MODAL LENGTH OF LIFE – METHODS OF CALCULATION

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Abstract

Prolonging of human life and aging population has been widely discussed topic in recent years, not only among demographers. Population aging is caused by decreasing mortality in higher ages. This is also accompanied by better medical care. That is why there is increasing talk about the changes that will have to be made to the social and health care system. This decision requires, among other things, the most accurate analysis of mortality.

Mortality can be analyzed by using several indicators. Life expectancy is the most widely used and the second one could be modal length of life. It is often used as an additional characteristic.

This article will use the modal length of life for this analysis. The Kannisto and Weibull models will be used for its calculation.
The aim is to demonstrate different ways of calculating of modal length and at the same time try to evaluate the suitability of their use. The contribution of this article is the derivation of an estimation function for the modal length of life calculation using Kannisto and Weibul model. The aim is also to propose own criterion for their suitability evaluation.

Key words: mortality, modal length of life, Kannisto and Weibull model

JEL Code: J10, J11, J19

Introduction

The population aging is still very often debated topic. Obviously, we will have to deal with its effects. That is why the reforms that will need to be done are increasingly being discussed (Langhamrová, Fiala, 2013).

Population aging is closely related to mortality. In order to get the best idea of future age structure of population, it is important to have the most accurate imagination of the population's mortality (Koschin, 1999).

Life expectancy is very often used to analyze mortality. However, there are the other indicators - modal or probable length of life. In this article, modal length of life will be used to describe mortality. After that obtained results will be evaluated according to proposed criterion.

1 Discussion

One way to model mortality is to use analytical functions. Many authors have already dealt with this topic. Logistic functions were used for modeling, for example, by Boleslawski and Tabeau in their article Comparing Theoretical Age Patterns of Mortality Beyond the Age of 80 (Boleslawski and Tabeau, 2001). The authors Burcin, Tesárková and Šídlo also deal with logistic functions in their article Nejpoužívanější metody vyrovnávání a extrapolace křivky úmrtnosti a jejich aplikace na českou populaci (Burcin et al., 2010). They also mention the possibility of using Weibull model. They show the other analytical functions in their article. Mortality modeling using analytical functions is also discussed by Thatcher, Kannistö and Vaupel in The Force of Mortality at Ages 80 to 120 (Thatcher et al., 1998). To select the most appropriate analytical function, it is necessary to have an idea of the development of mortality in older age. Koschin deals with this topic in his article Jak vysoká je intenzita úmrtnosti na konci lidského života? (Koschin, 1999).

Analytical functions are commonly used by authors to model mortality curve in ages 60 and higher. However, the use of analytical functions for modal length of life calculation is not so much discussed. Therefore, this article aims to find a procedure that could be used to calculate modal length of life and would include some of the existing models. The aim is to present another way of calculating modal length of life, which will be connected with function used in the adjustment and extrapolation of mortality curve and subsequent calculation of mortality tables. At the same time, the obtained results are evaluated using proposed criterion of the sum of weighted squares of deviations. At the end, the results of the evaluation criterion are confronted with the commonly used criterion - the adjusted multiple determination coefficient, which is obtained from the outputs of nonlinear regression.

2 Methodology

Several indicators can be used for the analyzing of mortality. One of the most often used is life expectancy. The other one can be modal length of life (Langhamrová, Arltová, 2014).

Life expectancy is a type of an average. That is why, it is good to use on more indicator for comarison – for example the modal length of life (Dotlačilová, 2019).

The modal length of life is a type of mode and it indicates the age at which most people die. For its calculations could be used analytical functions e.g. Weibull or Kannisto model (Garvrilov, Gavrilova, 2011, Thatcher et al., 1998 or Dotlačilová, 2016). Weibull and Kannisto model will be used like basic model which will be used for finding the estimating function. These functions will be used after that for calculating the values of modal length of life.

Weibull model

Modal length of life can be estimated like an age at which the density of death has got its maximum.

One of the aim of these article is to find estimating formula by using Weibull model (W).

