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Analyzing the Trend of Life Expectancy Evolution in Algeria from 1962 to 2018: The S-logistic Segmentation with Jumps

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Abstract

This paper analyzes the evolution of life expectancy in Algeria since Independence in 1962, using an epidemiological transition framework. The general transition trend was fitted with an S-logistic function, while a break-point analysis – including jumps – was performed to detect methodological changes and extreme event effects. Results show evidence of the epidemiological transition of the Algerian population. Apparent jumps in the time series of life expectancy evolution appear to be due to updates of the correction factors for death under registration, misestimation of the population structure during the intercensal periods, and impacts of the civil war during the 1990s.

Keywords

Life expectancy, epidemiological transition, S-logistic, break-points, jumps, Algeria

Introduction

After Independence in 1962, the Algerian population went through an epidemiological transition cycle. As in the case of many countries of the Middle East and North Africa (MENA), life expectancy increased from around 50 years during the 1970s to around 70 years in the 2000s (Tabutin and Schoumaker 2005). The transition is obvious despite the lack of data (Tabutin and Schoumaker 2005). Indeed, life expectancy in Algeria was estimated at 53.6 years in 1970 and passed to 77.7 years in 2018 (Office National des Statistiques [ONS] 2019). Such an evolution cannot be read independently from the ongoing epidemiological transition.

The term 'epidemiological transition' is used to describe the process of shifting from high mortality to a relatively low mortality level (Omran 1971). Such a transformation is often stimulated by a combination of factors, e.g., improvement of living conditions, discoveries in medicine and biotechnology, better public health care programs, and more economic development (Defo 2014; Bergeron-Boucher *et al.* 2015). The experiences of industrialized and developing countries regarding the epidemiological transition are quite different in terms of the time and/or pace of the transition. In industrialized countries, the transition started around the early 1800s and took around a century to fully mature. In developing countries, it started much later and is still not completed (Mackenbach 1994). According to Omran (1971), the transition starts with a stage of low and fluctuating life expectancy, followed by an accelerating improvement before decelerating when approaching a relatively high level. Such a definition may allow to detect the stage of epidemiological transition reached by a population and predict upcoming evolution of its life expectancy.

These three stages of life expectancy evolution comply with the definition of the S-logistic curve. By the end of the 20th century, many attempts had been made to model the time evolution of life expectancy as an S-logistic function (Bulatao *et al.* 1989; Marchetti *et al.* 1996; Marchetti 1997).

On the opposite side, many experiences support the hypothesis of linearity of life expectancy evolution. Oeppen and Vaupel (2002) stated that the world record life expectancy of females has improved following a steady line at least since the mid-19th century. Also, in many industrialized countries, life expectancy evolution trend has been linear for a long period (White 2002). Lee (2003) was not persuaded by such a hypothesis and stated that record life expectancy evolution both for males and females show a slight S-shape. Lee (2015) insisted on the fact that life expectancy increases following an S-shape curve in the long run. Also, he assumed that the linear trend observed for some countries can correspond to the medium phase of the S-shape transition cycle.

In my opinion, the linearity of life expectancy evolution does not contradict the epidemiological transition theory. Both hypotheses can be verified but on different populations or on different time-lapses. The S-logistic trend is often compatible with the case of developing countries, whereas the epidemiological transition is still ongoing. The linear trend can be observed in industrialized countries where the transition has already been achieved. Oeppen and Vaupel (2002), while defending the linearity hypothesis, suggested that life expectancy evolution in a given country cannot be treated independently from the rest of the world. Life expectancy in a country evolves following an accelerating trend to catch up with the world record line (Wilmoth 1998; Lee 2006); the more life expectancy approaches the record line the more it decelerates (White 2002; Medford 2017). In their statement, Oeppen and Vaupel (2002) did not proclaim, even implicitly, that life expectancy necessarily follows similar evolution trends in developing and industrialized countries.

Parallel to this heated debate, and due to the changing trend of life expectancy evolution in some industrialized countries, some authors suggest using piecewise linear segments to better undertake this evolution. A simpler and intuitive linear segmentation was first proposed by Vallin and Meslé (2009) based on the word record life expectancy at high ages. A few years later, Camarda *et al.* (2012) proposed a linear segmentation methodology inspired by Muggeo (2003), which suggested a methodology to divide a regression into piecewise linear segments. The exogenous variable in the model can be time. Initially, an assumption needs to be set about the number of turning points; different assumptions need to be compared based on the goodness-of-fit and the total number of parameters in the model. Later on, a similar methodology was expanded to other datasets (Gonzáles and Manuel 2014; Bergeron-Boucher *et al.* 2016) and even to other mortality indicators, such as the Crude Death Rate (CDR) (Ouelette *et al.* 2014) and the Modal Age at Death (MAD) (Bergeron-Boucher *et al.* 2015). Until this point, only changes in the evolution slope are considered for segmentation purposes; jumps are not addressed. Hence, segmentation leads to a kind of a broken, yet continuous line.

