of heat maps

Michaël Boissonneault[1] and Antoine Vilotitch[2, 3]

Working Paper no.: 2017/04

[1] Nederlands Interdisciplinair Demografisch Instituut / Universiteit van Groningen.
[2] Aix Marseille Univ, INSERM, IRD, SESSTIM, Sciences Économiques & Sociales de la Santé & Traitement de l'Information Médicale, Marseille, France.
[3] ORS PACA, Observatoire Régional de la Santé Provence-Alpes-Côte d'Azur, Marseille, France.

Corresponding author: Michaël Boissonneault, boissonneault@nidi.nl

November 2017

INTRODUCTION

Poor health is associated with an increased risk of leaving the labor force, especially among workers of age 50 and older (van Rijn et al. 2014; OECD 2010). Such labor force exits among this age group often lead to a permanent withdrawal of the labor force, which is known as early retirement (Fisher et al. 2016). Since health usually deteriorates with age, concerns have been raised as whether workers will be able to have longer active lives and thus counteract the negative effects of population aging on pension systems and economic output (OECD, 2010; Ilmarinen 2001). This is an especially important question given the postponement of the age of admissibility to pension benefits, which is taking place in many countries of the Organisation of Economic Co-operation and Development (OECD) (OECD 2015).

In order to better determine the extent of this problem, at least four questions are important: First, what is the proportion of the population that retires early due to poor health? Second, what is the form and intensity of the link between poor health and early retirement, i.e. what is the change in the probability of leaving the workforce when health changes by one unit, and is this change constant across values of health? Third, is the link between poor health and early retirement constant across age, i.e. is a worker with poor health aged 55 years old more or less likely to retire early compared to a worker with same health and aged 60 years old? Finally, is the link between poor health and early retirement constant over time, i.e. are today's workers with given level of health more or less likely to retire due to poor health as were workers with same health ten years ago?

To study these questions, we take advantage of the growing availability of data on objective measures of physical health collected among older people. These are made available by the Health and Retirement Study (HRS) and many of its sisters studies, including the English Longitudinal Study of Ageing (ELSA) and the Survey of Health, Ageing and Retirement in Europe (SHARE) from which we use data here. Objective measures of physical health include grip strength, different chair stand and balance tests, and peak expiratory flow[1]. These measures have many advantages over the other measures of health that have been previously used to study the relation between health and labor force participation at older ages (Lindeboom and Kerkhofs

[1] The reader can consult https://g2aging.org/ for more information on these measures and the surveys that collect data on them.

2009; Disney et al 2006; Bound et al., 2007). The two most important ones are that 1) they are measured using standardized protocols and devices, which mean that they are free of any interpretation or rationalization bias from the respondent; 2) and that they are measured on a continuous scale, which allows a more refined analysis and facilitates the interpretation of the results. These measures have also been shown to entertain a close link with the capacity to work at older ages (Kalwij and Vermeulen 2008; Boissonneault and De Beer 2017), subsequent mortality (Cooper 2010), and other health outcomes (Cooper et al. 2010).

In this paper, we aim to answer the questions raised above by means of visual representation. This will be done by means of a series of heat maps. Heat maps have been developed many decades ago among non-demographic disciplines to represent the variation in a variable of interest according to two continuous measures, which are often—although not necessarily—geographical coordinates. In demography, they have been mostly used to represent variation in rates of mortality or fertility according to calendar time and age simultaneously. Because of the evident similarity with the Lexis diagram, this type of heat map has been coined "Lexis surface" by Arthur and Vaupel (1984). The name and technique has since then been reused and sometimes adjusted to different needs (Vaupel et al. 1987; Schoeley and Willekens 2017; Riffe et al. 2017).

Here, we exploit the continuous nature of the objective measures of physical health and propose to use heat maps to represent the proportion of older people that participate to the labor force according to health and age simultaneously. By doing this, we aim at providing a global picture of the link between health, age and work at older ages. Such a global picture will be obtained through different ways. First, we will compare the situation of two countries and two groups of countries that differ considerably concerning the link between health, age and labor force participation. These are England, the United States and two groups of European countries. Second, we will present results using three different objective measures of physical health which cover fairly distinct aspects of health, namely, upper body muscular vitality (grip-strength test), lower body muscular vitality (chair stand test) and lung functionality (peak expiratory flow). Also, we will present results based on a measure of mental health (EURO-D scale) in order to verify whether we can generalize our results to non-physical dimensions of health. Finally, we will use data at two points in time, which will alow us to verify whether the link between health, age and labor force participation at older ages changed over time.

The paper is organized as follow. The second section presents the data sources. The third section briefly discusses the context around retirement legislation in the countries at hand. The fourth section presents the methods. The fifth section presents the results and the sixth section concludes.

DATA

Data sources

In order to offer a global overview of the link between health, age and labor force participation at older ages, three distinct data sources are used. These data sources—HRS, ELSA and SHARE—are considered as sister studies because they were set up in such a way that they offer highly comparable data. An important feature of these surveys is that participants are followed until they die or drop off. In-depth information on the participants' health, work and retirement is collected. We present each survey in chronological order of their first data collection.

The HRS takes place every second year since 1992 and is representative of the American population aged 50 years and older (Health and Retirement Study, 2016)[2]. HRS started a module on objective measures of physical health in 2004 through collecting data on walking speed, grip strength and lung strength in the framework of a pilot. Data on these tests, plus on some balance tests, have since 2006 been collected every two years on a rotating panel of half of the whole sample (i.e. data are collected on the same respondents every four years), and are representative of the American population aged 50 and older.

ELSA covers the population of age 52 and older residing in England and has been running biannually since 2002 (Marmot et al., 2016)[3]. It collects data on objective measures of physical health every four years since 2004. Similarly to HRS, ELSA collects data on walking speed, grip and lung strength, and on different balance tests, but also on the chair stand test.

[2] *The HRS (Health and Retirement Study) is sponsored by the National Institute on Aging (grant number NIA U01AG009740) and is conducted by the University of Michigan.*

[3] The data were made available through the UK Data Archive. ELSA was developed by a team of researchers based at the NatCen Social Research, University College London and the Institute for Fiscal Studies. The data were collected by NatCen Social Research. The funding is provided by the National Institute of Aging in the United States, and a consortium of UK government departments co-ordinated by the Office for National Statistics. The developers and funders of ELSA and the Archive do not bear any responsibility for the analyses or interpretations presented here.

SHARE took place in 2004-2005 and in 2006-2007, and every second year from 2009 onwards (Börsch-Supan, 2016a; Börsch-Supan, 2016b)[4]. Eleven European countries participated to this survey at the onset and ten more joined at different points later on. SHARE collects data on walking speed, grip and lung strength and on the chair stand test, but not on the balance tests. Data on grip strength have been collected at each wave, but data on the other measures have been collected inconsistently over time (see Figure 1 below).

Measurements

We limit our analyses to three measures of physical health: grip strength, lung strength and the chair stand test. We do not use walking speed since data are only collected among people age 70 and older and most people are already retired at that age. We also do not use any data on the balance tests since these are measured on a binary scale (the participant succeeds or fails in doing the test) and we prefer to use measures that are on a continuous scale. The measure of mental health is obtained using the EURO-D mental health scale, which is based on eleven questions pertaining to the participant's experience of everyday life (Prince et al. 1999). We describe each measure of health in detail in the appendix.

