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The Analysis of Mortality Changes in Poland and Selected European Countries in the Period 1960-2007

1. Introduction

Demographic changes in 20th century clearly reveal progressive ageing of whole societies. This phenomenon is connected with economic growth, improved life standards resulting from better financial situation, advancements in medical sciences, as well as the decrease in the number of children in a new family model. Ageing of populations influences the risk connected with calculating the products of insurance companies and pension funds, where calculated mortality is one of the most important factors.

In management of pension funds and insurance companies two risk sources play a fundamental role: the investment (financial) risk and the demographic risk. The demographic risk is divided into two components: the insurance risk and the longevity risk. The longevity risk is particularly important; it derives from improvements in mortality trends, which determine systematic deviations of the number of deaths from its expected values. This risk should be assuaged by replacing traditional mortality tables used in the assessment of insurance products with projected mortality tables which include a forecast of future trends in mortality.

It is thus essential to be able to estimate future changes in mortality trends and to be able to accurately identify the laws governing mortality. Mortality can be analysed from two perspectives: statistical and biological. The statistical approach takes into account historical data and, using them, analyses mortality trends in the past, as a means of predicting future trends. The biological approach is based on life standards, advancements in medicine, environment and lifestyle of the population.

The authors of the paper present the analysis of mortality changes in Poland and selected European countries conducted on the basis of historical data. The following countries have been chosen for the analysis: from Central Europe: the Czech Republic, Slovakia, and Hungary, from Western Europe: Italy, Sweden, France, and Spain. The analysis of the mortality changes has been conducted with the use of the following variables: m_x - *crude central rate of mortality*; q_x - *graduated initial rate of mortality*; e_x - *life expectancy*, which were proposed by J. P. Morgan in his work *LifeMetrics - A toolkit for measuring and managing longevity and mortality risks. LifeMetrics*^{SM}, developed in 2007, is an international toolkit used for measuring and managing the mortality risk and the longevity risk. These tools measure both risks using standarised methods.

LifeMetrics toolkit has been applied to analyse mortality changes in male and female populations in selected countries in the period 1960-2007. The data used for the analysis have been obtained from www.mortality.org. The van Broekhoven algorithm[1] was applied for smoothing crude mortality rates across different ages.

2. Life Expectancy and the GDP

The analysis of life expectancy at the age 0 both in male (Fig. 1) and female (Fig. 2) populations has revealed a significant difference between two groups of countries. From 1970's life expectancy at the age 0 has been substantially longer for Western European countries: Italy, Sweden, France, and Spain than for Central European countries: Poland, the Czech Republic, Slovakia, and Hungary. Table 1 presents the dynamics of the life expectancy growth in 2006 relative to 1960 for women and men in selected countries.

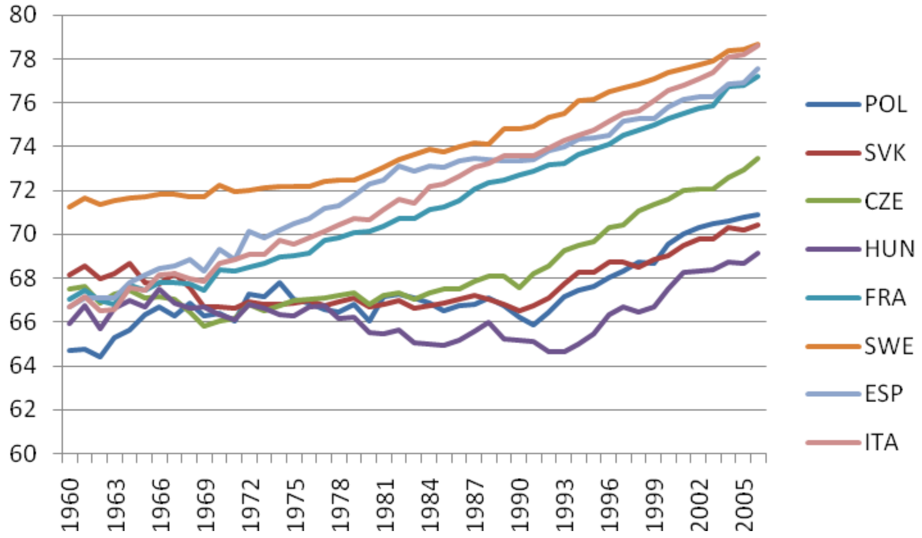
Table 1. The dynamics of the life expectancy growth in 2006 relative to 1960 for women and men in selected countries.

country	PL Poland	SK Slovakia	CZ Czech Republic	HU Hungary	FR France	SE Sweden	ES Spain	IT Italy
female	13%	8%	9%	11%	14%	11%	17%	17%
male	10%	3%	9%	5%	15%	10%	16%	18%

