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EVALUATING THE PERFORMANCE OF VARIANTS OF THE LEE-CARTER METHOD FOR MORTALITY FORECASTING IN THE POPULATION PROJECTION OF THE CZECH REPUBLIC FROM THE CZECH STATISTICAL OFFICE 2023–2100

David Morávek[1)]

Abstract

This article discusses the use of the Lee-Carter model, one of the most widely used methods for mortality forecasting. It also discusses its modified versions, namely the cohort and coherent variants, which were developed to improve the forecast accuracy of the model. This article compares them in terms of their ability to predict long-term mortality trends in the case of the Czech Republic. The projection of mortality was based on historical data on age-specific mortality rates from 1980 to 2019 for the so-called European mortality potential, which was constructed from the lowest observed mortality rates in developed European countries. On the basis of the results, the coherent Lee-Carter model was selected as the most appropriate model, which is described by the literature as more robust and suitable for projections with a long-term horizon.

Keywords: mortality forecasting, Lee-Carter method, European mortality potential, Czech Republic
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INTRODUCTION

Rising life expectancy beyond previously established limits underlines the continuing importance of mortality forecasting (*Booth – Tickle*, 2008). The Lee-Carter stochastic model, introduced in 1992 by Ronald Lee and Lawrence Carter for mortality projections in the US, marked a breakthrough in mortality forecasting. The Lee-Carter model provided the basis for the development of other

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mortality models. Its framework has inspired many subsequent studies and models that have extended and improved upon the original approach. The Lee-Carter model remains relevant and important today.

This article focuses on an evaluation of the model with two of its main variants – a cohort variant based on the Booth-Maindonald-Smith methodology (*Booth et al.*, 2002) and a coherent variant based on the Li-Lee methodology (*Li – Lee*, 2005) – and their application to mortality data for the Czech Republic. The cohort variant of the model was developed to improve the accuracy of forecasts by capturing both short- and long-term mortality trends. The coherent variant of the model was developed for multi-population mortality projection to capture common trends in different populations, e.g. between sexes or countries, assuming convergence of mortality rates. The aim of this article was to assess which of the considered Lee-Carter models provides the most reliable long-term mortality projection, which was produced as part of the Population Projection of the Czech Republic in 2023 by the Czech Statistical Office.

The article is divided into several sections. First, the methodology of mortality projection within the population projection of the Czech Republic prepared by the Czech Statistical Office is briefly described. The next section of the article is devoted to the description of the Lee-Carter method, including its considered modified variants. Subsequently, the forecast accuracy of the projections is evaluated and, based on this analysis, the most appropriate model is selected. The last part of the article presents the results and compares them with the other official forecasts.

PROJECTION METHODOLOGY

In 2023, the Czech Statistical Office published the Population Projection of the Czech Republic up to 2100 (*CZSO*, 2023a). The basis for estimating the future development in mortality rates was the introduction of the so-called European mortality potential (hereafter referred to as the potential) as a set of the lowest specific mortality rates by age and sex achieved between 1980 and 2019 in 17 demographically developed countries. The period analysed starts in 1980, when mortality in Western Europe was already relatively stable, and ends in 2019 so that long-term trends are not distorted by the effects of the pandemic (*Hulíková Tesárková et al.*, 2024). The population projection for the Czech Republic was prepared in three basic variants: medium, low, and high. The medium variant represents the most likely scenario of future population development, while the low and high variants place certain limits on the expected development of the population and its age distribution.

In order to eliminate random fluctuations in mortality rates and to extrapolate to the age of 110, the age-specific mortality rates of the potential were smoothed and modelled using the methodology for calculating life tables by the Czech Statistical Office (*CZSO*, 2024). The calculation of the potential life tables required data on the number of deaths and exposed population. The number of deaths was calculated by multiplying the observed age-specific potential mortality rates (up to 100+) by the population of the Czech Republic as at 1 July 2019. These standardized numbers of deaths and the population of the Czech Republic in 2019 were used as input data for the calculation (and smoothing) of the life tables. The mortality rates were smoothed using the method of generalized adaptive models combined with the so-called P-splines, sometimes referred to as the P-GAM method (*Eilers – Marx*, 1996). At the oldest ages, the model chosen was based on a logistic curve that takes into accounts the slowing pace of mortality decline with age. Specifically, this is the model first used by Kannisto (*Thatcher et al.*, 1998).

The mortality projection for the Czech Republic was based on the potential mortality development from the lowest observed mortality rates in developed European countries by age and sex, using the Lee-Carter method (*Lee – Carter*, 1992). Specifically, a coherent version of the Lee-Carter model by Li and Lee (*Li – Lee*, 2005), which is considered to be more robust and particularly suitable for projections with a long-term horizon, was chosen for the mortality forecast. The coherent version of the Lee-Carter model ensures the coherence of mortality trends between males and females. It is assumed that the differences between male and female mortality rates will not change significantly in the future and that mortality trends will be similar for both sexes. The input data used to estimate the parameters of the Lee-Carter model were potential mortality rates by age (up to 110+) and sex for the period 1980–2019.

In order to assess the differences between the Czech mortality rates and the potential, relative differences represented by excess mortality indices have been chosen, which give the age-specific mortality rates for the Czech Republic and the potential separately for each sex and each calendar year. These indices then express how many times the specific mortality rate of the Czech Republic is higher than the potential. The course of the indices as a function of age was analysed using joint-point regression and a function was proposed to model the course of the indices across ages and calendar years. The medium variant of the mortality forecast was based on the assumption that the level of the excess mortality indices will be kept constant, which is based on the average level in the period 2015–2019. Despite the constant level of the indices, the difference in life expectancy between the Czech Republic and the potential decreases, which is caused by a change in the mortality pattern of the potential and a shift in mortality towards age groups in which the level of the index is lower. In contrast, the low variant assumes a constant difference in life expectancy between the Czech Republic and the potential, as it was in the base year of the projection of 2023. The high variant assumes that the specific mortality rates of the Czech Republic will converge towards the potential, so that convergence leads to a higher life expectancy at birth than in the medium variant. A more detailed explanation of the excess mortality indices can be found in *Hulíková Tesárková et al.* (2024).

THE LEE-CARTER METHOD

One of the most commonly used mortality forecasting models is the Lee-Carter model (*Lee – Carter*, 1992). This model, which is based on the analysis of historical mortality data, allows long-term trends in age-specific mortality rates to be captured and extrapolated. Lee and Carter first used this model in 1992 to project US mortality rates from 1990 to 2065. Since then, the model has been used in many demographic studies. According to *Basellini et al.* (2023), the success and widespread use of the model is mainly due to its simplicity and performance. The advantage of the model is its stochastic nature, which allows confidence intervals to be calculated. In addition, the approach is purely extrapolative, i.e. does not require any subjective expert judgement other than the choice of the length of the input data period to estimate the model parameters.

The basic idea of the Lee-Carter model (*Lee – Carter*, 1992) is to decompose the logarithm of the mortality rate $\ln m_{x,t}$ at age x and time t into age- and time-specific factors (or parameters) as follows:

$$\ln\left(m_{x,t}\right) = \alpha_x + \beta_x \kappa_t + \varepsilon_{x,t},$$

where α_x is the average of the observed logarithms of the mortality rates at age x, $\beta_x \kappa_t$ is the coefficient of relative change in mortality at age x (the parameter of β_x) and the time coefficient κ_t at time t, $\varepsilon_{x,t}$ is the error term of a random event at age x and time t.