For finding it, we use the condition (Fiala, 2002):

$$\mu'(x) - \mu^2(x) = 0 , \quad (1)$$

where $\mu(x)$ is the intensity of mortality, which is modelled by Weibull model (Thatcher et al., 1998).

Weibull model would be substituted into expression (1) behind $\mu(x)$ (Boleslawski, Tabeau, 2001 or Burcin et al., 2010):

$$\mu(x) = b \cdot x^a , \quad (2)$$

where a and b are unknown parameters and x is the age.

The first derivative of the intensity of mortality is made like: $\mu'(x) = a \cdot b \cdot x^{a-1}$.

The second step is finding a formula for the second power of the intensity of mortality

$\mu^2(x) = b^2 \cdot x^{2a}$.

At the end we substitute it into the condition (1).

The estimating formula used for the calculation the modal length of life (Dotlačilová, 2020):

$$x = \left(\frac{a}{b}\right)^{\frac{1}{a+1}} ,$$

where a and b are estimated parameters from Weibull model (for more detailed derivation procedure see Dotlačilová, 2019).

Kannisto model

The second aim is to show procedure which could be used for finding the estimating formula from Kannisto model (K). One of the reasons for choosing the Kannisto model is that it is a logistic function. These are probably used most often to model mortality. Another reason is its use in calculating mortality tables in the Czech Republic. It is used by the Czech Statistical Office for its calculations (Czech Statistical Office, 2019).

The condition (1) will be reused for finding the estimation function.

The intensity of mortality will be represented by the Kannisto model (Kannisto et al, 1994 or Thatcher et al. 1998):

$$\mu_x = \frac{ae^{b.x}}{1+ae^{b.x}} \,, \tag{3}$$

where a and b are unknown parameters of the model, x is the age.

To simplify the calculation, substitution will be performed first:

$$\varphi = ae^{b.x}$$

After substitution we get:

$$\mu_x = \frac{\varphi}{1+\varphi} = 1-(1+\varphi)^{-1} .$$

In deriving the intensity of mortality, we come to an expression:

$$\mu_x' = \frac{\varphi'}{(1+\varphi)^2} .$$

We can write the square of the intensity of mortality in form:

$$\mu_x^2 = \frac{\varphi^2}{(1+\varphi)^2} .$$

After substituting into (1) we get to the expression:

$$\varphi' - \varphi^2 = 0 .$$

In the next step we return to the original substitution.

The resulting derived formula is:

$$x = \frac{\ln b - \ln a}{b} \,,$$

where *a, b* are unknown parameters from Kannisto model, *x* is the age.

For more detailed procedure see Dotlačilová, 2020.

Another point of this paper is the application of the test criterion which could be used for the evaluation of obtained results. This give us information about suitability of concrete model. After that it give us information wich from these models coud be better for calculating of modal length of life.

Evaluation of expected results

The other aim of this paper is to propose own criterion which could be used for the evaluation of obtained results. Here it could be used weighted squares of deviations (*WSD*) – minimization criterion. As weight will be used exposure to risk.

$$WSD = \frac{S_{t,x} + S_{t+1,x}}{2} \cdot (m_{t,x} - m_{t,x}^{(modelled)})^2 , \tag{4}$$

where $m_{t,x}^{(modelled)}$ is modelled intesity of mortality according to Kannisto (K) or Weibull model (W), $S_{t,x}$ is number of living at the beginning of year t and $S_{t+1,x}$ is number of living at the beginning of year t + 1 (or number of living at the end of year t).

Finally, the sum of *WSD* has to be calculated $\sum_{60}^{90} WSD$.

Sum of WSD is calculated in age interval <60; 90>. The same age interval was used for the estimation of unknown parameters for Kannisto and Weibull model. This criterion could be used for evaluation of analytical function suitability. Information about the analytical function suitability can also be used to select an estimation function to calculate modal length of life.

