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RESEARCH ARTICLE

Dynamics of modal age at death in 1959–2014 in Russia

Mikhail A. Maksimov[1]

1 *Lomonosov Moscow State University, Moscow, 199911, Russia*

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Abstract

The aim of this paper is to determine the trends of the main indicators of life expectancy in Russia in the 1950s to 2000s. For this purpose, life tables for Russia (former — RSFSR) from 1959 to 2014 for one-year age intervals were analyzed. The main indicators under review are the modal age at death and the standard deviation of life expectancy from the modal value for all ages and the mode. As a result, it is concluded that in Russia the modal age at death and the indicator of life expectancy have stagnated over the past 60 years, and definite trends can be traced only in short periods of time, namely after 2009 when all basic life expectancy indicators were steadily increasing. Life expectancy is far behind those of the developed countries by about half a century.

Keywords

life expectancy; modal age at death; mortality.

JEL Codes: J11, J14

Introduction

Over the past two centuries, the life expectancy of people around the world has increased significantly. In the economically developed countries of Europe, in the USA and Japan life expectancy increased by almost twice, from 30-45 years in the middle of the 19th century to 80 years in the beginning of the 21st century (Horiuchi et al. 2013). These changes have led to a significant increase in the number and share of elderly persons in developed countries.

The purpose of this paper is to demonstrate the possibilities of using the modal age at death as an analytical indicator of life expectancy in Russia and the RSFSR during the second half of the 20th and early 21st centuries. For these purposes, life tables for 1959—2014 were analyzed.

Two basic indicators are often used for life expectancy analysis: life expectancy at birth (e_0) and modal age at death (Acsádi and Nemeskéri 1970). The first one has been widely used in life expectancy studies, however, in recent years the second one, namely the modal age at death, is gaining popularity. The advantage of its use is that, unlike life expectancy at birth, it shows the age that accounts for the majority of deaths, excluding mortality patterns in younger ages.

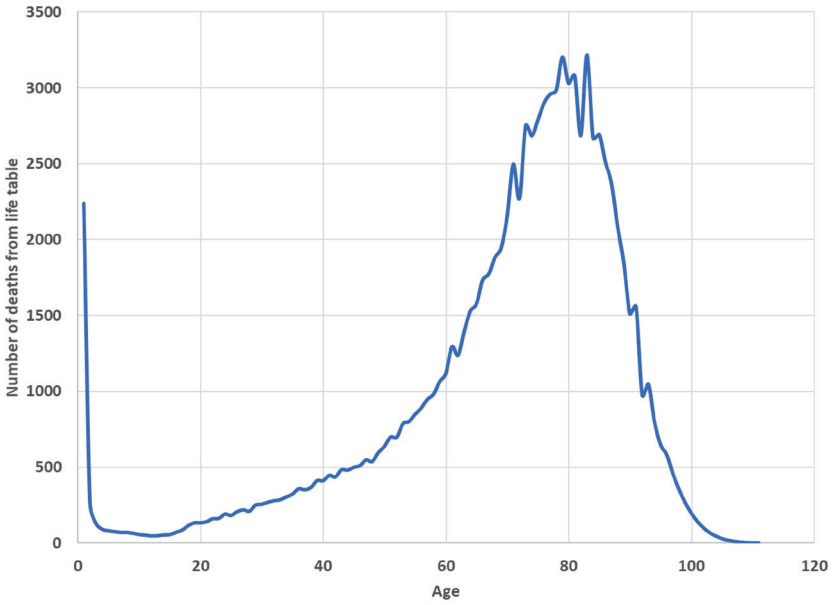

Figure 1. Distribution of numbers of deaths by age from life tables, total population, Russia, 1959. *Source*: compiled by the author on the basis of *HMD* data

The approach to life expectancy analysis on the basis of the modal age at death has been actively used over the past decade. In particular, Emily Clay (2014) analyzed a set of key life expectancy indicators for England and Wales from 1841 to 2010 (see table 1 below).

Let's discuss why, along with other indicators of life expectancy, it is necessary to analyze the modal age at death. First, by analyzing this indicator, it is possible to clearly identify the period during which the majority of the population dies in older ages, which will facilitate more accurate prediction of the necessary social guaranties for elderly persons. Secondly, the analysis of the dynamics of the modal age at death gives understanding of what is happening to the population, i.e. whether the population is growing in older ages, which is important for shaping the appropriate health care and welfare systems in the country. (In fact, if the modal age at death is constant, it may indicate that the country has reached its peak at the current level of social care for population.)