Genz (2017), while studying the evolution of MAD on different populations and trying to detect changes in the evolution trends, aimed at detecting jumps in the level of the time series of MAD. A similar methodology was reproduced by Börger *et al.* (2018). In my opinion, such a statement can also be applicable to life expectancy. According to Genz (2017), sudden jumps are assumed to be due to extremes events, such as wars, geopolitical restructuration or changes in data processing methods.

Many authors have studied the evolution of mortality in Algeria since Independence in 1962 using an approach similar to time segmentation. Three papers are noteworthy: Salhi (1984), Daoudi (2001), and Hamza Cherif (2011). Based on a simple visualization of the series of CDR, Salhi (1984) identified three stages of mortality decrease: a slow decrease from 1965 to 1972, a moderate decrease from 1972 to 1976, and finally a net decrease from 1976 to 1981. Daoudi distinguished three periods of mortality evolution between 1965 and 1993; a slight improvement from 1965 to 1977 followed by a significant improvement from 1977 to 1989 and stagnation or even a slight decline from 1989 to 1993. Following the same idea, Hamza Cherif (2011) studied the evolution of CDR and life expectancy from 1965 to 2007 while referring to four distinct sub-periods, i.e., 1965-1976, 1977-1989, 1990-1998, and 1999-2007. He mentioned a moderate mortality improvement during the first period, followed by a significant decrease before slowing down during the terrorism era in the 1990s. Later, evolution resumed its improvement trend.

Overall, the three authors (Salhi 1984; Daoudi 2001; Hamza Cherif 2011) agreed on the fact that mortality in Algeria evolved following different paces. Not really intending to detect accurately the turning points in mortality evolution in Algeria, the authors tried to study the evolution differences by period, but without any relation with the epidemiological transition theory.

Data and methods

In this paper, an S-logistic segmentation, including jumps, is proposed to analyze the evolution of life expectancy at birth in Algeria. The main objective is to highlight the ongoing epidemiological transition by fitting the historical evolution of life expectancy with an S-logistic function. This may allow analyzing the trend of life expectancy evolution from the three-stage transition model defined by Omran (1971). The break-point analysis with jumps aims to capture the effect of methodological changes and extreme events (e.g., civil wars) on the historical evolution of life expectancy. A break-point is defined to be the year where the change starts to occur, which means moving from a state to another. It can be manifested by a significant change in the pace of evolution, a change in the general level or both.

After Independence in 1962, there has been only one event which can be qualified as ‘extreme’. It consists of the civil war of the 1990s, also known as the ‘Black Decade’, when a political conflict ensued after the Islamic Salvation Front (FIS), an Islamic political party, won the first round of parliamentary elections in December 1991. Violence and terrorist attacks started in March 1992 (Mourad and Avery 2019) after the second round of elections was cancelled. The FIS was dissolved at the beginning of 1992 (ICG 2000; Schulhofer-Wohl 2007). The period from 1992 to the end of 1997 is often labelled as the ‘Bloody Era’ (Martinez 2003).

On the other side, methodological changes refer to changes in data processing methods or even methods used to correct raw data and estimate life tables. Here, we only focus on three main parameters that are supposed to have had major effects: 1) the revision of the correction factors for death under registration, 2) updating the population structure with data provided by the population censuses, and 3) changes in the mortality adjustment methods.

The first element is related to the incompleteness of death registration and the way that crude counts are corrected. Death registration completeness was first estimated at 60.6% in 1970 as a part of the Multi Rounds Demographic Survey (MRDS). In 1977-1980, this rate was estimated to be around 64% using indirect methods, which were not survey-based (Hamza Cherif 2011). The resulting correction factors for death under registration were used by the Office of National Statistics (ONS) to correct death records until them were revised in 1981 based on the Workforce and Demography Survey (MOD-1981). It turned out that death registration completeness had improved, reaching 81%. The data provided by the 2002 Algerian Family Health Survey (EASF) allowed having another estimation of death registration completeness. The new correction factors, which have not been published, were applied with a retroactive effect from 1998 and continue to be used for correcting vital statistics (ONS 2019). To keep using the same correction factors over a long period may lead to an overestimation of mortality rates (MSPRH 2002). The further the reference year, the more important the overestimating effect becomes. Eventually, updating the correction factors will smooth out the overestimating effect of the previous ones, leading to ‘sudden jumps’ in mortality trends.