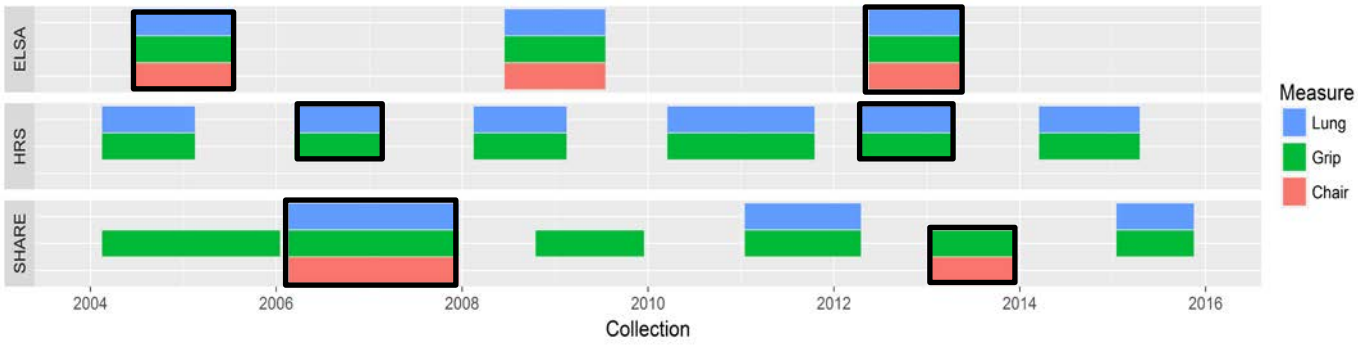


Figure 1 Data collection for grip strength, lung strength and chair stand test among ELSA, HRS et SHARE

[4] The SHARE data collection has been primarily funded by the European Commission through FP5 (QLK6-CT-2001-00360), FP6 (SHARE-I3: RII-CT-2006-062193, COMPARE: CIT5-CT-2005-028857, SHARELIFE: CIT4-CT-2006-028812) and FP7 (SHARE-PREP: N°211909, SHARE-LEAP: N°227822, SHARE M4: N°261982). Additional funding from the German Ministry of Education and Research, the U.S. National Institute on Aging (U01_AG09740-13S2, P01_AG005842, P01_AG08291, P30_AG12815, R21_AG025169, Y1-AG-4553-01, IAG_BSR06-11, OGHA_04-064) and from various national funding sources is gratefully acknowledged (see www.share-project.org).

Measurement periods

Figure 1 shows when data collection took place for each objective measure of physical health considered here. The data used here is shown by means of boxes. We present results at two points in time. Results will include data from each of the three surveys concerning grip strength. Data on lung strength will come from ELSA and HRS only. Data on the chair stand test will come from ELSA and SHARE only. Data on the EURO-D scale will come from SHARE only as ELSA and HRS use different scales to evaluate mental health. Analyses were ran using ELSA data from 2004-2005 and 2012-2013; HRS data from 2006-2007 and 2012-2013; and, finally, SHARE data from 2006-2007 and 2013. In the remaining of this article, we will refer distinctly to the periods 2004-2007 and 2012-2013.

Country coverage

We use all of the available data from ELSA and HRS thus covering the older populations of England and the United States, respectively. SHARE produces data representative of the older populations living in 11 to 21 countries depending on which point in time we consider. Rather than analyzing all of the data at hand, we choose to show results for two groups of countries. The groups were formed in a way that they differ as much as possible concerning the link between age, health and labor force participation of older people. For that, we used the Active Ageing Index (AAI) developed by the United Nations Economic Commission for Europe (UNECE). This index classifies countries according to different aspects concerning the life of older people. Of these aspects, labor force participation and health have a preponderant weight. We make two groups of three countries for which we have data at the points in time indicated above. The first group is formed of the countries that performed the best according to the 2014 classification (UNECE 2017). These are Sweden, Denmark and the Netherlands. The second group is made of the countries that performed the worst according to the same classification. These are Belgium, Italy and Spain. In the remaining of this article, we will refer to these groups as countries with high AAI and countries with low AAI.

CONTEXT

The accelerated demographic aging that is being experienced in most parts of the world (Lutz et al 2008) has brought about worries about the capacity of countries to keep pension expenditures low (Bongaarts 2004) and to maintain positive economic growth (Bloom et al. 2010). Higher participation among older people is thus supposed to slow down or stop the raising trend in spending in public pension systems and help fuel economic growth (OECD 2015). The feasibility of achieving higher participation among older people should be warranted by the longer—and presumably more healthy—lives that people enjoy. Furthermore, it is argued that prolonged economic participation can benefit individuals themselves through improving financial preparedness in front of retirement and increasing physical and mental fitness (Zaidi et al. 2012). We present in this section some trends in labor force participation in the countries studied. We also present some of the legislation changes that may have contributed to the raising trend in participation or that may have affected the link between work and health at older ages. Since we have no information that is specific to England, we present data and facts for the whole of the United Kingdom instead.

Labor force participation of people age 55-64 has been increasing for many years already among the countries studied here. As shown in Figure 2, each country (or group of countries) have seen the participation of people age 55-64 grow between 2004 and 2014, although to different extents. Participation grew more in countries (or groups of countries) with a lower initial level. Participation among countries with low AAI grew by almost 14%, while it grew by 7% among countries with high AAI (a raise mostly fueled by the one that took place in the Netherlands). Growth in the proportion of people active on the labor market was moderate in the United Kingdom (5.6%) and weak in the United States (0.8%).

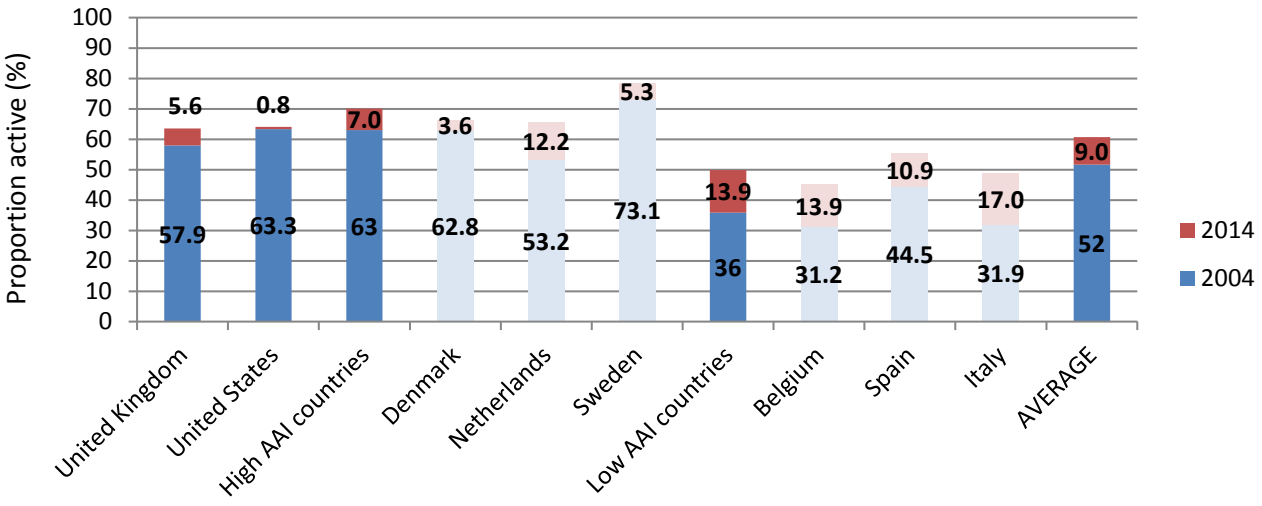


Figure 2 Proportion of people aged 55 to 64 participating to the labor market

Source : OECD data (2017)

Papers that studied the reasons for this raise have pointed to the greater participation of women (and, concomitantly, of their male spouses) and the higher level of education of the younger cohorts (Schirle 2008 ; Coile 2015). Other factors have been suggested to have played a role, although evidence is less conclusive. These are the shift in retirement plans from defined benefits to defined contribution, the better health of the aging workers, and the stricter accessibility to early retirement benefits (Coile 2015 ; Carriere et al. 2016).