Source: *Own calculations.*

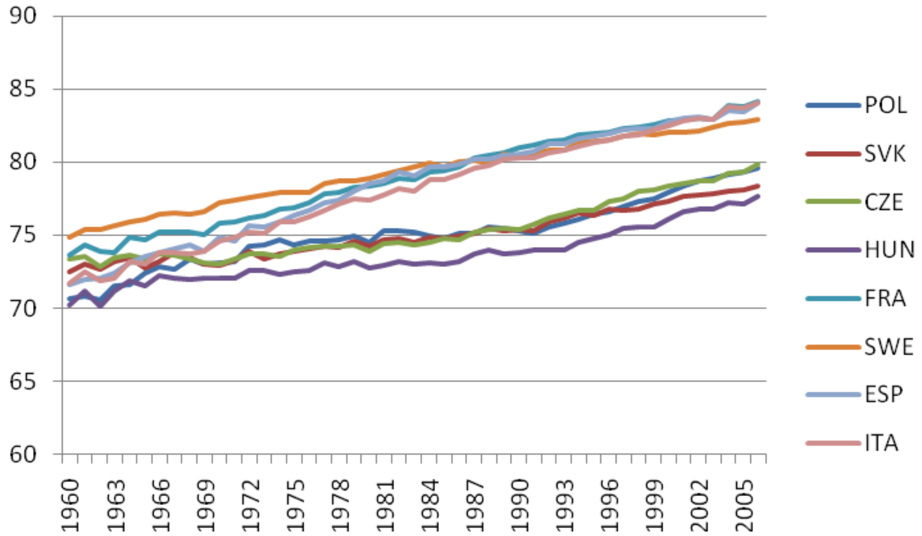
1 See: van Broekhoven, H. (2002). Market Value of Liabilities Mortality Risk: A Practical Model. *North American Actuarial Journal* 6(2), 95-106.

Fig. 1 Life expectancy for men at the age 0 in the period 1960-2006



Source: *Data obtained from* www.mortality.org

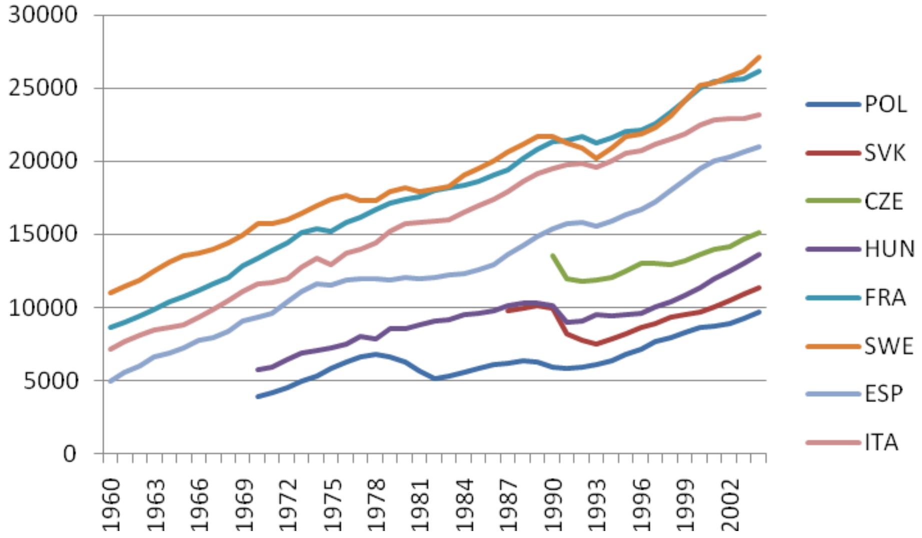
Fig. 2 Life expectancy for women at the age 0 in the period 1960-2006



Source: *Data obtained from* www.mortality.org

Figure 3 presents the values of GDP per capita in the countries analysed. The analysis of these values indicates that, similarly to the case of life expectancy, two distinct groups can be observed - one with higher values of GDP (Western European countries) and the other with lower values (Central European countries). This conclusion seems to confirm the statement of a Polish demographer, Edward Rosset, that life tables are "a barometer of social progress". Thus, the differences in life expectancy and the changes in mortality, i.e. lengthening of life expectancy, are a reflection of life conditions which consist of work, eating habits, natural environment, health care and education.

Fig. 3 Real GDP per capita (Constant Prices: Laspeyres) (I$ in 2000 Constant Prices)



Source: *Data obtained from* http://pwt.econ.upenn.edu/php_site/pwt62/pwt62_form.php

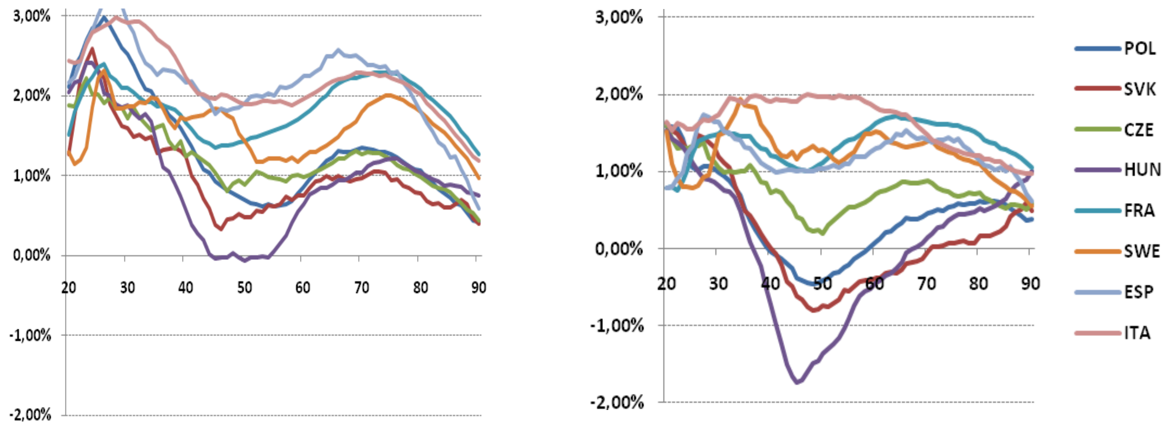
The countries selected for the analysis differ in such aspects as geography, climate or culture, yet the preliminary analysis (Fig. 1 and Fig. 2) shows that they do not have a significant impact on the values of life expectancy. It seems (Fig. 3) that the socio-economic development, which happens as a result of long-term socio-economic policy of a given country, has the greatest influence on life expectancy and mortality.