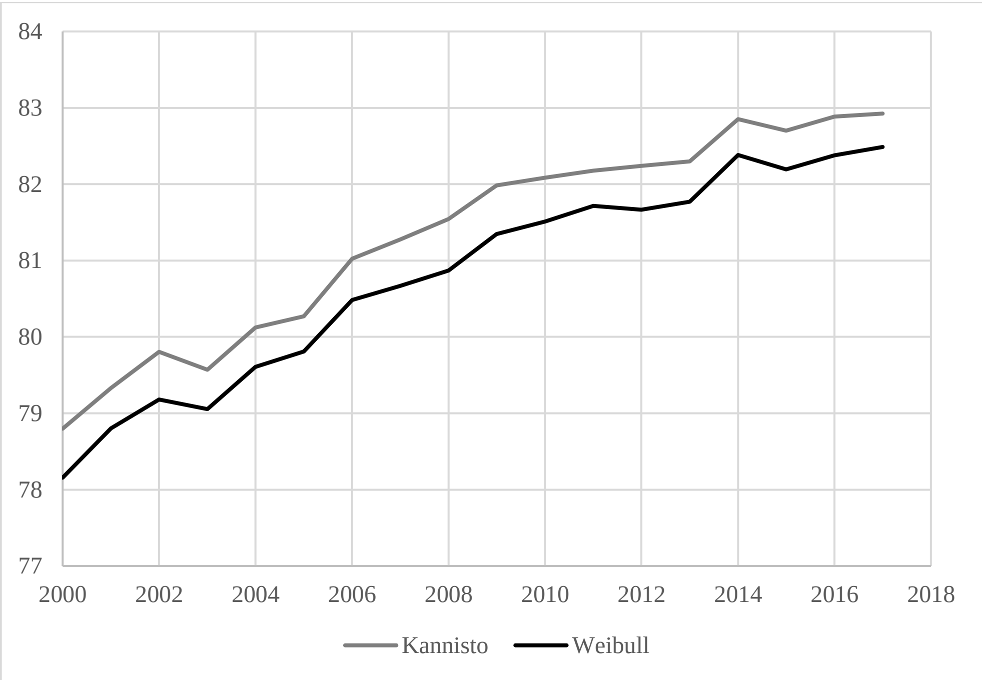
As an additional evaluation criterion will be used adjusted multiple determination coefficient (maximization criterion). These values will be used for comparison with values of proposed criterion. They are published in Attachment 5 and 6.

3 Results

The following figure shows the development of modal length of life obtained by Kannisto and Weibull models. It shows that Kannisto provides higher values. Which is consistent with the nature of this function. It is also clear that both functions give a similar development in modal length of life. The differences between these two results are mainly due to the differences in selected functions.

When comparing these two estimation functions, we find that the values of the difference range from 0.44 to 0.67. It can also be said that at the end of the observed period the difference decreased slightly (compared to the beginning of the observed period). To find out if the differences will continue to decrease, it is necessary to monitor an even longer time period.

Fig. 1: Modal length of life - males in the Czech Republic



Source: author’s calculations, data Eurostat 2019

Tab. 1: Values of sum of Weighted Squared Deviations – males in the Czech Republic