Among the legislative changes around retirement that have been taking place in the countries studied, we note a raise of the official age at retirement in Italy and Belgium. In the United States and in Denmark, admissibility to full pension benefits has been gradually increased past age 65 starting in 2004 and 2005, respectively. In Denmark, Belgium, Italy and the Netherlands the accessibility to early or partial retirement has been reduced or made less financially attractive (OECD 2005 ; OECD 2011 ; OECD 2015).

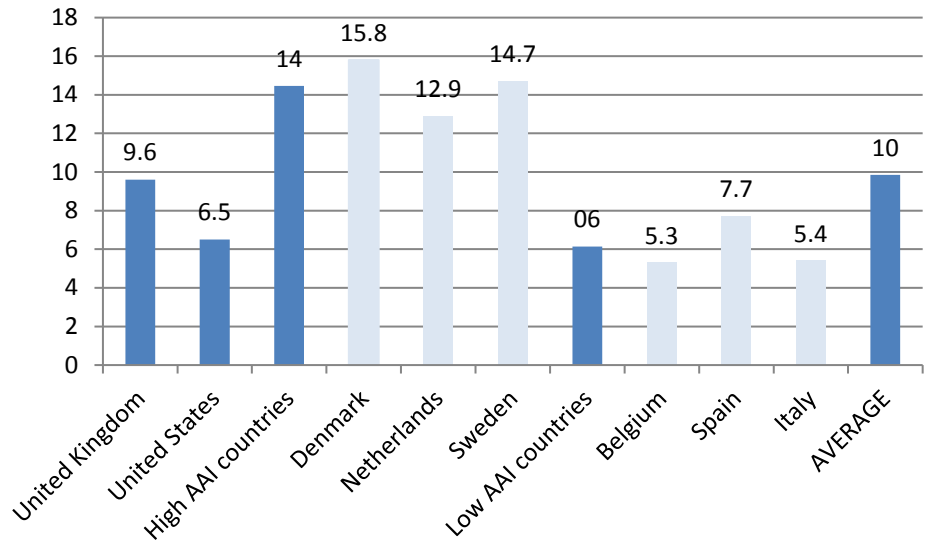


Figure 3 Proportion aged 50 to 65 that receives disability pension benefits

Source : Borsch-Supan 2011

In spite of the raise in labor force participation at older ages, many people continue to retire before the official age at retirement. Older people often have a poorer health, and are therefore more at risk of retiring because of a disability. Figure 3 shows the proportion of people aged 50 to 65 who receive disability benefits according to 2004 data[5]. The proportions are more than twice as high in countries with high AAI compared to countries with low AAI and the United States. The proportion in the United Kingdom lies in between. It was shown that this variation is likely due to variation in the conditions of admissibility to disability benefits programs (Borsch-Supan 2011). Actions to restrict the admissibility to such programs or to reduce their financial attractiveness have been undertaken in the Netherlands, Denmark, Spain and the United Kingdom (OECD 2010).

[5] These are the most recent data available.

METHODS

In the visualizations that will follow, the dependent variable is the proportion of people that participate in the labor market at a given point in time. Each survey from which we use data asks the respondents a similar question about labor force participation (see appendix). We consider respondents who are working or unemployed as participating in the labor market and assign them the value “1”. All other respondents are considered as not participating and are assigned the value “0”.

We present the results in such a way that it is possible to extract information about the proportion of people concerned by the values of health. To do that, we rely on the properties of the normal distribution. Each measure of physical health is on a continuous scale. Values for grip and lung strength are normally distributed. We use the natural logarithm of the values of the chair stand test as these were skewed to the right. For each of these measures, we convert the values in standard deviation inside of each sex and country. Mental health is measured on a discrete scale with values between 0 and 11 and strongly right skewed. We group these categories so that they approach a normal distribution (details available in the appendix).

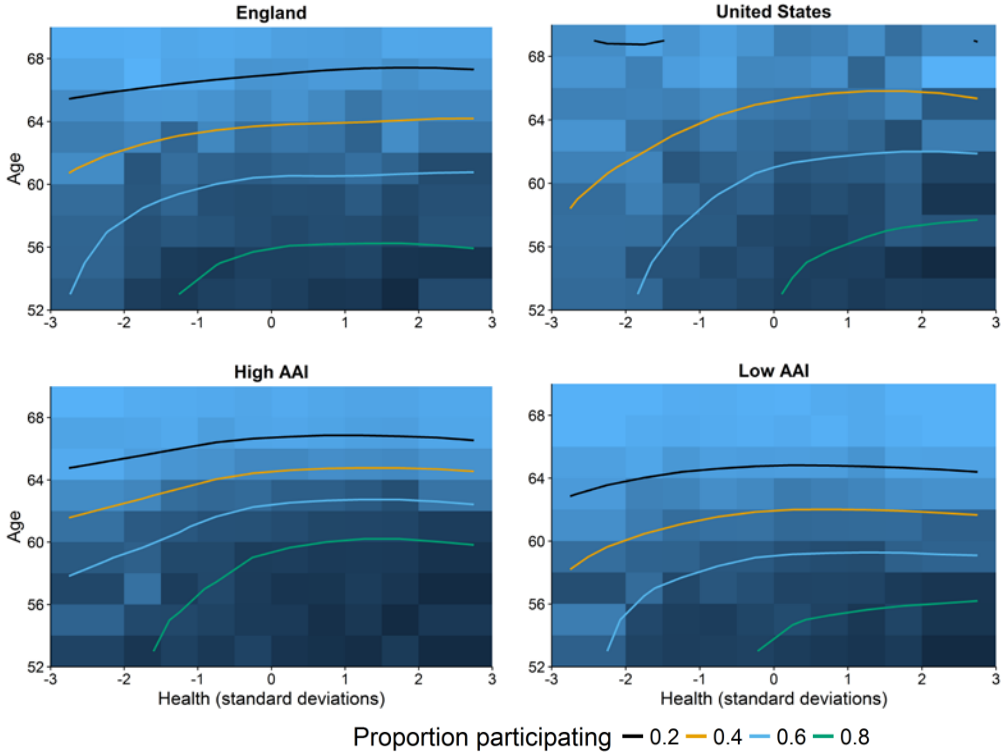
In the visualizations below, the *x* axis represents variation in health. Each tick mark indicates a variation of one standard deviation. The heat maps therefore also transmit information about the proportion of people that correspond to different values of health inside of each year of age. The *y* axis represents variation in age, which is common practice concerning the Lexis diagram. The *z* variable represents the proportion of people participating to the labor market. We graded health and age in a way that we have (10 * 9 =) 90 combinations between each level of health and each age group. For each combination, we computed specific levels of labor force participation. Variation in labor force participation is shown using variation in the degree of lightness (a darker tone meaning higher participation). Conform to common practice, we use isolines to help reading the maps. The isolines were smoothed using the *Loess* (locally weighted regression) function in base R (Cleveland et al. 1992; R Core Team 2013). Details about the specification of the axes and of the regression model are provided in the appendix.