It is not possible to use an ordinary regression model to estimate the model parameters because the equation in its basic form has an infinite number of solutions. The Singular Value Decomposition (SVD) method is used to find the beta and kappa parameters. To predict the time-varying coefficient κ_t at time t, Lee and Carter in 1992 used a random walk model with drift, which assumes that the parameter decreases in a constant linear. Therefore, each age-specific mortality rate is assumed to decrease with its constant exponential, which is determined by the individual beta parameter. The model has the following two constraints, which imply that the coefficient α_x is equal to the average of the logarithms of the mortality rates over time (*Lee – Carter*, 1992):

$$\sum_x \beta_x = 1 \text{ and } \sum_t \kappa_t = 0.$$

Estimates of age- and time-specific factors for the Czech Republic and the European mortality potential based on the Lee-Carter model for 1980–2019 are shown in Figure 1 for males and females.

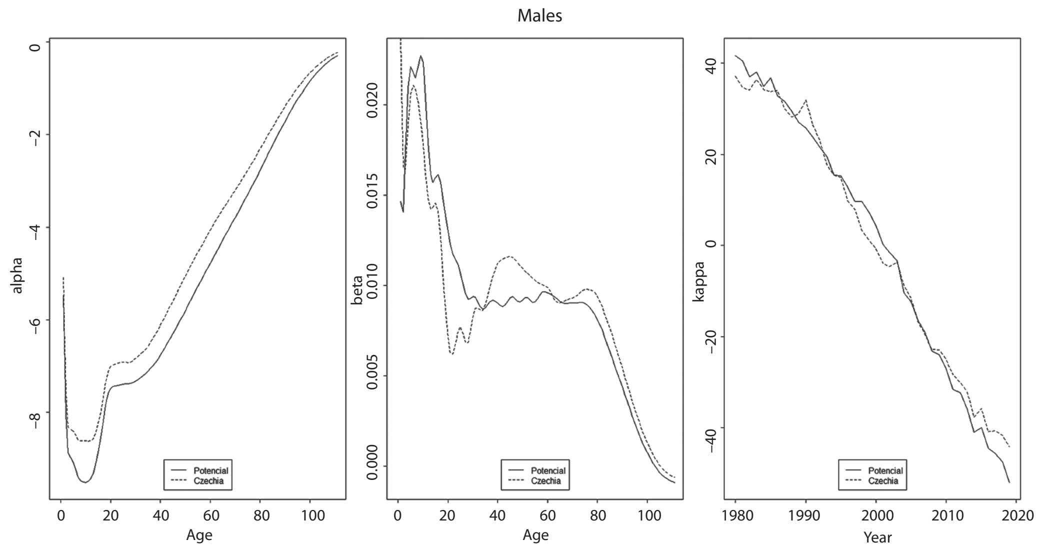
The alpha expresses the average dependence of mortality on age. For males, it initially decreases with age until about the age of 10, when mortality starts to increase again. An accelerated increase in mortality can be observed up to the age about 20, followed by a period of stagnation up to the age of about 30. In males, the mortality is more pronounced during adolescence and young adulthood, which is reflected in higher values of the alpha compared to females for these age groups. For females, the increase is less pronounced and the average mortality rate decreases with age earlier than for males. In the literature, this period of this increased mortality is referred to as the "adult mortality hump" and can be understood as excess mortality above the prevailing senescent mortality level (*Remund et al.*, 2017). After this period, mortality increases almost continuously with age and the increase slows down towards the end of life.

Comparing the average age dependency of the Czech male mortality rate with the potential mortality rate, the potential mortality rate initially falls faster at younger ages (up to 10 years). At later ages, mortality follows a similar pattern, with potential (from about age 90) declining later than Czech mortality (from about age 80). The average age dependency of potential mortality is lower than that in the Czech Republic at all ages, and this is true for both males and females.

The beta expresses the change in mortality over time at a given age compared to other age groups. The beta shows a very similar pattern for the potential and Czech mortality, both for males and females. The potential mortality for males has a slightly higher variability than for the Czech Republic, while the opposite is true for females. The youngest age groups contribute most to the change in mortality over time. With increasing age, the influence of age groups on the change in mortality gradually decreases and becomes almost constant. Later on, however, the influence on the change in mortality increases again for some age groups and decreases from around age 80.

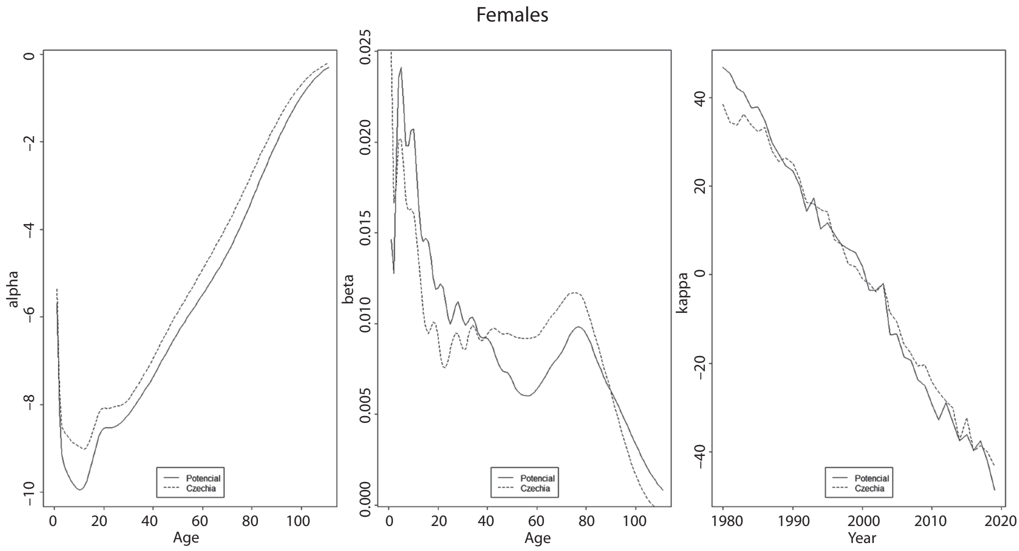
The kappa reflects the level of mortality over time for all age groups. Over the period 1980–2019, the overall level of mortality showed a decreasing trend. The potential mortality rate for males decreased faster over time than in the Czech Republic. Similarly, the mortality for females in the Czech Republic decreased less, indicating a slower improvement in mortality than in the potential mortality. Overall, the decline in mortality in the Czech Republic has been more stable and gradual in the Czech Republic than in the potential mortality. The development of mortality over time is more variable for females than males, both for the Czech Republic and for the potential mortality.

