AN EXERCISE ON THE FUTURE HEALTH DEVELOPMENTS IN GREECE

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Abstract

After developing a stochastic analysis for the estimation of healthy life expectancy of human populations, a demonstration of the application of a new and simplified method to assess the future health trends of a population will take place in this paper. Data comes from the population projections of Greece, carried out a few years ago, including the estimated mortality forecasts. In the form of complete life tables, these forecasts will be used to estimate healthy life expectancy until the year 2050, which will depend on the different scenarios created during the projections' procedure. The results of the analysis indicate the validity and applicability of the method used whenever lifetable data is available.

Key words: healthy life expectancy, population projections, mortality forecasts, Greece

JEL Code: I1, J10, J26

Introduction

During the last decades, many scholars tried to estimate the health level of a population, following WHO's (1948) definition of health, which is "*a state of complete, physical, mental and social wellbeing"*. Such measures were the *"index of health"* (Chiang, 1965), the *"effective life years"* (the years a person can fulfil its role in the society; Sanders, 1964), the *"expectation of life free of disability"* (Sullivan, 1966, 1971) and others.

In more recent years, more sophisticated procedures were developed both by the WHO, aiming to calculate *"healthy life expectancy"*, i.e., the difference between life expectancy at birth and the healthy years lost because of diseases (Vos et al., 2017), and by Eurostat (n.d.); based on Sullivan's method 1966, 1971). In the latter, health is defined by the absence of functionality/disability limitations. However, both methods require knowledge of the prevalence of diseases or disabilities in a population, which is not always available. For example, such data are absent for historical populations. Moreover, if one wishes to estimate health levels in the future, several problems denoting the inefficiency of these methods for such purposes will emerge.

Instead, another method originating from the stochastic theory (see Jansen and Skiadas, 1995) is fully functional and effective, based on lifetable data alone. Recently, Skiadas and Skiadas (2020) simplified this approach and found that the Weibull model and the cumulative hazard *"can express the additive process regarding what disabilities and diseases affect the human organism during the lifespan leading to healthy life years lost"*. Thus, they derived a general model of survival-mortality, estimating a parameter related to the healthy years lost (consequently to an estimation of healthy life expectancy) and leading to the Weibull model and its shape parameter as a particular case (see the Skiadas and Skiadas, 2020 for the mathematical formulas and calculations).

In that way, the scope of this paper is to demonstrate the application of this method with mortality forecast data, an essential element of populations' projection. Greece will be used as a case study.

1 Population projections and mortality forecast.

The population projections of Greece were conducted in 2016, aiming to estimate the population size and structure of the country until 2050 (Kotzamanis et al., 2016). By that time, the number of births and fertility was decreased, while the number of deaths increased due to the population ageing, and the negative balance of the vital rates. The negative immigration balance further burdened the Greek population, and the country was going through a severe economic and social crisis.

The base year for these projections was 2014; thus, these projections were carried out several years ago, ignoring any developments that occurred meanwhile (for example, the coronavirus crisis). Therefore, any future estimations of the healthy life expectancy should be treated with caution, while keeping in mind that the main scope of this paper is to demonstrate the application of the Skiadas and Skiadas (2020) method on mortality forecasts.

Considering Greece's economic and social situation in 2016, two paths were created to formulate the scenarios of the future trends of mortality, fertility, and migration, needed for the projections' procedure.

- Path 1: Resilience. Greece will follow an economic and developmental growth course, being part of the eurozone area without further deregulation of the labour market and social spending and welfare reductions. A progressive decrease in unemployment, especially among young people, will occur in the future.

- Path 2: Inequality. The economic crisis continues, exacerbating its adverse social effects and increasing inequalities.

1.1 The mortality forecasts

Within these paths 3 mortality forecasts scenarios were created (Tables 1 and 2):

- Scenario 1. Path 1. Progressive and mild reduction in the probabilities of death. "Medium-high" scenario. An increase in life expectancy at the end of the projection period. A deceleration of mortality decrease in the ages <10 and 30-65 years. A continuing decrease of mortality over 65 years. A slight increase of mortality in younger adult males (20-35 years), which will stabilize afterwards. Mortality in females of the same ages will remain almost stable.

Tab. 1: Probabilities of death forecasts by large age groups. Males.

