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Mortality and life expectancy trends for male pensioners by pension income level

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Abstract

A significant inverse relationship between mortality risk and different socioeconomic groups has almost always found. This paper deals with the case of Spain, since very little evidence concerning retirement pensioners is available for this country. We draw on the Continuous Sample of Working Lives (CSWL) to investigate the differences in socioeconomic mortality among retired men aged 65 and above over the longest possible period covered by this data source: 2005–2018. The only indicator of socioeconomic status we use is the amount of the initial pension of the retired population. For 2005-2010 we find a gap in life expectancy of 1.49 years between pensioners in the highest and lowest income groups. This gap widens over time and reaches 2.58 years for the period 2015–2018. The increase in life expectancy inequality cannot be attributed to the pension system reforms carried out over the period 2011-2013, given that the system has become more redistributive and there has been a clear increase in real terms in the amounts of minimum pensions over recent years. The causes might be traced back to the decrease in public spending on health over the period 2009-2018 and the increased spending on private health, which would presumably be of more benefit to those retirees with bigger pensions.

Keywords: Inequalities, Life Expectancy, Life Tables, Mortality, Socioeconomic Factors.

JEL Classification: C81, H55, I14, J26

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Abstract

We draw on the Continuous Sample of Working Lives (CSWL) to investigate the differences in socioeconomic mortality among retired men aged 65 and above over the longest possible period covered by this data source: 2005–2018. This paper deals with the case of Spain, since very little evidence concerning retirement pensioners is available for this country. The only indicator of socioeconomic status we use is the amount of the initial pension of the retired population. For 2005-2010 we find a gap in life expectancy of 1.49 years between pensioners in the highest and lowest income groups. This gap widens over time and reaches 2.58 years for the period 2015–2018. The increase in life expectancy inequality cannot be attributed to the pension system reforms carried out over the period 2011-2013, given that the system has become more redistributive and there has been a clear increase in real terms in the amounts of minimum pensions over recent years. The causes might be traced back to the decrease in public spending on health over the period 2009-2018 and the increased spending on private health, which would presumably be of more benefit to those retirees with bigger pensions.

Key words: Inequalities, Life Expectancy, Life Tables, Mortality, Socioeconomic Factors.

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Transparency declaration. The corresponding author, in the name of the rest of the signatories, declares that the data and information contained in the study are precise, transparent and honest; that no relevant information has been omitted; and that all the discrepancies among authors have been adequately resolved and described.

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Availability of data and material: Ethics approval is not required to use CSWL; its use for scientific purposes is regulated since inception. Researchers can request versions of the CSWL by post. A separate request must be made for each version. Requests consist of a user profile describing the project being carried out and a document accepting the CSWL's conditions of use. These are available at the following address:

http://www.seg-social.es/wps/portal/wss/internet/EstadisticasPresupuestosEstudios/Estadisticas/EST211

Mortality and life expectancy trends for male pensioners by pension income level

1.-Introduction

The connection between income and mortality could have implications for a wide range of social security regulations (Duggan *et al.*, 2008). The literature almost always reports a significant inverse relationship between mortality risk and socioeconomic groups. Discussion of these inequalities has tended to focus more on younger rather than older age groups. However, there is a growing literature on the subject and more researchers seem to be taking an interest in inequalities in mortality related to socioeconomic status in elderly populations (Huisman *et al.*, 2004).

Although the welfare state and welfare spending may have grown, health inequalities persist. And it is not those countries with more generous welfare states – such as those in Scandinavia – that present fewer health inequalities in relative terms, but countries like Italy, Spain and Portugal (Mackenbach, 2017; Mackenbach *et al.*, 2008). This paradox is known as the public health puzzle (Bambra, 2011).

A substantial decline in mortality in lower socioeconomic groups has been reported in most of the European countries analysed in the literature (as cited below), (Mackenbach *et al.*, 2016). However, relative inequalities in mortality have increased almost everywhere because percentage reductions are usually smaller in lower than in higher socioeconomic groups.

The literature reviewed which covers the UK (Longevity Science Panel, 2018, 2020), the USA (Waldron, 2007; Bosley *et al.*, 2018), Italy (Belloni *et al.*, 2013; Lallo & Raitano, 2018), Canada (Adam, 2012; Wen *et al.*, 2020), Germany (Kibele, 2013; Tetzlaff *et al.*, 2020; Wenau *et al.*, 2019), and the Netherlands (Kalwij *et al.*, 2013), generally indicates that mortality gaps by socioeconomic status have not remained constant over time and that inequalities in mortality measured by socioeconomic status have increased in recent years.

This paper looks at the case of Spain, since there is still very little evidence concerning retirement pensioners in this country. To the best of our knowledge, only one paper so far has focused on the inequalities in mortality in connection with socioeconomic status in the elderly population (Regidor *et al.*, 2012). We present results for mortality trends for Spanish male pensioners aged 65 and over since the mid-2000s. We use a large administrative data set (CSWL, the Continuous Sample of Working Lives) to estimate relative differences in mortality among Spanish pensioners grouped according to their initial pension income (PI) levels. We use this initial PI level as our one indicator of socioeconomic status. This approach enables us to accurately answer two basic research questions: (1) are there any differences in mortality between PI income groups? and (2) can any different trends in life expectancy be detected between PI groups that may lead to an increase or a reduction in inequalities over time?

In line with what has been reported for other Mediterranean countries, our paper find that mortality inequalities among older Spanish adults are small. The ubiquity of social safety nets, widespread adherence to the "Mediterranean diet", a later economic modernization process and the existence of better health assets may be responsible for this finding.

We find an inverse relationship between PI levels and mortality for male retirement pensioners. The trend over the full period analysed shows that the spread of life expectancy by PI level has widened. These inequalities are relatively small, but they are also statistically significant. It does not appear that the pension system could be responsible for this slight growth in inequality, given that the Spanish system has been moving away from its insurance-based roots towards an increasingly redistributive model. Further research needs to be done on this aspect, but the causes might be found in the decrease in spending on public health and the increased spending on private health during the period 2009-2018.