The second element relies on the fact that, within the developing countries context, population censuses are the main provider of population numbers and structure, which is used as a denominator to estimate death rates by age. Population censuses are often carried out every 10 years. Thus, estimating intercensal population structure evolution can be driven from vital statistics about deaths and births. Due to vital statistics incompleteness, and also to missing immigration data, a gap can be observed when new censuses are carried out. In some cases, updating the population structure with the data provided by population censuses may cause apparent changes in the time series of mortality indicators, including life expectancy. Since 1962, five Population & Housing Censuses (PHCs) have been carried out in Algeria, in 1966, 1977, 1987, 1998, and 2008 respectively. The next PHC is expected to be in mid-2020. Observing turning trends around the years were PHCs are carried out is expected. Unfortunately, such an element is neither treated by academicians when analyzing the evolution of life expectancy in Algeria, nor by ONS publications.

Another element, which could explain a break-point in the life expectancy trend, consists of changing the method used to adjust the crude mortality curves. Based on imperfect data, developing countries used to adjust crude mortality curves using the model life tables (Coale and Demeny 1966; Coale *et al.* 1983;

UNO 1981). A change in the techniques used to determine the model life table (MLT) corresponding to the national mortality pattern or a change of the 'family' of MLT may affect the evolution of the resulting life expectancy as a time series.

Basically, life expectancy at birth in Algeria is published as a part of abridged life tables based on vital records. The dataset used in this study is mainly taken from the annual publications of the ONS made available starting from 1977. The series until 2011 were gathered in a special edition named 'Retrospective statistical bulletin of the ONS' (ONS 2012). For the years from 2012 to 2018, values were deduced from the annual ONS publications '*Démographie Algérienne'*. Data were relatively less available during the period from 1962 to 1977. In 1979, the former Ministry of Planning (MP) published an estimation of life expectancy in Algeria in 1962 (MP 1979). Also, the MRDS 1969-1970 allowed to estimate the first life table of the Algerian population. These two estimates were added to the dataset in order to enlarge the time range for having more evidence of the evolution trend of life expectancy, which is assumed to be an S-logistic. Unlike linear trends, the S-logistic trend needs a longer time series to be assessed.

Table 1 retraces the evolution of life expectancy for both sexes in Algeria from 1962 to 2018.

Table 1: Evolution of life expectancy at birth e(0) in Algeria (1962 – 2018).

Year	e(0)	Source	Year	e(0)	Source	Year	e(0)	Source
1962	47	[1]	1994	67.38	[3]	2008	75.7	[3]
1970	53.6	[2]	1995	67.26	[3]	2009	75.5	[3]
1977	55.13	[3]	1996	67.74	[3]	2010	76.3	[3]
1978	56.95	[3]	1998	71.6	[3]	2011	76.5	[3]
1980	57.4	[3]	1999	71.9	[3]	2012	76.4	[4]
1981	58.44	[3]	2000	72.5	[3]	2013	77	[4]
1982	59.98	[3]	2001	72.4	[3]	2014	77.2	[4]
1983	62.43	[3]	2002	73.4	[3]	2015	77.2	[4]
1985	63.6	[3]	2003	73.9	[3]	2016	77.6	[4]
1987	65.41	[3]	2004	74.8	[3]	2017	77.6	[4]
1989	66.42	[3]	2005	74.6	[3]	2018	77.7	[4]
1991	67.34	[3]	2006	75.7	[3]			
1993	66.11	[3]	2007	75.7	[3]			

Data Sources: [1] Ministry of Planning (1979), [2] Multi Rounds Demographic Survey 1969-1970, [3] ONS (2012), [4] ONS annual publications 'Démographie Algérienne', Nos. 623, 658, 690, 740, 779, 816, and 853 respectively.

The dataset presented in Table 1 contains 37 observations extended over a period of 56 years. There are some years belonging to the 1977-1997 period, which had no estimates of life expectancy, i.e., 1979, 1984, 1986, 1988, 1990, 1992 and 1997.

These data were used to estimate the parameters of the S-logistic function. To model life expectancy evolution, Bulatao *et al.* (1989) used an S-logistic function, which provides the life expectancy at birth in the year (t) according to its reference value (e_0):

$$e_t = k_0 + \frac{k}{1+exp\ [logit(e_0)+rt]} \qquad (1)$$

With: $logit(e_0) = ln[\frac{k_0+k-e_0}{e_0-k_0}]$; k_0 represents the lower limit and k the potential total gain in life expectancy throughout the time interval, and r is a parameter to be estimated.

Fitting the evolution of life expectancy by an S-logistic function assumes that life expectancy is converging to a known upper limit represented by $(k_0 + k)$.