RESULTS

Figures 4 to 7 show variation in the proportion of people participating to the labor market according to age and health simultaneously for the 2012-2013 period[6]. The graphs are grouped by measure of health. We start out with presenting the results for grip strength. Then we show the results for the chair stand test, then for lung strength and finally for mental health.

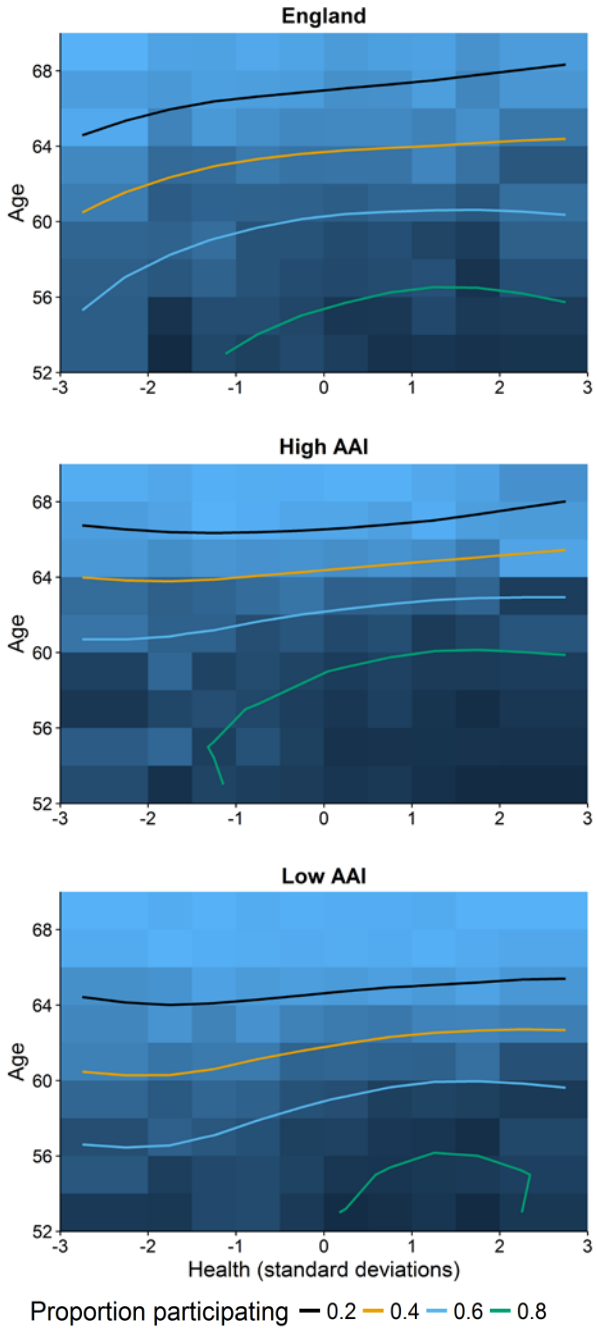
The Figures are probably best read considering both age and health at the same time. This is more easily done by paying attention to the isolines. In each heat map, the bottom right line (in green) shows for which combinations of age and health participation reaches 80%. Using the example of the United States in Figure 4, we see that participation reaches 80% among people age 52 years old with values of health near the median, as well as among people age 58 years old with health better than 2 standard deviations above the median. Furthermore, as shown by the orange line, participation reaches 40% among people age 60 with values of health worse than 2 standard deviations below the median, while the same participation rate is reached by people age 64 with health around the median or better.

Figure 4 Proportion participating to the labor market according to age and health as measured by grip strength, 2012-2013



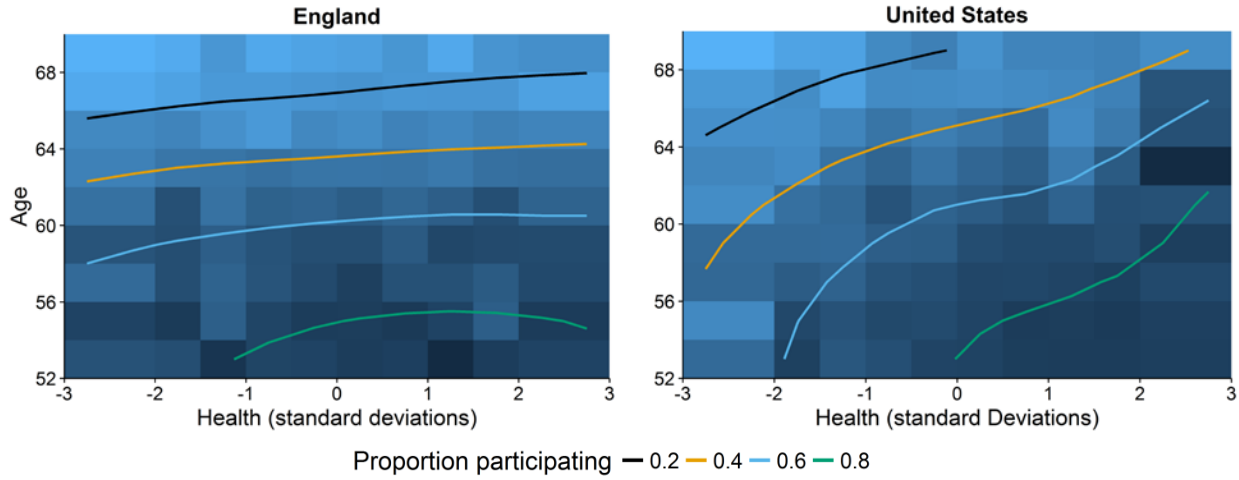
[6] The graphs for the 2004-2007 period are available upon request.

Figure 5 Proportion participating to the labor market according to age and health as measured by the chair stand test, 2012-2013



The figures all have a similar interpretation so we limit our further comments to the general aspect of the figures. In general, the form of the link between participation, age and health seems to stay roughly the same independently from the country (or group of countries), measure of health, or point in time considered. In each case, the isolines take a more vertical path on the left hand side of the graphs—in the part representing worse health—while they take a more horizontal path in the middle and the right hand side of the graph—in the parts representing average and better than average health. This pattern is identifiable by the "⌐" form of the isolines and is to be seen in almost all of the illustrations.