The rest of the paper is structured as follows: Section 2 describes the population studied and the methodology used to analyze mortality among Spanish pensioners. Section 3 presents the main results. Section 4 discusses some issues arising from the results. The paper ends with concluding comments and a brief technical appendix describing the methodology used to calculate crude death rates, relative mortality ratios, standard errors of life expectancy, and the significance test for checking the robustness of results.

2.-Methods

2.1.-Variables and population studied

As mentioned above, we use a large administrative data set. This has various advantages over the use of survey data, including larger sample sizes, lower costs and a lighter respondent burden. The CSWL is a random sample of around 1.2 million people, i.e. 4% of the reference population. It contains administrative data on the working lives that form the basis of the sample taken from Spanish Social Security records and comprises anonymized microdata with detailed information on individuals (Pérez-Salamero *et al.*, 2017).

The first wave covers people who had a financial link with the Social Security system in 2004 and provides the entire working history of the sample population. The sample is updated every year using information from variables selected from the Social Security system – dating back to when computerized records began – and from other administrative data sources that record additional information on individuals. The data available to researchers cover from 2004 to 2018. We use the CSWL without fiscal data because it contains a greater number of records than with fiscal data.

The sample reference population is defined as individuals who have had some connection (through contributions, pensions or unemployment benefits) to the Social Security system at any time during the year of reference. Individuals who for any reason have no connection to Social Security in a particular year do not appear in the CSWL. Nor are public employees included.

In our study the initial population comprises male retirement pensioners who retired from the general scheme at age 65 (the ordinary retirement age) or over. **Figure 1** provides a flow chart of the participants/records excluded from our study.

Because of lower labour force participation rates among the equivalent female cohorts and the fact that women sometimes have shorter careers (in terms of years of employment) and may work less intensively than men due to family roles and commitments, the PI level is not a suitable indicator for women's working-life income. The focus of our analysis in this research is therefore the social gradient in male mortality (**Figure 1**, box 3).

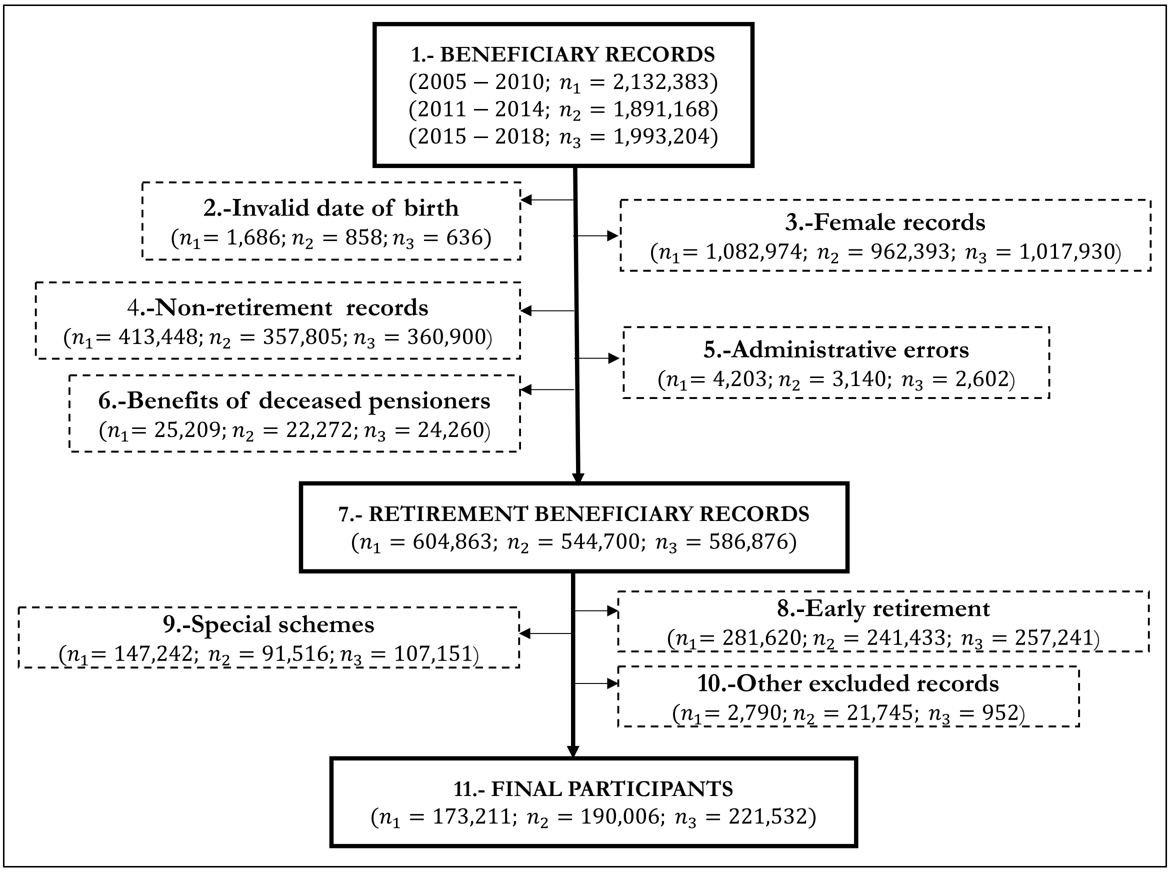


Figure 1: Flow chart showing participants/records excluded from the present study, CSWL, 2005–2018

Mortality among disabled people is far higher than among the general population (Gjesdal *et al.*, 2009; Duran, 2016; Park *et al.*, 2017), so combining the two populations (retirement pensioners and disabled pensioners) could have a seriously misleading effect when it comes to accurately determining the social gradient in mortality (**Figure 1**, box 4).

Given that poor health is an important reason for early retirement (Wu *et al.*, 2016), pensioners who access benefits before the statutory retirement age are also excluded (**Figure 1**, box 8).

Retirement pensioners belonging to the special system for the self-employed are also excluded because the pension rules make their benefits a poor proxy for lifetime income (**Figure 1**, box 9).