Figure 1 **Estimates of age- and time-specific factors of the Lee-Carter model, Czech Republic and European mortality potential, 1980–2019**



Note: From left – alpha, beta, kappa parameters of the Lee-Carter model.
Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

Figure 1 (continuation)



Note: From left – alpha, beta, kappa parameters of the Lee-Carter model.
Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

MODIFICATIONS OF THE LEE-CARTER METHOD

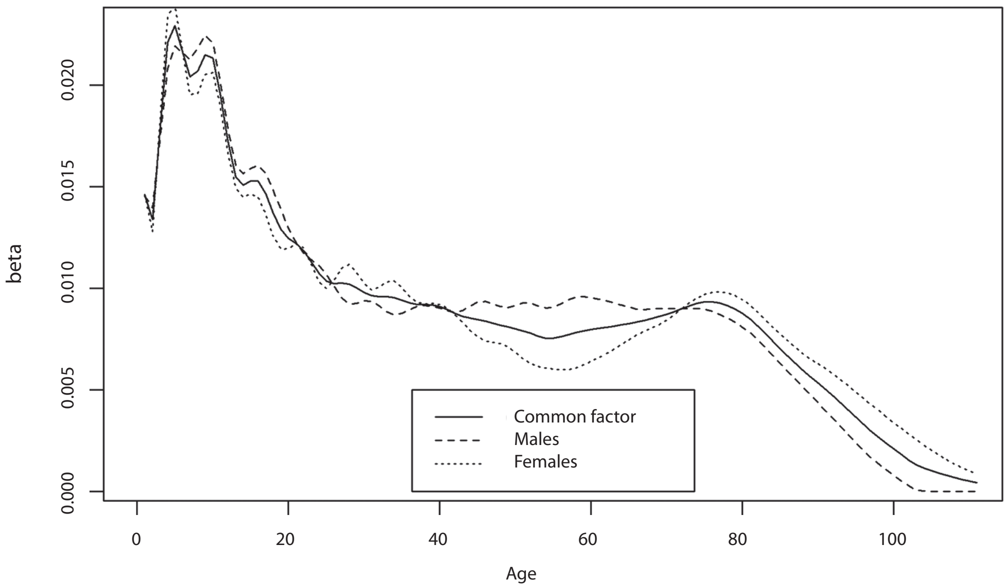
In some cases, the Lee-Carter model is not always be appropriate for given historical data (*Renshaw – Haberman*, 2003b; *Cairns et al.*, 2006). A major shortcoming of the model is considered to be "the lack of age coherence in forecasting", which means that "forecasts produced by the Lee-Carter model may differ infinitely in the long run and are not biologically reasonable" (*Shi*, 2024; *Chang – Shi*, 2023). Due to the shortcomings of the Lee-Carter model, several modified versions of the model were later developed. These modifications were primarily designed to increase the accuracy and flexibility of the model with respect to different specific needs and applications (*Renshaw – Haberman*, 2003a; *Booth et al.*, 2002). In particular, cohort and coherent versions of the original Lee-Carter model have been developed. For a comparison of different approaches to mortality forecasting, discussing the advantages and disadvantages of the Lee-Carter model, see for example *Basellini et al.* (2023) or *Lee – Miller* (2001).

The cohort version of the Lee-Carter model was introduced by Booth-Maindonald-Smith (BMS) with several improvements (*Booth et al.*, 2005), using the same formal model notation as in the original model. The first is the selection of the fit period based on statistical goodness-of-fit criteria assuming linearity of the time-varying parameter . The second improvement is the adjustment of κ_t, which involves fitting to the age distribution of deaths rather than the total number of deaths using the Poisson distribution to model the death process and the deviance statistic to measure goodness of fit. Finally, the jump-off rates are taken as the fitted rates used in the adjustment described above.

A further extension of the Lee-Carter model is the Li-Lee (LL) coherent variant. This variant of the model assumes that mortality patterns for similar populations will not differ much and that differences in mortality between populations are unlikely to increase in the long term (*Li – Lee*, 2005). That is, this variant focuses on keeping coherence between mortality projections for different populations (e.g. between males and females or between countries). The coherent Lee-Carter model according to *Li – Lee* (2005) is as follows:

$$\ln m_{x,t}^{(i)} = \alpha_x^{(i)} + \beta_x^{(i)}\kappa_t^{(i)} + b_x k_t + \varepsilon_{x,t}^{(i)},$$

Figure 2 **Estimates of the common factor, male and female values of beta parameters for the coherent Lee Carter model for the European mortality potential, 1980–2019**



Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

where $\alpha_x^{(i)}$ is the average of the observed logarithms of the mortality rates for population *i* at age *x*, $\beta_x^{(i)}\kappa_t^{(i)}$ is the coefficient of relative change in mortality for population *i* at age *x* (the parameter β_x) and the time coefficient κ_t at time *t*, $b_x k_t$, describes the change in mortality over time (the common factor for each population in the group), $\varepsilon_{x,t}^{(i)}$, is the error term of a random event for population *i* at age *x* and time *t*.

In addition, it is possible to calculate, the ultimate b_x^u as defined in *Li et al.* (2013). Based on empirical evidence and theoretical discussion, the ultimate is obtained by assuming a decline in mortality that decelerates at younger ages and accelerates at older ages.

In this article, using the coherent Lee-Carter model, the estimated beta parameters for male and female mortality rates were assumed to have the same value, which is the average of the age-specific beta parameters (see Figure 2). The estimated alpha and kappa parameters were based on the original Lee-Carter model (*Lee – Carter*, 1992) as described above for the European mortality potential for the period of 1980–2019 (Figure 1).

FORECAST ACCURACY

In order to assess the forecast accuracy of the different variants of the Lee-Carter model, the error measures averaged across ages and calendar years according to the variants of the Lee-Carter model were calculated for the European male and female mortality potentials for the period 1980–2019 (Table 1).

Based on the error averages across ages MPE (Mean Percentage Error) and MAPE (Mean Absolute Percentage Error), the coherent variant of the Lee-Carter model appears to be the most appropriate for mortality forecasting. The MPE indicates that the model has the lowest systematic forecast error. This is similar to the MAPE indicator, which measures the average absolute size of the percentage errors.

In the case of averages across years, the coherent version of the Lee-Carter model has the lowest error values for the Integrated Percentage Error (IPE), which reflects the percentage error integrated across all age groups. The IAPE (Integrated Absolute Percentage Error) indicator shows the lowest values for males in the original Lee-Carter model. For females, however, the values are comparable between the models, with the lowest values for the coherent Lee-Carter model.

Table 1 **Error measures of forecast accuracy averaged across years and ages according to variants of the Lee-Carter model for European male and female mortality potential, 1980–2019**

Indicator	Lee-Carter model (LC)		Cohort Lee-Carter model (Booth-Maindonald-Smith)		Coherent Lee-Carter model (Li-Lee)	
	Males	Females	Males	Females	Males	Females
Averages across ages						
MPE	0.003848	0.006016	0.004058	0.006060	0.002574	0.004418
MAPE	0.043668	0.058997	0.043696	0.058942	0.045404	0.057752
Averages across years						
IPE	0.427074	0.667756	0.450393	0.672676	0.285757	0.490409
IAPE	4.847112	6.548670	4.850231	6.542611	5.039825	6.410431

Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

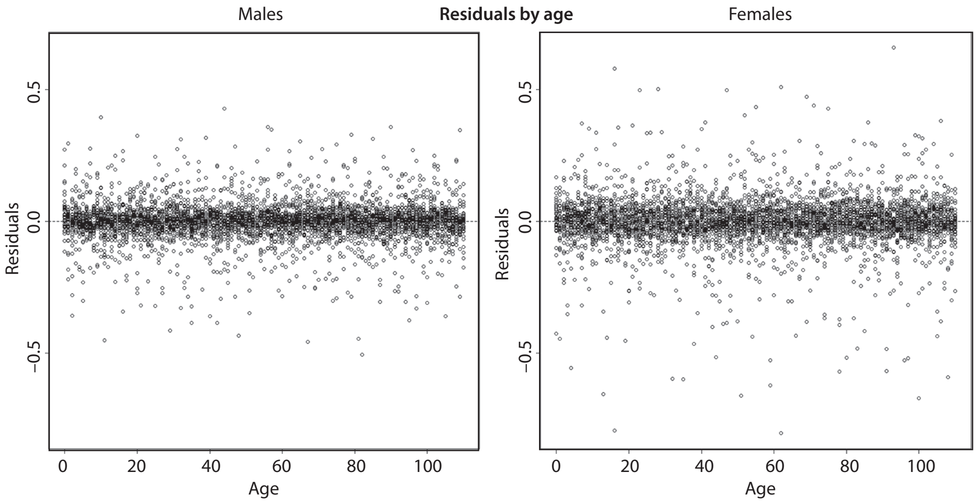
Validation of the Lee-Carter model using the prediction error Δ_t is essential to assess its accuracy in forecasting mortality (*Duerst et al.*, 2023):

$$\Delta_{t\,=}\, F_t - Y_t,$$

where F_t are the forecast (fitted) values and Y_t are the observed values.

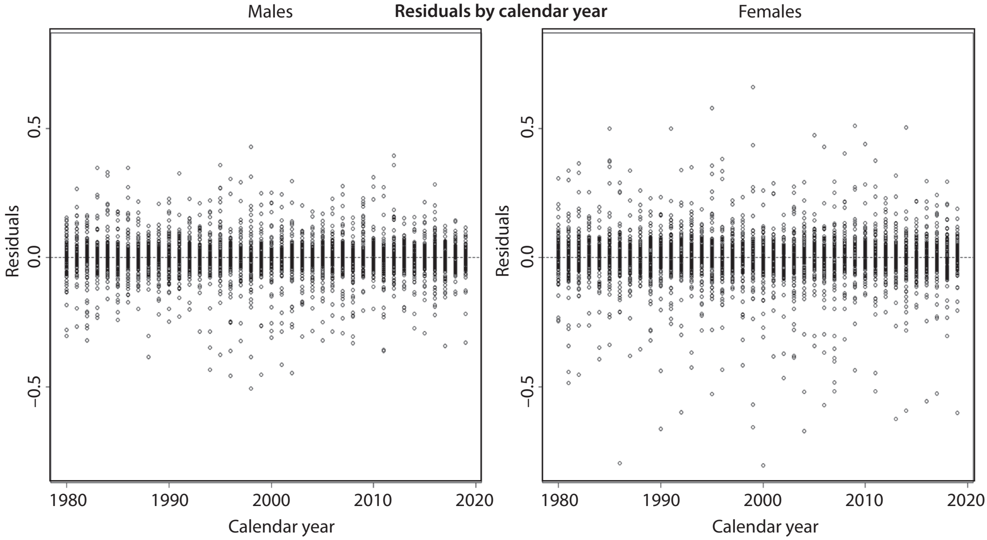
The results show that the coherent variant of the Lee-Carter model provides the most accurate forecast. An estimate of the difference (residuals) between fitted and observed values of mortality rates by calendar year and age for the coherent Lee-Carter model for the European male and female mortality potential for the period of 1980–2019 is shown in Figure 4. Randomly distributed residuals around zero indicate that the model fits the data well and that there is no systematic bias presence. This is true both when evaluating the residuals across ages and across years. The variance of the residuals is constant and does not change with increasing age or time.

Figure 3 **Estimates of the difference (residuals) between observed and fitted values of mortality rates by calendar year and age for the coherent Lee Carter model for the European male and female mortality potential, 1980–2019**



Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

Figure 3 (continuation)



Source: Eurostat 2023a; Eurostat 2023b; author's calculation.

LIFE EXPECTANCY TO 2100

To estimate the parameters of the Lee-Carter model, the `demography` (*Hyndman et al.* 2023) followed by `forecast` (*Hyndman et al.*, 2024) package can be used to forecast mortality in R. These packages provide functions for modelling and forecasting demographic indicators of mortality, fertility and migration. The R package `MortCast` (*Sevcikova – Li*, 2022) is available for estimating the parameters of the Lee-Carter coherent model.

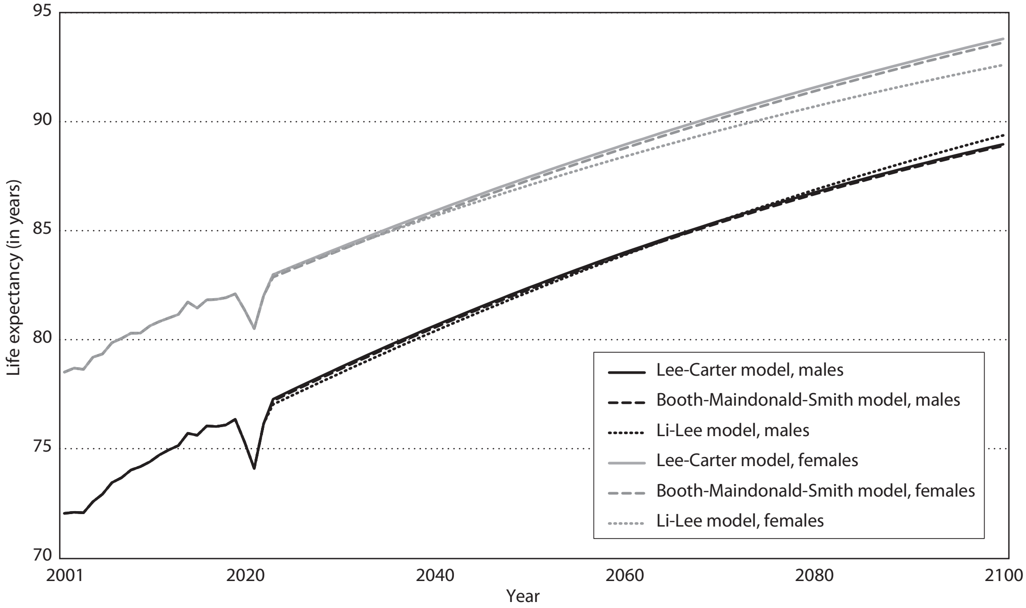
According to the population projection of the Czech Republic prepared by the Czech Statistical Office (*CZSO*, 2023a), future mortality trends have been projected using a coherent variant of the Lee-Carter model. The projected mortality rates reflect a continuous increase in life expectancy at birth (Table 2). The annual increase in life expectancy is expected to slow down slightly over time. In 2023, life expectancy at birth is projected to reach 77.0 years for males and 83.0 years for females. By 2050, life expectancy is projected to increase by 5.2 years to 82.2 years for males and by 4.1 years to 87.1 years for females. By the end of the century, life expectancy at birth will increase to 89.4 years for males and 92.6 years for females. The different pace of mortality decline between males and females is expected to further narrow the gap in life expectancy at birth from 5.9 years to 3.2 years.

