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ORIGINAL INVESTIGATION

# Life expectancy at 65, associated factors for women and men in Europe

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## Abstract

In Europe, the epidemiological transition has already taken place, while the demographic transition continues. Life expectancy at 65 is expanding for both women and men. The primary aim of this work is to identify the factors associated with life expectancy at 65 for women and men in Europe. The second aim is to confirm the influence of cultural factors on life expectancy. Finally, the link between spending on pensions, soil pollution, and life expectancy is also tested. Data for 31 European countries for the period 2004–2018 have been collected to estimate a linear panel data model. Life expectancy at 65 for women and men is the dependent variable. Independent variables are grouped into socioeconomic, cultural, and environmental conditions. The main result of this work is the importance of GDP per capita, and education and pension expenditure in explaining the heterogeneity of life expectancy at 65 across countries. Other significant results include the association of cultural characteristics, air pollution, and soil pollution with life expectancy. The design of policies for older adults and the improvement of their health and active life should consider not only differences in education but cultural characteristics, too. European directives that disregard people's cultural differences may not have the expected result.

**Keywords** Life expectancy · Older ages · Sex · Europe

## Introduction

Changes in demography and epidemiology have been taking place in Europe for a number of years. Demographic transition concerns the shift from a pattern of high fertility and mortality rates to one of low rates. The epidemiological transition, meanwhile, reflects what is happening in terms of the mortality aspect of that transition. It concerns shifting from a context of mortality in which the main cause was infectious disease to one in which non-communicable diseases dominate (McCracken and Phillips 2017). In this way, under ageing transition, life expectancy at birth continues to increase, and more importantly, life expectancy at age 65 continues to expand.

Life expectancy at 65 is measured by an indicator with the same name, and it is not the same for women and men. Previous studies have clearly identified a tendency in which women live longer than men (WHO 2020a; Kolp and Lange 2018). Biological and cultural factors have been suggested as possible explanations for this difference. Gender difference has been fairly constant over time, and it is about 3–4 years (Eurostat 2020a, b). Romania and Bulgaria have the lowest life expectancy at 65, while France and Switzerland the highest (Table SM1 in Supplementary Material).

The demographic and epidemiological transition can be explained by several factors related to economic development and modernization, technological innovation, urbanization, and improved health systems (McCracken and Phillips 2017; Omran 1971).

Explaining health improvements has been a matter of concern among researchers. Several empirical studies have been conducted to determine the factors associated with health outcomes, measured in mortality, morbidity, or longevity. The factors associated with population health have been conceptualized and tested by a number of authors (Dahlgren and Whitehead 1991; Solar and Irwin 2007; Marmot et al. 2008; Mackenbach et al. 2019). In general, these factors can be grouped

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according to whether they relate to socioeconomic, cultural, or environmental conditions, as proposed by the Dahlgren and Whitehead model (1991).

Of the various factors influencing the health of a population, culture is acknowledged to influence health (OECD 2012, p. 34; Oude Groeniger et al. 2020). Culture is an abstract concept that can be defined as a complex structure of learned behaviours and their products in a social and shared context (Hammel 1990, p. 459), which makes it difficult to measure. Studies generally use the country specific effect to account for cultural differences between countries. However, there are other attempts to proxy culture differences across countries. One well-known framework to characterize culture was proposed by Hofstede (1980, 1991) and expanded by the GLOBE Project (GLOBE 2020; House et al. 2004; Chokkar et al. 2007). This is a major study on culture and leadership across countries, which extended Hofstede's work. It groups countries according to nine cultural dimensions, namely: power distance, uncertainty avoidance, institutional collectivism, in-house collectivism, gender egalitarianism, assertiveness, performance orientation, future orientation, and humane orientation. These dimensions are briefly described in Supplementary Material under the title 'Cultural Dimensions Brief Definition'. A detailed description of the cultural clusters of countries can be found on the GLOBE project web page (GLOBE 2020). In our analysis, we have introduced the cultural controls based on five cultural clusters for Europe: Anglo-Saxon, Eastern Europe, German, Latin Europe, and Nordic.

The aim of our work is to estimate the factors related to life expectancy at 65 for both women and men in Europe, thus updating previous analyses. The associated factors across time and countries provide insights for understanding and assessing public health policies and international differences. Taking a wider perspective, our work contributes to the drive to achieve United Nations Sustainable Development Goals related to health. Understanding the factors linked to life expectancy at 65 helps us to better understand the potential sources of inequalities and also contributes towards devising better policies to promote healthy life at older ages for both women and men who, at least, differ in their biology. The novelty of our work comes from considering new factors to explain differences in life expectancy at 65. Specifically, we have accounted for country cultural differences, spending on pensions, and use of pesticides in agriculture, which have not been considered before.

## Conceptual background and previous studies

### Conceptual background

The conceptual background for explaining health includes two analytical perspectives. The first one is qualitative and describes the socioeconomic determinants of the health of individuals. This has been proposed by Dahlgren and Whitehead (1991) in a social ecological model. The model places the individual at the centre and then describes the determinants in layers around the individual: demographic, lifestyle, social and community networks, other general conditions. The first layer is the personal behaviour. The second layer is social and community influences. The third layer, a sort of umbrella layer, includes general socioeconomic, cultural, and environmental conditions, such as per capita income, pollution, poverty and social conditions, access to services, and provision of essential facilities. This last umbrella layer is the one that most matters to our analysis. Socioeconomic factors of health have been extensively explored by authors like M. Marmot (for instance, Marmot et al. 2008, 2012) and J. Mackenbach (for instance, Mackenbach et al. 2017, 2019).

The second pillar of the conceptual background for our analysis has a quantitative nature. The formal model of the relationship between health and its socioeconomic determinants is a health production function, first proposed by Grossman (1972). Health is taken as an output, and the combination of medical and non-medical factors is taken as an input. The estimation of health production functions is very often found in empirical studies. Zweifel et al. (2009, ch. 4) have revised and analysed several of these studies. Our approach could be summed up as the estimation of a health function based on the set of macro-socioeconomic determinants proposed in Dahlgren and Whitehead's model.