Thus, it might be useful to check from what age the changes in the course and the dynamics of mortality begin – the changes resulting from different political systems and the socio-economic development of particular countries.

3. Average rate and volatility of changes of graduated initial mortality rate

To analyse mortality, first graduated initial rate of mortality (q_x)was calculated for women and men at the age 20-90, and next the average rate of change of graduated initial mortality rate for the period 1960-2005 for women and men at the age 20-90. Figure 4 shows the average rate of the change of graduated initial mortality rate for the period 1960-2005 for women and men at the age 20-90. The analysis of Figure 4 reveals a considerably better situation in Western European countries as far as the average changes in the mortality rate for both men and women are concerned. It is especially true for men over 30 and for women over 40. The differences are less conspicuous for very young persons and people reaching 90. For example, in Italy, in the years 1960-2005 mortality rate for men at the age 35-57 systematically decreased by almost 2% every year. In Hungary at the same period mortality rate among men aged 45 increased by on average 1,73%. Such increasing mortality rate among middle-aged men was also visible in Slovakia and Poland in the period between 1960-2005.

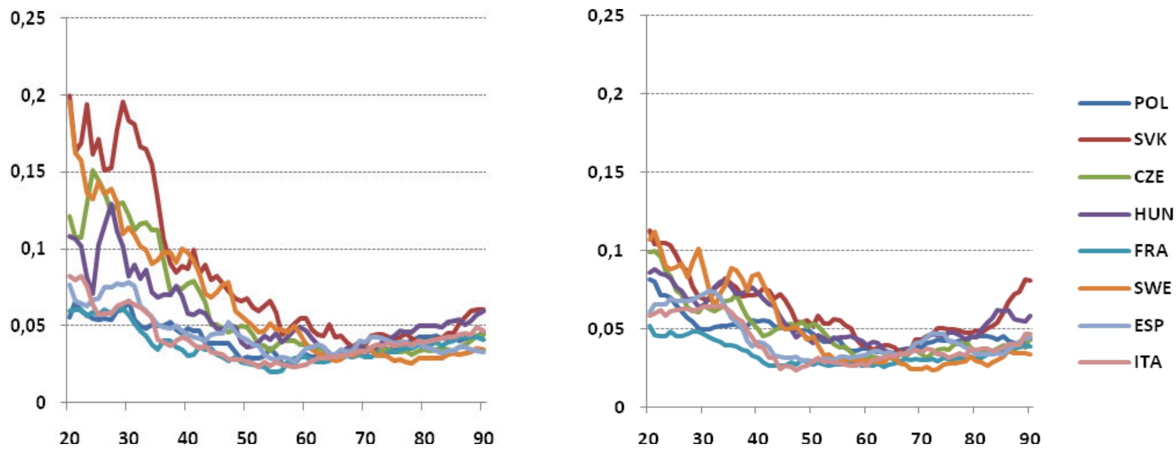
Fig. 4 Average rate of changes of graduated initial mortality rate in the period 1960-2005 at the age 20-90.



a) female *b) male*

Source: *Own calculations.*

Fig. 5 Volatilities of graduated initial mortality rate changes for selected countries for males and females at the age 20-90.