Table 2 **Mortality assumptions, a medium variant of Population projection of the Czech Republic up to 2100**

Indicator	2019	2022	2023	2030	2040	2050	2060	2070	2080	2090	2100
Male life expectancy at birth	76.3	76.1	77.0	78.5	80.4	82.2	83.9	85.4	86.9	88.2	89.4
Female life expectancy at birth	82.1	82.0	83.0	84.1	85.7	87.1	88.4	89.6	90.7	91.7	92.6
Sex gap in life expectancy	5.8	5.9	6.0	5.7	5.3	4.9	4.5	4.2	3.8	3.5	3.2

Note: The figures for 2019 and 2022 are real.
Source: CZSO 2023a.

Figure 4 **Estimated life expectancy at birth for males and females according to variants of the Lee-Carter model, Czech Republic, 2001–2100**



Source: CZSO 2023a; author's calculation.

Comparing the estimates of life expectancy at birth up to 2100 in relation to the variants of the Lee-Carter model (Figure 5) for males, a less optimistic increase can be observed based on the original Lee-Carter model and its cohort variant, whose estimation results are very similar to the coherent variant of the model, but towards the end of the projection period they start to diverge more. For females, on the other hand, the estimates of life expectancy at birth are more optimistic in the original model and its cohort versions than in the coherent version of the model.

CONTRIBUTIONS TO LIFE EXPECTANCY GAP

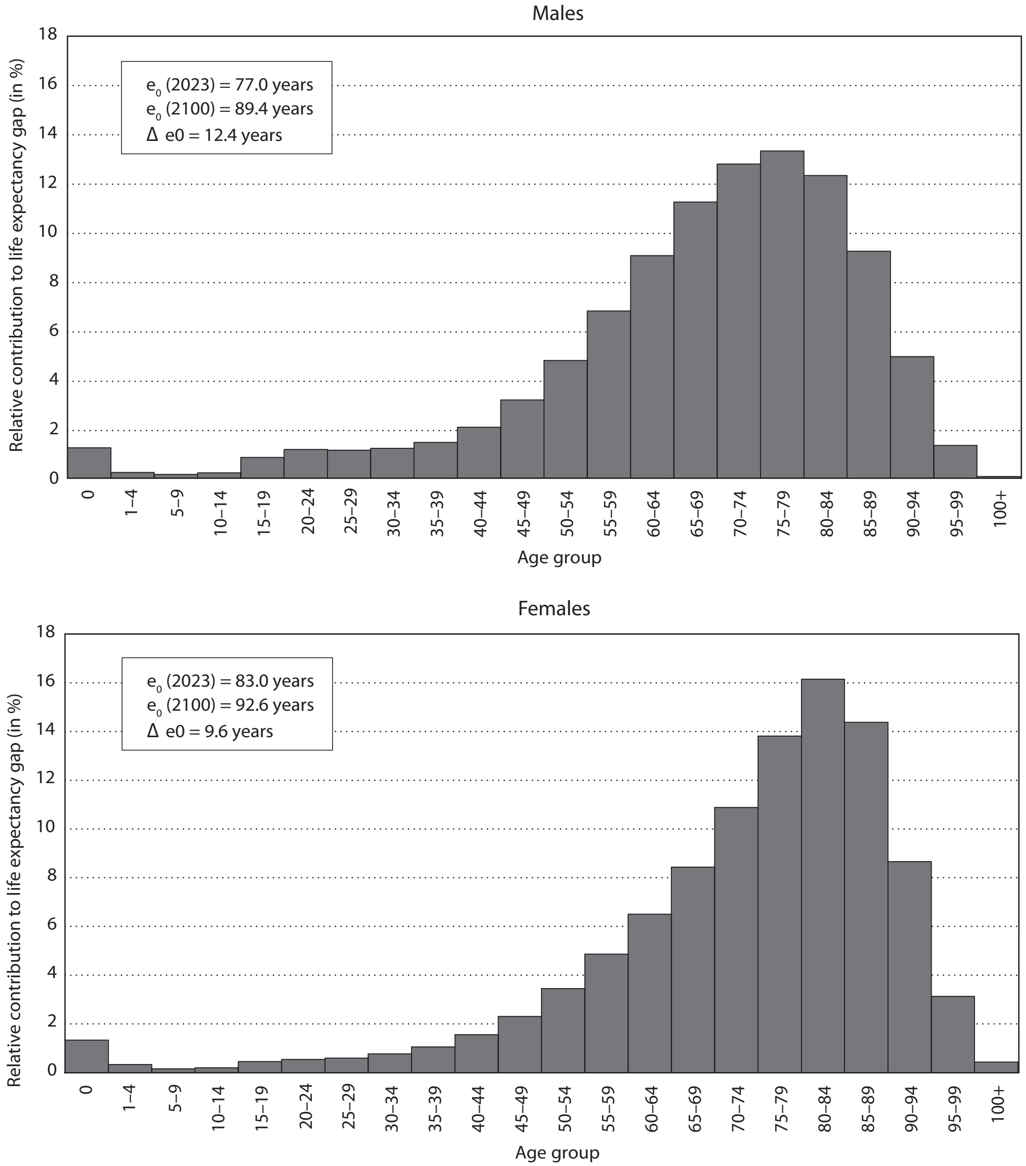
The decomposition of the difference in life expectancy is useful for estimating how differences in mortality rates in a given age group contribute to the overall change in life expectancy at birth (*Preston et al.*, 2001). The decomposition method of *Pressat* (1985) was used to decompose the difference in life expectancy at birth into age contributions by sex:

$$\Delta\left(e_0^2 - e_0^1\right) = \frac{\left(e_x^2 - e_x^1\right)\left(l_x^2 + l_x^1\right)}{2} - \frac{\left(e_{x+n}^2 - e_{x+n}^1\right)\left(l_{x+n}^2 + l_{x+n}^1\right)}{2},$$

where l_x^1, l_{x+n}^1 and l_x^2, l_{x+n}^2 are the number of survivors at age x, $x + n$ in period 1, 2; e_x^1, e_{x+n}^1 and e_x^2, e_{x+n}^2 are the life expectancies at age x, $x + n$ in period 1, 2. It is assumed that $l_0 = 1$.

The difference in life expectancy at birth between 2023 and 2100 is 12.4 years for males and 9.6 years for females (Figure 6). Given the very low levels of infant and child mortality, the impact on life expectancy is almost negligible, despite the decline in mortality in these groups. The increase in life expectancy shifts to the age groups 70–74 years for males and 80–84 years for females, and in the last 20 years of the projection to the age groups 80–84 and 85–89, respectively. Thus, the number of deaths is increasingly concentrated around the modal age of death (the most common age), which corresponds to the ongoing process of mortality compression that is evident in the observed long-term trends in all developed countries of the world (*CZSO*, 2023).

Figure 5 **Contributions to the life expectancy gap at birth by sex based on the coherent Lee-Carter model, Czech Republic, 2023–2100**



Source: CZSO 2023a; author's calculation.

COMPARISON WITH OTHER PROJECTIONS

This part of the article compares the results of the mortality assumptions and methodology used in the Population projection of the Czech Republic (*CZSO*, 2023) with other official projections, in particular with an earlier version of 2018 (*CZSO*, 2018). The Eurostat "EUROPOP" population projections from 2019 (*Eurostat*, 2019) and 2023 (*Eurostat*, 2023) and the United Nations "World Population Prospects" are also taken into account.