### Previous studies

Several empirical studies have set out to understand the macro-level factors that might explain the health of a population. Minagawa and Jagger (2020) summarized current knowledge of macro-level factors related to health expectancy measurements. Population health can be proxied by different indicators, and empirical analysis can be more descriptive or more quantitative. In more descriptive approaches, Cutler et al. (2006) and Marmot et al. (2012) aimed to identify the factors influencing the health of a population. Cutler et al. (2006) focused on explaining the mortality. Based on a historical and descriptive analysis, these authors concluded the link between social status and health is too complex for a single explanation. This explanation would involve factors such as knowledge and education, science and technology, public administration, increased productivity, and income. Marmot et al. (2012) concluded that improvements in health and health equities should consider wider societal conditions, such as social protection, the broader context of societies, such as the economy and the environment, and the systems needed for delivery, such as the health system.

Based on the estimation of panel data models, some studies are worth highlighting for their valuable contribution to the literature (Table 1). The first is by Or (2000), who conducted a study on the OECD; the second is by Spijker (2005); the third is by Arah et al. (2005); the next is by Joumard et al. (2008) in an OECD working paper; and finally, the last is one that has recently been published by Mackenbach et al. (2019), who were more concerned about health inequalities.

Or (2000) measured population health using gender-specific potential years of life lost. She estimated a health function using determinants related to socioeconomic indicators, medical systems, environmental conditions, and people's lifestyles. Spijker (2005) used a larger number of explanatory variables than Or (2000) to compare two groups of countries: Western and Eastern European countries. In addition to the per capita income, public health expenditure, education, pollution, and lifestyle variables, he also tested variables related to the employment structure, divorce, and urbanization. Arah et al. (2005) explained the mortality rate and premature death rates using socioeconomic, lifestyle, and health system indicators in the same way as Or (2000) and Jourmard et al. (2008). These latter authors also focused their attention on the determinants of life expectancy at 65. Finally, in the most recent work by Mackenbach et al. (2019) the authors aimed to explain inequalities in mortality rates. They introduced democracy transition as a determinant of health and found it was prejudicing health and widening inequalities.

Summing up, the factors used to explain the health outcomes are grouped in macro-socioeconomic, environmental, and lifestyle conditions, as described in Dahlgren and Whitehead's model (Dahlgren and Whitehead 1991).

## Methods

The econometric analysis is based on a short or small panel data, meaning that the number of years is small and the number of countries is large. We considered 31 European countries over the period 2004–2018. We collected data from the Eurostat database, the WHO European Health for All database (Eurostat database 2020a; WHO-HFA 2020), and also FAOSTAT database (FAO 2020). The econometric estimates were performed in STATA 16.

### Dependent variable

The dependent variable is life expectancy at 65 (LE65), and it is collected by Eurostat for men and for women. This variable gives the mean number of years of life remaining for men or women who have reached the age of 65, if the rest of their life is subjected to the current mortality conditions (that is, age-specific probabilities of dying are considered).

### Independent variables

The independent variables are described in Table 2. Of them, two are measured separately for women and men, these being 'Risk of Poverty' and 'Tertiary Education'. In addition to these independent variables, we also include cultural clusters of countries (GLOBE 2020; Mensah and Chen 2012) which are described below.

**Table 1** Selected studies based on panel data analysis

| Authors (year) | Countries (years) | Health outcomes | Independent variables |
|---|---|---|---|
| Or (2000) | 21 OECD countries (1970–1992) | Potential years of life lost by sex | GDPpc; total health expenditure; public health expenditure; share of white collar employees; air pollution; alcohol, tobacco, fat, sugar consumption |
| Spijker (2005) | 43 European countries (1968–1999) | Mortality rates by sex | GDPpc; government health expenditure; Gini index; education; share of working people in agriculture and industry; divorce rate; alcohol; air pollution; unemployment; urbanization; tobacco, fruit and cereal consumption |
| Arah et al. (2005) | 18 OECD countries (1970–1999) | Mortality rate and potential years of life lost | GDPpc; health expenditure; tobacco, alcohol, fat, fruit and veggie, protein consumption; air pollution; physician density; doctors' visits; share of population over 65 |
| Joumard et al. (2008) | 22 OECD countries (1981–2003) | Life expectancy, premature mortality and infant mortality by sex | GDPpc; health spending; tobacco, alcohol, fruit consumption; education; air pollution; physician density |
| Mackenbach et al. (2019) | 15 European countries (1990–2015) | Mortality rates and life expectancy by sex | GDPpc; healthcare expenditure; Gini index; education; democracy index; smoking; material deprivation |

Independent variables considered in our model are aligned with the umbrella layer of the Dahlgreen and Whitehead (1991) model of determinants of health. In this way, variables are grouped as socioeconomic, cultural, and environmental.

1. Socioeconomic variables

Socioeconomic conditions include several macro influences, not only economic conditions, but also health system, social and welfare system, and education system conditions (Or 2000; Spijker 2005; Joumard et al. 2008; Mackenbach et al. 2019).

Population health is influenced by health expenditure, both public and private. We consider this influence in the variable 'public health expenditure'. It has a strong negative correlation with (private) out-of-pocket payments (OECD 2019), and so, there is no need to account for both types of expenditure.

The 'public health expenditure' variable reflects the compulsory nature of the health system financing. 'Public health expenditure' includes government schemes and compulsory contributions to healthcare financing schemes in the country.

Population health is strongly influenced by health systems, but it is also influenced by social welfare systems (Esser and Palme 2010). Despite the importance of pensions to the health of older people, this variable has not been considered in previous studies.

Income inequality is another concern as poverty results in ill-health (WHO 2010). Here, we consider the percentage of women and men older than 65 at risk of poverty. That is, people with an equivalized disposable income below the risk-of-poverty threshold, which is set at 60% of the national median equivalized disposable income (after social transfers). The advantage of this variable is that it collects data for women and men.