Methodology

The distribution of numbers of deaths in life tables has two local modal values: the first is fixed at 0 years (infant mortality), and the second is in adults. Fig. 1 shows that in 1959

the peak number of deaths was infancy (about 4% of the population died), while the peak in older ages was 80 years (approximately 3.5% of the total population died). Modal age at death is useful in studying the mortality of older persons, as it takes into account the level of mortality in older ages. In this paper, we will use the second peak as the modal age at death.

Modal age at death, despite its rare use, is not a new indicator of life expectancy. Back in the 18th century this indicator was considered as central in the distribution of deaths, limited only by biological law (Quetelet 1835, 1848, 1871). Lexis (1878) describes the modal age at death as the most "normal". The distribution of deaths is divided into three sections — a *J*-shaped curve describes infant mortality, deaths around modal age, which, however, do not have the form of normal distribution, since they are affected by biological laws, and the section of transition from infant mortality to death in modal age. During the 20th century, most researchers did not use the modal age at death as a key indicator of life expectancy. Kannisto (2001) explained that the modal age at death is constant over time and depends only on the distribution of deaths in a particular time period. Since the beginning of the 20th century, many studies have been published on life expectancy under different conditions that used the modal age at death. The main empirical question for most researchers was whether the trends of modal age at death can differ from trends shaped by other indicators?

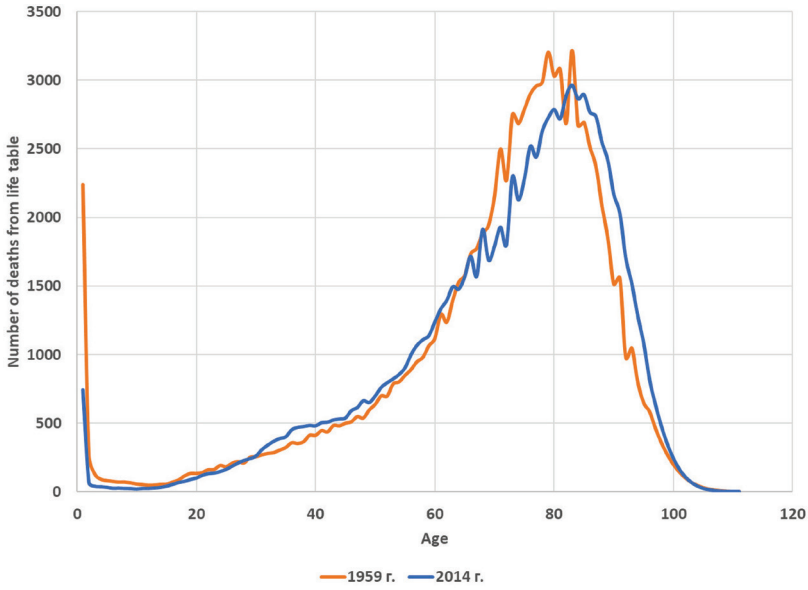

Figure 2. Distribution of numbers of deaths from life tables, total population, Russia, 1959 and 2014.
Source: compiled by the author on the basis of *HMD* data

Increase in the modal age at death means shifting the distribution of deaths towards older ages. For example, we can observe the modal age at death in 1959 and 2014 in Russia (Fig. 2). In 1959 it was about 80 years, in 2014 — about 82 years. If we look at the distribution of deaths by age in these years, we can see that the number of deaths in older ages increased in 2014. It should also be noted that the number of deaths in pre-retirement ages in 2014 slightly increased compared to 1959, so we can conclude that the change in the modal age at death is closely linked to the distribution of deaths in older ages.

However, modal age alone cannot say anything about life expectancy, as it strongly depends on the dynamics of death in older ages (which, however, does not deny its virtue, because it is not affected by the dynamics of middle-age deaths). Therefore, it is important to apply also the analysis based on standard deviation from the modal age in order to determine what is the most "normal" age at death.