		2015-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
Scenario 1	$_{1}q_{0}$	3.8	3.3	3.0	2.7	2.6	2.4	2.3
	$_{9}q_{1}$	1.1	1.0	1.0	1.0	0.9	0.9	0.9
	$_{10}q_{10}$	2.1	2.1	2.2	2.3	2.3	2.2	2.3
	$_{15}q_{20}$	9.9	10.3	10.7	11.2	11.1	11.1	10.9
	$_{30}q_{35}$	135.0	128.4	124.4	122.0	119.6	117.2	114.7
	$_{20}q_{65}$	530.7	510.0	480.4	460.6	440.9	421.2	401.5
Scenario 2	$_{1}q_{0}$	4.5	6.3	7.6	7.4	7.3	7.2	7.0
	$_{9}q_{1}$	1.2	1.3	1.5	1.6	1.5	1.4	1.4
	$_{10}q_{10}$	2.1	2.0	2.1	2.1	2.0	2.0	2.0
	$_{15}q_{20}$	10.0	10.5	10.9	11.0	11.1	11.0	11.3
	$_{30}q_{35}$	139.7	142.6	149.2	157.0	166.6	171.6	174.1
	$_{20}q_{65}$	535.1	534.9	535.0	535.7	536.2	536.4	536.7
Scenario 3	$_{1}q_{0}$	5.9	7.8	8.3	8.3	8.2	8.2	8.2
	$_{9}q_{1}$	1.6	1.8	1.9	1.9	1.8	1.9	1.8
	$_{10}q_{10}$	3.2	3.5	3.6	3.6	3.5	3.5	3.4
	$_{15}q_{20}$	11.8	15.0	15.6	15.5	15.4	15.3	15.3
	$_{30}q_{35}$	144.3	147.8	157.4	163.6	170.6	179.1	185.6
	$_{20}q_{65}$	535.5	535.5	535.7	536.0	536.4	536.8	537.2

Source: own calculations

- Scenarios 2 and 3. Path 2. Extremely unfavourable. A progressive slow decrease in life expectancy and lower values in the end year (2050) compared to the start year (2014), especially for the younger and middle ages, and a slight increase for the older ones (over 65 years). In these scenarios, the probabilities of death in childhood (<10 years) will increase sometime until 2030. Mortality in the ages 30-65 will also increase. A reversal of the declining trend occurs in the older ages (>65 years) in males. In females of the same age, mortality will not change much. For people aged 20-35 years, the mortality rates will either stabilize to low levels or increase firstly and stabilize later.

For further details on the methodology used to calculate these estimates, see Kotzamanis et al. (1026).

Tab. 2: Probabilities of death forecasts by large age groups. Females.

		2015-2019	2020-2024	2025-2029	2030-2034	2035-2039	2040-2044	2045-2049
Scenario 1	$_{1}q_{0}$	3.2	2.8	2.5	2.3	2.1	2.1	2.0
	$_{9}q_{1}$	0.9	0.8	0.8	0.8	0.7	0.7	0.7
	$_{10}q_{10}$	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	$_{15}q_{20}$	3.8	3.9	3.7	3.8	3.8	3.8	3.8
	$_{30}q_{35}$	61.4	61.8	57.8	55.8	55.1	54.5	53.4
	$_{20}q_{65}$	385.6	366.5	355.1	340.2	325.2	310.3	300.3
Scenario 2	$_{1}q_{0}$	3.8	5.3	6.4	6.2	6.1	6.1	6.0
	$_{9}q_{1}$	0.9	1.1	1.3	1.3	1.3	1.3	1.3
	$_{10}q_{10}$	1.0	1.0	0.9	0.9	0.9	0.9	0.9
	$_{15}q_{20}$	3.7	3.7	3.8	3.8	3.8	3.9	3.9
	$_{30}q_{35}$	62.9	63.0	67.7	69.2	71.4	72.4	73.9
	$_{20}q_{65}$	394.8	393.9	396.1	394.9	394.8	394.7	394.7
Scenario 3	$_{1}q_{0}$	5.0	6.6	7.0	7.0	6.9	6.9	6.9
	$_{9}q_{1}$	1.3	1.4	1.6	1.5	1.6	1.5	1.5
	$_{10}q_{10}$	1.3	1.5	1.6	1.6	1.6	1.6	1.6
	$_{15}q_{20}$	4.3	5.2	5.4	5.3	5.3	5.2	5.2
	$_{30}q_{35}$	64.5	65.0	70.1	74.3	76.6	78.8	83.1
	$_{20}q_{65}$	395.5	394.6	395.7	394.4	394.3	394.7	394.7