Marchetti *et al.* (1996) suggested an S-logistic function to model life expectancy, total fertility rates, and population numbers. Marchetti (1997) used a similar formulation and ended by writing a formula similar to Equation 1 to model the potential gain in life expectancy at birth by replacing $logit(e_0)$ by a constant $(-b)$ and r by $-a$:

$$e_t - k_0 = \frac{k}{1+exp-(at+b)} \qquad (2)$$

Marchetti (1997) estimated the model parameters by linearizing the logistic curve using the Fisher-Pry transformation (Fisher and Pry 1971). If we let $F_t = \frac{e_t - k_0}{k}$ be the saturation level of the function, the Fisher-Pry transformer results in:

$$ln[\frac{F_t}{1-F_t}] \approx at + b \qquad (3)$$

Also, a simple reformulation of Equation 2 leads to the same linear transformation of the S-logistic curve:

$$-ln[\frac{k}{e_t - k_0} - 1] = at + b \qquad (4)$$

In order to detect trend and level changes, a break-point analysis was applied to the linearized curve using the methodology proposed by Aksoy *et al.* (2007), which aims at segmenting a time series into linear segments, including upward and downward jumps. The method of Aksoy *et al.* (2007) was not proposed to model life expectancy evolution or any other mortality indicator but for general purposes in times series or regressions. Here, this methodology is adopted for life expectancy evolution segmentation purposes.

The application of the method requires the availability of a continuous data series. So, only the period from 1977 to 2018 was considered for the segmentation. Data that were missing in the life expectancy at birth series were estimated according to the evolution of CDR, which was available from 1964 to 2018 without interruption.

The segmentation proposed by Aksoy *et al*. (2007) requires the predefinition of the number of segments. The optimal number of segments can be obtained in order to optimize the Bayesian Information Criteria (BIC) as adapted to the Least Squares Estimates (LSE) (Gedikli *et al*. 2010). Hence, different numbers of segments were evaluated and compared. The BIC is calculated by the formula (Hansen 2007):

$$BIC = n * ln(\frac{SSE}{n}) + p * ln(n) \qquad (5)$$

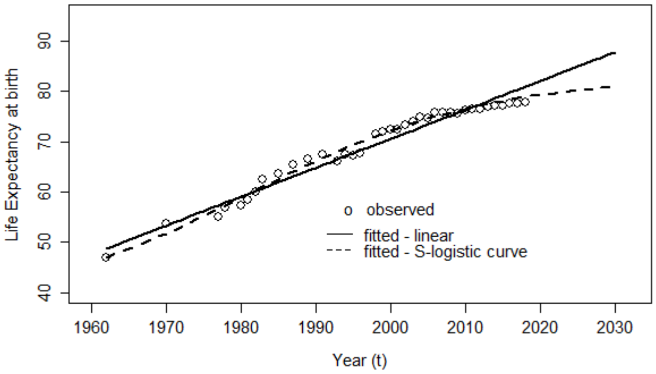
With n being the number of observations, p the number of the parameters in the model, and SSE the sum of squared errors.

Since the segmentation is applied to the transformed series (linearized), the resulting segments become logistic when transformed into the initial formulation. Hence, the historical series of life expectancy evolution is segmented into S-logistic segments instead of linear ones as in Camarda *et al*. (2012), Vallin and Meslé (2009), Gonzáles and Manuel (2014) and Bergeron-Boucher *et al*. (2016).

Results

Before starting, it seems reasonable to confirm that the evolution of life expectancy in Algeria follows an S-logistic instead of a linear trend. Graphical visualization of Figure 1 clearly shows that the S-logistic curve fits the historical evolution of life expectancy in Algeria better than the linear regression.

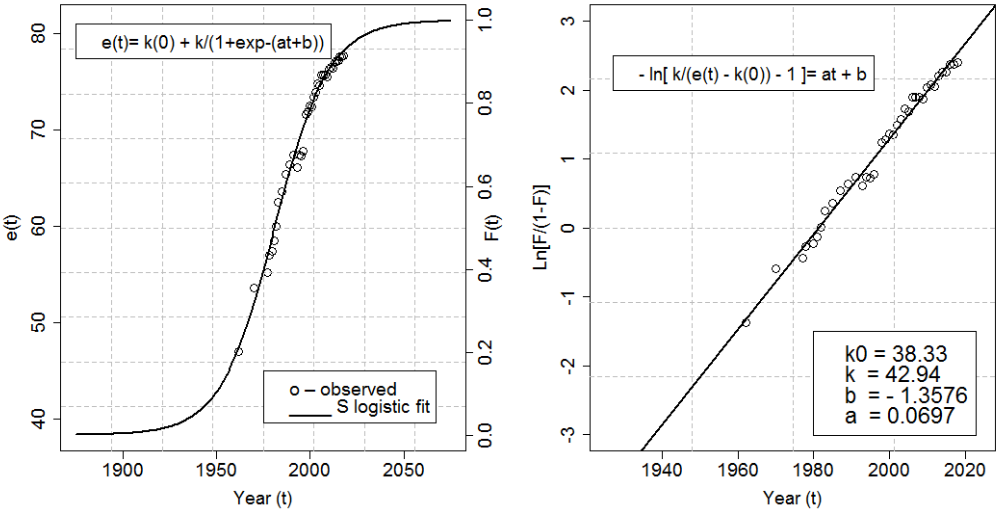
Figure 1: The evolution of life expectancy at birth in Algeria (1962 – 2018) - linear vs. S-logistic fits



Data source: 1962: estimates of the Ministry of Planning (1979), 1970: Multi Rounds Demographic Survey 1969-1970, 1977-2011: ONS (2012), 2012-2018: Annual publications of ONS.