Of all the initial beneficiary records for each of the periods considered (box 1), by the end (box 11) – once the whole process of sifting and excluding had been completed – only 8.13% of the original records remain for the first period, along with 10.05% for the second and 11.11% for the third.

The following variables are available in the CSWL data: month and year in which the pension was first paid and ended (if ended), regulating base used to calculate the amount of the benefit, years contributed under each pension regime, benefit type (old age pension, early retirement, disability insurance, survivor's benefits, other) and sex. The design of the Spanish pension system guarantees that retirement benefits are closely linked to lifetime earnings. The contributory system is structured into different "regimes" or schemes, each of which covers a group of workers of a particular type. The General Regime is the basic core of the entire system and includes all employed people over 16 who are not included in any other "special regime."

Table 1: Hypothetical pensioner income levels: exposures in person-years and number of deaths by period (absolute values and percentages)						
		Groups				Total
Periods	Items	Low	Med-Low	Med-High	High	
2005-2010	Exposures	22,146	70,622	26,169	28,165	147,102
	% Exposures	15.05	48.01	17.79	19.15	100
	Deaths	1,132	3,379	937	781	6,229
	% Deaths	18.17	54.25	15.04	12.54	100
2011-2014	Exposures	20,116	74,562	23,958	37,129	155,764
	% Exposures	12.91	47.87	15.38	23.84	100
	Deaths	970	3,539	902	874	6,285
	% Deaths	15.43	56.31	14.35	13.91	100
2015-2018	Exposures	21,562	83,420	25,995	49,921	180,897
	% Exposures	11.92	46.11	14.37	27.60	100
	Deaths	1,009	4,003	1,040	1,138	7,190
	% Deaths	14.03	55.67	14.46	15.83	100
Source: Own work based on CSWL 2005-2018						

Table 1 shows the exposures in person-years and number of deaths (absolute values and percentages) for "hypothetical pensioner income levels" and periods studied. To analyse the data we group the records into four PI levels (B_m): "1-Low"; "2-Medium-Low", "3-Medium-High" and "4-High". We ruled out using benefit level quartiles because, given the features of the sample, some individuals could change quartile due to the appearance of new entrants in each wave.

We assign pensioners to each group according to the minimum (Min) and maximum (Max) benefits in force at the time of their retirement: Low: $B_1 \leq$Min; Medium-Low: Min $<$ $B_2 \leq$ (0.5Max+0.33Min); Medium-High: (0.5Max+0.33Min)$<$ $B_3 \leq$ 0.75Max; and High: $B_4 >$ 0.75Max. Based on the benefit rates in force, the ranges vary over the years reported, e.g. between €36,121.82 (Max) and €8,727.60 (Min) per year in 2018. For the 2018 calendar year, the cut-off points between the four PI level intervals are €8,727.60, €20,679.19, and €27,091.37 respectively.

2.2.-Methodology

We study the social gradient in mortality in two ways. First we estimate an indicator known as "relative mortality", which we use to compare the graduated death rates among retired male pensioners by age group and PI level with the annual death rate for retired male pensioners in the same age group for three different periods: P_1: 2005-2010, P_2: 2011-2014, and P_3: 2015-2018. The first period covers five years, while the second and third cover four. The actual number of deaths and the risk exposure used to calculate the crude annual death rate come from the CSWL (**Table 1**).

For each age group we calculate relative mortality rates at various PI levels. A relative mortality rate of 1.00 for any PI level indicates that it is the same as the death rate for that age group as a whole. If it is lower (higher) than 1.00, the death rate for that PI level is lower (higher) than the rate for that age group as a whole (or any other group of interest). (see technical appendix for details)

Second, we estimate the changes in total life expectancy by PI level at age 65 (LE_{65}) over time. To do this we use the Mort1Dsmooth function in the MortalitySmooth R package

(Camarda, 2012) – specially designed for use in mortality research – to construct complete period life tables from age 65 to age 101 and to calculate LE_{65} for each of the three periods analysed. (see technical appendix for details).

3.-Results

Table 2 shows relative mortality rates by age group and PI level for the three different periods considered, which together cover from 2005 to 2018: P_1: 2005-2010, P_2: 2011-2014 and P_3: 2015-2018.

For 2005-2010 the relative rates for the 65-69 age group are 1.49, 1.03, 0.95 and 0.77 in ascending order from the lowest PI level to the highest. The figure of 1.49 for the lowest means that the death rate is 49% higher than for that age group as a whole, while the figure of 0.77 for the highest PI level means that it is 23% lower than for that age group as a whole. Table 2 shows that for groups covering higher ages there is less of a difference in relative mortality rates between PI levels.

If we compare interval P_1: 2005-2010 and P_2: 2011-2014, we see a generalized increase in relative inequality in mortality for almost all age groups. The exception is the 75-79 age group, where the difference in relative mortality between the lowest and highest PI levels drops from 0.23 (1.12-0.89) to 0.17 (1.11-0.94), i.e. the relative inequality in mortality for this age group is lower than in the previous period.

When we compare interval P_2: 2011-2014 and P_3: 2015-2018, we see a substantial increase in relative inequality in mortality for the youngest age groups (65-69; 70-74 and 75-79) and a slight reduction for the rest (80-84; and 85+).

Table 2: Relative mortality rates by age group and PI level

Periods	Age Group	PI level: Low	Med-Low	Med-High	High
2005-2010	65-69	1.49	1.03	0.95	0.77
	70-74	1.18	1.05	0.86	0.83
	75-79	1.12	1.04	0.92	0.89
	80-84	1.05	1.02	0.95	0.92
	85+	1.00	1.01	0.90	0.90
	Total	**1.18**	**1.13**	**0.86**	**0.61**
2011-2014	65-69	1.59	1.02	0.94	0.85
	70-74	1.21	1.05	0.89	0.82
	75-79	1.11	1.00	0.96	0.94
	80-84	1.06	1.03	0.95	0.84
	85+	1.05	1.05	0.89	0.81
	Total	**1.21**	**1.15**	**0.80**	**0.59**
2015-2018	65-69	1.67	1.09	0.93	0.75
	70-74	1.37	1.07	0.91	0.79
	75-79	1.22	1.07	0.95	0.85
	80-84	1.07	1.06	0.91	0.86
	85+	1.05	1.08	0.85	0.83
	Total	**1.25**	**1.19**	**0.78**	**0.58**

Source: Own work based on CSWL 2005-2018

Table 2 shows the trend in relative mortality rates for the whole range of age groups and periods analysed. It reveals that the spread of death rates across PI levels has been widening for male retirement pensioners aged 65 and over.