Data

To calculate all indicators we have used life tables of the population of Russian Federation (after 1991) and the RSFSR (from 1959 to 1991) for one-year age intervals. The data for 1959–1969 are not ideal due to the imperfections of the data collection system in the RSFSR during these years, which also applies to the data after 1991.

We have used life expectancy at birth (e_0), at 60 years (e_{60}) and modal age at death, as well as standard deviation of life expectancy from modal throughout the population and above the mode. This choice of parameters is due to the fact that in similar studies appropriate approaches were applied, which enables comparing conclusions. In particular, Canudas-Romo (2008) analyzed the standard deviation of life expectancy from the modal value, while Thatcher et al. (2010) and Kannisto (2001) used only standard deviation of life expectancy from the modal age. Canudas-Romo explained that the only limitation on the use of the general standard deviation was that it did not differentiate infant, child and elderly mortality.

When calculating the indicators, we assumed that within the table age intervals the death are distributed linearly.

The following formula (Canudas-Romo 2008) was used to calculate the modal age:

$$M = x + \frac{d_x - d_{x-1}}{2d_x - d_{x-1} - d_{x+1}},$$

where x is the table age with the maximum number of deaths.

The standard deviation of life expectancy has been calculated separately for the entire population and for those who are older than the modal age at death:

$$SD = \sqrt{\frac{\sum\{(x + 0.5 - M)^2 * d_x}{n}},$$

where the sum for deviation around the modal value *(SD(M))* is taken for all ages, while for deviation over than the modal value *(SD(M)+)* is taken for ages older than the modal; n is the number of people living in the corresponding ages.

Another important point is the fact that only age ranges starting from 10 years will be used in the calculation of standard deviation and in some graphs, instead of 0. There are several reasons for this: first, in some years infant age is modal (statistically), second, a number of studies of life expectancy used data from 10 years, not from 0, so for comparison with other studies, this age range is preferable.

Results and conclusions

Fig. 3 shows the dynamics of the modal age at death in Russia (RSFSR). As can be seen from the graph, the modal age at death in the Soviet Union fluctuated between 77 and 82 years,

but no trend can be shaped. Between 1991 and 2010, there were two major collapses: in 1995 and 2003, between which the modal age of death returned to the level of Soviet Russia in 2000. In the last four years of observation, there was a positive trend of the modal age at death. From 2010 to 2014 it grew up to 82.5 years.

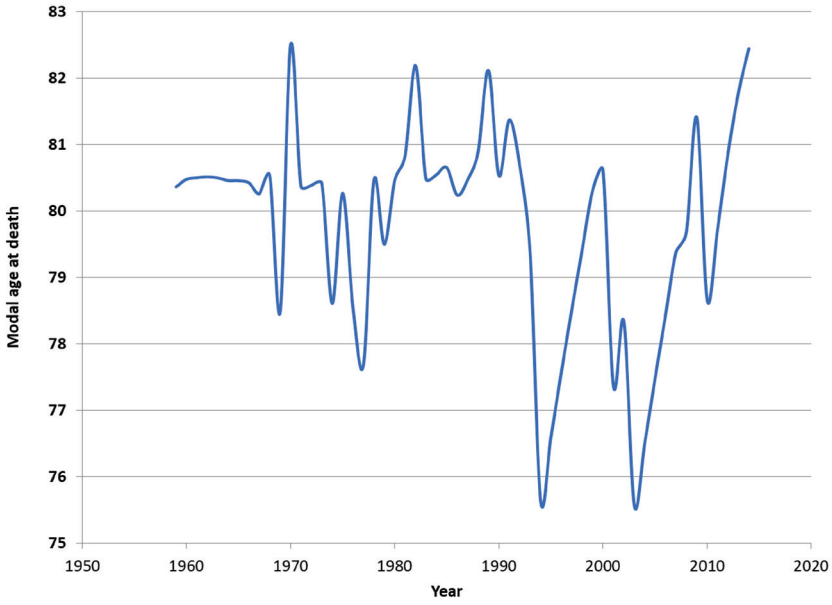

Figure 3. The modal age at death in Russia in 1959–2014 (total population). *Source:* compiled by the author on the basis of *HMD* data.