Separate data for women and men are also available for education. We have considered the percentage of people completing tertiary education which is the level that has most influence on people's knowledge and thus their ability to understand and use information about health. Education has therefore a well-recognized benefit for people's health status (for instance, Cutler and Llera-Muney 2006; Feinstein et al. 2006).

2. Environmental variables

Air pollution and soil pollution were the environmental variables we considered. Although air pollution, measured by exposure to air particulate matter (PM) < 2.5 µm, has been considered in previous studies, the use of pesticides had not yet been tested. Both air pollution and pesticides

**Table 2** Independent variables description

| Variable name | Abbreviation | Description | Source |
|---|---|---|---|
| **Socioeconomic variables** | | | |
| *Economic conditions* | | | |
| GDP per capita | lnGDPpc | Natural logarithm of the gross domestic product at market prices per capita, chain-linked volumes (2010) (online code nama_10_gdp) | Eurostat |
| *Health system conditions* | | | |
| Public Health Expenditure | PHE | Government schemes and compulsory contributory healthcare financing schemes as a percentage of GDP (online code hlth_sha11_hf) | Eurostat; WHO[a] |
| Practice Physicians | Physicians | Practising, or closest concept, physicians per 100,000 people | WHO |
| *Social and welfare conditions* | | | |
| Pensions | Pensions | Pensions as percentage of GDP (online code spr_exp_pens) | Eurostat |
| People at risk of poverty | RiskPoverty | Percentage of people at risk of poverty or social exclusion aged 65 years or over, by sex (online code ilc_peps01) | Eurostat |
| Education System conditions | | | |
| Tertiary Education | Education | Percentage of population attaining tertiary education (levels 5–8) aged 55–74, by sex (online code edat_lfs_9903) | Eurostat |
| **Environmental variables** | | | |
| Air pollution | AirPollution | Exposure to air pollution of particulates < 2.5 µm (online code sdg_11_50) | Eurostat |
| Pesticides | Pesticides | Pesticides (total) used per area of cropland in kg/ha | FAO |
| **Cultural variables** | | | |
| Alcohol consumption | Alcohol | Pure alcohol consumption in litres per capita, by people older than 15 | WHO |
| Cultural clusters | | Cultural clusters: Anglo-Saxon, Eastern Europe, German, Latin Europe, and Nordic | GLOBE; Mensah and Chen (2012) |

[a]Eurostat is the sole data source for Austria, Belgium, Estonia, Finland, Germany, Netherlands, Portugal, Spain, Sweden; for the remaining countries, some data were collected from WHO up to 2014

have health impacts. Air pollution measured by pollutants such as particulate matter of less than 2.5 µm penetrates the lungs and enters the bloodstream, causing cardiovascular, cerebrovascular, and respiratory diseases (WHO 2020b; EEA 2018). Pesticides are chemicals used in agriculture which not only degrade soil and the surrounding environment, but also pass along the food chain to people and harm health by toxin accumulation in the body (Tago et al. 2014; Ozkara et al. 2016; WHO 2020c).

3. Cultural variables

Finally, cultural variables include alcohol consumption and cultural characteristics of countries grouped in clusters.

Alcohol consumption is a risk factor for several major chronic diseases in Europe, including cancer and cardiovascular diseases (Shield et al.2013; WHO 2020a, b, c, d), and it leads to high mortality rates (Nash et al. 2017). Additionally, alcohol consumption is associated with smoking (Bobo and Husten 2000; Room 2004). So, given the availability of data, we consider alcohol consumption and not smoking.

Cultural influences are considered in our analysis by five cultural clusters (Global 2020; Mensah and Chen 2012): Anglo-Saxon, Eastern, Latin, German, and Nordic (Table 3).

## Econometric model and hypothesis

The econometric model to be estimated, which is sex-specific, is as follows:

$$\begin{aligned} \text{LE65}_{it} = \text{cons}_i + \beta_1 \ln \text{GDPpc}_{it}^{(+)} + \beta_2 \text{PHE}_{it}^{(+)} + \beta_3 \text{Physicians}_{it}^{(+)} + \beta_4 \text{Pensions}_{it}^{(+)} + \beta_5 \text{RiskPoverty}_{it}^{(-)} \\ + \beta_6 \text{Education}_{it}^{(+)} + \beta_7 \text{AirPollution}_{it}^{(-)} + \beta_8 \text{Pesticides}_{it}^{(-)} + \beta_9 \text{Alcohol}_{it}^{(-)} + u_i + \varepsilon_{it} \end{aligned}$$

where $i$ means the country, $t$ is the year, $u_i$ refers to the country-specific or cluster-specific effects (depending on the regression), and $\varepsilon_{it}$ is the regression error term. Because we have country fixed effects and cultural cluster fixed effects, we have adopted a model of fixed effects. We estimated a least square dummy variable regression, which is the same as fixed-effects panel data linear regression.

We have carried out several preliminary tests. We calculated pairwise correlations among independent variables, computed variance inflated factors (VIF) for checking for multicollinearity, and performed the Hausman test for comparing fixed- or random-effects specification (even though we are already taking a fixed-effects model). We have also run post-estimation testing. We carried out the Breusch–Pagan/Cook–Weisberg test for heteroskedasticity and tested for model specification using the link test. In the case of heteroskedasticity, we have estimated robust standard errors based on the Huber/White/sandwich estimator. We have performed the Wooldridge test for autocorrelation in the panel data as well. And we also performed Fisher-type ADF panel unit-root test, which is presented in Appendix.

We have also estimated Driscoll-Kraay (1998) standard errors for robustness check. These standard errors are robust to general forms of cross-sectional and temporal dependence, so they mitigate heteroskedasticity and autocorrelation up to some lag, which we take as equal to one.

The hypothesis for the sign of each estimated coefficient is given in brackets next to the variable's name in the base econometric model above. The sign (+) hypothesizes a positive correlation and (−) a negative correlation with LE65.