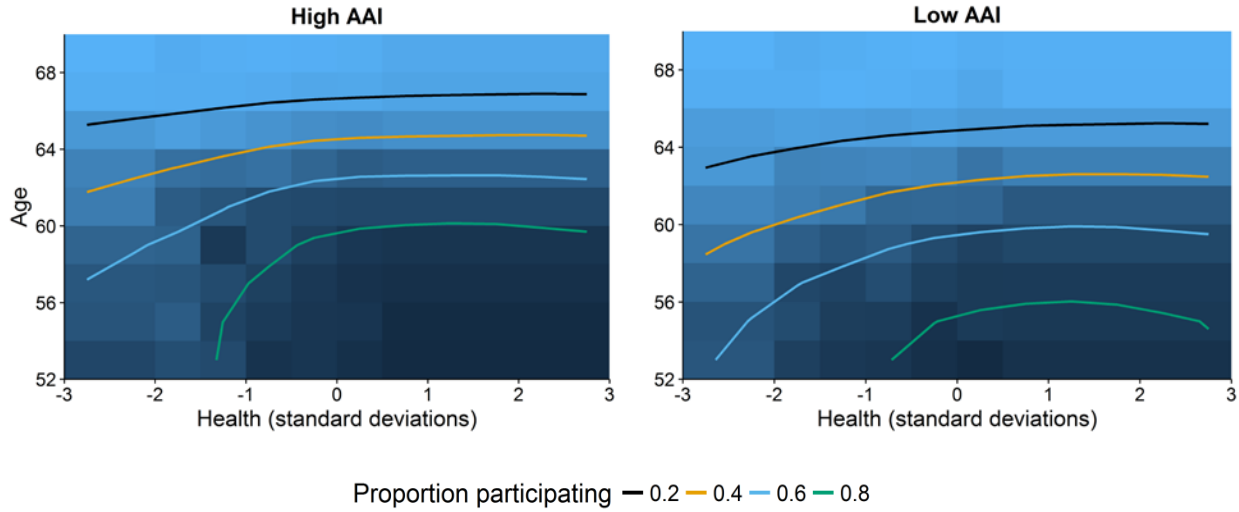
Figure 6 Proportion participating to the labor market according to age and health as measured by lung strength, 2012-2013



One interpretation is that improvements in health induce large gains in participation when health is very poor, but that such improvements only induce slight gains in participation when they occur among the healthier part of the population.

The apparent consistency in the general aspect of the figures may be hiding some more subtle discrepancies. The form of the link between participation, age and health may be somewhat different across countries. For example, in Figure 4, the isolines are further apart concerning the United States, while they are closer to each other concerning the European countries. Furthermore, an interesting question is whether the form of the link changed over time inside of each country and for each measure of health. In the next two subsections, we present two other series of visualizations that allow to better answer these questions.

Figure 7 Proportion participating to the labor market according to age and health as measured by mental health, 2012-2013

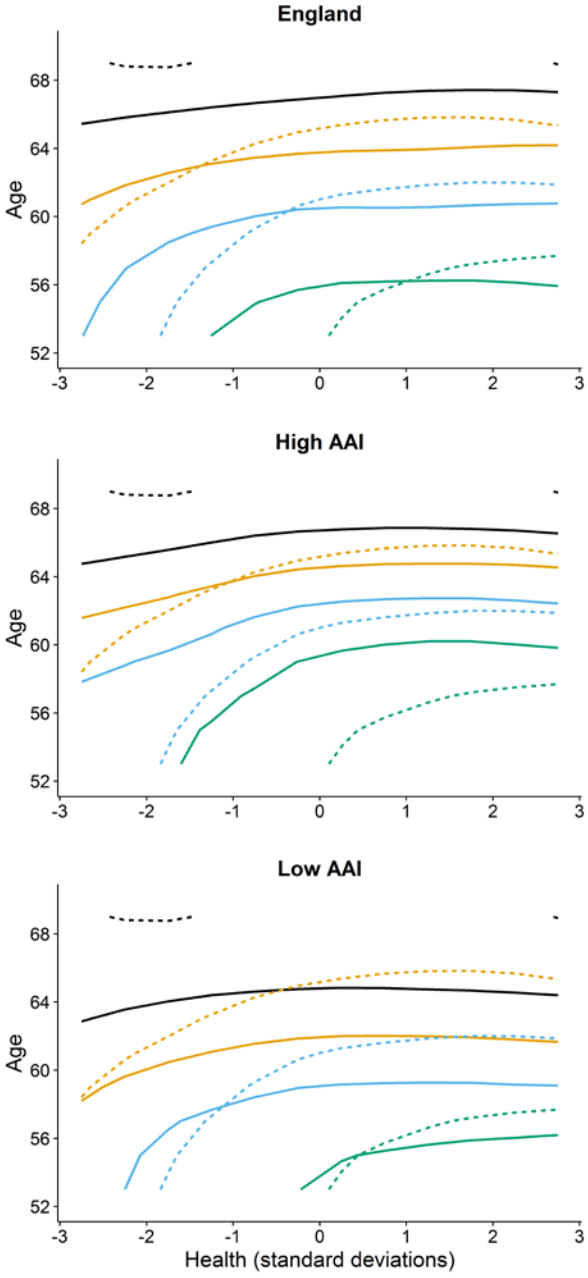


Country differences

Figures 8 shows between country variation in participation according to age and health. We compare countries using grip strength as a measure of health since it is the only measure that is common to all countries. Because of the large number of possible country combinations, we choose to present results referring each time to the United States. We directly compare countries two by two on a single graph using isolines only (no tones). The full lines represent the country specified in the title while the dotted lines ones represent the United States.

Our observations made in the previous subsection are to a large extent confirmed as we observe relatively little difference between the pattern of the United States and that of each of the other countries. Two discrepancies are however worth mentioning. First, we notice the sometimes wide gaps between the lines when reading from top to bottom. These are due to country differences in the age specific risk of retiring. The

Figure 8 Cross-country differences in participation according to age and health as measured by grip strength (the dotted lines represent the United States)