If we compare the situation in Russia with the situations in developed economies, we can see that the modal age at death in Russia is subject to large fluctuations and is generally lower. For comparison, we take the data for England (Table 1). Between 1961 and 2010, the modal age at death for both men and women in England grew steadily, which cannot be said about Russia. In England, the modal age at death of women and men during this period grew by 10 years, and in Russia only by two years.

Table 1. Modal Age at Death in England in some years.

Sex	1961	1981	2001	2010
Men	75.22	76.9	83	85.44
Women	81.46	84.31	87.09	85.53

Source: (Clay 2014).

The table number of deaths in the modal interval (Fig. 4) has tended to decrease over 50 years (it decreased from approximately 3,500 deaths in 1959 to 3,000 deaths in 2014). The most significant drop in the modal age at death is recorded in the first half of the 1990s and in the first years of the 21st century. This decline can be attributed to the overall disastrous

situation in the economy, which has caused more deaths in young ages. It should also be noted that the rise in the modal number of deaths that started in 2010 may indicate that more people live longer.

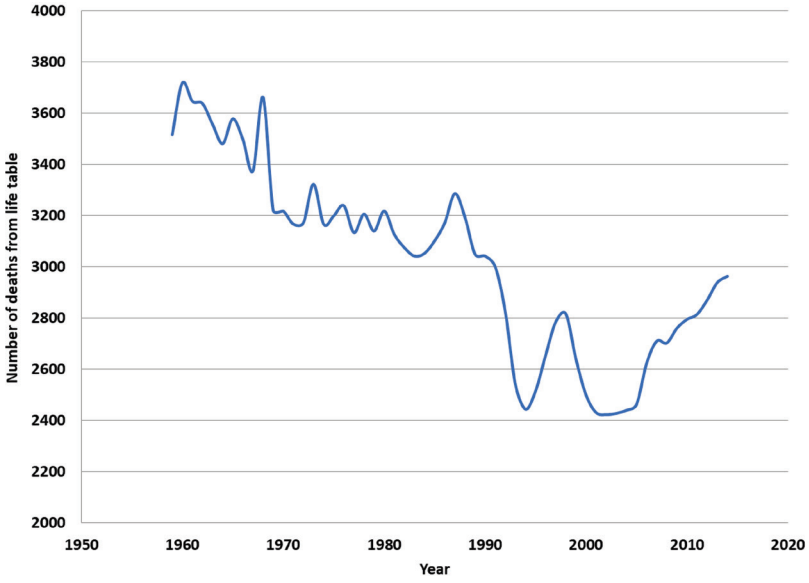

Figure 4. Dynamics of the number of deaths at modal age in Russia in 1959–2014. *Source:* compiled by the author on the basis of *HMD* data.

However, life expectancy in Russia over the last 50 years has fluctuated greatly, and it is impossible to identify any relevant trend on the basis of the modal age at death.

Survival curves are useful for determining trends in life expectancy (Fig. 5). The graph shows that by 1999 the curve moved down, i.e. more deaths happened in the younger and middle ages compared to 1959. However, in 2014 more people survived to older ages, and the distribution of deaths after modal age became even more even.

Survival curves of 1979 and 2009 in older ages are almost identical, while in younger ages in 2009 the number of survivors was higher. This is primarily due to the significant decrease in infant mortality, as well as the high number of deaths between 40 and 60 years of age (i.e. pre-retirement age).

On the basis of survival curves, there are no reasons to affirm that life expectancy in Russia has increased significantly within 50 years; on the contrary, the result obtained in the analysis of modal age is confirmed: life expectancy in Russia is fluctuating, and some positive trend can be identified only starting from 2010.

Another useful tool is the age distribution of deaths. Fig. 6 shows that by 2014 distribution of deaths had shifted towards older ages. At the same time, in middle and young ages, the number of deaths was approximately the same as in the Soviet period.

Noteworthy, in 2014 deaths are less evenly distributed than in previous years. The decline in the number of deaths in older ages is mostly due to the increase in the number of deaths from 25 to 60 years of age. The strong fluctuation of data for 1959 can be attributed to the imperfection of their collection and analysis, as mentioned earlier.