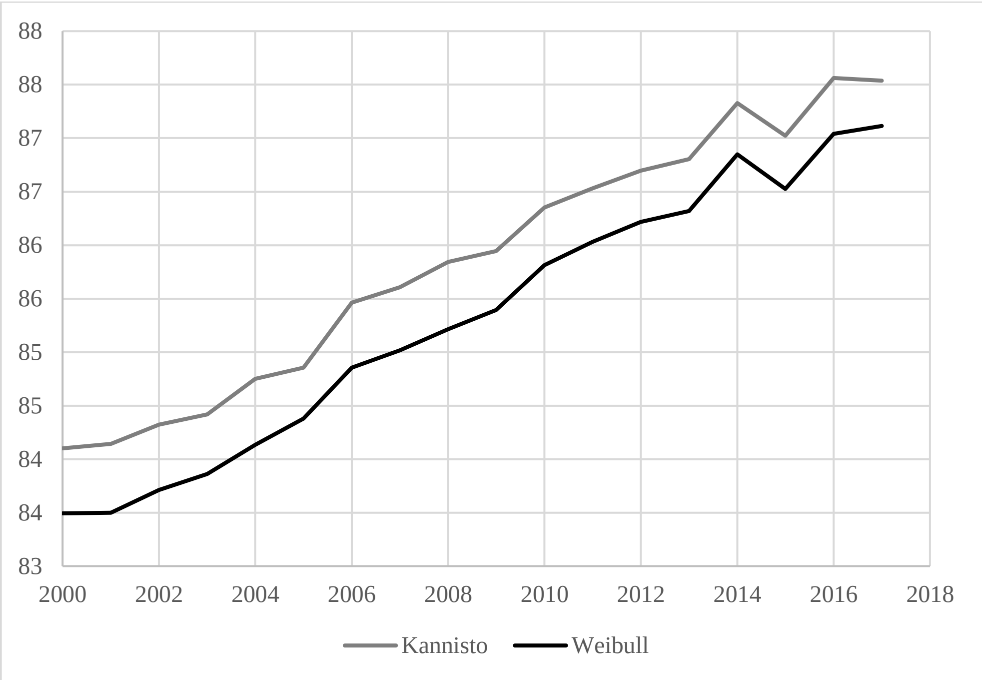
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
sum of wsd (W)	20,3	19,6	31,1	26,0	26,0	25,8	33,2	34,0	36,4	51,8
sum of wsd (K)	11,2	9,4	19,8	13,1	14,2	13,4	19,1	21,4	23,4	38,3
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
sum of wsd (W)	47,3	46,2	43,6	44,8	48,1	49,7	38,7	42,9		
sum of wsd (K)	32,6	26,4	27,0	26,7	28,4	31,4	20,9	20,7		

Source: author’s calculations

The first table (Table 1) shows test criterion values used to evaluate the obtained results. From its values we can conclude that Kannisto model is more suitable for modeling of mortality in males‘ population in the Czech Republic during this period. Obtained values of the weighted squared deviations are lower for Kannisto model than for Weibull model. This criterion could be also used for selection of better way for modal length of life calculation. It means that estimation function from Kannisto model give us more accurate results for modal length of life.

The following figure shows the development of females' modal length of life. Here, the results obtained from the derived estimation functions from Kannisto and Weibull models are compared too.

Fig. 2: Modal length of life - females in the Czech Republic



Source: author’s calculations, data Eurostat 2019

From the development of modal length of life it is possible to observe similar trend like in males‘ population. The estimation function obtained from Kannisto model give us higher values of modal length of life. We could also observe that both functions have a similar trend. Obtaining differences between them are thus caused by a different character of function.

If we compare these two estimation functions, we find out that the values of the difference range from 0.42 to 0.65. It can also be said that at the end of the observed period the difference decreased slightly (compared with the beginning of the observed period). To find out if the differences will continue to decrease, it is necessary to monitor an even longer time period.

Tab. 2: Values of sum of Weighted Squared Deviations – females in the Czech Republic

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
sum of wsd (W)	25,3	21,5	24,3	22,7	22,8	23,1	26,1	26,9	28,5	29,2
sum of wsd (K)	7,9	5,4	9,9	8,5	6,9	7,9	8,7	10,4	11,3	9,2

	2010	2011	2012	2013	2014	2015	2016	2017
sum of wsd (W)	29,2	28,7	30,6	30,5	29,7	31,4	28,5	36,3
sum of wsd (K)	11,0	8,4	11,1	11,9	10,5	11,7	11,9	14,9

Source: author's calculations, data Eurostat

Table 2 (Tab. 2) shows values obtained for the assessment criterion of sum of weighted squared deviations for females‘ population in the Czech Republic. Here also Kannisto model returns lower values of the criterion used. It therefore seems to be a more suitable function for modeling of mortality for females in the Czech Republic. It is therefore likely to be more suitable for modal length of life modeling. Formula obtain from Kannisto model could give us more accurate values of modal length of life. But i tis very important to say that selection of suitable calculation is depend on analyzed population.

Conclusion

Kannisto and Weibull models were used to model modal length of life. The estimation functions were derived using both Kannisto and Weibull models.