a) female b) male

Source: *Own calculations.*

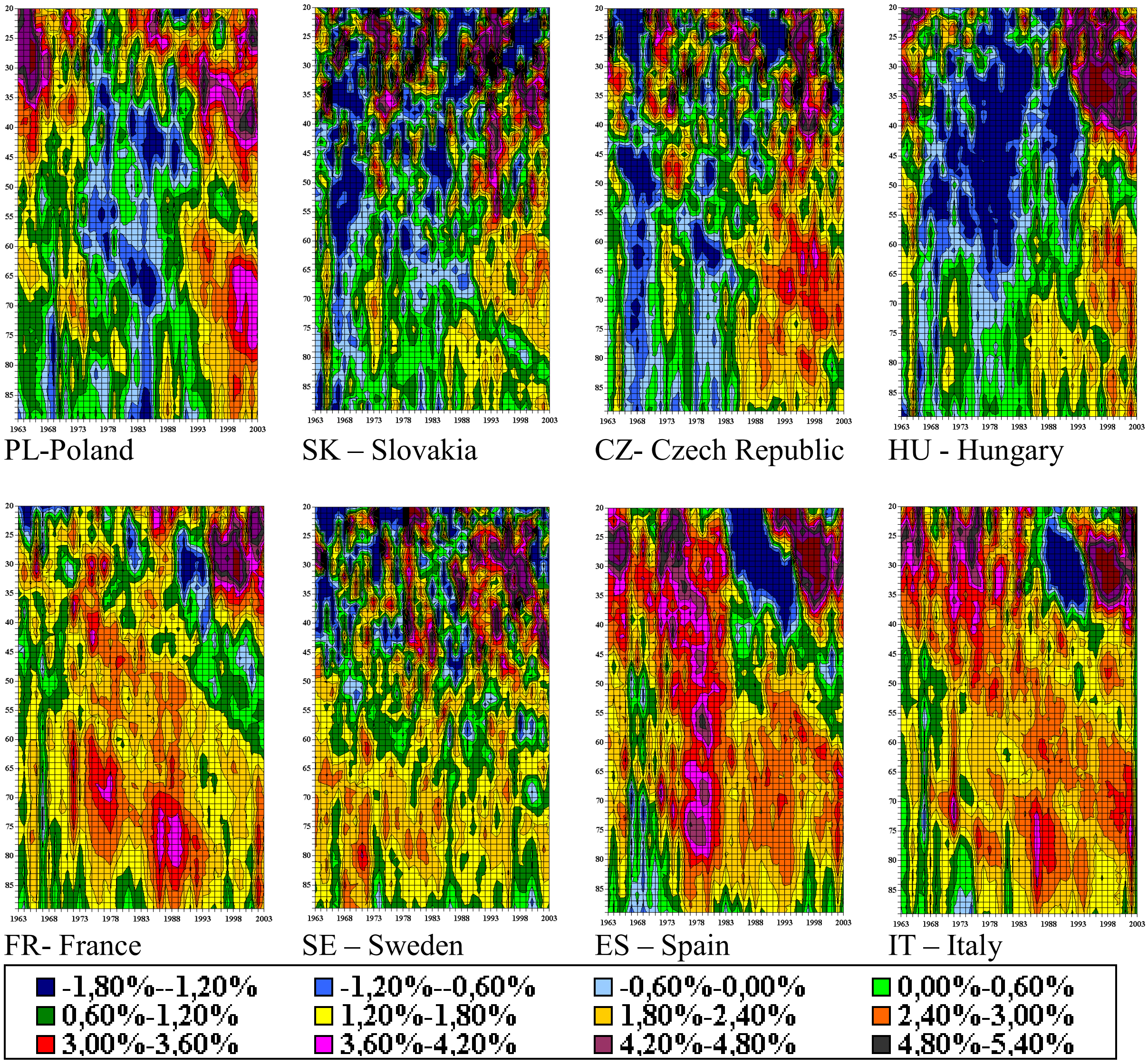
Figure 5 presents volatility values calculated using standard deviation for selected countries for men and women at the age 20-90 in the period 1960-2005. It is worth paying attention to the curves representing women at the age 20-40, especially the high values of standard deviation for Slovakia, France, the Czech Republic and Hungary.

4. Heat maps

An alternative method of illustrating the trends in mortality changes is plotting so called “heat maps”. To do this, it was necessary to calculate the values of 1-year mortality changes in the period 1960-2005 for selected countries in female and male populations at the age 20-90. To highlight general trends in mortality, these values have been smoothed through time (by taking the average over 5 years). These values are presented in Figure 6 –“heat maps”, which reflects graphic changes in mortality of persons at different ages in successive years. So, on the basis of those maps it is also possible to notice mortality changes in cohorts. Cool colors, like blues, indicate that mortality is deteriorating (increasing); greens indicate a slight improvement in mortality (the values of q_x go down about 1,2%); while warm colors, like yellow and red and violet, indicate fast improvements (mortality rates are decreasing). Precisely, for yellow colour the values of q_x go up about 1,2%, and for red improvement is much faster - the values of q_x go above 3%.

The analysis of “heat maps” makes it possible to show the differences in mortality trends depending on sex and the geographic location of a given country. The conclusions are drawn for four groups: female population in selected Western European countries, female population in selected Central European countries, male population in selected Western European countries and male population in selected Central European countries.