The series of life expectancy reported in Table 1 was fitted using the S-logistic function in Equation 2. The parameters a and b were estimated by minimizing the Sum of Squared Errors (SSE) between the two parts of Equation 4, with 1962 taken as time origin ($t = 0$). Then, k_0 and k, based initially on arbitrary starting values of 40 and 45 respectively, were re-estimated to improve the goodness-of-fit of the model. Results are shown in Figure 2.

Figure 2: S-logistic fitting and linear transformation of the series of life expectancy at birth



Note: The left subplot shows the evolution of life expectancy at birth, simultaneously represented on the real scale (right vertical axis) and as saturation function (left vertical axis). Also, the subplot shows the S-logistic fit of life expectancy at birth. The right subplot shows the same series after being linearized with the Fisher-Pry transformer.

In order to perform the segmentation, the series of life expectancy at birth was linearized using the Fisher-Pry transformer. Putting the series of life expectancy in a linearized form makes it suitable to undergo a linear segmentation. The segmentation was achieved using the tool *SEGMENTER 2.1* following the methodology proposed by Aksoy *et al.* (2007) and Gedikli *et al.* (2010).

Table 2 shows a comparison of the segmentation for different numbers of segments from one to six. *SEGMENTER 2.1* also provides the SSE for each case. Based on the SSE, the corresponding BIC is calculated following Equation 5. Note that the total number of parameters is calculated considering three parameters for each linear segment (Gedikli *et al.* 2010).

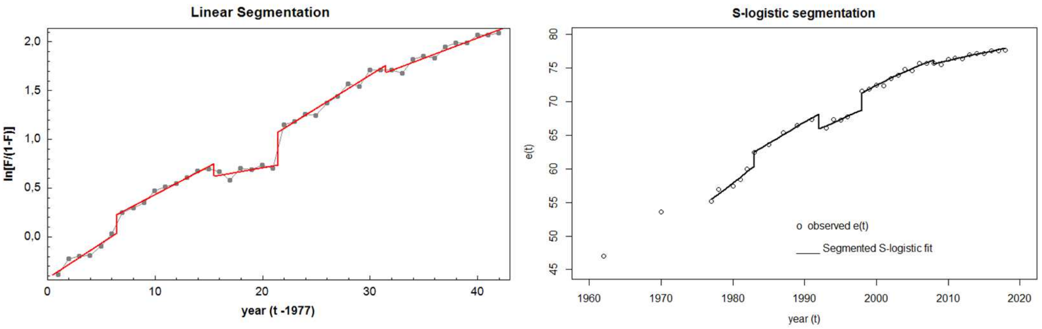
Table 2: Comparison of the segmentation results compared to the number of segments

Number of segments	SSE	p	n	BIC
1	0.5553	2	42	-174,21
2	0.4081	6	42	-172.20
3	0.1089	9	42	-216.48
4	0.0714	12	42	-222.97
5	0.0472	15	42	-229.13
6	0.0375	18	42	-227.62

Following the results given in Table 2, the optimal number of segments appears to be five, since it corresponds to the lowest value of BIC.

Figure 3 exposes the segmentation performed on the linearized series of life expectancy along with the segmentation results represented on the real scale.

Figure 3: Segmentation of life expectancy linearized series



Note: The left subplot shows the results of the linear segmentation of the series Ln[F/1-F] obtained with SEGMENTER 2.1. The right subplot visualizes the segmentation results represented on the real scale.

The segmentation of the series of life expectancy resulted in five S-logistic segments separated by four break-points corresponding to 1983, 1992, 1998 and 2008. If the magnitude of jumps is considered, the most significant break-point corresponds to 1998, followed by 1992, 1983 and finally 2008. The characteristics of the main periods of life expectancy evolution in Algeria are shown in Table 3. Indeed, life expectancy evolution has been segmented into S-logistic segments instead of linear ones. Each segment can be expressed by a formula similar to Equation 2 with the same k_0 and k for all segments; only the parameters a and b differ from one segment to another. The magnitude of a jump is calculated by the gap between the value that should be displayed at the end of one segment and the level where the next segment starts. No jump means that the segments are connected, and only a (as reported in Equation 2) changes. In the last column of Table 3, for simplification issues, the average annual improvement (in days per year) is provided.