**Table 3** Cultural clusters and countries

| Cultural clusters | Countries | | |
|---|---|---|---|
| Anglo-Saxon | Ireland | | |
| | UK | | |
| Eastern Europe | Bulgaria | Czechia | Poland |
| | Croatia | Greece | Slovenia |
| | Cyprus | Hungary | Slovakia |
| German | Austria | Germany | Netherlands |
| | Belgium | Luxembourg | Switzerland |
| Latin European | France | Malta | Romania |
| | Italy | Portugal | Spain |
| Nordic | Denmark | Iceland | Norway |
| | Estonia | Latvia | Sweden |
| | Finland | Lithuania | |

# Results

## Descriptive analysis

We begin by describing life expectancy at 65 for females and males (Table 4). The overall mean difference is about 4 years, and data account for about 465 observations across time and country.

The life expectancy at 65 for females and males across cultural clusters of countries is different and is shown in Table 5. Based on the ANOVA test, the differences of means across clusters are statistically significant.

The description of the independent variables is given in Table 7 in Appendix.

## Estimated results

The pairwise correlation between independent variables is given in Table 8 in Appendix. In general, correlations have low values. However, those resulting from the correlation between GDP per capita, public health expenditure,

**Table 4** Descriptive statistics for dependent variable by sex

| Variable LE65 | | Mean | SD | Min | Max | Observations |
|---|---|---|---|---|---|---|
| Females (F) | Overall | 20.4 | 1.647 | 15.7 | 24 | $N^*T=465$ |
| | Between | | 1.537 | 17.173 | 23.253 | $N=31$ |
| | Within | | 0.648 | 18.537 | 21.777 | $T=15$ |
| Males (M) | Overall | 16.8 | 1.939 | 12.3 | 20.2 | $N^*T=465$ |
| | Between | | 1.834 | 13.333 | 19.16 | $N=31$ |
| | Within | | 0.704 | 15.081 | 18.741 | $T=15$ |

**Table 5** Descriptive statistics for life expectancy at 65 across cultural clusters by sex

| Cultural clusters | Obs | Mean | | SD | | Min | | Max | |
|---|---|---|---|---|---|---|---|---|---|
| | | F | M | F | M | F | M | F | M |
| German | 90 | 21.3 | 18.0 | 0.731 | 0.857 | 19.9 | 16.3 | 23 | 20.2 |
| Eastern | 135 | 19.2 | 15.7 | 1.462 | 1.681 | 16.2 | 13.1 | 21.9 | 19.1 |
| Nordic | 120 | 20.2 | 16.5 | 1.334 | 2.229 | 17 | 12.3 | 22.2 | 20.1 |
| Latin | 90 | 21.3 | 17.5 | 2.023 | 1.770 | 15.7 | 12.9 | 24 | 19.7 |
| Anglo-Saxon | 30 | 20.6 | 17.9 | 0.573 | 0.848 | 19.5 | 16.1 | 21.6 | 19.1 |
| *F* statistics | | 42.35 | 35.34 | | | | | | |
| Prob > *F* | | 0.00 | 0.00 | | | | | | |

*F* female, *M* male

pension expenditure, and risk of poverty have values around 0.5 and 0.6, as it would be expected due to the nature of the variables.

The results of the estimation of the econometric model are shown in Table 6. In this table, results are sex specific. A visually friendly table with the summary of the results is presented in Table SM2 in Supplementary Material.

Concerning diagnostic testing, we found no multicollinearity (VIF test is presented in Table 9 in Appendix); heteroskedasticity is possibly found the cultural fixed-effects estimation, but not in the country fixed-effects estimation; Hausman testing supports fixed-effects in estimation for males, but not for females; the link test indicates the absence of error specification.

First, the significance of estimated coefficients using LSDV and Driscoll–Kraay standard errors is similar. Secondly, there are three statistically significant estimated coefficients in nearly all estimations: 'ln GDPpc', 'Pensions', and 'Education'. These findings are in line with previous results (Minagawa and Jagger 2020).

Third, environmental variables show that 'air pollution' is significant in cultural fixed-effects estimation, but not in country fixed-effects, while 'pesticides' are significant in country fixed-effects estimation in both sexes. Both variables contribute to lower life expectancy.

Fourth, there are two sex-related results. For women, 'risk of poverty' was found significant for in country fixed-effects estimation and 'public health expenditure' was significant in cultural fixed-effects estimation, but the sign is unexpectedly negative. For men, drinking 'alcohol' was significant in cultural fixed-effects estimation. However, these results are only partially verified across all estimations.

Fifth, we also found that the number of 'physicians' is significant in nearly all estimations, pointing to a positive influence of this variable on life expectancy at 65.

Last, but not least, the results indicate that cultural clusters are significant in explaining LE65.

The Fisher-type ADF panel unit-root test is presented in Table 10 in Appendix, and panels tend to be stationary. (In supplementary material, Table SM3, the Levin–Lin–Chu unit-root test for LE65 is also presented.)

## Discussion

Life expectancy at 65 has been increasing as ageing transition takes place in Europe. However, there is a difference in life expectancy between women and men. Understanding the main factors associated with this evolution and sex difference is important to designing appropriate policy measures that better contribute to Sustainable Development Goals on health. Previous literature on this topic has not been updated, and it did not consider the importance of cultural factors, pensions, and soil pollution. So, our main aim is to improve on previous studies and contribute to an updated insight on factors associated with LE65 in Europe.