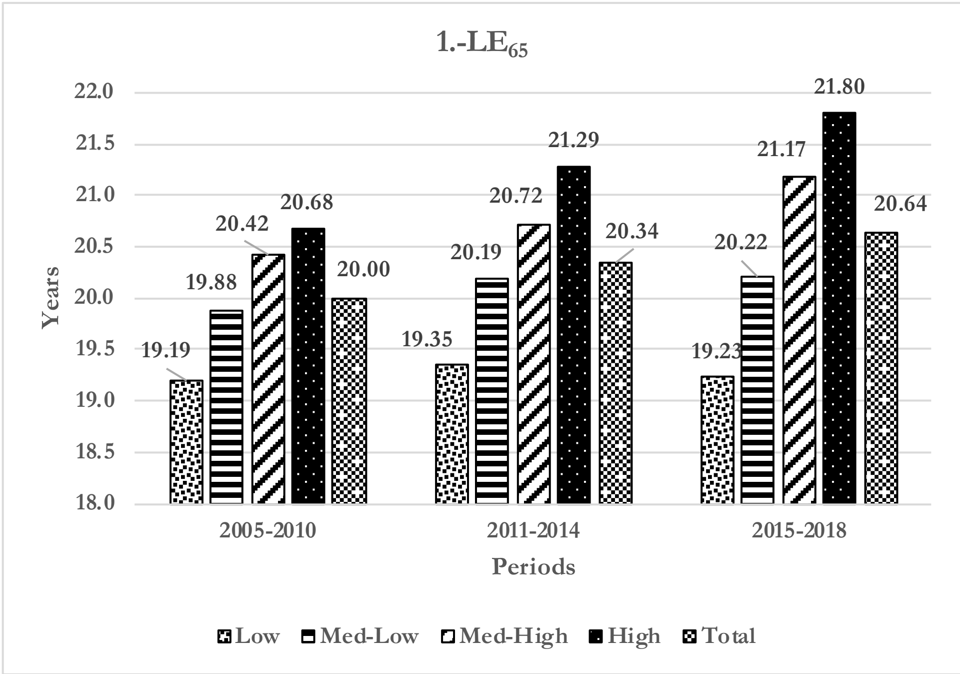
The decrease in death rates by PI level between intervals P_1 and P_3 fully explains the change in the relative inequality in mortality. This decrease is (much) larger for the "High" (14.18%) and "Medium-High" groups (10.91%) than for the group as a whole (8.76%). Given that the previous relative mortality rates were less than 1.00 for both groups (0.61 and 0.86 respectively in P_1), the figures for these two groups in the third period (0.78 and 0.58 respectively) indicate that inequality in mortality has increased over time. In the case of the "Low" and "Medium-Low" groups the improvements in mortality are (much) smaller (2.97% and 3.73% respectively) than for the group as a whole (8.76%), and therefore their rates in this third period (1.25 and 1.19 respectively) are further from 1.00 than they were in the first period (1.18 and 1.13 respectively).

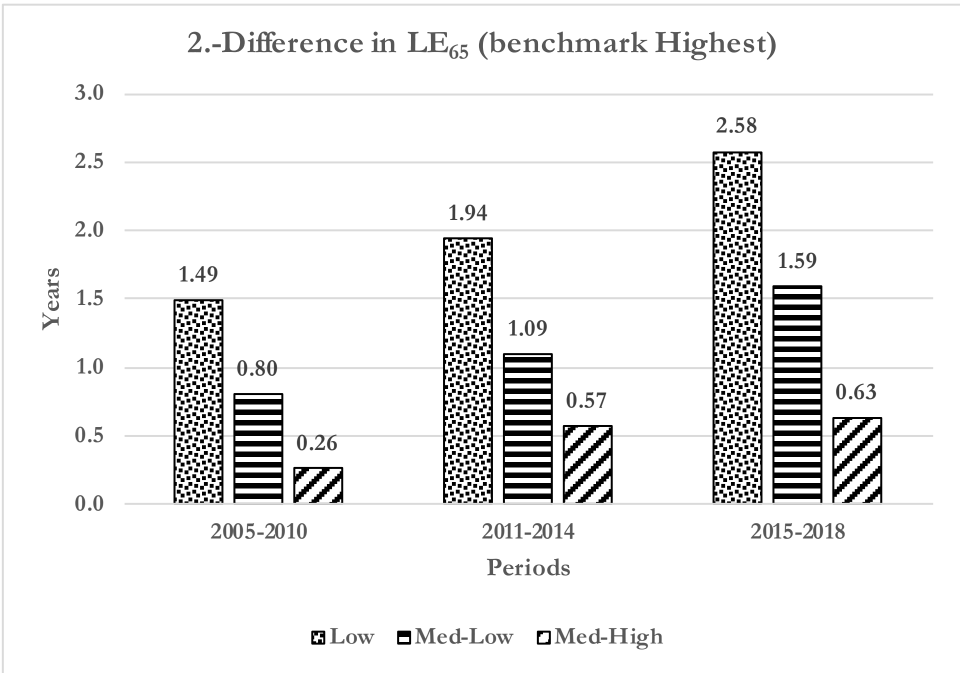
At first glance it might appear that the relative mortality rates observed for the periods analysed would imply enormous differences in life expectancy between the groups of pensioners categorized by PI level. However, as we can see below, this is not strictly true.

Figure 2 shows ~~s~~ full life expectancy at age 65 along with several variations by PI level for the periods studied. The information has been broken down into 4 graphs.