The CZSO mortality projection from 2018 was based on an analysis of mortality rates in the Czech Republic and developed European countries. The methodology for the calculation of life tables remained unchanged in both the 2018 and 2023 projections of the CZSO. The CZSO assumed that the development in the Czech Republic would follow the trend observed in European countries with high levels of life expectancy. The mortality projection was based on a model of age-specific mortality decline through an indicator called ROMI (Rates of Mortality Improvement). The medium variant was based on a 95% decline in mortality rates observed in 15 developed European countries between 1980 and 2015. The decline in mortality rates was expected to slow down gradually, and to be more pronounced in younger age groups. For a more detailed description, see (*Pechholdová*, 2018). In the case of Eurostat's mortality projections from 2019 and 2023, the input age-specific mortality rates were smoothed using a weighted B-spline regression. Eurostat assumed that the rates converge to a common life table (the "ultimate" life table), which includes recent mortality trends for selected countries. This interpolation results in a higher rate of mortality decline at the beginning of the period and a slower rate in the long term, consistent with the assumption of a declining rate of mortality improvement. The United Nations method of projecting mortality from 2024 uses a moving average method to smooth mortality rates and replace inconsistencies in the data with estimates. It uses interpolation across any gaps in the time series using the limited Lee-Carter method (*Li et al.*, 2004). The Lee-Carter method is used to extrapolate age-specific mortality and is adapted for non-sequential or sparse data.

The projections of life expectancy at birth for the Czech Republic up to 2100, broken down by sex and according to different projection sources, are shown in Table 3. The development during the 21st century shows a gradual increase in life expectancy for both sexes. The CZSO 2023 projection predicts the highest increase in life expectancy for males. Eurostat projections predict a steady increase in life expectancy in the Czech Republic for both sexes. The UN projection suggests a slightly more optimistic, but still moderately conservative, development of life expectancy for males compared to the other projections. In all projections, the increase in life expectancy is faster for males than for females. This trend could lead to a narrowing of the sex gap in life expectancy over time.

Table 3 **Projections of life expectancy by sex for the Czech Republic, 2019–2100**

Projection	Sex	2019	2022	2023	2030	2040	2050	2060	2070	2080	2090	2100
CZSO 2018	Males	76.4	77.1	77.3	78.7	80.5	82.1	83.6	84.8	85.9	86.8	87.7
	Females	82.2	82.7	82.9	84.0	85.5	86.7	87.9	88.9	89.7	90.5	91.2
CZSO 2023	Males	76.3	76.1	77.0	78.5	80.4	82.2	83.9	85.4	86.9	88.2	89.4
	Females	82.1	82.0	83.0	84.1	85.7	87.1	88.4	89.6	90.7	91.7	92.6
EUROPOP 2019	Males	76.5	76.9	77.1	78.4	80.2	81.8	83.4	84.8	86.2	87.4	88.5
	Females	82.3	82.6	82.8	83.9	85.4	86.7	88.0	89.2	90.4	91.4	92.4
EUROPOP 2023	Males	76.4	75.9	76.2	77.9	79.8	81.6	83.3	84.8	86.3	87.6	88.8
	Females	82.2	81.9	82.2	83.5	85.1	86.6	87.9	89.2	90.5	91.6	92.6
UN WPP 2024	Males	76.3	76.2	77.0	78.3	80.0	81.6	83.0	84.3	85.6	86.7	87.8
	Females	82.1	82.1	82.6	83.4	84.5	85.6	86.7	87.8	89.0	90.1	91.2

Source: CZSO 2018; CZSO 2023a; EUROPOP 2019; EUROPOP 2023; UN WPP 2024.

CONCLUSION

The article deals with the forecasting of mortality and the comparison of different variants of the Lee-Carter model for the population of the Czech Republic. The main objective was to find out which model provides the most accurate forecast of long-term mortality trends in the Czech Republic by comparing different methods of mortality forecasting (namely the original Lee-Carter model and its cohort and coherent variants). The results suggest that while the original Lee-Carter model remains valuable, the coherent variant offers greater accuracy and robustness for projections in populations expected to experience similar long-term mortality trends.

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References

- Basellini, U. – Camarda, C. G. – Booth, H. 2023. Thirty years on: A review of the Lee–Carter method for forecasting mortality. *International Journal of Forecasting*, 39(3), 1033–1049. https://doi.org/10.1016/j.ijforecast.2022.11.002.
- Booth, H. – Tickle, L. 2008. Mortality modelling and forecasting: A review of methods. *Annals of actuarial science*, 3(1–2), 3–43. https://doi.org/10.1017/S1748499500000440.
- Booth, H. – Maindonald, J. – Smith, L. 2002. Applying Lee-Carter under conditions of variable mortality decline. *Population Studies*, 56(3), 325–336. https://doi.org/10.1080/00324720215935.
- Booth, H. – Tickle, L. – Smith, L. 2005. Evaluation of the variants of the Lee-Carter method of forecasting mortality: a multi-country comparison. *New Zealand Population Review*, 31(1), 13–34.
- Cairns, A. J. – Blake, D. – Dowd, K. 2006. A two-factor model for stochastic mortality with parameter uncertainty: theory and calibration. *Journal of Risk and Insurance*, 73(4), 687–718. https://doi.org/10.1111/j.1539-6975.2006.00195.x.
- Chang, L. – Shi, Y. 2023. Forecasting mortality rates with a coherent ensemble averaging approach. *ASTIN Bulletin: The Journal of the IAA*, 53(1), 2–28. https://doi.org/10.1017/asb.2022.23.
- Czech Statistical Office (CZSO). 2023. Population projection of the Czech Republic. *Czech Statistical Office*. Available at: https://csu.gov.cz/produkty/projekce-obyvatelstva-ceske-republiky-2023-2100.
- Czech Statistical Office (CZSO). 2024. *Life tables – Methodology*. Czech Statistical Office. Available at: https://csu.gov.cz/life-tables-methodology.
- Duerst, R. – Schöley, J. – Bohk-Ewald, C. 2023. *A validation workflow for mortality forecasting*. Max Planck Institute for Demographic Research. https://doi.org/10.4054/MPIDR-WP-2023-020.
- Eilers, P. H. – Marx, B. D. 1996. Flexible smoothing with B-splines and penalties. *Statistical science*, 11(2), 89–121. https://doi.org/10.1214/ss/1038425655.
- Hulíková Tesárková, K. – Mazouch, P. – Pola, A. 2024. Předpoklady a metodika prognózování úmrtnosti v projekci obyvatelstva Česka na období 2023 až 2100 z dílny ČSÚ. *Demografie*, 66(3), 202–210. https://doi.org/10.54694/dem.0344.
- Hyndman, R. J. – Athanasopoulos, G. – Bergmeir, C. – Caceres, G. – Chhay, L. – O'Hara-Wild, M. – ... – Wang, E. 2024. Package 'forecast'. Available at: https://cran.r-project.org/web/packages/forecast/index.html.
- Hyndman, R. – Booth, H. – Tickle, L. – Maindonald, J. – Wood, S. – Team, R. C. – Hyndman, M. R. 2023. Package 'demography'. Available at: https://cran.r-project.org/web/packages/demography/index.html.
- Lee, R. D. – Carter, L. R. 1992. Modeling and Forecasting U. S. Mortality. *Journal of the American Statistical Association*, 87(419), 659–671. https://doi.org/10.1080/01621459.1992.10475265.
- Lee, R. – Miller, T. 2001. Evaluating the performance of the Lee-Carter method for forecasting mortality. *Demography*, 38(4), 537–549. https://doi.org/10.1353/dem.2001.0036.