The obtained results show us that Kannisto model provides higher values of modal length of life (both for males‘ and for females‘ population). Interestingly, both estimation functions show a similar trend in values of modal length of life. It can therefore be said that the differences in results are mainly due to the different character of the functions used. For a more detailed analysis, the differences among obtained values for modal length of life according used methods. Here we could say that diffrences obtained are in the interval 0.44 to 0.67 (for males) and the second interval 0.42 to 0.65 (for females). It is also interesting that the differences are declining slightly to the present. So it means that it might be interesting to examine a longer time series.

The important thing is that Kannisto model is used in mortality tables in the Czech Republic. According to test criterion Kannisto model give us more accurate values of modal length of life. So the new formula obtained from Kannisto model could be used for its calculation.

An important part was also the design of a suitable evaluation criterion. The sum of weighted squared deviations was used. The obtained results show us that Kannisto model is more appropriate in this period. Thus, Kannisto model is likely to provide more accurate values of modal length of life relative to the population analyzed. The same conclusions are reached by using the well-known evaluation criterion adjusted multiple determination coefficient. Multiple determination criterion was used like additional evaluation criterion. According to these results we could conclude that weighted squared deviations could be used for evaluation.

References

BOLESLAWSKI, L., TABEAU, E. Comparing Theoretical Age Patterns of Mortality Beyond the Age of 80. In: Tabeau, E., van den Berg J., A. and Heathcote, Ch. (eds.) 2001. *Forecasting Mortality in Developed Countries: Insights from a Statistical, Demographic and Epidemiological Perspective*. s. 127 – 155. ISBN 978-0-7923-6833-5.

BURCIN, B., TESÁRKOVÁ, K., ŠÍDLO, L., Nejpoužívanější metody vyrovnávání a extrapolace křivky úmrtnosti a jejich aplikace na českou populaci. *Demografie* 52, 2010, pp. 77 – 89.

CZECH STATISTICAL OFFICE. https://www.czso.cz/csu/czso/umrtnostni-tabulky-metodika [cit. 23.11.2019]

DOTLAČILOVÁ, P. Comparison of selected methodologies used for smoothing and extrapolation of mortality curve. In: *The 10th International Days of Statistics and Economics (MSED 2016)* [online]. Praha, 08.09.2016 – 10.09.2016. Slaný: Melandrium, 2016, s. 382–399. ISBN 978-80-87990-10-0. Available from: https://msed.vse.cz/msed_2016/article/234-Dotlacilova-Petra-paper.pdf.

DOTLAČILOVÁ, P. Methods used for the calculations of normal length of life. In: *Aplimat 2019* [flash disk]. Bratislava, 05.02.2019 – 07.02.2019. Bratislava: Publishing house SPEKTRUM STU, 2019, s. 261–265. ISBN 978-80-227-4884-1.

DOTLAČILOVÁ, Petra. Modal length of life – calculation using Kannisto and Weibull models. In: *Aplimat* [flash disk]. Bratislava, 04.02.2020 – 06.02.2020. Bratislava: Publishing House Spektrum STU, 2020, s. 368–373. ISBN 978-80-227-4983-1.

EUROSTAT. https://ec.europa.eu/eurostat/data/database [cit. 1.11.2019]

FIALA, T.. *Výpočty aktuárské demografie v tabulkovém procesoru*, 1. vyd. Praha: Oeconomica, 2002. 218 s. ISBN 80-245-0446-4.

GAVRILOV, L., A. & GAVRILOVA, N., S. (2011). "Mortality measurement at advanced ages: a study of social security administration death master file." *North American actuarial journal* 15 (3): 432 – 447.

KANNISTO, V., LAURITSEN, J., THATCHER, A., R., VAUPEL, J., W. Reductions in mortality at advanced ages - several decades of evidence from 27 countries. *Population and development review*, 1994, vol. 20, no. 4, pp. 793-810.

KOSCHIN, F. "Jak vysoká je intenzita úmrtnosti na konci lidského života?" *Demografie* 41 (2), 1999: 105 – 109.

LANGHAMROVÁ, Ja., ARLTOVÁ, M. Life Expectancy and Modal Age at Death in the Czech Republic in 1920-2012. In: *Mathematical Methods in Economics (MME2014)* [CD]. Olomouc, 10.09.2014 – 12.09.2014. Olomouc: Palacký University in Olomouc, 2014, s. 572–577. ISBN 978-80-244-4208-2. CD ISBN 978-80-244-4209-9.