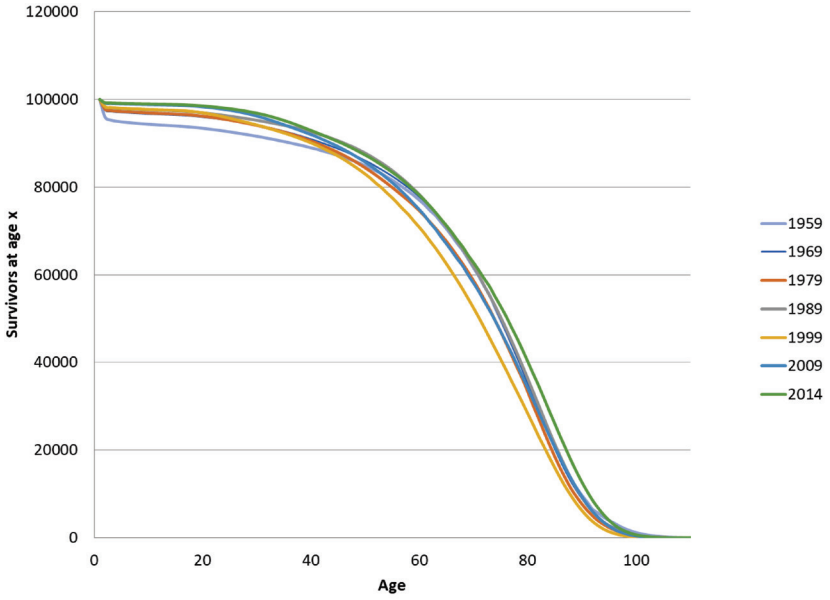

Figure 5. Survival curves for Russia in 1959–2014. *Source:* compiled by the author on the basis of *HMD* data.

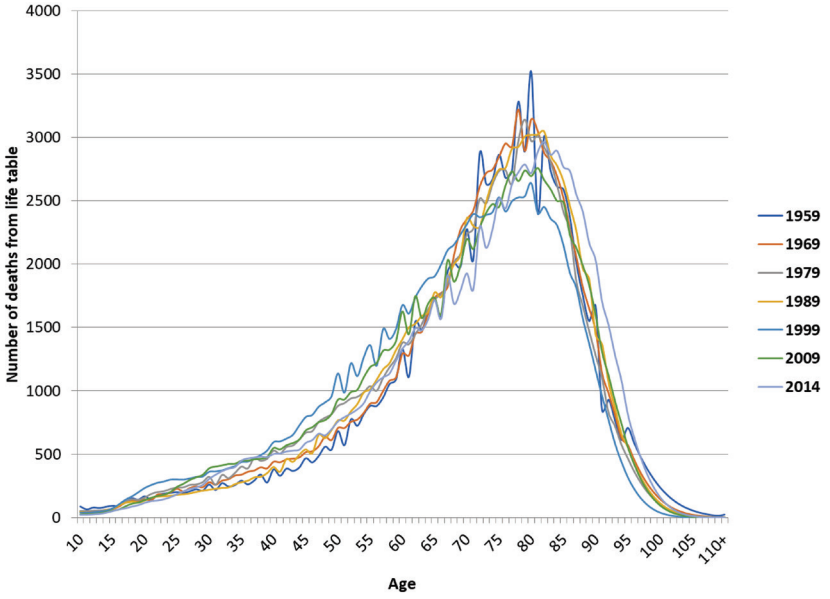

Figure 6. Distribution of deaths in Russia in 1959—2014. *Source:* compiled by the author on the basis of *HMD* data.

A further step towards understanding how life expectancy has changed over the past 60 years is to compare the modal age at death with the life expectancy at the ages of 0, 10 and

60 years (Fig. 7). The graph shows the dynamics of these indicators, and life expectancy here takes into account the age of survival .