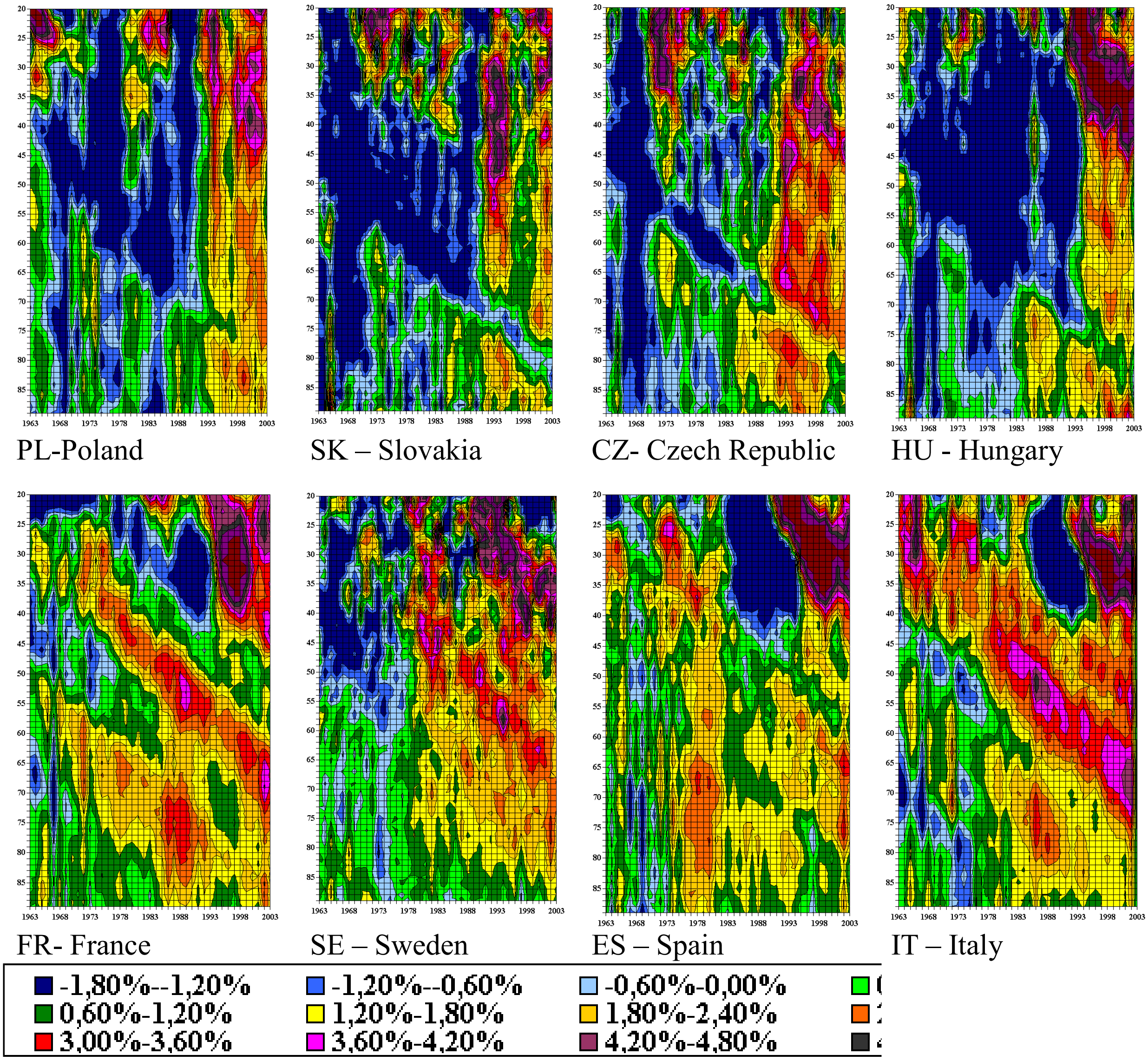
Fig. 6a. Heat map changes for selected countries for female populations
a) female



Source: *Own calculations*.

The analysis of colours on heat maps for female population (fig. 6a) in selected Central European countries shows that independent of the female's age in the period 1960-1990 the mortality was deteriorating (increasing) or indicates a slight, very slow improvement in mortality (green colour). An extensive blue area for Hungarian female population is particularly interesting. It represents a considerable deterioration (an increase of graduated initial mortality rate) of mortality for females under 60 in the years 1960-1990. Since 1990's decreasing mortality rate (red and purple) can be observed irrespective of age. It seems to be caused by political and economical transformations in Central European countries. For female populations from Western European countries in the period 1960-2005, the improvement of mortality initial rate can be observed and, year by year, the values of q_x decrease irrespectively of the female's age, with the exception of Spain and Italy, where for younger women (under 40) deterioration can be observed in the period 1985-1995. The question arises about the reason for such a phenomenon. On the other hand, in Sweden a significant improvement among younger women (under 40) can be noticed in this period, after deterioration before 1985. The Swedish lifestyle seems to bring positive results and might be an explanation of this phenomenon.

Fig. 6b. Heat map improvements for selected countries for male populations
b) Male



Source: *Own calculations*.

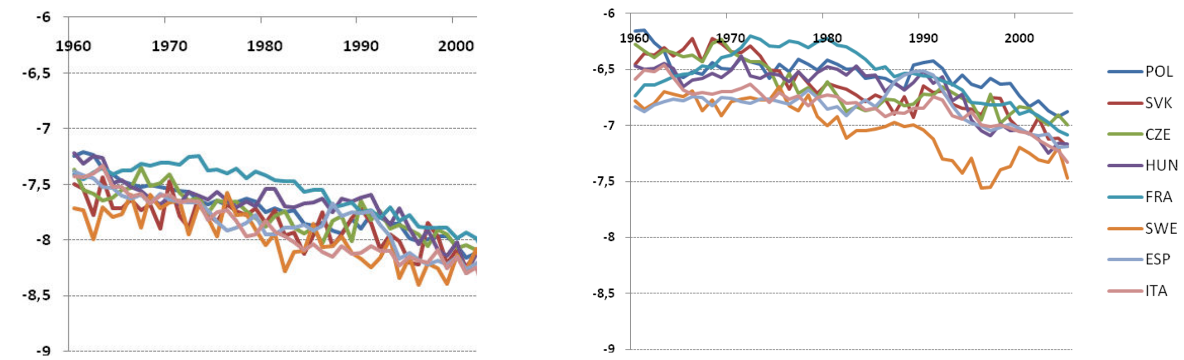
Figure 6b presents heat maps for male populations. Between 1960-1990 in male populations from Central European countries the situation seems to be similar to female populations - constant deterioration irrespective of age can be noticed. What is more, men's situation is more serious than women's, because the improvement is almost imperceptible. A great blue area on Hungarian men's map is particularly alarming. It means that year by year in the period 1960-1990 irrespectively of age the deterioration proceeded. Fig. 4 and Fig. 5 confirm the results for Hungarian male populations. It might be worth considering the reasons for this trend. Decreasing values of graduated initial mortality rate which began in 1990 can be observed for men from Central Europe. Those values decreased fast (yellow and even red in recent years), which means a significant improvement in mortality rate in this period. Men from Western European countries live longer than men from Central Europe, with the exception of younger men (under 40) in Spain, Italy and France, where a serious deterioration of mortality (the increase of graduated initial mortality rate) can be observed in the period 1985-1995.

