THE RISK OF LONGEVITY ON THE EXAMPLE OF POLAND

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Abstract: *In recent decades, changes in the demographic structure of the world's population have been observed. According to the latest report of the United Nations "World Population Prospects 2019" in 2019, the average life expectancy of a person at birth in the world was 75 years for women and 70.2 years for men. However, in 1960 these values were 50 years for women and 50.73 years for men, respectively. This means an almost 30% increase in life expectancy over the past six decades.*

The purpose of this work is to present the phenomenon of longevity and its impact on the structure of society. An analysis of the effectiveness of the Lee-Carter model was performed using the GUS data. The paper reviews the tools and methods of longevity risk transfer.

The analysis showed that the model used in Polish realities has high prognostic value. However, if the average life expectancy maintains the current upward trend, it will be necessary to take measures to ensure the stability of the pension system and continuous payments made by insurance companies. The stability of pension systems can be ensured through legislative changes and structural measures, while the insurance market should look for solutions on financial markets.

Key words: *Longevity risk, Lee–Carter model, Longevity risk transfer*
JEL codes: *G23, J32, C18*

1. Introduction

The last decades have brought significant changes in the demographic structure of the world's population, which affects many aspects of modern life. Especially developed countries are characterized by a high level of aging of the population, caused on the one hand by the persistently low fertility rate and on the other by the increase in life expectancy. Among the factors affecting the growing life expectancy, the most frequently mentioned are (Costa, 2005, p. 23): a high level of medical care, increasing the effectiveness of preventing infectious diseases, preventive healthcare, healthy eating, improving the material situation and increasing the level of education. They allowed to reach advanced age while maintaining good health. According to the United Nations report 'World Population Prospects 2019' published in 2019, the current average life expectancy at birth is (United Nation, 2019a) 75 years for women and 70.2 years for men, respectively. However, in 1960 these values were 50 years for women and 50.73 years for men. According to the same institution, in the same period the indicators for Poland were (United Nation, 2019b) respectively 82.37 years for women and 74.48 years for men. This means an almost 30% increase in life expectancy over the past six decades.

It should be noted that the percentage of older people in the total population of industrialized countries is also steadily increasing. This situation causes irreversible changes in social policy. The basic problem is spending on social security in the form of retirement benefits and health care. Currently, total expenditure on pensions in Poland accounts for approx. 11% of Gross Domestic Product (Wojciechowski, 2020). Contemporary pension systems are largely based on the pay-as-you-go system (Owsiak, 2017) consisting in an intergenerational agreement as a result of which benefits are financed from contributions paid by professionally active people. The aging process of the population caused far-reaching changes in the proportion between the number of young and middle-aged people and the number of older people called the potential support ratio (Długosz et al., 2011, p. 17). According to World Bank data in Poland, in 1960 there were on average 9.4 people over 64 years old per 100 working people, while in 2018 this figure was 26 (The World Bank, 2020). This state of affairs may pose a threat to the public finance system over time, which is why legislative measures are being taken at both national and international level to change demographic trends and reform pension systems.

In addition, it should be remembered that the increase in longevity has a huge impact on the financial and insurance sector. The activities of insurance companies and pension funds, as entities established to provide financial security for the elderly, become particularly difficult.

The functioning of these institutions is largely based on life expectancy estimates based on using mortality models. One of the main problems facing the statistical institutions of many countries is the underestimation of mortality forecasts called the risk of longevity. For this reason, attempts are constantly being made to find a model that will allow for accurate mortality forecasts.

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2. Methodology and Data

In this work, a meta-analysis of the results of previous studies was carried out. Using demographic data from 1958-2000, a forecast of life expectancy for the Polish population was made. The forecast was made using the "R" statistical calculation environment and average life expectancy data for men and women made available by the Human Mortality Database (HMD) and processed using statistical packages (Spedicato & Clemente, 2013) lifecontingencies and demography. The predictions were made using a stochastic mortality model developed by R. D. Lee and L. Carter. The obtained calculations allowed to compare the results of predictions with real values. This, in turn, made it possible to assess the effectiveness of the model used to predict average life expectancy.