We have used panel data of 31 European countries for the period 2004–2018 to estimate a health production function. Based on the Dahlgren and Whitehead (1991) ecological model, we have accounted for macro-socioeconomic,

**Table 6** Estimation results

| | Coef | LSDV<br>Std. err | Driscoll–Kraay<br>Std. err | Coef | LSDV<br>Std. err | Driscoll–Kraay<br>Std. err |
|---|---|---|---|---|---|---|
| *Females* | | | | | | |
| lnGDPpc | 2.465 | 0.395*** | 0.651*** | 1.724 | 0.168*** | 0.104*** |
| PHE | − 0.020 | 0.034 | 0.042 | − 0.169 | 0.045*** | 0.028*** |
| Physicians | 0.003 | 0.001** | 0.001*** | 0.000 | 0.001 | 0.000 |
| Pensions | 0.200 | 0.036*** | 0.027*** | 0.170 | 0.023 | 0.020*** |
| RiskPoverty | − 0.014 | 0.004*** | 0.002*** | − 0.009 | 0.006 | 0.005 |
| Education | 0.038 | 0.010*** | 0.013*** | 0.073 | 0.010*** | 0.006*** |
| AirPollution | − 0.010 | 0.006 | 0.007 | − 0.038 | 0.009*** | 0.004*** |
| Pesticides | − 0.057 | 0.026** | 0.013*** | − 0.008 | 0.020 | 0.025 |
| Alcohol consumption | − 0.047 | 0.028* | 0.039 | − 0.020 | 0.026 | 0.034 |
| _cons | − 7.747 | 4.417* | | 2.100 | 2.141 | |
| Country fixed effects | | Yes | Yes | | No | No |
| Cultural clusters | | No | No | | Yes | Yes |
| German | Reference category | | | | | |
| Eastern | | | | 0.603 | 0.207*** | 0.259*** |
| Nordic | | | | − 1.069 | 0.232*** | 0.095*** |
| Latin | | | | 1.773 | 0.138*** | 0.153*** |
| Anglo-Saxon | | | | − 0.782 | 0.166*** | 1.557*** |
| Robust SE | | No | | | Yes | |
| Number of obs | 291 | | | 291 | | |
| $F$ (Prob > $F$) | | 235.53 (0.00) | 423.02 (0.00) | | 130.23 (0.000) | 2.9e + 07(0.00) |
| $R^2$ | | 0.972 | 0.733 | | 0.822 | 0.822 |
| Adj. $R^2$ | | 0.968 | | | | |
| Breusch–Pagan/Cook–Weisberg test | | | | | | |
| $\chi^2$ (Prob > $\chi^2$) | | 1.13 (0.288) | | | 5.06(0.024) | |
| Linktest | | | | | | |
| _hatsq ($P > t$) | | − 0.003 (0.593) | | | − 0.009 (0.535) | |
| Hausman test | | | | | | |
| $\chi^2$ (Prob > $\chi^2$) | | 14.34 (0.112) | | | | |
| Wooldridge test | | | | | | |
| $F$(1,26) (Prob > $F$) | | 0.776 (0.387) | | | | |
| | Coef | LSDV<br>Std. err | Driscoll–Kray<br>Std. err | Coef | LSDV<br>Std. err | Driscoll–Kray<br>Std. err |
| Males | | | | | | |
| lnGDPpc | 2.991 | 0.382*** | 0.575*** | 1.432 | 0.120*** | 0.143*** |
| PHE | − 0.006 | 0.037 | 0.054 | 0.049 | 0.030 | 0.026 |
| Physicians | 0.006 | 0.001*** | 0.001*** | 0.002 | 0.000*** | 0.001*** |
| Pensions | 0.283 | 0.035*** | 0.042*** | 0.131 | 0.021*** | 0.017*** |
| RiskPoverty | 0.002 | 0.005 | 0.004 | − 0.007 | 0.005 | 0.004 |
| Education | 0.068 | 0.012*** | 0.011*** | 0.046 | 0.009*** | 0.007*** |
| AirPollution | − 0.004 | 0.007 | 0.009 | − 0.050 | 0.010*** | 0.007*** |
| Pesticides | − 0.048 | 0.028* | 0.013*** | − 0.001 | 0.017 | 0.019 |
| Alcohol consumption | − 0.022 | 0.030 | 0.036 | − 0.152 | 0.025*** | 0.026*** |
| _cons | − 21.242 | 4.135*** | | 1.276 | 1.606 | |
| Country fixed effects | | Yes | Yes | No | | No |
| Cultural clusters | | No | No | Yes | | Yes |
| German | Reference category | | | | | |
| Eastern | | | | 0.735 | 0.176*** | 0.216*** |

**Table 6** (continued)

| | Coef | LSDV<br>Std. err | Driscoll–Kray<br>Std. err | Coef | LSDV<br>Std. err | Driscoll–Kray<br>Std. err |
|---|---|---|---|---|---|---|
| Nordic | | | | − 0.673 | 0.168*** | 0.186*** |
| Latin | | | | 1.443 | 0.160*** | 0.133*** |
| Anglo-Saxon | | | | 0.849 | 0.133*** | 0.095*** |
| Robust SE | | No | | | Yes | |
| Number of obs | 291 | | | | | |
| $F$ (Prob > $F$) | | 269.60 (0.00) | 742.46 (0.00) | | 239.45 | 9201.39 (0.00) |
| $R^2$ | | 0.975 | 0.772 | | 0.897 | 0.897 |
| Adj. $R^2$ | | 0.972 | | | | |
| Breusch–Pagan/Cook–Weisberg test | | | | | | |
| $\chi^2$ (Prob > $\chi^2$) | | 0.07 (0.793) | | | 6.42 (0.011) | |
| Linktest | | | | | | |
| _hatsq ($P > t$) | | 0.0001 (0.984) | | | 0.007 (0.551) | |
| Hausman test | | | | | | |
| $\chi^2$ (Prob > $\chi^2$) | | 57.32 (0.00) | | | | |
| Wooldridge test | | | | | | |
| $F$(1,26) (Prob > $F$) | | 3.509 (0.072) | | | | |

***$p$ value < 0.01

**$p$ value < 0.05

*$p$ value < 0.1

cultural, and environmental factors to explain the evolution of LE65 for women and men in Europe. Health is a complex status and one that is strongly related to life course events, and so health is a result of long-run effects and also short-run events. Since we are using an approach based on contemporaneous observations of independent variables, we shall refer to these effects as associated factors or effects rather than determinants, to prevent any interpretation of causality between factors and life expectancy.