Table 3: Characteristics of life expectancy evolution by sub-periods

Period [t, s]	**Initial Value (e_t) in years**	**Upward/downward jump in years**	**Annual average improvement (days per year)**
1962 – 1977	47.0	-	203
1977 – 1983	55.4	-	303
1983 – 1992	62.5	+2.06	228
1992 – 1998	65.9	-2.18	171
1998 – 2008	71.3	+2.51	178
2008 – 2018	75.6	-0.55	85

As shown in Table 3, life expectancy at birth was 55.4 years in 1977. With an annual average gain of 303 days/year, it could have increased only to 60.4 years in 1983. The upward jump that occurred in that year, however, brought it to 2 years higher.

Considering the upward jump in 1983, the annual average gain in life expectancy recorded between 1983 and 1992 – a value of 228 days/year – should have brought life expectancy at birth from 62.5 to 68.1 years in 1992. However, a downward jump was recorded in 1992 of a magnitude of 2.2 years, which was maintained until 1998, and in 1998, the general level of life expectancy climbed back by more than 2.5 years compared to its initial trend. Another downward jump of 0.6 years was recorded in 2008.

Discussion

If we look at the evolution of the annual average improvement of life expectancy from one period to another in Algeria, we observe a continuous decrease starting from an annual improvement of 10 months per year during the period from 1977 to 1983 and arriving to less than 3 months per year during the period from 2008 to 2018. Globally, and excluding the period of terrorism during the 1990s, the life expectancy annual improvement is decreasing from one period to another. Taking into consideration the upward/downward jumps already determined is supposed to bring more evidence about the decreasing improvement of life expectancy and about the epidemiological transition in Algeria compared to when jumps are not considered. Based on the results, the Algerian population should have reached the end of the second stage or the beginning of the third stage of the epidemiological transition cycle. In what follows, the break-points obtained by the segmentation process are discussed.

1983 – Updating correction factors and change of mortality adjustment methods

The break-point of 1983 could result from an overestimation of mortality during the [1977, 1982] period, which was offset in 1983 following the revision of the correction factors for death under registration. Updating the estimates of death registration completeness from 64% to 81% would result in reducing the corrected number of deaths by over 26% and consequently in a jump of life expectancy at birth. However, it seems that the correction factors of 1981 have been utilized starting from 1983, not earlier. Figure 4 shows this evidence through a comparison of the mortality age patterns of the Algerian population before and after 1983.

Figure 4: Mortality age patterns of the Algerian population, both sexes combined, before and after 1983

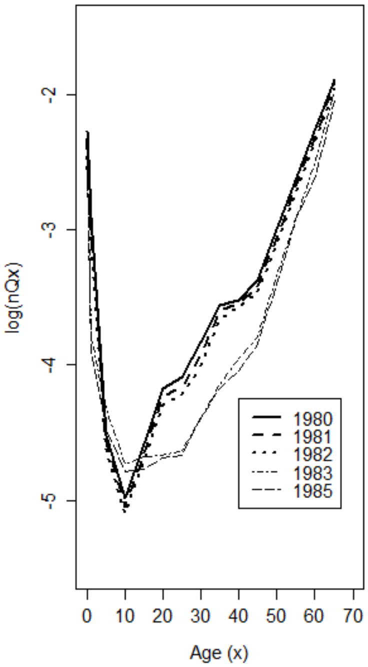
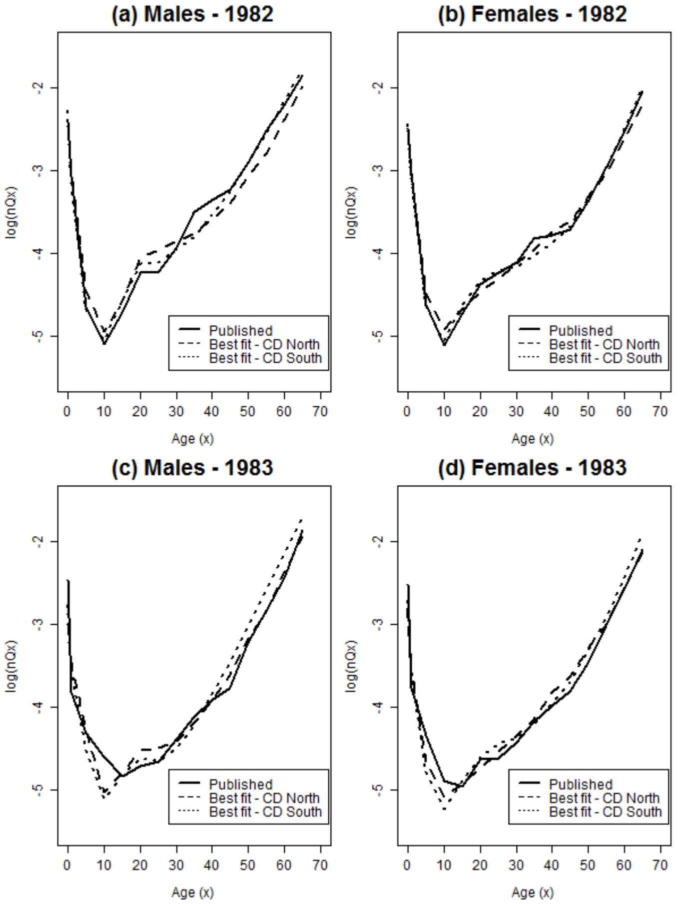