Source: own calculations

1.2 Calculation of full life tables

So far, only an estimation of the future trends of the probabilities of death in large age groups - except the first one took place: $_{1}q_{0}$, $_{9}q_{1}$, $_{10}q_{10}$, $_{15}q_{20}$, $_{30}q_{35}$ and $_{20}q_{65}$. Note that the number on the left of the letter q denotes the size of an age group in years and the number on the right the first age at that group. Consequently, the question is how to expand these probabilities in one year-long age classes and construct a full life table afterwards. The entire procedure used, and its evaluation have been published by Zafeiris (2018).

This procedure begins with the relational method, developed by Kostaki (2000). According to this method, an abridged life table is expanded to a full one in relationship to another and known full life table, which is used as standard. The latter is denoted in the following formulas with the letter *S*. In an abridged life table, the one-year death probabilities q_{x+i} ($i=0. 1. 2 \ldots n-1$) in each of its *n* years intervals are equal to:

$$1-\left(1-q_{x+i}^{(S)}\right)^{nKx} \quad (1)$$

The term *nKx* equals to:

$$nKx=\frac{\ln(1-nqx)}{\sum_{i=0}^{n-1}\ln\left(1-q_{x+i}^{(S)}\right)} \quad (2)$$

Thus, after calculating *nKx* using (2), q_{x+i} are calculated with (1). The following property must be fulfilled:

$$1-\prod_{i=1}^{n-1}(1-q_{x+i})=nqx \quad (3)$$

The second step of this procedure is to smooth the one-year death probabilities curve. For this reason, a modified 9 parameters Heligman-Pollard formula was applied (see Heligman and Pollard, 1980; Kostaki, 1992).

$$\frac{q_x}{p_x}=\begin{cases}A^{(x+B)^C}+De^{-E_1(lnx-lnF)^2}+GH^x, & for\ x\le F\\ A^{(x+B)^C}+De^{-E_3(lnx-lnF)^2}+GH^x, & for\ x>F\end{cases} \quad (4)$$

where, A, B, C, D, E_1, E_2, F, G, H are parameters that must be estimated by minimizing the term:

$$\sum_x\left(\frac{\widehat{q_x}}{q_x}-1\right)^2 \quad (5)$$

where $\widehat{q_x}$ is the fitted value for age *x* and q_x is the observed one. Before that, and because of the deviations of the "Heligman-Pollard" fitting process, three third order polynomials (see also http://mathworld.wolfram.com/CubicSpline.html) were used until the age of 84 years:

$$\hat{q}_i=\hat{q}_x+a_k(x_i-x)+b_k(x_i-x)^2+c_k(x_i-x)^3 \quad (6)$$

The age-specific probabilities of death after the age of 84 years, were calculated by applying the last cubic spline of the fit. Finally, the life tables until the age of 110 years were calculated using conventional methods.

2 Calculation of Healthy Life Expectancy.

After calculating the q_x values, the age-specific mortality values (m_x) were calculated by solving the well-known Chiang equation for m_x. Then, following Skiadas and Skiadas (2020), the Healthy Life Years Lost (HLYL) because of diseases and disabilities are coming from the following formula:

$$HLYL = max\frac{xm_x}{\sum_0^x m_x}(7)$$

The healthy life expectancy at birth results from the substruction of HLYL from Life expectancy at birth, calculated by the full life tables.

3 Results of the analysis.

Table 3 presents the results of the analysis. In scenario 1, the average longevity increases 3.4 years in males and 2.5 in females (Table 3). Consequently, the healthy life expectancy increases 3.3 and 2.6 years, respectively.

Tab. 3: Life expectancy at birth (e0), Healthy Years Lost (HYLY), and Healthy Life expectancy (HLE).