We found several associated factors with LE65. Most relevant and consistent across all model estimations seem to be GDP per capita, education, and pensions. We also found that cultural characteristics are associated with LE65. Other partial findings emerged from our estimations such as the association between health resources, pollution, lifestyles, and income inequality and LE65.

Let us start by the most relevant factors associated with long life expectancy at 65 for women and men are GDP per capita, education, and pensions.

The relevance of the GDP per capita in enhancing population health has been generally acknowledged in the literature. Higher GDP per capita reflects economic development. There may be negative effects of economic development such as increased pollution, traffic, and crime, but higher per capita income enables people to access more healthcare services and purchase better quality goods; higher GDP per capita may also be related to better working conditions and jobs that are not so prejudicial to health; and finally, higher GDP per capita is implicitly related to a better educated population (Or 2000; Spijker 2005; Arah et al. 2005; Cutler et al. 2006; Jourmard et al. 2008; Mackenbach et al. 2015; Minagawa and Jagger 2020).

Education is in fact strongly related to economic development and therefore to GDP per capita. Better educated societies enjoy better health levels and so longer lives (Cutler et al. 2006; Marmot et al. 2012; Mackenbach et al 2019; Murtin et al.2017). This result is a long-standing relationship in health economics and public health.

The importance of social expenditure in promoting health has been recognized in some studies. In general, countries with more generous welfare systems also enjoy better levels of health (Eikemo et al. 2008; Bradley et al. 2011; Bergqvist et al.2013; Reeves et al. 2016). We found a positive association between the share of GDP devoted to pension expenditure and LE65. On the one hand, due to ageing transition, as the share of older people in the population increases, so does spending on pensions. On the other, increased pension expenditure could also be related to ensuring some social protection against the burden of ageing, minimizing unmet health needs, and ensuring some income distribution across society.

The second relevant finding is the importance of cultural characteristics. Because of the non-measurable nature of culture, it has received much lower attention by researchers. (One example of the importance of culture in health outcomes was published by Oude Groeniger et al. 2020.)

We have tried to overcome this void by applying the cultural cluster construction based on Hofestead cultural dimensions.

Our results show that there is some association between cultural clusters and LE65, for both women and men. For instance, after accounting for the socioeconomic and environmental influences, the Nordic cluster seems to have the lowest LE65 for both sexes, while Latin cluster the highest. From a cultural perspective, Nordic cluster has the lowest scores in power distance, the highest in institutional collectivism and a strong level of gender egalitarianism. That is, there is a low expectation for equal power distribution, an encouraging approach for collective action, and strong concern for minimizing gender inequalities. On the other hand, the Latin cluster has a high level of LE65 for both sexes and it has an average score in gender egalitarianism, a low level of institutional collectivism and human orientation, and high score for power distance. Future research will look for the potential links between these cultural characteristics and life expectancy.

Concerning other findings of our analysis, specifically those related with the association between health resources, pollution, lifestyles, and income inequality and LE65, several issues are next discussed.

Let us start with health resources measured by public health expenditure and practising physicians. The association between health expenditure and health is often reported in the literature (de Meijer et al. 2013; Jaba et al.2014; Or et al. 2005; Spijker 2005; Arah et al. 2005; Joumard et al. 2008; Bradley et al. 2011; Mackenbach et al. 2019). The greater the spending on health, the better the levels of health outcomes, despite cases where this may be dubious (like in the USA, Papanicolas et al. 2018). Our results are not significant for men, but they are significant for women; however, this association is negative. This was unexpected, and we find it difficult to explain. May be there is some inverse causality effect, where due to a negative effect on LE65, the response is an increase in public health expenditures. Certainly, future research will study this relationship and its causality.

The association with the physical resources of health as represented by practising physicians, however, is less often mentioned in studies. Our results indicate that higher availability of physicians in the country contributes to higher LE65. This is in line with previous work by Joumard et al. (2008), Arah et al. (2005), and Or et al. (2005). They tested the relationship between the human resources indicator and population health and found a positive association. Despite the differences in health systems and their performance across countries, the availability of human resources contributes to the health of people. From a marginal point of view, increasing the availability of one doctor in a country means that more health care can be provided. There is no report as yet about the point of inflexion where the marginal benefit of one more physician results in a decrease of people's health.

Regarding pollution, our findings are as expected and people's health is affected by the levels of pollution. While the results for air pollution are well known in the literature (WHO 2020b; EEA 2018; Or 2000; Arah et al. 2005; Joumard et al. 2008), a less common result is the one correlating the use of pesticides with a decrease in life expectancy. This result is found for the models with country fixed-effects as is supposed to happen because agriculture has a different importance in the economy of each country, and regulations for pesticide use are different across countries. Some studies show that using pesticides to improve productivity and quality of crops does affect consumer health. Pesticide residues in food are ingested and accumulate in the human body, which in the long term can lead to the development of cancer and diabetes, for instance (Ozkara et al. 2016; Tago et al. 2014).

Regarding lifestyles, the relationship between lifestyles and health has been thoroughly studied and it is well recognized that alcohol consumption is a risk factor for chronic diseases (WHO 2020d). As expected, we found a negative correlation between alcohol consumption and men LE65; the same result was not found for women. Given the positive association between smoking and alcohol consumption (Room 2004; Bien and Burge 1990), a negative association would be expected between smoking and life expectancy (Or 2000; Spijker 2005; Arah et al. 2005; Joumard et al. 2008; Mackenbach et al. 2019). Alcohol and smoking are risk factors for most non-communicable diseases and for premature death. Controlling their consumption by changing people's lifestyle could contribute to a longer active life.

Last, but no less important, income inequality was found to be significant in models accounting for cultural clusters, but not for countries effects. Income inequality was measured by the percentage of people at risk of poverty. This approach is slightly different from other models which used the Gini index (Spijker 2005; Mackenbach et al. 2019). However, the Gini index is computed at national level and it does not differentiate between sexes. In fact, women face a higher risk of poverty than men (Eurostat 2020b) and this can be seen in the larger estimated coefficient for women than for men in regressions with a cultural fixed-effects. This association is not found in models with country fixed-effects, and this could be because there might not be sufficient heterogeneity across countries to generate a clear result. However, when accounting for cultural differences, the association between risk of poverty and life expectancy becomes significant, which could indicate that cultural features might influence women's and men's social status and, consequently, their health and life expectancy. And this may be worth additional future research.