Graph 1 in **Figure 2** shows that LE_{65} is positively linked to PI levels. The higher the PI level, the higher the life expectancy at age 65. In Graph 2 we see that for 2005-2010 there is a gap of 1.49 years between pensioners in the lowest and those in the highest income groups. This gap widens over time to 2.58 years in 2015–2018. A similar trend can be observed if the highest PI group is compared to the other two groups. The trend sketched out by the columns points to constantly increasing differences in socioeconomic mortality for all groups, but with a steeper social gradient in the lowest PI group.

Given these results, we now need to find out whether or not the LE_{65} differences between PI levels are statistically significant. **Table 3** and Graph 3 in **Figure 2** can shed some light on this matter.


1.-LE65
22.0
21.5
21.0
20.5
20.0
19.5
19.0
18.5
18.0
Years
19.19
19.88
20.42
20.68
20.00
19.35
20.19
20.72
21.29
20.34
19.23
20.22
21.17
21.80
20.64
2005-2010
2011-2014
2015-2018
Periods
Low
Med-Low
Med-High
High
Total


2.-Difference in LE65 (benchmark Highest)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Years
1.49
0.80
0.26
1.94
1.09
0.57
2.58
1.59
0.63
2005-2010
2011-2014
2015-2018
Periods
Low
Med-Low
Med-High

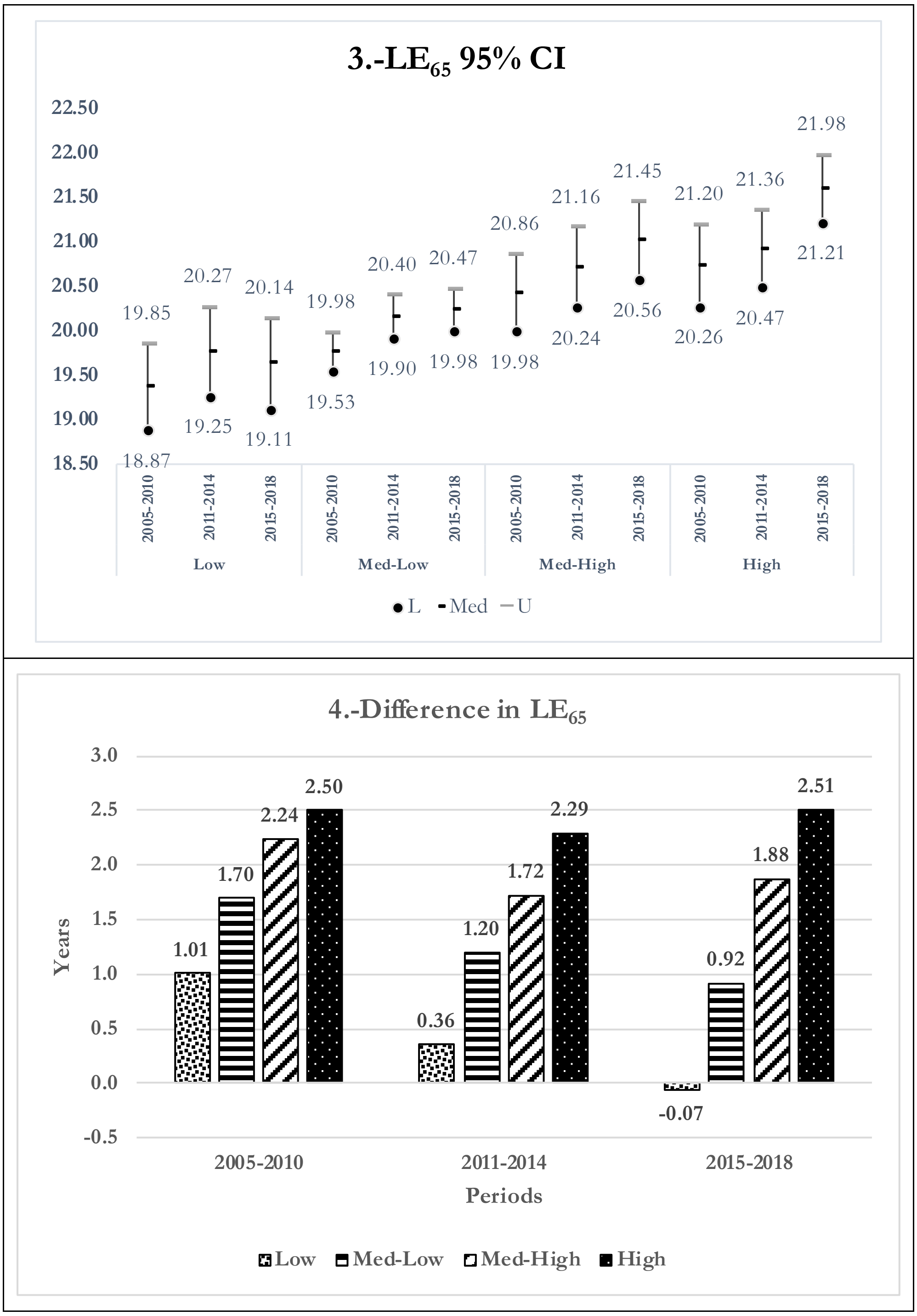


Figure 2: LE_{65} and variations by PI level.

For all three periods analysed, **Table 3** shows the differences in LE_{65} (DLE_{65}) between one PI group and another, from Med-Low and Low to High and Med-High, along with the standard error for those differences and the z-score of the test statistic. Thus we can test the null hypothesis that the difference in life expectancy is zero against the alternative of its being positive. The results show that most DLE_{65} are statistically significant at 1% or 5%, with the sole exception being the difference between the High and Med-High PI groups in 2005-2010, which is not significant at 10%. These results therefore support the idea that there is highly significant evidence of a positive relationship between LE_{65} and PI groups.