6. Cluster Analysis

Figures 7-10 present the values of q_x on a logarithmic scale at the age of 20, 45, 55 and 65 in the period 1960-2005. They show that both in male and female populations the curves in selected countries of Central and Western Europe differ. To find out at what age a significant difference in q_x can be observed cluster analysis has been applied. Cluster analysis is the assignment of a set of "similar" observations into subsets (called *clusters*). After clustering, significantly "different" observations should be found in different clusters. To cluster countries into sets with "similar" q_x the Euclidean distance and Ward's method have been applied. The Ward procedure is one of the most efficient agglomerative hierarchical clustering methods. It uses an analysis of variance approach to evaluate the distances between clusters.

Fig. 7a The values of q_x on a logarithmic scale at the age of 20 in the period 1960-2005

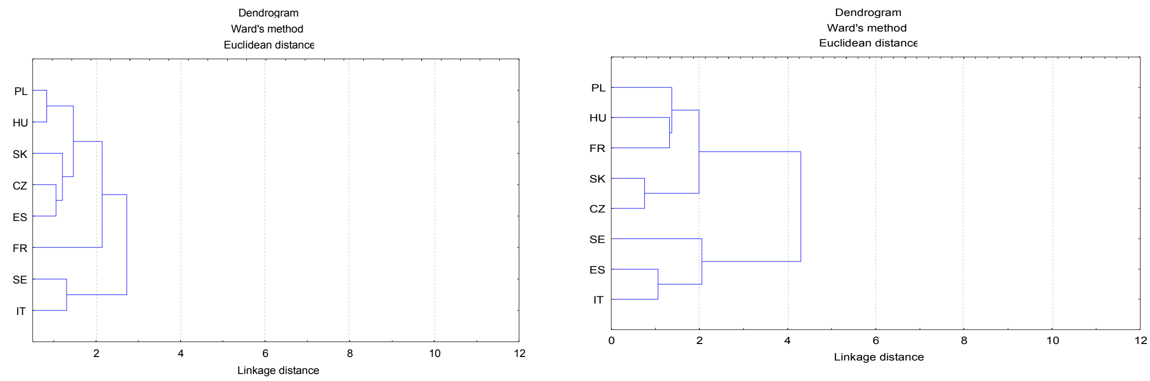
a) female *b) male*



Source: *Own calculations*.

Fig. 7b The dendrograms of the clustering of the logarithm q_x at the age of 20 in the period 1960-2005 obtained using the Euclidean distance and Ward's method.

a) female *b) male*



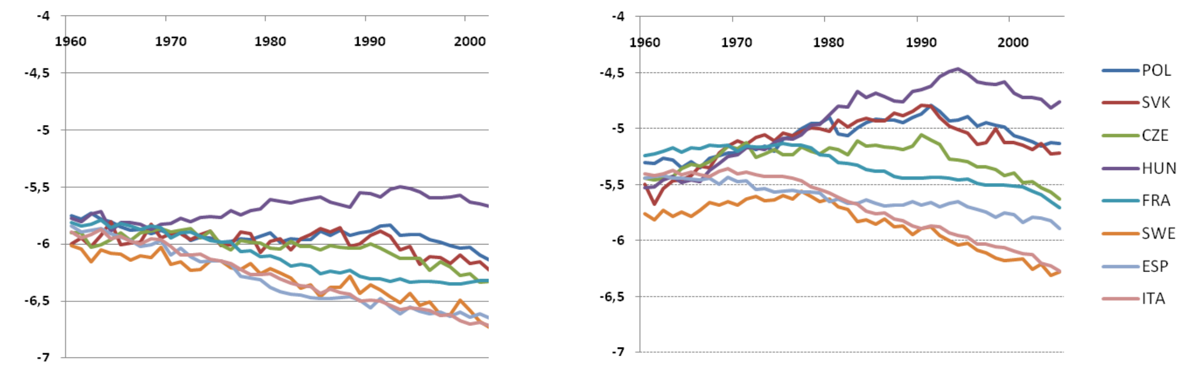
Source: *Own calculations in* STATISTICA *8.0.*

The objects of the analysis were the selected countries and the variables were the values of logarithms q_x in the years 1960-2005. So, the observation matrix consists of 8 objects and 45 variables. The calculations were obtained using the STATISTICA program. The results are presented in Figures 7-10.