Figure 5: Fitting the 1982 and 1983's life tables using Model Life Tables of Coale-Demeny



As can be seen in Figure 4, the drop in mortality from 1982 to 1983 is significant compared to the slight changes observed from 1980 to 1982 and also from 1983 to 1985. Such a change cannot only be assigned to an update of the correction factors. If we know that death registration completeness in Algeria is not estimated as age-specific (Iles 1990), except the case of age 0, an updating would result in a shift of the curve of mortality rates but not in a distortion. Indeed, when comparing 1983 to 1982 (Figure 4), we notice a significant decline of mortality rates at all ages except the age groups [5, 9], [10, 14], and [15, 19] which recorded an increase. Mortality at age 0 recorded a slight decline. Such a distortion would result from a change in the mortality adjustment methods.

By using the Least Squared Errors method, it appears that the male and female life tables of 1982 perfectly comply with the pattern of the 'South' family of the Coale-Demeny model life tables (MLT). However, tables for 1983 seem to fit the 'North' family better than the 'South' one. Figure 5 reveals that the mortality at some young ages in the 1983's life tables diverge significantly from the values given by MLT. It is not feasible to go into further details on this point since the ONS publications do not explain the methodology of constructing national life tables. However, it is certain that, in addition to the updating of the correction factors starting in 1983, a change in the adjustment method may have occurred.

1992 – The beginning of the civil war

The civil war started in March 1992. There are no exact official statistics about total deaths due to violence. Some references, however, estimate deaths at around 100,000 (ICG 2004) to 150,000 (Martinez 2003) or even 200,000 (Mourad and Avery 2019). No other details, such as the distribution of deaths by sex and age, have been published. This disallows estimating accurately the effect of the Black Decade on the evolution of life expectancy in Algeria. If the downward jump recorded in 1992 can be assigned to the beginning of the civil war, the Algerian population may have lost more than two years in life expectancy at birth because of terrorism. This must include direct and indirect terrorism-related deaths. Besides people killed by violence, many others certainly died because of the associated deterioration of living and sanitary conditions.

1998 – The end of the Black Decade, updating the crude data correction factors, and updating population structure with the latest census data

The importance of the magnitude of the jump recorded in 1998 relies on the fact that it combines three factors: 1) updating the correction factors for death under registration, 2) updating the population numbers by age and sex by the data provided by the recent PHC, and 3) the end of the civil war.

Even if it is not easy to provide a specific date of the end of terrorism in Algeria, the end of September 1997 was determinant in ending the Black Decade. The ceasefire agreement between the Government and the AIS (ICG 2001), the military wing of FIS and one of the biggest terrorist groups at that time, represented a landmark point signifying the end of terrorism in Algeria and a reduction in the intensity of violence. Some forms of violence persisted after that date but with much lesser intensity. The law of 'Civil Concord' – legislation 99-08 introduced in September 1999 (ICG 2001) – followed by the 'Charter for Peace and National Reconciliation' of 2005 (Boumghar 2015), helped end the remaining terrorism.

On the other hand, 1998 corresponds to the second revision of death registration completeness. Initially, the life tables for 1998 were published using the previous correction factors before being corrected using the new ones.

The third elements consist of updating the population age structure by the new data provided by the PHC of 1998. A similar effect was observed in 2008. Thus, a better explanation is provided in the next part.

2008 – The effect of updating the population age structure by the census data

Even if the break-point that occurred in 2008 is not too significant, it must be carefully considered. The main event that occurred in 2008 is the achievement of the fifth PHC. Accordingly, a jump in life expectancy series can be driven by a sudden change (update) of the population age structure used as a denominator to calculate the age-specific death rates.

Through the annual ONS publications on demography, the population structure by five age intervals was provided. It seems that the evolution of the population structure from 2004 to 2007 was taken from the population projections made by ONS (2004). After the PHC 2008 was carried out, the population age structure was updated accordingly. The same structure served to calculate the life tables of Algeria for 2009 (ONS 2010). Starting from 2010 (ONS 2011), new population projections have been made to allow calculating the life tables for the years after 2010. The next PHC is expected to take place in mid-2020.

In order to go further with this idea, the evolution of the population age structure of Algeria from 1990 to 2018 was examined. One way to summarize the evolution of this structure using one indicator consists in focussing on the evolution of the average age of the Algerian population during this period. Figure 6 shows the evolution of the population average age from 1990 to 2018.