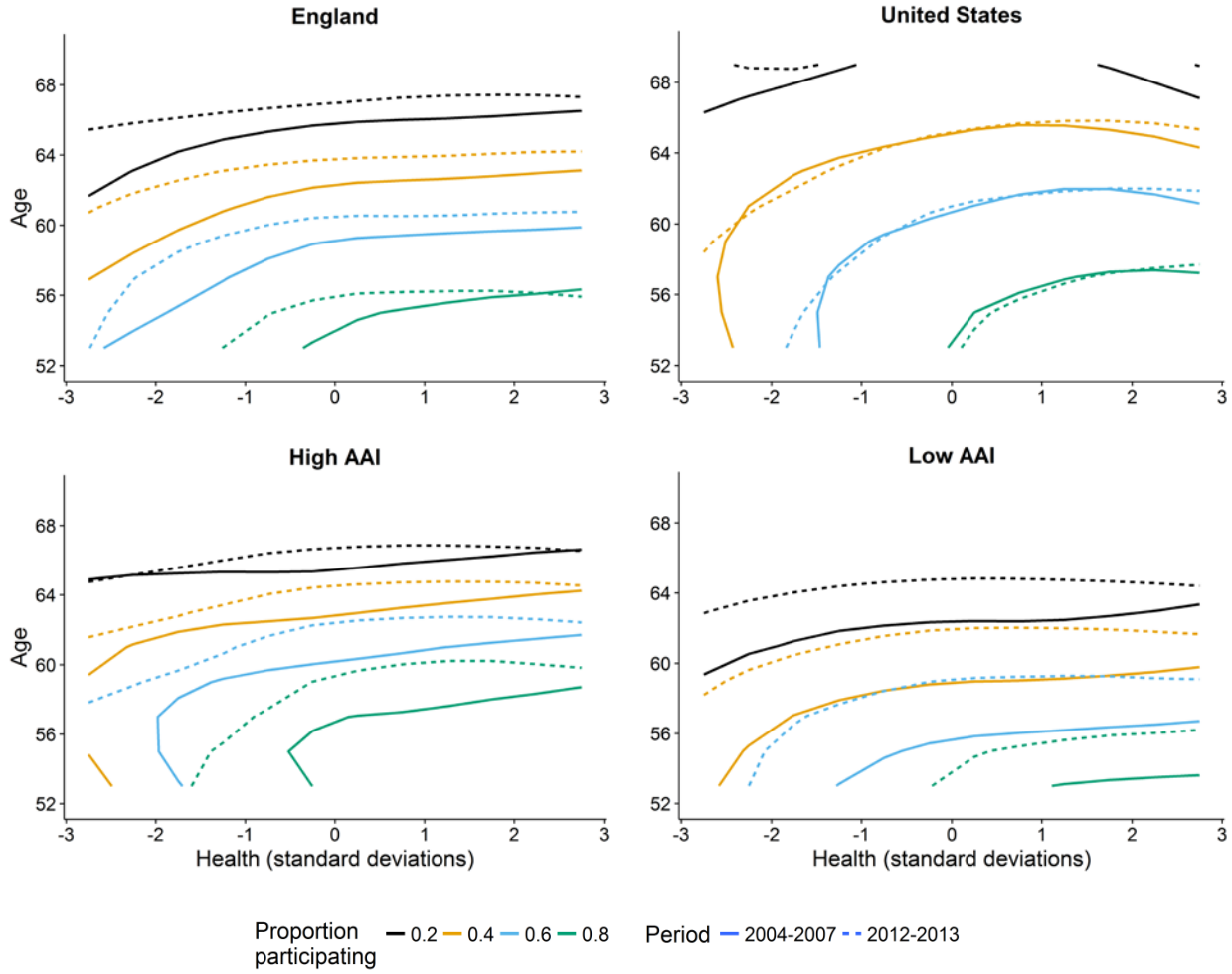
wider gap between the isolines translate a more spread out risk in the United States than in the other countries. Second, we notice on the left hand side of the graphs the more pronounced slope of the dotted lines representing the United States compared to the full lines representing the other countries (or group of countries). We interpret these differences as a stronger health effect on the decision to retire in the United States, possibly translating more unequal access to the labor market between people in good and poor health in this country.

Time differences

Figure 9 shows variation in labor force participation according to age and health as measured by grip strength, inside of each country, between the periods 2004-2007 and 2013-2014. Once again, we rely solely on the isolines to transmit information, where the full lines represent the former period and the dotted ones the latter one.

Each graph illustrates a slightly different evolution across countries. First, we witness very little change in the United States, which is not surprising given the labor force participation figures presented above. In the countries with low AAI, the isolines moved up in a surprisingly uniform way, with the isolines representing different levels of participation almost exactly overlapping each other. In fact, a worker with any given level of health and of any given age in 2004-2007 has in almost all cases an exactly 0.2 points higher propensity to be active on the labor market in 2012-2013. The raise in labor force participation thus was equally spread among people of different levels of health. In the countries with high AAI, as well as in England, the flatter pattern of the lines for 2012-2013 compared to the lines for 2004-2007 suggests a higher raise in labor force participation among people with poorer health than among people with better health.

Figure 9 Differences in participation according to age and health as measured by grip strength between the 2004-2007 and 2012-2013 periods



DISCUSSION

In this article, we constructed heat maps in order to show the link between health, age and labor force participation at older ages. This was done using data from two countries (England and the United States) and two groups of European countries, and was based on 4 measures of health (grip strength, chair stand test, lung strength and mental health). Three of the four measures of health are known as objective measures of physical health, and have advantageous properties over measures of health typically used in this context (i.e. they are objective and measured on a continuous scale). These measures of health are collected in a large—and growing—number of

countries and points in time in the framework of national longitudinal studies on older people, also known as sister studies of the American HRS.

The heat maps allowed to identify some patterns. First, health has a big influence on the proportion of people participating to the labor market among people with lower values of health (beyond 1 standard deviation below the median), while age has a bigger influence among people with better health (as shown by the "⌐" form of the isolines in Figures 4 to 7). This pattern is to be observed in different countries, and across different measures of health. Thus the relationship between health and labor force participation is not linear. We note two possible implications. First, we note that relatively few people are affected by lower participation rates in relation to poorer health. In most cases. participation is only slightly lower among people with health between 0 and 1 standard deviations below the median. Participation tends to be significantly lower among people with health below 1 or 2 standard deviations; however, the proportion of these people in the population is by definition rather small. Second, the way that participation changes according to health—as highlighted by the form of the isolines—may have implications for the interpretation and assumptions usually made when modeling the link between labor force participation and health. One unit change in health seems not to always induce the same change in the propensity to work. Rather, it seems that changes of one unit of health have a greater impact on participation when health is poor compared to when it is good.

Visualizations were also used to show differences between countries (or groups of countries). They showed differences in labor force participation that varied mostly according to age and not so much according to health. This observation echoes the ones made in earlier literature, where between country variation in the average retirement age is more due to differences in institutional factors such as differences in legislation around retirement than to other factors such as health (Blöndal et Scarpetta 1998 ; Wise 2012).

Finally, we presented heat maps showing differences in participation between the periods 2004-2007 and 2012-2013 inside of each country (or groups of countries). In England and in countries with high AAI, the greatest gains in labor force participation are attributable to people with worse health. We saw that these countries have passed laws that reduce the access or the financial attractiveness of programs that offer disability benefits (OECD 2010). Therefore, it is probable that fewer people with poorer health could afford to be out of the labor market in the

second period compared to the first one; in other words, people with poorer health may be "forced" to remain in the labor force in spite of having a poor health. However, other factors may have played at the same time. Programs that promote the integration to the labor market of people with disability are being reinforced in many countries (OECD 2010). Also, work in general is becoming physically less demanding over time (Johnson 2011). Therefore, our observations may translate a greater willingness and a greater range of possibilities for older people with poorer health to participate to the labor market.

We conclude with some comments on the methods used in this paper. We considered the association between age, health and labor force participation inside of different countries and at two points in time. We saw that this association varied between the different countries and at different points in time. Health, however, may vary across countries or over time, although our analyses did not account for that. Therefore, our results are of higher relevance for studying change in participation at the individual rather than at the aggregate level. This finding is useful for further, more detailed and advanced analyses. In addition, the method is flexible and allows for modifications that can help answering different questions, for example on disparities between countries and over time. The HRS and its sister studies continue to collect data on the health and labor force participation of the elderly. Moreover, new studies that have the HRS as model are being implemented in more countries. Thus, the method presented here can be used to compare the link between health and labor force participation of older people in a growing number of countries and at more points in time. This may contribute to a better understanding of the link between work and health in the context of the major changes taking place around work at older ages.

References

Arthur, W. B., & Vaupel, J. W. (1984). Some general relationships in population dynamics. *Population Index*, 214-226.

Blöndal, S., & Scarpetta, S. (1999). The retirement decision in OECD countries.

Bloom, D. E., Canning, D., & Fink, G. (2010). Population aging and economic growth. *Globalization and Growth*, 297.

Boissonneault, M., & de Beer, J. (2017). The impact of physical health on the postponement of retirement. *Vienna Yearbook of Population Research*, *2016*, 107-130.

Bongaarts, J. (2004). Population aging and the rising cost of public pensions. *Population and Development Review*, *30*(1), 1-23.