- Li, N. – Lee, R. 2005. Coherent mortality forecasts for a group of populations: An extension of the Lee-Carter method. *Demography*, 42(3), 575–594. https://doi.org/10.1353/dem.2005.0021.
- Li, N. – Lee, R. – Gerland, P. 2013. Extending the Lee-Carter method to model the rotation of age patterns of mortality decline for long-term projections. *Demography*, 50, 2037–2051.
- Li, N. – Lee, R. – Tuljapurkar, S. 2004. Using the Lee–Carter method to forecast mortality for populations with limited data. *International Statistical Review*, 72(1), 19–36. https://doi.org/10.1111/j.1751-5823.2004.tb00221.x.
- Pechholdová, M. 2019. Mortality Assumptions and Forecasting Methodology: Population Projection of the Czech Republic from the Czech Statistical Office, 2018-2100. *Demografie*, 61(4), 261–280.
- Pressat, R. 1985. Contribution des écarts de mortalité par âge à la différence des vies moyennes. *Population (French edition)*, 766–770. https://doi.org/10.2307/1532986.
- Preston, S. H. – Heuveline, P. – Guillot, M. 2000. *Demography: measuring and modeling population processes*. Blackwell.
- Remund, A. – Camarda, C. G. – Riffe, T. 2017. A cause-of-death decomposition of the young adult mortality hump. *Documento de trabajo*, (2017-007). https://doi.org/10.4054/MPIDR-WP-2017-007.
- Renshaw, A. E. – Haberman, S. 2003a. Lee–Carter mortality forecasting with age-specific enhancement. *Insurance: Mathematics and Economics*, 33(2), 255–272. https://doi.org/10.1016/S0167-6687(03)00138-0.
- Renshaw, A. E. – Haberman, S. 2003b. Lee–Carter mortality forecasting: A parallel generalized linear modelling approach for England and Wales mortality projections. *Journal of the Royal Statistical Society Series C: Applied Statistics*, 52(1), 119–137. https://doi.org/10.1111/1467-9876.00393.
- Renshaw, A. E. – Haberman, S. 2006. A cohort-based extension to the Lee–Carter model for mortality reduction factors. *Insurance: Mathematics and economics*, 38(3), 556–570. https://doi.org/10.1016/j.insmatheco.2005.12.001.
- Sevcikova H. – Li, N. – Gerland, P. 2022. MortCast: Estimation and Projection of Age-Specific Mortality Rates. R package version 2.7-0, Available at: https://cran.r-project.org/web/packages/MortCast/index.html.
- Shi, Y. 2024. Coherent mortality forecasting with a model averaging approach: Evidence from global populations. *North American Actuarial Journal*, 28(1), 218–235. https://doi.org/10.1080/10920277.2023.2185260.
- Thatcher, A. R. – Kannisto, V. – Vaupel, J. W. 1998. The force of mortality at ages 80 to 120.

Sources of data

Czech Statistical Office (CZSO). 2018. Population Projection of the Czech Republic - *2018 – 2100*. Czech Statistical Office. Available at: https://csu.gov.cz/produkty/projekce-obyvatelstva-ceske-republiky-2018-2100.

Czech Statistical Office (CZSO). 2023a. Population Projection of the Czech Republic - *2023–2100*. Czech Statistical Office. Available at: https://csu.gov.cz/produkty/projekce-obyvatelstva-ceske-republiky-2023-2100.

Eurostat. 2019. EUROPOP2019 – Population projections at national level (2019–2100) (proj_19n). Available at: https://ec.europa.eu/eurostat/databrowser/view/proj_23nalexp/default/table?lang=en&category=proj.proj_23n:

Eurostat. 2023. EUROPOP2023 – Population projections at national level (2022–2100) (proj_23n). Available at: https://ec.europa.eu/eurostat/databrowser/view/proj_23nalexp/default/table?lang=en&category=proj.proj_23n.

Eurostat. 2023a. Deaths by age and sex. Available at: https://ec.europa.eu/eurostat/databrowser/view/demo_magec/default/table?lang=en&category=demo.demo_mor.

Eurostat. 2023b. Population on 1 January by age and sex. Available at: https://ec.europa.eu/eurostat/databrowser/view/demo_pjan/default/table?lang=en&category=demo.demo_pop.

United Nations (UN). 2024. World Population Prospects 2024. Available at: https://population.un.org/wpp/Download/Standard/Mortality/.

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The 16th Conference of Young Demographers Will Take Place in February 2024

The Conference of Young Demographers traditionally offers an exceptional opportunity to spend three days discussing current demographic issues. It gives students and early career researchers the chance to learn and get feedback and advice from their colleagues from all over the world in a very friendly environment. This year the conference is again being co-organised in cooperation with the Association for Young Historical Demographers (AYHD).

The 16th annual Conference of Young Demographers will take place **from 5 to 7 February 2025** in Prague at the Faculty of Science, Charles University. Although the conference is mainly focused on (historical) demography, all young researchers (including those who are young at heart) from various fields of population studies (sociology, epidemiology, and maybe even economics) are welcome. The working language of the conference is English.

As in previous years, we support the use of posters as the main presentation format, not only for finished projects, but also for works in progress. Posters are the best!

Abstract submission is already closed. However, you can still join us as at the conference a passive participant. Registration for passive participation will open in January 2025.

The final programme of the conference will also be announced in January.

For more information, including information about passive participation in the conference, please visit our website at: youngdemographers.github.io. Please feel free to contact us with any questions at: yd.demographers@gmail.com.

We look forward to seeing you in Prague!

On behalf of the Organising Committee:
Anna Altová, Kateřina Brázová, Klára Hulíková, Joris Kok (AYHD), Barbora Janáková, Tim Riswick (affiliated supporter), Jitka Slabá, Adéla Pola and Lukáš Kahoun

An Interview with Jitka Rychtaříková

To mark a significant anniversary in the life of Prof. Jitka Rychtaříková, we are bringing you a short interview with her.

When and why did you decide to pursue demography at the scientific level and as an educator?

It wasn't a long-term decision, but rather an accident. To some degree it's true that the world favours the prepared...

When we had to choose out thesis topic (I completed my studies in 1973 in geography at the Faculty of Sciences and in French at the Faculty of Arts of Charles University), I said to myself that the easiest thing would be to calculate something using the recent 1970 census, given that I had previously graduated from a general education secondary school in the maths and physics class. Prof. Zdeněk Pavlík at that time had just returned from the USA and had no dissertation students, and I was 'left' for him. He assigned me the topic of marriage. At that time, I knew only that demography deals with the study of population. Thanks to self-study, borrowing Prof. Pavlik's French textbooks, and the interest and help of JUDr. Vladimír Srb and Ing. Milan Kučera, I managed to write my master's thesis, the defence of which was attended by the French demographer Roland Pressat, who then initiated my being invited to INED (Institut National d'Etudes Démographiques) in Paris. During my time at the Institute I also studied at Université Paris I Panthéon-Sorbonne and obtained a diploma in Démographie générale. After returning to Prague, however, it was not at all easy to be employed at the university.