LANGHAMROVÁ, Ji., FIALA, T. Ageing of Population of Productive Age in the Czech Republic. In: *International Days of Statistics and Economics* [online]. Prague, 19.09.2013 – 21.09.2013. Slaný: Melandrium, 2013, s. 748–757. 1624 s. ISBN 978-80-86175-87-4. Available from: http://msed.vse.cz/files/2013/105-Langhamrova-Jitka-paper.pdf.

THATCHER, R., A., KANISTÖ, V. & VAUPEL, J., W., *The Force of Mortality at Ages 80 to 120*. Odense University Press, 1998. ISBN 87-7838-381-1.

Attachment 1 Parameters and p-value - Kannisto – males

	2000		**2001**		**2002**		**2003**		**2004**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	2,85E-05	0,0000	2,26E-05	0,0000	1,55E-05	0,0000	1,76E-05	0,0000	1,65E-05	0,0000
parameter b	0,104105	0,0000	0,106634	0,0000	0,111254	0,0000	0,109826	0,0000	0,109878	0,0000
	2005		**2006**		**2007**		**2008**		**2009**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	1,58E-05	0,0000	1,13E-05	0,0000	1,32E-05	0,0000	0,000012	0,0000	6,54E-06	0,0000
parameter b	0,11026	0,0000	0,113754	0,0000	0,111213	0,0000	0,112118	0,0000	0,119717	0,0000
	2010		**2011**		**2012**		**2013**		**2014**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	7,47E-06	0,0000	8,96E-06	0,0000	8,87E-06	0,0000	8,87E-06	0,0000	8,24E-06	0,0000
parameter b	0,117747	0,0000	0,115128	0,0000	0,115172	0,0000	0,115172	0,0000	0,115214	0,0000
	2015		**2016**		**2017**					
	value	**p-value**	**value**	**p-value**	**value**	**p-value**				
paraneter a	7,32E-06	0,0000	9,94E-06	0,0000	9,03E-06	0,0000				
parameter b	0,117046	0,0000	0,112627	0,0000	0,113866	0,0000				

Source: author's calculations, data Eurostat

Attachment 2 Parameters and p-value - Weibull – males

	2000		2001		2002		2003		2004	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	7,309913	0,0000	7,586462	0,0000	7,877571	0,0000	7,845133	0,0000	7,910116	0,0000
parameter b	1,36E-15	0,0000	3,94E-16	0,0000	1,10E-16	0,0000	1,28E-16	0,0000	9,13E-17	0,0000
	2005		**2006**		**2007**		**2008**		**2009**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	7,960002	0,0000	8,204516	0,0000	8,028423	0,0000	8,066043	0,0000	8,582119	0,0000
parameter b	7,22E-17	0,0000	2,36E-17	0,0000	4,90E-17	0,0000	4,08E-17	0,0000	4,25E-18	0,0000
	2010		**2011**		**2012**		**2013**		**2014**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	8,539244	0,0000	8,497923	0,0000	8,400919	0,0000	8,406407	0,0000	8,601109	0,0000
parameter b	5,01E-18	0,0000	5,84E-18	0,0000	8,90E-18	0,0000	8,59E-18	0,0000	3,47E-18	0,0000
	2015		**2016**		**2017**					
	value	**p-value**	**value**	**p-value**	**value**	**p-value**				
paraneter a	8,636289	0,0000	8,389367	0,0000	8,557224	0,0000				
parameter b	3,05E-18	0,0000	8,62E-18	0,0000	4,14E-18	0,0000				