Börsch-Supan, A. (2016a). Survey of Health, Ageing and Retirement in Europe (SHARE) Wave 2. Release version: 5.0.0. SHARE-ERIC. Data set. DOI: 10.6103/SHARE.w2.500

Börsch-Supan, A. (2016b). Survey of Health, Ageing and Retirement in Europe (SHARE) Wave 5. Release version: 5.0.0. SHARE-ERIC. Data set. DOI: 10.6103/SHARE.w5.500

Börsch-Supan, A. (2011). Health and Disability Insurance. ZAF (2011) 44:349–362 DOI 10.1007/s12651-011-0058-6

Bound, J., & Turner, S. (2007). Cohort crowding: How resources affect collegiate attainment. *Journal of public Economics*, *91*(5), 877-899.

Carrière, Y., Légaré, J., Léger St-Cyr, M., Ronteix, C., and V. Diaconu. (2015). "Vivre et travailler plus longtemps dans une société vieillissante: Vers une croissance des inégalités?," Population Change and Lifecourse Strategic Knowledge Cluster Discussion Paper Series/ Un Réseau stratégique de connaissances Changements de population et parcours de vie Document de travail: Vol. 3: Iss. 2, Article 3.

Cleveland, W. S., Grosse, E., & Shyu, W. M. (1992). Local regression models. *Statistical models in S*, *2*, 309-376.

Coile, C. C. (2015). ECONOMIC DETERMINANTS OF WORKERS'RETIREMENT DECISIONS. *Journal of Economic Surveys*, *29*(4), 830-853.

Cooper, R., Kuh, D., Cooper, C., Gale, C. R., Lawlor, D. A., Matthews, F., ... & FALCon and HALCyon Study Teams. (2010). Objective measures of physical capability and subsequent health: a systematic review. *Age and ageing*, *40*(1), 14-23.

Cooper, R., Kuh, D., & Hardy, R. (2010). Objectively measured physical capability levels and mortality: systematic review and meta-analysis. *Bmj*, *341*, c4467.

Disney, R., Emmerson, C., & Wakefield, M. (2006). Ill health and retirement in Britain: A panel data-based analysis. *Journal of health economics*, *25*(4), 621-649.

Fisher, G. G., Chaffee, D. S., & Sonnega, A. (2016). Retirement timing: A review and recommendations for future research. *Work, Aging and Retirement*, *2*(2), 230-261.

Health and Retirement Study. (2016). 2006 and 2012 HRS Core Fat File (Final) RAND public use dataset. Produced and distributed by the University of Michigan with funding from the National Institute on Aging (grant number NIA U01AG009740). Ann Arbor, MI.

Ilmarinen, J. E. (2001). Aging workers. *Occupational and environmental medicine*, *58*(8), 546-546.

Richard W. Johnson, Gordon B. T. Mermin & Matthew Resseger. (2011). Job Demands and Work Ability at Older Ages, Journal of Aging & Social Policy, 23:2, 101-118, DOI: 10.1080/08959420.2011.551465

Kalwij, A., & Vermeulen, F. (2008). Health and labour force participation of older people in Europe: What do objective health indicators add to the analysis?. *Health economics*, *17*(5), 619-638.

Lindeboom, M., & Kerkhofs, M. (2009). Health and work of the elderly: subjective health measures, reporting errors and endogeneity in the relationship between health and work. *Journal of Applied Econometrics*, *24*(6), 1024-1046.

Lutz, W., Sanderson, W., & Scherbov, S. (2008). The coming acceleration of global population ageing. *Nature*, *451*(7179), 716-719.

Marmot, M., Oldfield, Z., Clemens, S., Blake, M., Phelps, A., Nazroo, J., Steptoe, A., Rogers, N., Banks, J. et A. Oskala. (2016). *English Longitudinal Study of Ageing: Waves 0-7, 1998-2015*. [data collection]. *25th Edition.* UK Data Service. SN: 5050,http://dx.doi.org/10.5255/UKDA-SN-5050-12

OCDE (2005), *Panorama des pensions 2005 : Les indicateurs de l'OCDE et du G20*, Éditions OCDE, Paris.

OCDE (2010), *Maladie, invalidité et travail : Surmonter les obstacles : Synthèse des résultats dans les pays de l'OCDE*, Éditions OCDE, OCDE (2011), *Panorama des pensions 2011 : Les systèmes de retraites dans les pays de l'OCDE et du G20*, Éditions OCDE, Paris.

Paris.OCDE (2016), *Panorama des pensions 2015 : Les indicateurs de l'OCDE et du G20*, Éditions OCDE, Paris.

OECD data. 2017. Labour force participation rate. https://data.oecd.org/emp/labour-force-participation-rate.htm. [consulted 27 March 2017].

Prince, M. J., Reischies, F., Beekman, A. T., Fuhrer, R., Jonker, C., Kivela, S. L., ... & Van Oyen, H. (1999). Development of the EURO-D scale--a European, Union initiative to compare symptoms of depression in 14 European centres. *The British Journal of Psychiatry*, *174*(4), 330-338.

R Core Team. (2013). R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Riffe, T. Chung, P. H., Spijker, J. et J. MacInnes. (2017). Time-to-death patterns in markers of age and dependency. Vienna Yearbook of population research. 2016 vol. 14.

Schirle, T. (2008). Why have the labor force participation rates of older men increased since the mid-1990s?. *Journal of Labor Economics*, *26*(4), 549-594.

Schöley, J., & Willekens, F. (2017). Visualizing compositional data on the Lexis surface. *Demographic Research*, *36*, 627-658.

UNECE. (2017). Active Ageing Index Home. [en ligne] https://statswiki.unece.org/display/AAI/Active+Ageing+Index+Home , consulté le 15 juillet 2017.

van Rijn, R. M., Robroek, S. J., Brouwer, S., & Burdorf, A. (2014). Influence of poor health on exit from paid employment: a systematic review. *Occup Environ Med*, *71*(4), 295-301.

Vaupel, J.W., B.A.Gambill et A.I. Yashin. (1987). Thousands of Data at a Glance : Shaded Contour Maps of Demographic Surfaces. Research Report RR-87-16. Laxenburg, Austria: international Institute for Applied Systems Analysis (IIASA).

Wise, D. A. (Ed.). (2012). Social security programs and retirement around the world: Historical trends in mortality and health, employment, and disability insurance participation and reforms. University of Chicago Press.

Zaidi, A., Gasior, K., Hofmarcher, M.M., Lelkes, O., Marin, B., Rodrigues, R., Schmidt, A., Vanhuysse, P. et E. Zolyomi. (2013). Active Ageing Index 2012: Concept, Methodology and Final Results european center Vienna march 2013

APPENDIX

Data preparation

Imputation

Tables a1 and a2 describe the number of observations used to produce the heat maps. The total number of observations is the total number of participants that was eligible for the tests that measure physical health. All respondents did not necessarily complete all the tests. Reasons for not completing a test may include refusal or misunderstanding of the instructions, but most often the missing values are due to the inability of the respondents to complete the test. As this situation is more likely to occur with respondents in poor health, it is important to make statistical corrections. To compensate for the bias, we estimated health values using a multiple imputation model (Little and Rubin 2002). We estimated a sequential imputation based on an ordinal logistic regression for the mental health variable and on a linear regression for the grip strength, lung strength and chair test variables. The analyzes were produced based on the mean of 25 imputations. The *mi impute* command available on Stata 14 was used to estimate the model (Stata Corp 2013).