Table 3: Absolute differences in life expectancy between PI groups at age 65 by period

Items	Dif. between Med-Low and Low PI groups			Dif. Between Med-High and Med-Low PI groups			Dif. Between High and Med-High PI groups		
Periods	P_1	P_2	P_3	P_1	P_2	P_3	P_1	P_2	P_3
DLE_{65}	0.689	0.843	1.228	0.541	0.524	0.714	0.261	0.569	0.631
$Se(DLE_{65})$	0.269	0.283	0.282	0.255	0.264	0.263	0.330	0.337	0.312
z-score	2.56^{***}	2.98^{***}	4.36^{***}	2.12^{**}	1.96^{**}	2.71^{***}	0.79	1.69^{**}	2.02^{**}

*** significant at 1% one-tailed test. ** significant at 5% one-tailed test. * significant at 10% one-tailed test.

Source: Own work based on CSWL 2005-2018

The details given in **Table 3** can be seen more intuitively in Graph 3, which shows 95% confidence intervals (CIs) for the LE_{65} for all PI groups of pensioners and all three periods analysed.

Graph 4 in **Figure 2** compares our results with the LE_{65} for the Spanish population as a whole. As expected, those individuals included in the sample live longer than the general population because one of the requirements for obtaining a retirement pension is to have contributed for at least 15 (currently 20) years, including at least 2 of the last 15 (20) years. This is likely to exclude some of the most at-risk members of the population because of the strong correlation between labour force participation and health observed in various countries (Waldron, 2007; Urbanaviciute *et al.*, 2019; Piłat, 2020). Disability pensioners and early retirees are also excluded. The most striking thing is that LE_{65} for pensioners in the lowest PI group is actually lower than for the general population in the third period. Absolute differences in life expectancy for the most disadvantaged groups are seen to narrow over time, while for the most advantaged groups they remain fairly stable

4.-Discussion

We find an inverse relationship between PI levels and mortality for male retirement pensioners. The trend over the full period analysed shows that the spread of life expectancy by PI level has widened. This result is in line with studies on Germany, which have also reported increasing inequalities among elderly men based on pension fund data (Kibele *et al.*, 2013; Tetzlaff *et al.*, 2020; Wenau *et al.*, 2016).

Overall, the literature reviewed (Mackenbach *et al.*, 2016; Longevity Science Panel, 2018, 2020; Waldron *et al.*, 2007; Bosley *et al.*, 2018; Belloni *et al.*, 2013; Lallo and Raitano, 2018; Adam, 2012; Wen *et al.*, 2020; Kibele *et al.*, 2013; Tetzlaff *et al.*, 2020; Wenau *et al.*, 2019; Kalwij *et al.*, 2013) generally indicates that when mortality gaps have widened over time in the past, the probabilities of death have usually decreased more rapidly for high-income groups than for low-income groups. We also find evidence of this for Spain using the data from the CSWL.

Our findings show that inequalities in mortality for retirement pensioners are small. This is in line with previous findings for Spain involving older adults (Regidor *et al.*, 2012; Kulhánová *et al.*, 2014; Solé-Auró *et al.*, 2020). The ubiquity of social safety nets (Regidor *et al.*, 2012), widespread adherence to the "Mediterranean diet", a later economic modernization process and the existence of better health assets may be responsible for this finding.

Along with behavioural and structural aspects (Mackenbach, 2017), a combination of other factors such as the design of the pension system (EU, 2018), the universality and good quality of the health system (Fullman, 2018) and high levels of family support (Lorenzo-Carrascosa, 2015) could explain why inequalities in life expectancy for retired Spanish men are relatively small.

Nevertheless, although the differences are small, they have grown. It does not appear that the pension system could be responsible for this growth in inequality, given that the Spanish system has one of the highest aggregate replacement rates in Europe. Spanish pensioners largely maintained their relative standard of living during the recent economic crisis (2008-2014) (EU, 2018), and the percentage of people in Spain aged 65 and above whose income is less than 50% of median equivalized disposable household income is lower (9.4%) than the figure for the total population (15.5%). This rate is also 4.1 percentage points below the average for OECD countries (13.5%) in 2016 (OECD, 2019b).

The contributory retirement pension system in Spain has been moving away from its insurance-based roots towards an increasingly redistributive model. The minimum retirement pension for a single pensioner at age 65 increased by 15.24% in real terms between 2000 and 2018 and the maximum benefit decreased by 5.86% in real terms. The ratio between the maximum and minimum pensions has greatly decreased over time, from 5.07 (2000) to 4.14 (2018). Around 91% of people aged 65 and over live in owner-occupied homes, and only 1.8% were found to be living in overcrowded households (EU, 2018).

The Spanish health system is based on the principle of universality and is one of the most efficient healthcare systems in Europe. Indeed, in the Healthcare Access and Quality Index, Spain is ranked 19th out of 195 countries for healthcare and access. Perhaps the reason for this increase in inequality in life expectancy can be found in the lack of investment in the public health system. Over the period 2008-2013, annual per-capita spending on health (in real terms) decreased by -1.9%, better than only Greece, Portugal and Iceland of the OECD36 countries (OECD, 2019a). Growth during the period 2013-2018 was positive at 2.3%, very close to the average for the period for all the 36 countries of the OECD studied (2.4%).

Similarly, the macroeconomic figures for total spending on health fell from 9.4% of GDP in 2009 to 9.1% in 2018, but the variation in the proportions of public and private spending was very different (OECD, 2019a). This could partly explain the increase in inequality, since the socioeconomic groups with bigger pensions would presumably benefit the most from these private health services. Public spending on health fell from 7.1% of GDP in 2009 to 6.4% in 2018, while spending on the private health sector rose from 2.3% to 2.7% over the same period.

Establishing the reasons behind this increased inequality in life expectancy calls for more research to be carried out. An analysis of all Spanish Social Security records instead of just a sample could shed some light on the matter.

4.1.-Strengths and limitations

As far as the authors are aware, this is the first time the CSWL has been used to study the differences in mortality and life expectancy from the socioeconomic point of view of retirement pensioners aged 65 and above. As far as the sample finally selected is concerned, the initial amount of pension seems to be a reliable socioeconomic indicator, as shown by the results obtained. However, some limitations to the study should be taken into account. First, we focused on male mortality alone. Second, we excluded groups of pensioners for whom the application of our socioeconomic indicator might not have been suitable for several reasons (disabled pensioners, early retirees, beneficiaries in special schemes such as the self-employed). Third, due to the fact that they are not included in the database used, we were unable to work with the collective of pensioners belonging to the Régimen de Clases Pasivas (civil servants). Finally, despite the fact that the results we have obtained are coherent, the analysis could be carried out in much greater depth if we had access to all the records held by the Department of Social Security, along with details of any additional sources of income the pensioners may have.