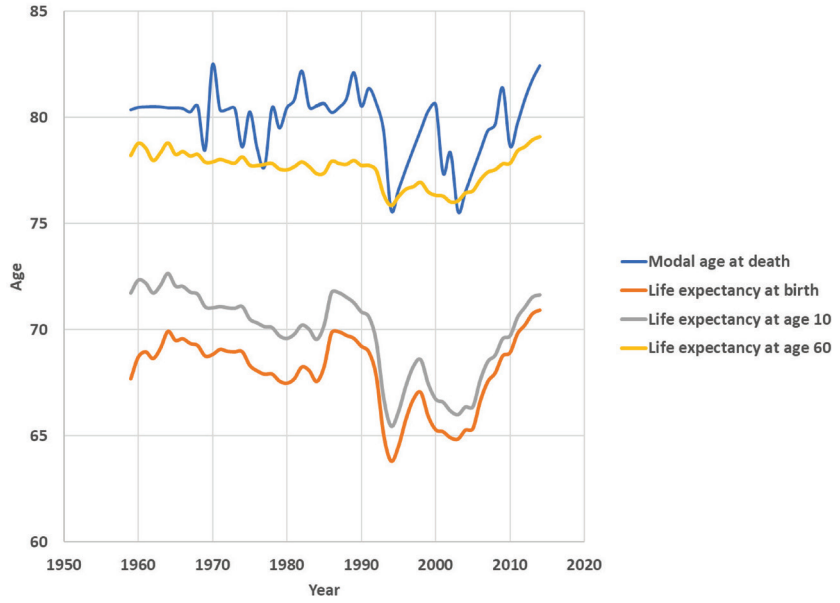

Figure 7. Some life expectancy indicators for Russia in 1959–2014. *Source:* compiled by the author according to *HMD* data.

As can be seen from the graphs, the dynamics of all indicators are co-directed, but the modal age at death fluctuates more than life expectancy. At the same time, there are some differences in dynamics: Thus, between the early 1960s and the early 1980s life expectancy declines, while the modal age of death actively "leaps". Although the modal age at death and life expectancy have been changing in a co-direction since the 1990s, the modal age at death fell sharply in 2010 while the expectancy grew, albeit slower.

It should be noted that life expectancy at the age of 60 years is lower than the modal age at death, but goes closer to this indicator in the recent years. This confirms the fact that the modal age is not affected by the frequency of deaths in younger ages.

Let us now discuss the standard deviation of life expectancy. Recent studies (Canudas-Romo 2008; Ouellette and Bourbeau 2011] show that standard deviation in economically developed countries with low mortality rates is decreasing and equalizing in the group of economically developed countries.

As can be seen in the graphs in Fig. 8, the standard deviation around the modal life expectancy increased from 17.9 years in 1959 to 19.9 years in 2014, and the deviation from the modal age at death fell from 7.01 to 6.41 years in the same period.

According to Kannisto's research (2006), the ratio between the standard deviation of modal age from the mode and life expectancy in economically developed countries ranges around 1.22; data for Russia is also consistent with this regularity. This fact confirms Lexis' theory (1878) that the distribution of deaths is a normal distribution (since in fact $e(M)$ is

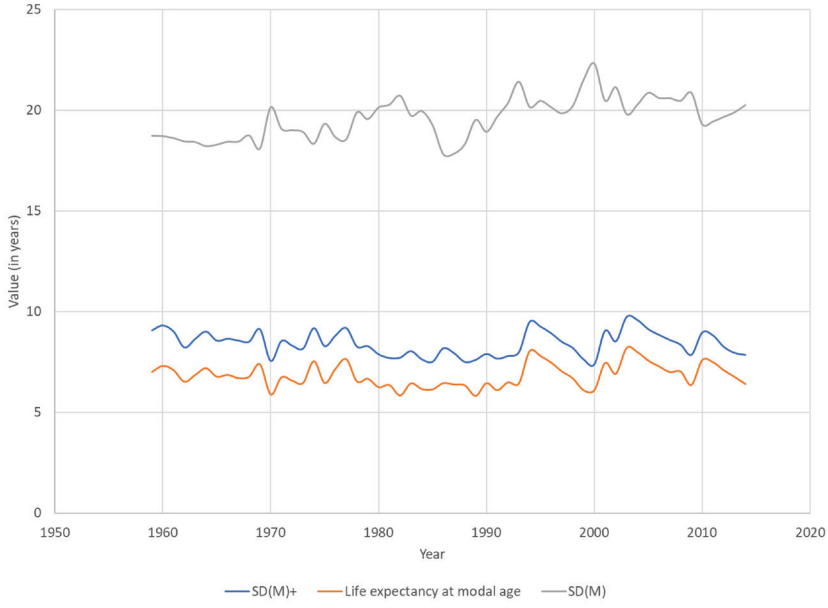

Figure 8. Standard deviation of modal age and life expectancy in Russia in 1959–2014. *Source:* compiled by the author on the basis of *HMD* data.

the average of positive deviations of age from the modal value, and for normal distribution the ratio of standard deviation from the average deviation is 1.253).