Table a1 : Number of observations by country (or country group) et health measure, 2004-2007 (% of total sample with valid value)

	Total	Grip Strength		Lung Strength		Chair stand		Mental health	
England	5 682	4 832	(85,0)	4 601	(81,0)	4 313	(75,9)	---	---
United States*	4 532	4 021	(88,7)	4 028	(88,9)	---	---	---	---
High AAI countries	5 077	4 896	(96,4)	---	---	4 525	(89,1)	4 992	(98,3)
Low AAI countries	5 025	4 684	(93,2)	---	---	3 789	(75,4)	4 965	(98,8)

* Total concerns the number of eligible participants only. The full HRS sample contained 9 720 observations for this wave.

Table a2 : Number of observations by country (or country group) et health measure, 2012-2013 (% of total sample with valid value)									
	Total	Grip Strength		Lung Strength		Chair stand		Mental health	
England	6 275	4 710	(75,1)	4 248	(67,7)	4 153	(66,2)	---	---
United States*	4 896	4 496	(91,8)	4 567	(93,3)	---	---	---	---
High AAI countries	7 823	7 601	(97,2)	---	---	7 204	(92,1)	7740	(98,9)
Low AAI countries	9 621	8 954	(93,1)	---	---	8 022	(83,4)	9 430	(98,0)

** Total concerns the number of eligible participants only. The full HRS sample contained 9 445 observations for this wave.

Labor force participation variables

ELSA

Which one of these, would you say best describes [your] current situation?
1. Retired
2. Employed
3. Self-employed
4. Unemployed
5. Permanently sick or disabled
6. Looking after home or family
95 Other
96 SPONTANEOUS : Semi-Retired

HRS

Are you working now, temporarily laid off, unemployed and looking for work, disabled and unable to work, retired, a homemaker, or what?
1. Working now
2. Unemployed and looking for work
3. Temporary laid off, on sick or other leave
4. Disabled
5. Retired
6. Homemaker
7. Other
8. Don’t know
9. Refused

SHARE

In general, which of the following best describes your current employment situation?
1. Retired
2. Employed or self-employed (including working for family business)
3. Unemployed
4. Permanently sick or disabled
5. Homemaker
97. Other (Rentier, Living off own property, Studen, Doing voluntary work)

Health variables

Each respondent was classified among 10 categories of health according to the following scale (the values refer to standard deviations) :

[-3; -2[-2; -1.5[-1.5; -1[-1; -0.5[-0.5; 0[0; 0.5[0.5; 1[1; 1.5[1.5; 2[2; 3[

Values above 3 standard deviations above the median or below 3 standard deviations below the median were excluded.

Table a3 describes the categorization of the mental health variable and the number of observations for each of them.

Table a3 : Mental health scale with value conversion

Measures		**Number of participants**			
EURO-D scale	Standard deviations	High AAI 2004-2007	High AAI 2012-2013	Low AAI 2004-2007	Low AAI 2012-2013
0	[0.5; 3[	1 474	2 278	1 136	2 345
1	[0; 0.5[	1 265	1 944	1 105	2 027
2	[-0.5; 0[	881	1 347	823	1 433
3	[-1; -0.5[	612	858	585	1 094
4	[-1.5; -1[	328	603	418	776
5	[-2; -1.5[	215	302	308	643
6-11	[-3; -2[	223	408	590	1 112

The age categories are the following :

[52 ; 54[54 ; 56[56 ; 58[58 ; 60[60 ; 62[62 ; 64[64 ; 66[66 ; 68[68 ; 70[

Estimation of the values represented by the heat maps

The proportions represented in Figures 4 to 9 are derived from raw data. In order to obtain a smoother look, the isoligns were calculated on the basis of a polynomial local regression (also called Loess, Cleveland, 1992). We use a span of 0.5. The span, when less than 1, represents the proportion of the points around x representing the neighborhood of the span on which is performed the local regression attached to the point *x*. The points constituting the neighborhood of *x* are weighted depending on their distance from *x*. We experimented with different span values and 0.5 seemed the best compromise between smooth reading of the trends while taking into account the particularities of the data. This technique was applied in a similar context by Riffe et al. (2015). The smoothing and graphics were done on R (R Core Team, 2013). Differences between countries (or groups of countries) and over time within each country (Figures 10-14) are also based on the proportions calculated from the polynomial local regression.

Description of the health measures

Grip strength

Grip strength is a measure of upper body vitality and general muscle strength. It is a predictor of disability, morbidity, hospital stays, death, and even cognitive decline. These associations have been found in younger and older people. These results are documented in several dozen articles; Good syntheses have been made by Sanderson and Scherbov (2014) and Bohannon (2008), among others.

In both ELSA, HRS and SHARE, grip strength was measured with a Smedley type dynamometer. The result is given in kilograms and usually varies between 0 and 80 kg. HRS and SHARE ask respondents to repeat the exercise twice with each hand, ELSA three times with each hand. For each respondent, we take the highest measure in the first two attempts of each hand.

The chair raise test

The chair raise test was designed to measure lower-body vitality and is a proxy for general health (Jones et al., 2000; Rozanska-Kirschke et al., 2006). This test involves asking the respondent, who is seated in a chair with his or her arms crossed, to stand and sit without the help of his or her arms. The interviewer checks the time taken, in seconds, to make different numbers of repetitions (usually 5 or 10), or asks the respondent to do as many repetitions as possible in a given amount of time. We use the variant where the respondent is asked to do 5 repetitions.

Peak expiratory flow

The variation in the force with which an aging person can expel air from his or her lungs (peak expiratory flow) is primarily an indicator of respiratory problems such as asthma and emphysema. It is a measure that predicts mortality (Cook et al., 1991) and the decline in cognitive abilities (Albert et al., 1995) and is linked to other measures of physical capacity (Seeman et al., 1994)

This test is performed using a special device called *Mini-Wright Peak Flow Meter*. The result is given in liters per minute and is normally between 0 and 800. The interviewer asks the respondent to blow as hard as possible and registers the maximum level reached. The exercise is repeated three times; We use the highest result achieved.

The Mental Health Scale (EUROD)

SHARE provides information on mental health according to the *Euro-D* scale, developed jointly by 11 European countries (Prince et al., 1999).

This scale is based on answers to a battery of 12 questions that describe everyday life; The results are a good indicator of the presence of depression.

Older workers with poorer health are at greater risk of retiring early. Since higher labor force participation is expected among older people, and health tends to deteriorate with age, it is important to know and understand the form of the link between health, age and labor force participation at older ages. We examine this link by means of heat maps using data collected in the US, England and two groups of European countries. We analyze four different measures of health, including three objective measures of physical health. We find that the form of the link between health and labor force participation is relatively constant between countries and over time, and is robust to the choice of the health measure. In all cases, participation tends to be more sensitive to changes in the values of health among people with worse health compared to people with better health. In two cases, over a period of about seven years, the people who contributed the most to the increases in participation rates are those in poorer health. We discuss this development against a background of changes in pension programs, particularly those for disabled people.

The Netherlands Interdisciplinary Demographic Institute (NIDI) is an institute for the scientific study of population. NIDI research aims to contribute to the description, analysis and explanation of demographic trends in the past, present and future, both on a national and an international scale. The determants and social consequences of these trends are also studied.

NIDI is a research institute of the Royal Academy of Arts and Sciences (KNAW).