Sce-nario	e0	HLYL	HLE	e0	HLYL	HLE	e0	HLYL	HLE	e0	HLYL	HLE
	Males											
1	2014			2015-2019			2020-2024			2025-2029		
	78.42	10.67	67.75	78.76	10.50	68.26	79.33	10.56	68.77	79.96	10.60	69.36
	2030-2034			2035-2039			2040-2044			2045-2049		
	80.38	10.62	69.76	80.84	10.65	70.19	81.31	10.67	70.64	81.79	10.70	71.09
2	2014			2015-2019			2020-2024			2025-2029		
	78.42	10.67	67.75	78.47	10.68	67.79	78.26	10.31	67.96	77.95	10.04	67.91
	2030-2034			2035-2039			2040-2044			2045-2049		
	77.76	9.59	68.17	77.49	9.60	67.89	77.36	9.56	67.80	77.29	9.61	67.68
3	2014			2015-2019			2020-2024			2025-2029		
	78.42	10.67	67.75	78.02	10.71	67.31	77.63	10.20	67.43	77.32	9.58	67.75
	2030-2034			2035-2039			2040-2044			2045-2049		
	77.16	9.56	67.60	76.96	9.55	67.41	76.70	9.53	67.17	76.52	9.52	67.00
	Females											
1	2014			2015-2019			2020-2024			2025-2029		
	83.58	11.98	71.60	83.81	11.85	71.96	84.27	11.64	72.63	84.61	11.90	72.72
	2030-2034			2035-2039			2040-2044			2045-2049		
	85.00	11.87	73.13	85.37	11.85	73.52	85.74	11.82	73.91	86.02	11.81	74.22
2	2014			2015-2019			2020-2024			2025-2029		
	83.58	11.98	71.60	83.54	11.90	71.64	83.41	11.86	71.55	83.18	11.60	71.58
	2030-2034			2035-2039			2040-2044			2045-2049		
	83.12	11.81	71.32	83.07	11.76	71.31	83.07	11.64	71.43	83.04	11.63	71.41
3	2014			2015-2019			2020-2024			2025-2029		
	83.58	11.98	71.60	83.28	11.87	71.41	83.07	11.83	71.24	82.89	11.58	71.31
	2030-2034			2035-2039			2040-2044			2045-2049		
	82.74	11.79	70.95	82.68	11.74	70.94	82.66	11.57	71.08	82.52	11.54	70.98

Source: own calculations

In the less favourable scenarios 2 and 3, the situation is quite different. The unfavourable conditions that are supposed to prevail in Greece will reduce the average longevity by the end of the projection period by 1.13 years according to scenario 2 and 1.9 according to scenario 3. However, the differential mortality developments in the large age groups will not seriously disturb the healthy life expectancy in scenario 2. On the contrary, they will decrease it by one year in scenario 3.

In females, a similar situation persists. The average longevity is expected to decrease marginally by about 0.5 years following scenario 2, and almost one if scenario 3 will be confirmed. The decrease of healthy life expectancy will be marginal according to scenario 2 and half a year according to scenario 3.

Therefore, the average longevity during the projections period will change significantly in males and in a more moderate way in females, where the changes in health life expectancy are expected to be smaller. However, one must note once again that these results come after the formulation of mortality forecasts scenarios. Such scenarios could be either different or may cover a wide range of time. Thus, the estimations of future healthy life expectancy may vary a lot.

Conclusion

In this paper, a presentation of the application of a direct method for calculating healthy life expectancy took place. After several elaborations, modifications and simplifications, this method (initially originated from the stochastic analysis) allows the direct estimation of the Healthy Life Years Lost in a population from life table data. Thus, it does not require any knowledge of the prevalence of diseases and disabilities, like the others described in the introductory section of this paper. Moreover, it can be used not only in contemporary populations but also in historical ones. One further application is its applicability and efficiency using mortality forecast data.

Such an application was demonstrated in this paper, presenting the expected levels of healthy life expectancy in the future of the population of Greece. By taking into consideration that data come from a research project which was completed several years ago, and considering the different scenarios, small but significant changes are expected to occur in the population of Greece in the future.

However, one must note that the quality of the findings of this direct method depends on the effectiveness of the projection and the time range it covers. Therefore, when this method is applied on mortality forecast data, quite expectedly, each result will depend on the quality, or the assumptions made for acquiring that data.

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