To achieve the goals set out in the introduction, Polish and English-language literature was queried. The review allowed defining and characterizing the tools and methods of transferring longevity risk used on insurance and capital markets. The obtained results allowed establishing perspectives for the development markets for transferring longevity risk.

Analyzes and researches mentioned above allowed a discussion regarding the necessity of further development of forecasting models as well as methods of dealing with possible estimation errors. The final conclusions were constructed thanks to the triangulation of the research methods used.

3. Results and Discussion

The risk of longevity is closely related to mortality defined as the number of people who died in a given period of time, most often in a calendar year. Describing this phenomenon requires analyzing a more general concept, which is the risk of mortality, which according to the literature can actually occur mainly in three types (Cairns, et al. 2006, p. 82): individual, aggregate and catastrophic, which appear depending on the observed demographic dynamics. We talk about the individual risk of mortality when a person lives longer or shorter than the estimated average life expectancy of the entire population to which he belongs. Observed mortality rates can be both higher and lower than expected for a given population, without any noticeable trend. In this case, there is dispersion around expected mortality rates, and the risk of mortality is referred to as the risk of accidental fluctuations (Pitacco, 2009, p. 1). The randomness of events perceived as a process is the basis of the activities of insurance institutions, therefore the individual risk of mortality is insignificant if it is assessed in the context of the entire portfolio, therefore it is a challenge for insurance companies causing difficulties in the valuation of insurance products and management of the insurance portfolio. This risk can be managed through an appropriate pooling effect, i.e. increasing the number of policies in the portfolio to reduce risk or using traditional risk transfer instruments. Aggregate mortality risk occurs when the average life span of the population is different than would be expected. In this context, mortality rates can systematically take higher or lower values than forecast by statistical offices. The systematic nature of the changes taking place is of key importance. The reasons for this can be various, such as incorrect construction of the mortality model or incorrect estimation of individual parameters. The first situation is called model risk, while the second is known as parameter risk (Jajuga, 2013, p. 73). Both risks show the scale of uncertainty of the phenomenon under study. From the point of view of the age of adult members of a given population, this uncertainty is particularly important in the event of an unexpected decrease in mortality rates. It then takes the name of longevity risk. The last category is the catastrophic risk of mortality. It occurs when there is a sudden increase in the frequency of deaths in a short period of time. It may be caused by the occurrence of such phenomena as epidemics or natural disasters. While mortality and the associated risk is an extremely important phenomenon in terms of constructing life expectancy tables and calculating demographic indicators, the risk of longevity is an opposite phenomenon. The total risk of longevity consists of individual and aggregate risk. The individual risk of longevity is that a person will live to a longer age than expected. However, the aggregate risk of longevity is that in a given year (cohort) the average life expectancy will be longer than expected. In other words, it is a risk of incorrect estimation of the future mortality rate trend.

Estimates of the total global longevity risk exposure associated with disability and pensions range from $ 15 trillion to $ 25 trillion (Basel Committee on Banking Supervision, 2013). Globally, the annual cost of underestimating life expectancy is estimated at $ 450 billion to $ 1 trillion (Sidley global ..., 2015).

3.1. Historical approach to life expectancy

In addition to defining the concept of longevity risk and attempting to estimate it, it is important to find a solution that measures the scale of the financial effects they cause. For this purpose, actuarial methods are used, they allow to determine future mortality trends, forecast life expectancy and estimate the associated risk. The actuarial account is particularly important when measuring continuous benefits covering a very long time horizon, such as pensions. When estimating them, a key element is to avoid potential undervaluation of liabilities. Entities obliged to pay benefits should have the most accurate forecasts regarding future mortality and its trends. In actuarial practice, the valuation of contracts for life benefits is based on taking into account the life expectancy of the insured, which is based on the concept of probability of surviving a certain number of years or death at a certain age. The literature on the subject can refer to many methods of modeling mortality, including analytical and extrapolative approaches (on which the construction of life expectancy tables is based). The extrapolation method has a long historical tradition. However, only the pattern of life expectancy tables developed in the 17th century gained widespread recognition and the modified form is used today by the statistical institutions of many countries.