For younger populations (under 40-45) the differences in q_x (measured on a logarithmic scale) for particular countries are not very significant. For older cohorts the linkage distances are getting bigger which indicates more significant differences. Beginning in 1970's, both for male and female populations in Western Europe $\ln q_x$ increased faster, and the improvement in mortality was faster than in Central European countries. It is most clearly visible from the age of 45 (Fig.8-10).

Fig. 8a The values of q_x on a logarithmic scale at the age of 45 in the period 1960-2005

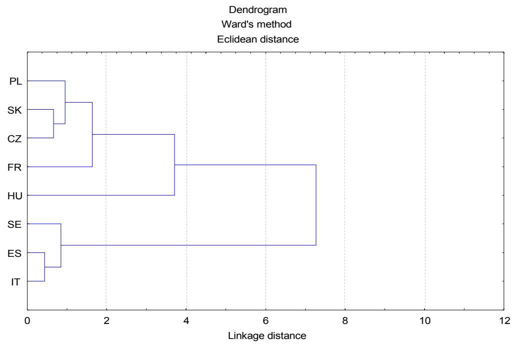
a) female *b) male*

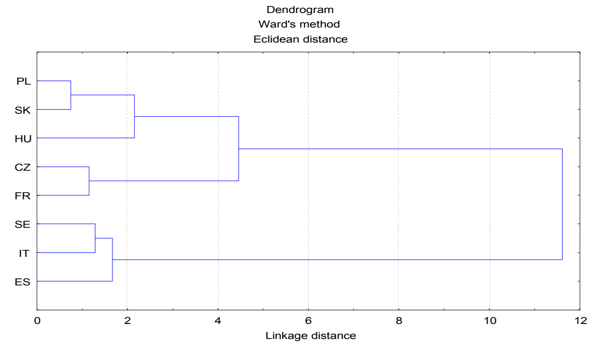


Source: *Own calculations*.

Fig. 8b The dendrograms of the clustering of the logarithm q_x at the age of 45 in the period 1960-2005 obtained using the Euclidean distance and Ward's method.

a) female *b) male*

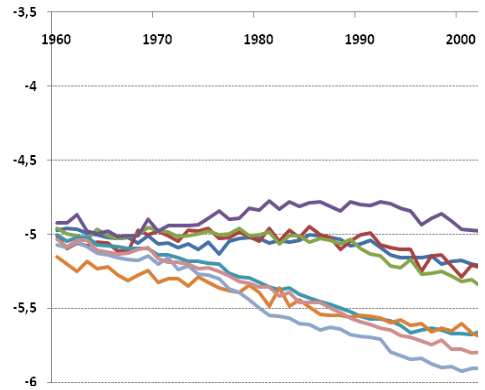


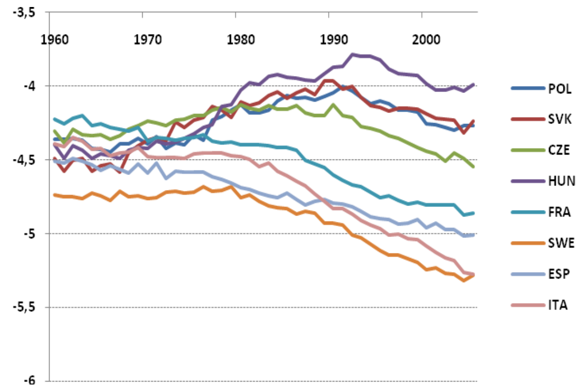


Source: *Own calculations*.

Fig. 9a The values of q_x on a logarithmic scale at the age of 55 in the period 1960-2005

a) female *b) male*

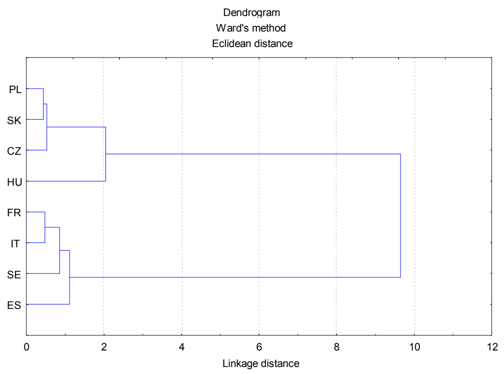


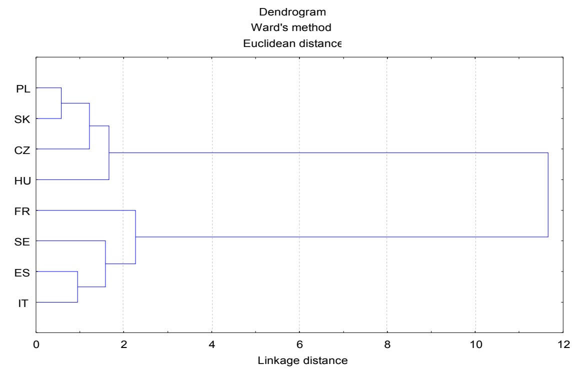


Source: *Own calculations*.