Figure 6: Evolution of the average age of the Algerian population from 1990 to 2018

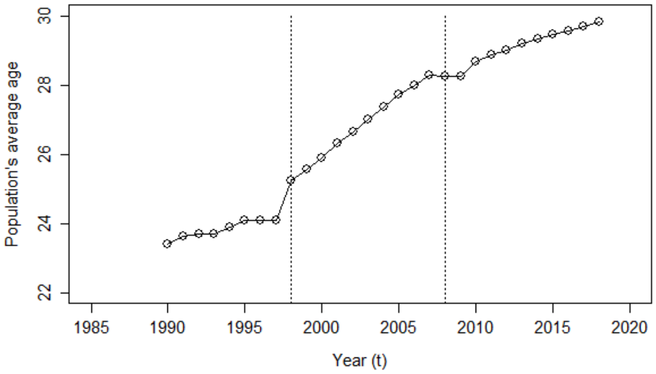


Figure 6 shows how the population average age has evolved steadily from 27.4 to 28.3 years old from 2004 to 2007. Then, contrary to its initial trend, it remained at this level until 2009 before suddenly jumping to 28.7 in 2010. There is no explanation for such an evolution trend within the natural evolution hypothesis. The only explanation resides in changes in the population structure. A similar effect was observed in 1998 compared to the period from 1995 to 1997. Hence, one would expect a similar effect after the next PHC is carried out.

Conclusions

Analyzing mortality evolution within an epidemiological transition framework may help researchers to understand past evolution and predict future trends. The future trend of life expectancy depends on the stages achieved in the transition cycle. Using an S-logistic function to reveal the historical evolution of life expectancy, this paper provides evidence of an epidemiological transition in Algeria.

Turning-points/jumps in the evolution of life expectancy were identified and compared to general trends, and necessary explanations were provided. More specifically, following the methodology proposed by Bulatao *et al.* (1989), Marchetti *et al.* (1996) and Marchetti (1997), it was shown that the S-logistic function fits perfectly with the evolution of life expectancy in Algeria from 1962 to 2018. According to the results, following Omran (1971), the Algerian population should have reached the end of the second stage or the beginning of the third stage of the transition cycle, and life expectancy improvement should slow down significantly during the coming decades. This general trend, however, hides variations by sub-periods where the local evolution has deviated compared to the general trend.

To assess the significance of the above changes, a segmentation was performed on the linearized series of life expectancy, which was initially fitted with an S-logistic function. The segmentation was performed using *SEGMENTER 2.1* (Aksoy *et al.* 2007; Gedikli *et al.* 2010) with the aim to detect the turning points where significant changes of the slope, a jump of the general level, or both were observed. Thus, the historical life expectancy evolution was divided into S-logistic segments instead of linear ones, as in Camarda *et al*. (2012) and Vallin and Meslé (2009). In addition, jumps in life expectancy were addressed. The segmentation gave four significant turning points, corresponding to 1983, 1992, 1998 and 2008.

The detected turning points correspond to methodological changes and to the civil war during the 1990s. The jump observed in 1983 is partially due to the first revision of the correction factors for death under registration. The effect of the civil war, which started in Algeria during the first months of 1992, was obvious. The Algerian population lost two years in life expectancy because of terrorism-related mortality. The war persisted until the end of the 1990s, but the intensity of the violence declined significantly after a ceasefire agreement between the Government and one of the main terrorist groups was implemented by the end of 1997. The turning point of 1998 is due to a combination of the end of the civil war and a set of methodological changes, which consisted of updating the population numbers and structure by the data provided by the population census of 1998, and the second revision of correction factors for death under registration. The effect of updating population structure with census data was also observed in 2008.

Despite the relevant improvement made in mortality and longevity modelling, the robustness of mortality projections continues to be related to the quality of historical data. Before using historical mortality data on Algeria for mortality projection purposes, some corrections are recommended. The findings of this paper highlight the nature of data quality problems and their magnitude. One element that needs to be corrected is the evolution of the population age structure during the intercensal periods. Even though incomplete, population census data must be used to redraw both the evolution of population numbers and structure in a consistent way from 1977 to 2018. The evolution of the average age of the population should be smooth and regular without sudden jumps. On the other hand, using fixed correction factors for death under registration for long periods is not realistic; it tends to overestimate mortality far away from the reference date. Updating these correction factors leads to upward jumps in life expectancy. To correct such an effect, correction factors need to be interpolated and regulated based on the estimates provided in 1970, 1981 and 2002. But this is not feasible because both crude mortality data and the methodology used by the Office of National Statistics to estimate national life tables are not published. Knowing how the crude mortality counts were corrected from incompleteness and how the crude mortality curves were adjusted would help researchers correct the historical life tables of Algeria.

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