## There are three main limitations to our work

First, we have not included lagged independent variables and we have assumed, like Joumard et al. 2008, the challenging assumption that contemporaneous explanations could reflect long-term effects. However, we are not looking for causal effects but associations. There are insufficient available data to do a long-run analysis and, as Spijker (2005) concluded, determining the optimal lag time might not be straightforward. We have obtained reasonable results that are in line with previous literature, which implies that using contemporaneous data is an acceptable approach to finding factors associated with LE65. May be future analysis could include data for longer period of time.

Secondly, data for health expenditure are not given for the 65+ age group. It would be a great step forward to have health expenditure for age groups, but it is very hard to organize this sort of national accounting. Only three OECD countries report this information, and they do so for a very limited number of years (OECD database). While Korea and Czechia show a decline in health expenditure at older ages, the Netherlands shows an increase. Data and empirical analysis are still needed to better evaluate what happens to health expenditure in older age groups and how it relates to health outcomes.

Thirdly, we have taken a cultural classification which may be criticized because of the dimensions used to build the cultural clusters. However, culture is very hard to measure and the GLOBE project approach is a well-accepted cultural classification of countries. On the other hand, limiting culture effects to country effects, as several studies have done, may be short-sighted because fixed-effects in a country are not restricted to culture effects but include historical, institutional, political, and geographical effects, too, while culture traits may be expressed in other specific dimensions.

Future research will relate the scores of each cultural dimension that defines each cultural cluster with health outcomes, such as LE65. Moreover, future research will aim to understand what the links are and what are the mediators between cultural dimensions and health outcomes. Well-designed policies should account for cultural characteristics and understand how they can be used to achieve the purposes of improving health outcomes. European programmes and directives may not be effective at promoting a healthy and active life for older people because they do not account for culture heterogeneity.

In conclusion, our work has identified several factors associated with LE65, for women and men, in 31 countries, for the period 2004–2018. The associations found do not differ largely for women and men, so the socioeconomic, cultural, and environmental conditions are influencing women's and men's life expectancy in a similar way. Exceptions found were related to women's risk of poverty and men consuming alcohol, which may call for specific policy measures. We have shown that cultural differences do matter when it comes to explaining life expectancy at 65, as do environmental factors, like pesticide use, and this is our main contribution to the literature.

## Appendix

See Tables 7, 8, 9 and 10.

**Table 7** Descriptive statistics for independent variables

| Variable | Mean | SD | Min | Max | Observations |
|---|---|---|---|---|---|
| GDPpc | | | | | |
| Overall | 10.008 | 0.687 | 8.27 | 11.35 | $N*T=465$ |
| Between | | 0.6911 | 8.56 | 11.30 | $N=31$ |
| Within | | 0.0896 | 9.68 | 10.34 | $T$ bar = 15 |
| PHE | | | | | |
| Overall | 6.255 | 1.597 | 2.58 | 9.76 | $N*T=431$ |
| Between | | 1.533 | 3.04 | 8.87 | $N=31$ |
| Within | | 0.5171 | 4.52 | 7.53 | $T$ bar = 13.9 |
| Physicians | | | | | |
| Overall | 347.088 | 76.740 | 207.91 | 612.21 | $N*T=439$ |
| Between | | 71.438 | 225.58 | 570.30 | $N=31$ |
| Within | | 27.513 | 264.44 | 454.85 | $T$ bar = 14.16 |
| Pensions | | | | | |
| Overall | 10.388 | 2.702 | 4.90 | 17.70 | $N*T=441$ |
| Between | | 2.544 | 6.44 | 15.30 | $N=31$ |
| Within | | 0.985 | 6.73 | 13.13 | $T$ bar = 14.23 |
| RiskPoverty M | | | | | |
| Overall | 18.537 | 11.052 | 3.40 | 70.70 | $N*T=444$ |
| Between | | 10.286 | 5.18 | 52.27 | $n=31$ |
| Within | | 4.880 | 1.97 | 38.28 | $T$ bar = 14.32 |
| RiskPoverty F | | | | | |
| Overall | 25.715 | 13.023 | 4.4 | 75.90 | $N*T=444$ |
| Between | | 12.180 | 8.22 | 62.36 | $N=31$ |
| Within | | 5.580 | 8.12 | 46.42 | $T$ bar = 14.32 |
| Education M | | | | | |
| Overall | 20.622 | 7.254 | 5.30 | 40.70 | $N*T=465$ |
| Between | | 6.898 | 8.12 | 35.68 | $N=31$ |
| Within | | 2.545 | 11.74 | 29.84 | $T$ bar = 15 |
| Education F | | | | | |
| Overall | 16.907 | 8.072 | 4.40 | 43.2 | $N*T=465$ |
| Between | | 7.248 | 6.04 | 34.93 | $N=31$ |
| Within | | 3.769 | 6.61 | 28.61 | $T$ bar = 15 |
| AirPollution | | | | | |
| Overall | 16.084 | 6.620 | 4.6 | 44.7 | $N*T=459$ |
| Between | | 5.393 | 7.73 | 30.32 | $N=31$ |
| Within | | 4.047 | 3.41 | 36.57 | $T$ bar = 14.81 |

**Table 7** (continued)

| Variable | Mean | SD | Min | Max | Observations |
|---|---|---|---|---|---|
| Pesticides | | | | | |
| Overall | 2.824 | 2.465 | 0.02 | 11.32 | $N*T=406$ |
| Between | | 2.415 | 0.03 | 9.29 | $N=29$ |
| Within | | 0.653 | 0.53 | 6.42 | $T=14$ |
| Alcohol | | | | | |
| Overall | 10.530 | 2.193 | 5.97 | 17.75 | $N*T=397$ |
| Between | | 2.078 | 6.35 | 15.93 | $N=31$ |
| Within | | 0.757 | 7.83 | 13.04 | $T$ bar = 12.81 |