5.-Conclusions

While acknowledging that using the initial pension income level as the sole indicator of socioeconomic status for the retired population has its limitations, we have found an inverse relationship between PI levels and mortality for male retirement pensioners. We have also found highly significant evidence of a positive relationship between LE_{65} and pension income.

The trends for the entire period analysed show that the spread of life expectancy as measured by PI levels has widened.

The increased inequality in life expectancy does not appear to stem from the pension system reforms carried out over the period 2011-2013, given that the Spanish system has become more redistributive and the amount of the minimum pensions has clearly increased in real terms over recent years. The causes might be found in the decrease in spending on public health during the period 2009-2018 and the increased spending on private health, which would presumably be of greater benefit to those pensioners with higher incomes.

Independently of the causes of differential mortality, a direct link between PI level and life expectancy has important implications for pension policy. Mortality gaps by socioeconomic status should be taken into account for a variety of issues involving social security schemes, e.g. to establish the eligibility age for retirement pensions and early access to benefits, to compute the annuity factors used to determine initial retirement benefits, and to value liabilities to retirement pensioners.

6.-References

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Appendix: Technical Appendix

A1.-Mortality rates

Mortality rates (or probabilities of dying) are indicators commonly used in demographics, medicine, and actuarial practice. They usually refer to one or more variables, the most common being age, calendar years, and duration. To describe the actual but unknown mortality pattern of a population (retirement pensioners grouped by initial PI levels and more variables in our case), it is necessary to calculate the crude mortality rates from raw data.

For all beneficiary groups classified by PI level m, the crude mortality rate for a given period-year interval, $\mathrm{P} = \{a, a+1, \cdots, n\}$, age x, and sex j, is defined as the observed probability that a person of age x nearest birthday will die between ages x and $x+1$ during the period-year interval P. n represents 31st December for the last calendar year within the period and a represents 31st December for the first year.

The observed probabilities of death is calculated by simply dividing the relevant number of deaths[1] ($D_{x,\mathrm{P}}^{j,m}$) by the number of life-years of exposure over the given year or period ($E_{x,\mathrm{P}}^{j,m}$). The size of the exposure population is estimated by averaging the population sizes at the beginning and end of the year. In our case, the crude mortality rate $\hat{q}_{x,\mathrm{P}}^{j,m}$ is calculated as follows:

$$\hat{q}_{x,\mathrm{P}}^{j,m} = \frac{D_{x,\mathrm{P}}^{j,m}}{E_{x,\mathrm{P}}^{j,m}} = \frac{\overbrace{D_{x,a+1}^{j,m} + \cdots + D_{x,n}^{j,m}}^{Deaths}}{\underbrace{\frac{1}{2}\left(D_{x,a+1}^{j,m} +..+ D_{x,n}^{j,m} + L_{x,a}^{j,m} + L_{x,n}^{j,m}\right) + L_{x,a+1}^{j,m} .. + L_{x,n-1}^{j,m}}_{Exposed\ to\ Risk}} \tag{1}$$

where, $D_{x,\mathrm{t}}^{j,m}$ is the observed number of deaths of individuals who have attained age x on their nearest birthday for PI level group m, gender j in the calendar year $t \in \{a+1, \cdots, n\}$, and $L_{x,\mathrm{t}}^{j,m}$, with $t \in \{a, \ldots. n\}$ is the observed number of retirement pensioners aged x at their nearest birthday in PI level group m and gender j, at the end of year $t \in \mathrm{P}$.

The average crude death rate $\hat{q}_{h,\mathrm{P}}^{j,m}$ for age group h, PI level m, gender j for the period-year interval P can be expressed as:

$$\hat{q}_{h,\mathrm{P}}^{j,m} = \frac{\overbrace{D_{h,a+1}^{j,m} + \cdots + D_{h,n}^{j,m}}^{D_{h,\mathrm{P}}^{j,m}}}{\underbrace{\frac{1}{2}\left(D_{h,a+1}^{j,m} + \cdots + D_{h,n}^{j,m} + L_{x,a}^{j,m} + L_{x,n}^{j,m}\right) + L_{x,a+1}^{j,m} +. \ldots + L_{x,n-1}^{j,m}}_{E_{h,\mathrm{P}}^{j,m}}} \tag{2}$$

where $D_{h,t}^{j,m}$ is the observed number of deaths for age group P, PI level m, gender j in calendar year t, and $L_{h,t}^{j,m}$ is the registered number of retirement pensioners in age group h, PI level m, gender j, at the end of year $t \in \mathrm{P}$.

[1] Death rates are estimated using observed numbers of deaths and exposures of population. Death counts are inherently random, leading to sampling variation in estimated death rates.

It is straightforward to see that the average crude death rate can also be calculated as a weighted average of the crude death rates for the beneficiaries with ages included in age group h, with the weighting being the number of pensioners-years exposed to risk of death:

$$\hat{q}_{h,\mathrm{P}}^{j,m} = \frac{\sum_{\forall x \in h} \hat{q}_{x,\mathrm{P}}^{j,m} \cdot E_{x,\mathrm{P}}^{j,m}}{\sum_{\forall x \in h} E_{x,\mathrm{P}}^{j,m}} = \frac{\sum_{\forall x \in h} \hat{q}_{x,\mathrm{P}}^{j,m} \cdot E_{x,\mathrm{P}}^{j,m}}{E_{h,\mathrm{P}}^{j,m}} \quad (3)$$

where $E_{h,\mathrm{P}}^{j,m}$ is the number of pensioners exposed to risk included in age group h, PI level m, gender j, for the period-year interval P.