The fact that the standard deviation gradually decreases shows that in general the modal period of deaths has decreased, which is also reflected in the "hump" of the distribution curve around the modal values.

It should be noted that indicators of modal age at death and standard deviation in Russia are far behind the indicators of economically developed countries. In the Netherlands, for example, the modal age of death was 80.8 years in the 1950s-1960s, with a *SD* (*M*) + of 7.0 years, and in 1990-1995 the standard deviation decreased to 6.5 years at the modal age at death of 86.7 years.

Differences between the male and female population

It is reasonable to consider the differences between the male and female population, as it is well-known that in Russia there is a large gap between men and women in terms of life expectancy in favour of women.

The modal age at death in women fluctuates much less, and demonstrates an upward trend, while the male population has significant dips (Fig. 9). The modal age at death in women increased from 80 years in 1959 to 85 years in 2014. The male modal age at death varied between 78 years (1960) and 60 years (early 2000s), the largest dips were in the early 1990s and early 2000s. These drops coincide with those in the modal age at death for the entire population. In 2014, the modal age at death of the male population was at the level of the mid-1980s.

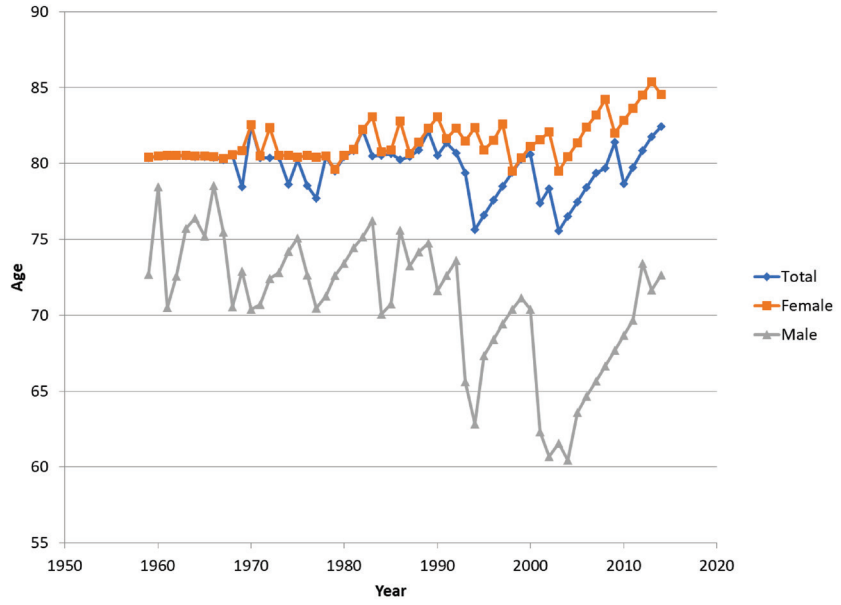

Figure 9. Modal age at death in Russia (RSFSR) in 1959–2014 for male, female and total population. *Source:* compiled by the author on the basis of *HMD* data.

These trends show that in Russia there is an unstable situation in male mortality, with the age at death of men being much lower than that of women. Male mortality is more dependent on the general situation of a particular period.

Research prospects

In future it is necessary to compare the modal age at death and standard deviation in Russia and other countries with a similar level of economic development, for example, with countries of Latin America America or the CIS countries (primarily with the former republics of the USSR, which are experiencing economic growth, such as the Baltic countries).

It is also necessary to make a decision which indicator should be be the key one when forecasting life expectancy; it matters in the establishment of a retirement age or assessment of healthcare funding.

Conclusion

The article analyzes the main indicators of life expectancy in Russia for 1959–2014. The obtained results enable concluding that during this period life expectancy in Russia increased just a little, but the concentration of deaths in older ages enlarged, which testifies the growth of life expectancy. We also proved that the trends of modal age almost coincide with those of life expectancy in Russia.

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Authors information

- **Mikhail Antonovich Maksimov,** the graduate year student of the Bachelor Program at the Faculty of Economics of Lomonosov Moscow State University. E-mail: mihailmaximov000@gmail.com