Source: author's calculations, data Eurostat

Attachment 3 Parameters and p-value - Kannisto – females

	2000		2001		2002		2003		2004	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	2,33E-06	0,0000	2,63E-06	0,0000	2,32E-06	0,0000	1,39E-06	0,0000	1,80E-06	0,0000
parameter b	0,129952	0,0000	0,128294	0,0000	0,129632	0,0000	0,136133	0,0000	0,132202	0,0000
	2005		**2006**		**2007**		**2008**		**2009**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	1,58E-06	0,0000	1,27E-06	0,0000	1,18E-06	0,0000	1,09E-06	0,0000	7,81E-07	0,0000
parameter b	0,133711	0,0000	0,135466	0,0000	0,136156	0,0000	0,13676	0,0000	0,140817	0,0000
	2010		**2011**		**2012**		**2013**		**2014**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	5,33E-07	0,0000	6,15E-07	0,0000	4,67E-07	0,0000	4,97E-07	0,0000	4,40E-07	0,0000
parameter b	0,144909	0,0000	0,142785	0,0000	0,145939	0,0000	0,144965	0,0000	0,145535	0,0000
	2015		**2016**		**2017**					
	value	**p-value**	**value**	**p-value**	**value**	**p-value**				
paraneter a	4,13E-07	0,0000	3,89E-07	0,0000	3,21E-07	0,0000				
parameter b	0,146879	0,0000	0,146637	0,0000	0,149062	0,0000				

Source: author's calculations, data Eurostat 2019

Attachment 4 Parameters and p-value - Weibull – females

	2000		2001		2002		2003		2004	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	9,49E+00	0,0000	9,37E+00	0,0000	9,48E+00	0,0000	9,90E+00	0,0000	9,69E+00	0,0000

parameter b	6,48E-20	0,0000	1,1E-19	0,0000	6,68E-20	0,0000	1,09E-20	0,0000	2,6E-20	0,0000
	2005		**2006**		**2007**		**2008**		**2009**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	9,96E+00	0,0000	9,98E+00	0,0000	1,00E+01	0,0000	1,00E+01	0,0000	1,04E+01	0,0000
parameter b	7,74E-21	0,0000	6,66E-21	0,0000	5,8E-21	0,0000	5,26E-21	0,0000	8,29E-22	0,0000
	2010		**2011**		**2012**		**2013**		**2014**	
	value	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**	**value**	**p-value**
paraneter a	1,07E+01	0,0000	1,07E+01	0,0000	1,10E+01	0,0000	1,09E+01	0,0000	1,10E+01	0,0000
parameter b	2,08E-22	0,0000	2,22E-22	0,0000	7,08E-23	0,0000	1,12E-22	0,0000	5,17E-23	0,0000
	2015		**2016**		**2017**					
	value	**p-value**	**value**	**p-value**	**value**	**p-value**				
paraneter a	1,11E+01	0,0000	1,11E+01	0,0000	1,14E+01	0,0000				
parameter b	4,14E-23	0,0000	4,41E-23	0,0000	8,1E-24	0,0000				

Source: author's calculations, data Eurostat 2019

Attachment 5 Values of adjusted multiple determination coefficient – males in the Czech Republic

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
R^2 adj. Weibull	0,9995	0,9992	0,9988	0,9990	0,9990	0,9991	0,9988	0,9988	0,9987	0,9978
R^2 adj. Kannisto	0,9995	0,9993	0,9987	0,9992	0,9992	0,9994	0,9990	0,9991	0,9989	0,9979
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
R^2 adj. Weibull	0,9983	0,9980	0,9983	0,9978	0,9975	0,9974	0,9979	0,9980		
R^2 adj. Kannisto	0,9984	0,9985	0,9985	0,9980	0,9970	0,9972	0,9974	0,9971		

Attachment 6 Values of adjusted multiple determination coefficient – females in the Czech Republic

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
R^2 adj. Weibull	0,9998	0,9999	0,9997	0,9998	0,9998	0,9997	0,9996	0,9994	0,9992	0,9998
R^2 adj. Kannisto	0,9998	0,9999	0,9996	0,9998	0,9998	0,9997	0,9997	0,9995	0,9995	0,9999
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**		
R^2 adj. Weibull	0,9997	0,9997	0,9997	0,9996	0,9996	0,9996	0,9994	0,9992		
R^2 adj. Kannisto	0,9998	0,9998	0,9997	0,9997	0,9996	0,9996	0,9995	0,9993		

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