Similarly, if all PI levels are considered the average crude death rate $\hat{q}_{h,\mathrm{P}}^{j,T}$ for the pensioners in age group h, sex j for the period-year interval P can be expressed as:

$$\hat{q}_{h,\mathrm{P}}^{j,T} = \frac{\sum_{m=1}^{s} \hat{q}_{h,\mathrm{P}}^{j,m} \cdot E_{h,\mathrm{P}}^{j,m}}{\sum_{m=1}^{s} E_{h,\mathrm{P}}^{j,m}} = \frac{\sum_{m=1}^{s} \hat{q}_{h,\mathrm{P}}^{j,m} \cdot E_{h,\mathrm{P}}^{j,m}}{E_{h,\mathrm{P}}^{j,T}} \quad (4)$$

where $E_{h,\mathrm{P}}^{j,T}$ is the number of beneficiaries exposed to risk included in age group h, at any PI level m, gender j, for the period-year interval P.

Given that the levels of exposure are not sufficiently high for some groups (see Subsection 2.1), the initial estimates must be revised to produce smoother estimates (graduated mortality rates) using a procedure called graduation[2]. In our case the average crude death rates are graduated through the age, sex, PI pension, and period dimensions to reflect a compromise between smoothness and fit.

The final graduated beneficiary mortality rates, $q_{x,\mathrm{P}}^{j,m}$, represent the best estimates of the rates for the period-year interval P. Once the graduation process has been concluded, the relative mortality ratio, $RM_{h,\mathrm{P}}^{j,m}$, can be obtained immediately. This is the ratio between the death rate of a subgroup and the death rate of the group as a whole. For the subgroup of pensioners in the age interval h, with PI level m, gender j, for the period-year interval P it is:

$$RM_{h,\mathrm{P}}^{j,m} = \frac{q_{h,\mathrm{P}}^{j,m}}{q_{h,\mathrm{P}}^{j,T}} \quad (5)$$

A2.-Life expectancy

Once graduated death rates are obtained it is easy to construct complete period life tables (LT) from age 65 to age 101 and calculate life expectancy at several ages. Life expectancy, LE_x , is an estimate of the average number of additional years that a person of a given age, x, can expect to live. This measure of remaining life is the ratio between total number of person-years lived by the cohort from age x until all members of the cohort have died (T_x) and the number of persons alive at age x (l_x). For complete LE_x half a year is added.

[2] Graduation has two basic characteristics: smoothness and goodness of fit to the observed data. These two characteristics are in competition and to achieve one of them it is necessary to sacrifice the other.

According to Li (2015), one important purpose of measuring mortality is to detect differences between populations. To that end, deterministic life tables could specify whether a life-table variable for one population is bigger than the same variable for another population, while a probabilistic life table can further test whether such differences are statistically significant or may appear merely by random chance.

Following Chiang (1984), an observed LE_x is a sample mean of future lifetime. Therefore, statistical tests based on normal distribution can be used to draw inferences in comparing LE between two groups for a given age and period ($LE^m_{x,\mathrm{P}}$). We are interested here in testing whether there is a significant positive difference in $LE^m_{x,\mathrm{P}}$ between two pensioner income groups, one with higher PI than the other.

Under the null hypotheses this difference will be zero and under the alternative it will be positive, so it is a one-tailed test. The statistic to be used, the z score, is the ratio of the difference in LE between the groups ($DLE^{m_i-m_j}_{x,\mathrm{P}}$) to the standard error of that difference $Se(DLE^{m_i-m_j}_{x,\mathrm{P}})$, which is computed as the square root of the sum of the variances of the corresponding life expectancy at age x for each group, $VLE^{m_i}_{x,\mathrm{P}}$ and $VLE^{m_j}_{x,P}$ respectively.

$$z^{m_i-m_j}_{x,\mathrm{P}} = \frac{DLE^{m_i-m_j}_{x,\mathrm{P}}}{Se(DLE^{m_i-m_j}_{x,\mathrm{P}})} = \frac{DLE^{m_i-m_j}_{x,\mathrm{P}}}{\sqrt{VLE^{m_i}_{x,\mathrm{P}} + VLE^{m_j}_{x,\mathrm{P}}}} \tag{6}$$

By analogy with the development by Chiang (1984), the standard error for life expectancy at age x, $Se(LE^m_{x,\mathrm{P}})$, can be calculated as follows[3]:

$$Se(LE^m_{x,P}) = \sqrt{\sum_{k=0}^{w-1-x} \left[({}_k p^m_{x,\mathrm{P}})^2 \cdot (LE^m_{x+k+1,\mathrm{P}})^2 \cdot \frac{(q^m_{x+k,\mathrm{P}})^2 \cdot (1-q^m_{x+k,\mathrm{P}})}{D^m_{x+k,\mathrm{P}}} \right]} \tag{7}$$

where ${}_k p^m_{x,\mathrm{P}}$ is the is the probability of surviving from age x to age x+k, $q^m_{x+k,\mathrm{P}}$ is the probability that an individual aged $x+k$ will die within the year, $LE^m_{x+k+1,\mathrm{P}}$ is life expectancy at age $x+k$, and $D^m_{x+k,\mathrm{P}}$ is the number of deaths at age x+k. These elements refer to period P and PI group m.

At a given level of significance α, the null hypothesis is rejected if the sample value of the statistic $z^{m_i-m_j}_{x,\mathrm{P}}$ is greater than the critical value in the normal distribution corresponding to that level of significance (2.33 at 1%, 1.64 at 5%, and 1.28 at 10%). If that is the case, there is statistically significant evidence that $LE^m_{x,\mathrm{P}}$ is greater for the higher PI group than for the other.

Finally, it is worth indicating that 95% confidence intervals (CIs) of $LE^m_{x,\mathrm{P}}$ are determined by:

$$95\%CI(LE^m_{x,\mathrm{P}}) = LE^m_{x,\mathrm{P}} \pm 1.96 \cdot Se(LE^m_{x,\mathrm{P}}) \tag{8}$$

[3] According to Scherbov and Ediev (2011), Chiang's method may be used without significant problems with population sizes from about 10,000 upwards.