3.2. Lee-Carter model on the example of Poland

It should be noted that the methods described so far are deterministic. This means that they allow for general mortality trends, but are free of random components. As a result, forecasts made with their help are created as a result of a predetermined scheme based on rigidly defined initial parameters resulting from historical changes in the demographic structure of a given population, events related to a given community. This state of affairs causes that the forecasts received often turn out to be underestimated. The demand for precise mortality forecasts combined with limitations imposed by deterministic models have resulted in the development of research in this area. Consequently, it was decided to use stochastic methods that would allow the inclusion of random events in the structure of predictive models. This approach actually turns out to be more functional than deterministic because it takes into account the uncertainty on which the forecast is based and the underlying risk called model risk. Among the stochastic models, it is worth mentioning the model developed in 1992 by R. D. Lee and L.

Carter and its subsequent modifications. These models allowed for inclusion of random components related to age and calendar year, now they are widely used in many countries. The starting point is a matrix of central mortality rates, with years (t) usually placed on columns, while age (x) placed in rows. The goal is to obtain a matrix that predicts mortality rates over a specific time range, taking into account age changes. The central mortality rate determines the probability of death and is determined by the ratio of deaths to the average number of people in the population. In other words, it is the central mortality rate at the age x in t. Forecasts of central mortality rates are obtained assuming the exponential distribution of the mortality rate for each age x; therefore, mortality rates for each specific age at different time intervals can be determined using a relationship linking death rates with central death rates. The general form of the model is as follows (Lee & Carter, 1992, p. 659):

$$\ln m_{x,t} = a_x + b_x k_t + \varepsilon_{x,t} \tag{1}$$

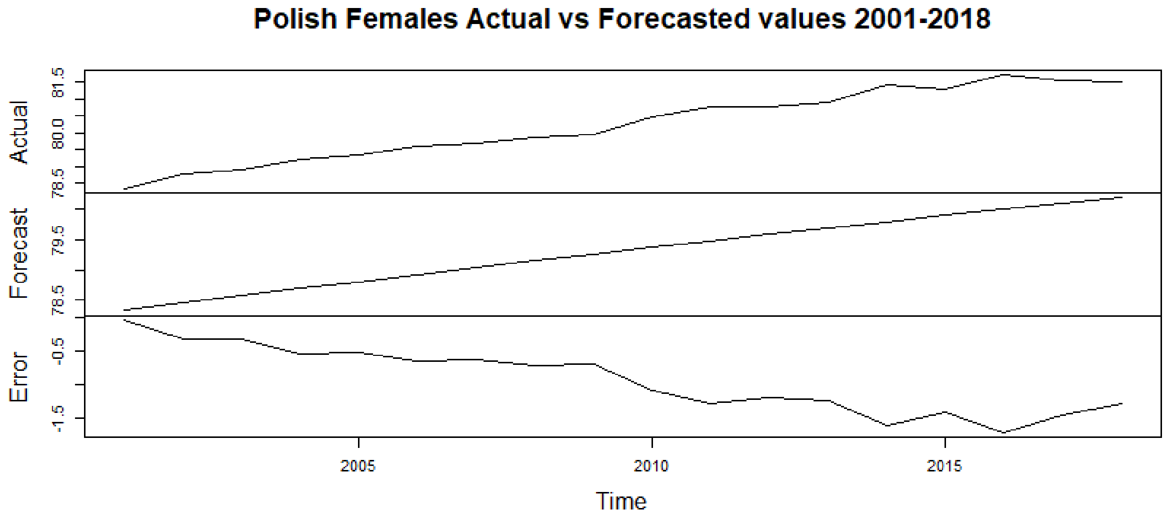
The individual components were defined as follows: $\ln m_{x,\ t}$ - logarithm of central mortality at the age of x in the year t, a_x defines mortality in age groups, i.e. the average level of logarithm of the death rate, averaged over a calendar year; bx - deviations from the average mortality level related to the influence of k_t changes, this parameter shows how quickly the logarithms of partial death rates change in the respective age groups; k_t - changes in the level of mortality over time (modeled using a random drift process), i.e. the general trend of changes in mortality over the period under consideration, the effect of the effect of calendar time t on the change in the level of partial death rates is treated; ε_{xt}, an independent random component with the normal distribution, the expected value equal to 0 and a constant variance (so-called Gaussian white noise) determining the uncertainty of the explained variables, is melting down. Additionally, the following assumptions were made: sum $b_x = 1$ and sum $k_t = 0$. Whereas the kt element constituting a groundbreaking change in relation to the models used so far has been defined using the following elements:

$$k_t=c+k_{t-1}+e_t \tag{2}$$

c- represents a certain constant (drift); e_t - random component with normal distribution with expected value equal to 0 and some finite variance.