*F* female, *M* male

**Table 8** Pairwise correlations for independent variables

| | lnGDPpc | PHE | Physicians | Pensions | RiskPovertyF | RiskPovertyM | EducationF | EducationM | AirPollution | Pesticides |
|---|---|---|---|---|---|---|---|---|---|---|
| PHE | 0.5545* | 1 | | | | | | | | |
| Physicians | 0.1100* | 0.2080* | 1 | | | | | | | |
| Pensions | 0.1631* | 0.5532* | 0.3642* | 1 | | | | | | |
| RiskPovertyF | − 0.5409* | − 0.6382* | − 0.0391 | − 0.3702* | 1 | | | | | |
| RiskPovertyM | − 0.5091* | − 0.5794* | − 0.0459 | − 0.2791* | | 1 | | | | |
| EducationF | 0.2644* | 0.1774* | 0.0403 | − 0.1102* | − 0.0342 | | 1 | | | |
| EducationM | 0.6246* | 0.3963* | 0.1095* | 0.0665 | | − 0.3184* | | 1 | | |
| AirPollution | − 0.4867* | − 0.3997* | − 0.1234* | − 0.0951* | 0.4303* | 0.4758* | − 0.4886* | − 0.4605* | 1 | |
| Pesticides | 0.1452* | 0.3262* | − 0.0735 | 0.4619* | − 0.2308* | − 0.0903* | − 0.2607* | 0.0102 | − 0.0063 | 1 |
| Alcohol | − 0.2892* | − 0.3097* | − 0.2032* | − 0.2692* | 0,2654* | 0.2048* | 0.0217 | − 0.0207 | 0.1437* | − 0.0382 |

*F* female, *M* male

*$p$ value < 0.1

**Table 9** Multicollinearity test—Variance Inflated Factor

| Variable | Females | | Males | |
|---|---|---|---|---|
| | VIF | 1/VIF | VIF | 1/VIF |
| lnGDPpc | 3.530 | 0.283 | 4.400 | 0.227 |
| PHE | 2.760 | 0.363 | 2.690 | 0.371 |
| RiskPoverty | 2.650 | 0.377 | 2.180 | 0.459 |
| AirPollution | 2.170 | 0.460 | 2.130 | 0.469 |
| Pension | 2.010 | 0.498 | 1.990 | 0.502 |
| Education | 2.000 | 0.500 | 1.720 | 0.583 |
| Pesticides | 1.550 | 0.646 | 1.540 | 0.650 |
| Physicians | 1.400 | 0.716 | 1.320 | 0.758 |
| Alcohol | 1.250 | 0.797 | 1.310 | 0.761 |
| Mean VIF | 2.150 | | 2.140 | |

**Table 10** Fisher-type ADF panel unit-root test

| Statistic (lags = 1) | (With drift) | | | | (With trend) | | | |
|---|---|---|---|---|---|---|---|---|
| | Inverse chi-squared (P) | Inverse normal (Z) | Inverse logit t (L*) | Modified inv. chi-squared (Pm) | Inverse chi-squared (P) | Inverse normal (Z) | Inverse logit t (L*) | Modified inv. chi-squared (Pm) |
| **LE65 male** | 207.631 | − 9.210 | − 9.928 | 13.078 | 54.265 | 2.378 | 2.492 | − 0.695 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.747 | 0.991 | 0.993 | 0.756 |
| **LE65 female** | 212.218 | − 9.743 | − 10.300 | 13.490 | 44.869 | 2.328 | 2.387 | − 1.538 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.950 | 0.990 | 0.991 | 0.938 |
| **lnGDPpc** | 148.560 | − 6.729 | − 6.700 | 7.773 | 127.271 | − 3.686 | − 4.095 | 5.862 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **PHE** | 184.855 | − 8.575 | − 8.857 | 11.033 | 140.360 | − 2.410 | − 4.301 | 7.037 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 | 0.000 | 0.000 |
| **Physicians** | 79.126 | − 1.351 | − 1.450 | 1.746 | 182.842 | − 3.655 | − 6.358 | 11.214 |
| *p*–value | 0.050 | 0.088 | 0.075 | 0.040 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Pensions** | 173.485 | − 7.923 | − 8.063 | 10.012 | 71.479 | 1.075 | 1.026 | 0.851 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.192 | 0.859 | 0.847 | 0.197 |
| **RiskPoverty male** | 219.168 | − 9.880 | − 10.619 | 14.114 | 105.830 | 0.145 | − 1.213 | 3.936 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.558 | 0.113 | 0.000 |
| **RiskPoverty female** | 151.009 | − 6.992 | − 6.893 | 7.993 | 49.924 | 2.770 | 2.792 | − 1.085 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.865 | 0.997 | 0.997 | 0.861 |
| **Education male** | 111.076 | − 4.757 | − 4.582 | 4.407 | 170.489 | − 5.654 | − 6.689 | 9.743 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Education female** | 64.990 | − 0.640 | − 0.695 | 0.269 | 117.309 | − 4.190 | − 4.299 | 4.967 |
| *p*–value | 0.373 | 0.261 | 0.244 | 0.394 | 0.000 | 0.000 | 0.000 | 0.000 |
| **AirPollution** | 144.842 | − 7.145 | − 7.156 | 8.395 | 119.244 | − 2.819 | − 3.666 | 5.686 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 |
| **Pesticides** | 196.745 | − 8.813 | − 9.612 | 12.882 | 114.500 | − 2.240 | − 2.764 | 5.246 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.013 | 0.003 | 0.000 |
| **Alcohol** | 176.258 | − 7.631 | − 8.027 | 10.261 | 110.467 | − 1.463 | − 2.249 | 4.352 |
| *p*–value | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.072 | 0.013 | 0.000 |

$H_0$: All panels contain unit roots against $H_1$: At least one panel is stationary

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