Fig. 9b The dendrograms of the clustering of the logarithm q_x at the age of 55 in the period 1960-2005 obtained using the Euclidean distance and Ward's method.

a) female *b) male*

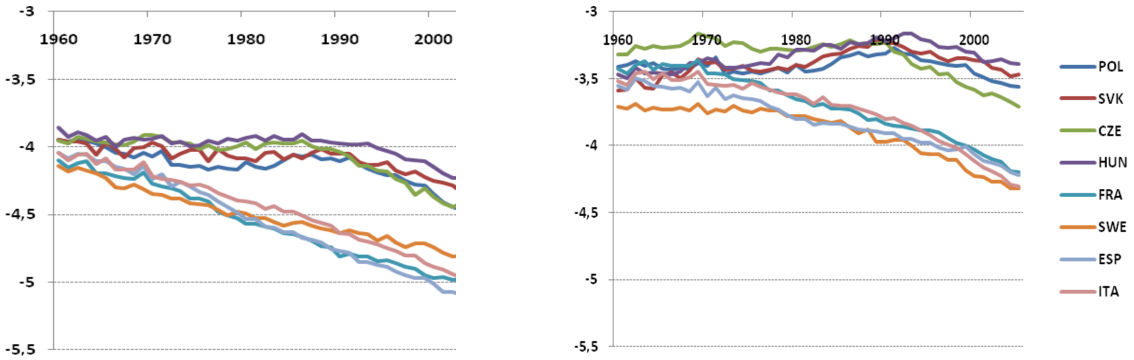




Source: *Own calculations*.

Fig. 10a The values of q_x on a logarithmic scale at the age of 65 in the period 1960-2005

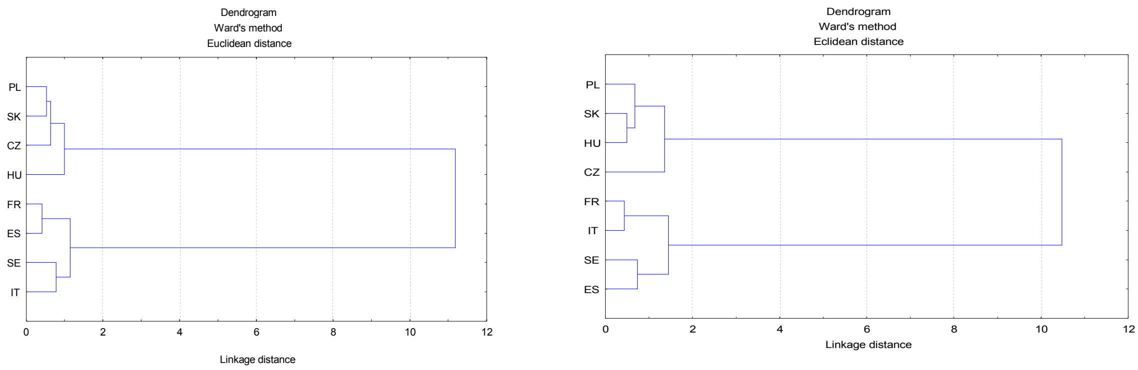
a) female *b) male*



Source: *Own calculations*.

Fig. 10b The dendrograms of the clustering of the logarithm q_x at the age of 65 in the period 1960-2005 obtained using the Euclidean distance and Ward's method.

a) female *b) male*



Source: *Own calculations*.

7. Conclusions

The analysis of mortality changes in Poland and selected European countries in the period 1960-2007 has shown considerable differences in the changes of initial mortality rate. Four distinct groups have been analysed: female populations in selected Western European countries, female populations in selected Central European countries, male populations in selected Western European countries and male populations in selected Central European countries. Apart from obvious differences in male and female mortality, significant differences in the dynamics of mortality between Western and Central European countries were revealed. In spite of their geographic, climatic and cultural differences, the countries constituting both groups seemed quite homogenous.

The most significant differences in the change of graduated initial mortality rate have been observed for people above 40-45 from Central and Western European countries. The period of most striking disproportions in the change of graduated initial mortality rate were the years 1970-1990, which seems to be the result of the socio-economic policy in Central European countries. The transformations which took place in 1990's helped to reduce the differences in the dynamics (decrease) of mortality, yet the differences in life expectancy between the Western and Central European countries will probably still be visible in the next years (life expectancy in the Western countries will continue to be longer).

Another important phenomenon is connected with the fact that, irrespective of geographic and political factors, in the 1990's the process of aging of the whole populations began. In the future ageing can constitute a serious obstacle in the socio-economic development. Firstly, labour resources will grow old, i.e. there will be fewer and fewer young workers on the job market which will become dominated by less mobile older workers. Secondly, the number of people in the productive age will decrease, which means that maintaining a fast rate of economic growth will be possible only if productivity increases and a bigger percentage of people in their productive age will work. One of the ways of assuaging the problem of ageing is lengthening productive periods, also called lifting the actual retirement age, which will slow down the process of diminishing the number of professionally active workers. Such policy is also in accordance with demographic tendencies regarding lengthening life span. Lengthening productive periods means resigning from a contemporary trend of early retirement and lengthening the duration of the period of 'well-deserved rest'. As a result, changes in the area of employment and social security are needed.

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