Based on the data from 1958-2000, an estimation of the Lee-Carter model parameters was made, which were then used to estimate mortality rates and to make predictions of life expectancy in the years 2001-2018 for the Polish population. The following charts show a comparison of the values predicted by the model with the actual values published by the Central Statistical Office.

Fig. 1 Forecasted life expectancy of females in Poland in 2001-2018 compared to real values and the value of forecast errors



Source: Own calculations based on HMD, GUS data

The analysis of errors allowing to determine the accuracy of the forecast for the population of women in Poland gave the results described below.

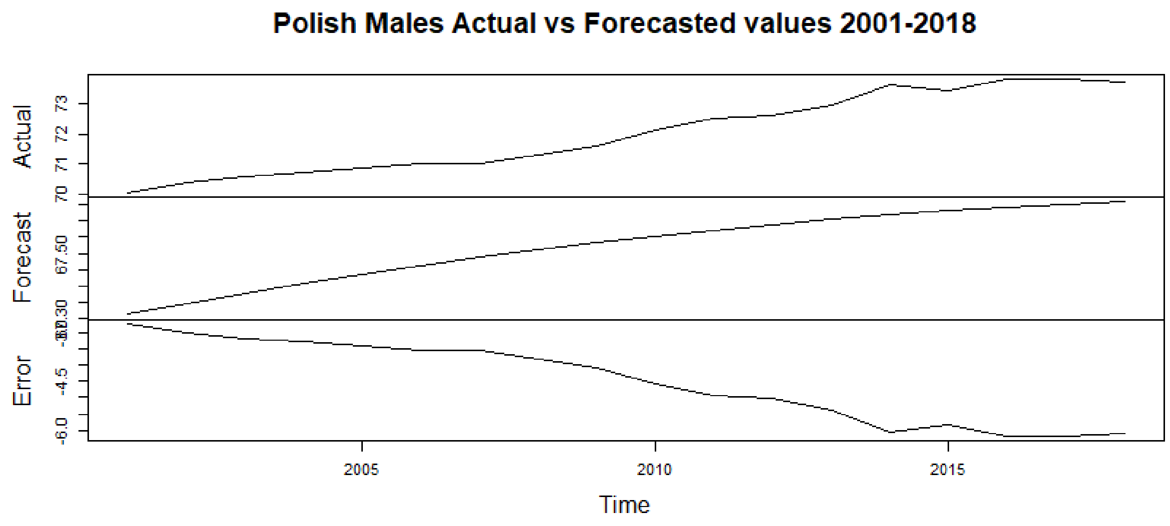
Mean error (ME) -0,91 The mean error is term that refers to the average of all the errors in a set. An error is an uncertainty in a measurement, or the difference between the measured value and real value.

MAE Mean Absolute Error 0,931 Measures the average size of errors in a set of forecasts, not including their direction. This is the average of the test sample of the absolute differences between forecasting and actual observation, with all individual differences having the same weight.

Mean Absolute Percentage Error (MAPE) 1,1711 The mean absolute percentage error MAPE is a statistical measure of how accurate a forecast system is. It measures this accuracy as a percentage, and can be calculated as the average absolute percent error for each time period minus actual values divided by actual values. The mean absolute percentage error is the most common measure used to measure forecast accuracy.

For males we received the following error values ME -4.49, MAE 4.49 MAPE 6.65. It means that forecasts for women in Poland are more accurate than for men.

Fig. 2 Forecasted life expectancy of males in Poland in 2001-2018 compared to real values and the value of forecast errors



Source: Own calculations based on HMD, GUS data

Based on the calculations made, the following conclusions were drawn: the forecasts obtained using the model used differ from the actual values in a different manner depending on gender, they are more precise for the female part of the Polish population, while less accurate for men. The obtained results also indicate that despite over 40 years of input data series with high precision can only be spoken in a short period of time. However, it should be recalled that due to its high prognostic effectiveness, the method is used in many countries. The obtained differences between the forecasted and actual values in the case of Poland make us search for the reasons for this situation. One of them is too short series of data that can be used for calculations. Another reason is the distribution of deaths in the population other than in Western Europe. Consequently, it must be stated that it is necessary to search for more effective forecasting methods, but first and foremost the extensive use of financial and legislative instruments ensuring protection against the risk of longevity.

3.3. Longevity risk transfer

Although the risk of longevity is a desirable phenomenon in society, there may be a series of consequences behind it, also negative from the economic point of view. Thus, the risk of longevity will affect in particular:

• natural persons who independently collect and manage funds intended for retirement purposes,

• institutions responsible for the functioning of the social security system,

• entities whose products rely on the lifetime payment of funds.

From the point of view of natural persons, the risk of longevity is associated with the possibility of accumulating insufficient funds or disposing of them improperly. When analyzing the impact of longevity risk on the pension system, it should be noted that an excessive burden with the same level of income can result in a long-term reduction in the amount of retirement benefits. Considering this, it may turn out that the best solution will be the transfer of longevity risk to private institutions – in particular insurance companies that have extensive knowledge and experience needed to analyze and estimate the effects of this phenomenon (Bartkowiak, 2019).

At the beginning of the 21st century, a "life market" began to appear – a market of assets and liabilities related to longevity and mortality (Dionne, 2013). Despite very slow development, to date, there are premises in favor of further development and internationalization of this market, in connection with the growing importance of longevity risk. The longevity risk transfer market includes various types of transactions, in particular these may be (Dionne, 2013):

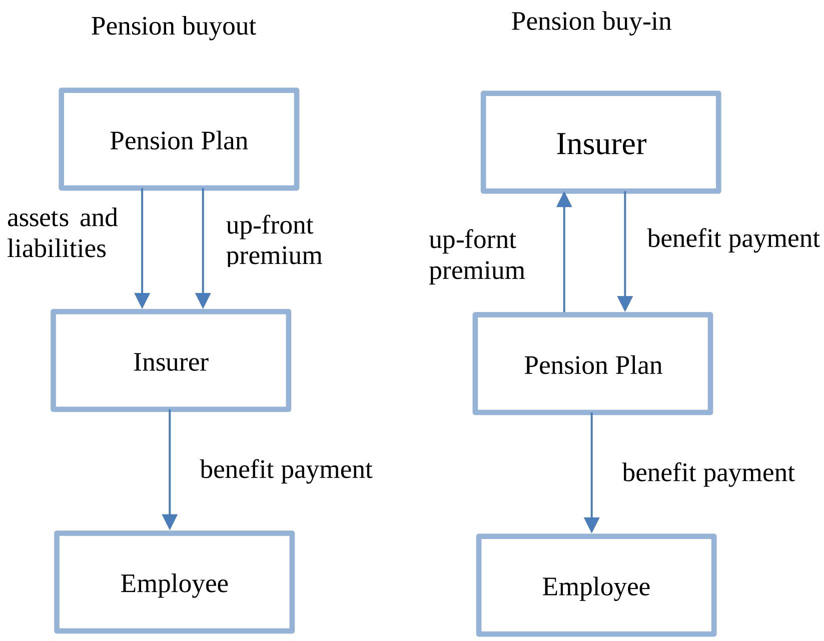
- ❖ Insurance solutions:
  - ➢ Pension buyouts – transfer of pension assets and liabilities as well as risks related thereto to an insurance company.
  - ➢ Pension buy-ins – transfers part of the longevity risk and investment risk by mass purchase of disability insurance for participants of retirement plans.
  - ➢ Collective transfer of risk from disability insurance contracts to other insurance and reinsurance undertakings
- ❖ Capital market solutions:
  - ➢ Longevity Bond longevity swaps, forward contracts, - instruments transferring longevity risk to other capital market entities
  - ➢ Life securitizations – instruments transferring a specific group of risks from insurance companies to capital markets

In the case of insurance market solutions, it is worth discussing pension buyouts and pension buy-ins. In the case of pension buyouts, the fund's resources are transferred to the insurance company. In exchange for the premium, the insurer assumes the obligations to its fund participants, and hence the risks associated with the management and disposal of assets –

including the risk of longevity. Finally, the insurance undertaking pays payments to the beneficiaries of the fund at the maturity of the contracts.

The situation is slightly different in the case of pension buy-in. In this case, the action coincides with disability insurance – the fund transfers part of the accumulated funds as a one-off, paid premium in advance to the insurance company in return for which it periodically receives a set amount of payments. These funds, in turn, are used to settle obligations arising from contracts concluded with beneficiaries. In the case of such contracts, the disbursement of funds by the insurance company occurs even if the participants of the retirement plan live longer than originally assumed (Bartkowiak, 2019). Thanks to this construction, it is possible to transfer longevity risk to insurance companies. The scheme of operation of Pension buyout and pension buyin is shown in Figure 3.

Fig. 3 Structure of Pension buyout and buy-In Transactions



Sources: (Basel Committee on Banking Supervision, 2013)

Other instruments used to transfer longevity risk are related to the capital market. It is worth analyzing Longevity Bond first - these are securities in which the coupon amount depends on the survival rate in a given population. Therefore, an entity exposed to the risk of longevity can protect itself against it by purchasing Longevity Bond. In this situation, the implementation of this risk will involve additional costs. However, with adequate security, these costs should be offset by additional funds obtained from the coupon of the bonds, which in turn will exceed their expected value.

Another tool presented worth mentioning is q-forward. In the said contract, payments between two parties are made within the expiry date. A party who wants to hedge against longevity risk transfers a value equal to the product of the contract nominal value with a determined probability of death in a given population and in a given period. The other party is obliged to pay the product of the denomination with the actual value of this probability. Survival forward contracts work in a similar way, in which the multiplier is the probability of surviving the x + t age of the person at the age of x. In the case of the first page it is a real probability, while in the case of the second page it is a probability predetermined by the contract.

The last instrument of transferring longevity risk analyzed here are swap contracts. Longevity swaps are based on the exchange of payments between at least two parties. One party transfers funds at a predetermined amount that is constant throughout the period. The second one is obliged to pay tranches, the amount of which depends on the agreed rates of mortality or longevity. Therefore, the main difference between forward and swap contacts is the number of transfers - in the first case the settlement takes place once (at the end of the contract) in the second case they are cyclical settlements.

The longevity risk transfer market is relatively young, as a consequence products on it are not complex. The launch of the first such transactions has allowed the public to become aware of longevity risk while providing the opportunity to hedge against this risk. Due to imperfections in estimating life expectancy, further development of this market can be expected.

4. Conclusions

The analysis carried out in the study allowed to present the phenomenon of longevity and its impacts on the structure of society. The risk of longevity can have a significant impact on the functioning of their units. This applies in particular to the way general pension systems operate, but also to insurance companies, natural persons and pension funds. Currently, there are models that allow predicting the average life expectancy. An example of such a model is the Lee-Carter model, which has been analyzed and assessed for its effectiveness in this work. However, as the present study shows, models are not able to estimate the exact values. Hence, it increases the risk of longevity.

From the point of view of the social security system, which is mainly a pay-as-you-go system, underestimation of life expectancy may result in its inefficiency and the need for additional public funds. On the other hand, in the cases of other entities it may have a significant impact on their liquidity. The above situation indicates the need to develop opportunities to transfer longevity risk. Therefore, the study indicates tools and methods for longevity risk transfer. On the other hand, however, one should also remember about barriers to further development of this market. The risk of longevity has been described in the nomenclature for a relatively short time. At the same time, to a broader extent, it mainly concerns specialized entities whose work is largely based on actuarial research, which in turn boils down to the relatively greater competences of these entities in risk management.

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