Can you think of a project you were involved in that surprised you with its outcome?

For me the US project 'Gestational Selection, Birth Weight and Infant Survival', supported by the National Institute of Child Health & Human Development, was very important. It addressed the question of whether the better survival of babies born with a low birth weight is the result of biological or social factors. Although in the USA children born at low birth weight to African-American mothers had lower infant mortality rates than similar children of other races, in the Czech Republic this pattern was mainly true for children born to mothers with lower education. I should add that these results were standardised for age, birth order, marital status, and were specified by education.

Do you think that sufficient use is made of demographic data by people in positions of responsibility?

I would like to see greater use, especially in political decision-making – consider, for example, the recent discussions around pension reform. Here I feel the lack of comparisons with the situations and systems in other countries. I'd mainly place the emphasis on years worked and payments into the pension system and devote less discussion to the age of retirement.

Which demographic issue do you think is the most overrated and which is the most underrated?

I believe that the most overrated issue in the Czech Republic at this time is demographic ageing and foreign migration. The Czech Republic does not yet rank among the countries with the largest share of people aged 65+, and, unlike 'western' Europe, we have very few foreign migrants from 'third' countries.

Which demographic topics do you think are the subject of the most discussion nowadays and which, conversely, are the most overlooked?

As I already said, there are excessive concerns about demographic ageing. Fortunately, in this connection I have not yet seen our mass media using terms such as the new population bomb or demographic panic. A topic that is overlooked is the mortality of seniors. Leaving aside the Covid period, our life expectancy at age 65 is still short compared to the rest of Europe (North, South, West).

As well as geography, you have a degree in French, you were in France on a foreign internship at INED, and you are a recipient of an award from the French state. Do you also like traveling back to France privately?

I used to travel to France frequently for work, first to INED and more recently as a visiting professor at Université Paris I Panthéon-Sorbonne. I was there privately before that, visiting friends of my father, who was imprisoned with them in the Buchenwald-Dora concentration camp during World War II.

Many students never encounter demography during their studies at primary and secondary school (unlike other science subjects). Do you think that more attention should be paid to the basics of demography?

I believe that demography is becoming more important than it was in the past. For this reason I do think that more attention should be devoted to it in some subjects at secondary schools. Here, however, the problem is that every year new figures come out, new information is released, and demographic behaviour sometimes changes unexpectedly and relatively fast, demographic projections to the year 2100 are being refined. It would probably be necessary for demographers to get involved and systematically prepare the resources and teaching materials for teachers.

You have completed a number of engagements abroad. Could any of them be considered pivotal?

The most important engagements for me were in Paris (INED and Sorbonne) and in the USA at the University of South Carolina. This may in part be because I was not there as a visiting student but as an employee who had to 'work' like everyone else, which, on the other hand, was beneficial for me and required a lot of responsibility.

There are a number of films and books (non-academic) in which the subject is a demographic process. Do you have a favourite film or book of this kind or, on the contrary, do you often avoid the lay perspectives of filmmakers and writers?

I remember one book by the very famous American writer Dan Brown, 'Inferno', which was published in 2013 and focused on the topic of overpopulation. In it the author talks not just about the problem of rapid population growth but also about the planet's other problems. Its subject of a viral pandemic caused by laboratory-produced viruses is interesting, but in this case it's a virus that limits fertility.

You also do a lot of teaching. Has there ever been a time when a student has startled you with a question or made you angry or laugh?

Students today are rather passive and sometimes it's necessary to push them into discussions.

MP

The Statistical Geoportal of the Czech Statistical Office Has Been Expanded with Interesting (and Not Just) Demographic Data

Since June 2023 the Czech Statistical Office (CZSO) has been offering anyone interested a new way of presenting, visualising, and analysing selected statistical data using its **Statistical Geoportal**[1]. The Statistical Geoportal offers several web-based user applications that can be employed to display selected, geographically oriented statistical indicators or topics relating to a specific territory in the form of clear interactive maps. This gives users new information and a more visual, intelligible, and attractive picture of statistical data than what traditional tables or graphs are able to provide. Since it was publicly launched, the Statistical Geoportal has undergone dynamic development in terms of its content and functions. It has won several prestigious awards[2] and it has become a highly accessible, easy to understand, and widely used platform for presenting statistical data in a map format.

The most popular application of the Statistical Geoportal in terms of the number of visits is the **Statistical Atlas**, which presents indicators that are available in sufficient spatial detail in the form of cartograms (choropleth maps), cartodiagrams and kilometre grids[3]. The application offers thematic maps of various administrative and statistical territorial units, ranging from the level of municipalities and the urban districts of statutory cities to 'cohesion regions' (NUTS 2) and senate electoral districts. The application already contains 1,783 maps for 311 indicators, which is more than three times the number of maps that were available after it first launched. The largest share are thematic maps based on the *2021 Population and Housing Census* that depict a wide range of indicators on the population, houses, dwellings, and now also on households. A total of 157 thematic maps have been prepared for 27 indicators analysing households by type, household size, and the number of dependent children. By early 2025 users of the Statistical Atlas will also be able to find cartograms and cartodiagrams depicting the spatial distribution, intensity, and volume of residents who commute to work and school in reference to various territorial levels based on the recent census.

Over the course of this year, data have been added to the Statistical Atlas and maps have been created from other sectoral statistics. The first source other than census to be presented in the atlas was that of *electoral statistics*, using which a series of maps were successively published on the election of the President of the Republic in 2023, the elections to the European Parliament in 2019 and 2024, and, most recently, the elections to the regional councils in 2020 and 2024 and the elections to the Senate in 2022 and 2024. Next year, maps will be added showing the results of the most recent and the upcoming elections to the Chamber

1) https://geodata.statistika.cz

2) In 2023 the Czech Statistical Office won the prestigious IT Project of the Year Award, which is announced each year by the Czech Association of Chief Information Officers (Česká asociace manažerů informačních technologií – CACIO). It was also successful in the *Egovernment The Best 2023*, which is a showcase of the most interesting projects devoted to the digital transformation on public administration, where it finished second place in the central authorities category.

3) These are square cells 1 x 1 km in size, which represent an alternative to the varying sizes and spaces of the administrative units.

of Deputies of the Parliament of the Czech Republic and the results of the elections to the municipal councils.

Positive news for demographers in particular was the publication in May of 62 maps for 14 indicators from *demographic statistics* for 2022. These maps can be used to analyse, for example, territorial differences in life expectancy at birth by sex for the administrative districts of municipalities with extended powers (SO ORPs) or population changes in municipalities and regions of Czechia from the perspective of natural change or migration. There are plans to add by the end of this year maps produced with the latest data for 2023 on almost all indicators already published. Users of the Statistical Atlas will be able to move between different time frames for the presented indicators along a timeline or will be able to play the timeline automatically using a time slider tool, which will allow them to observe the spatial distribution of a given indicator over time.

In October, a set of maps from another statistical source – *the Business Register* – were added to the content of the Statistical Atlas. This provides users with a clear spatial picture of the distribution of registered economic subjects with identified activity, along with a breakdown of active registered businesses by selected legal forms, size categories, or principal economic activity.

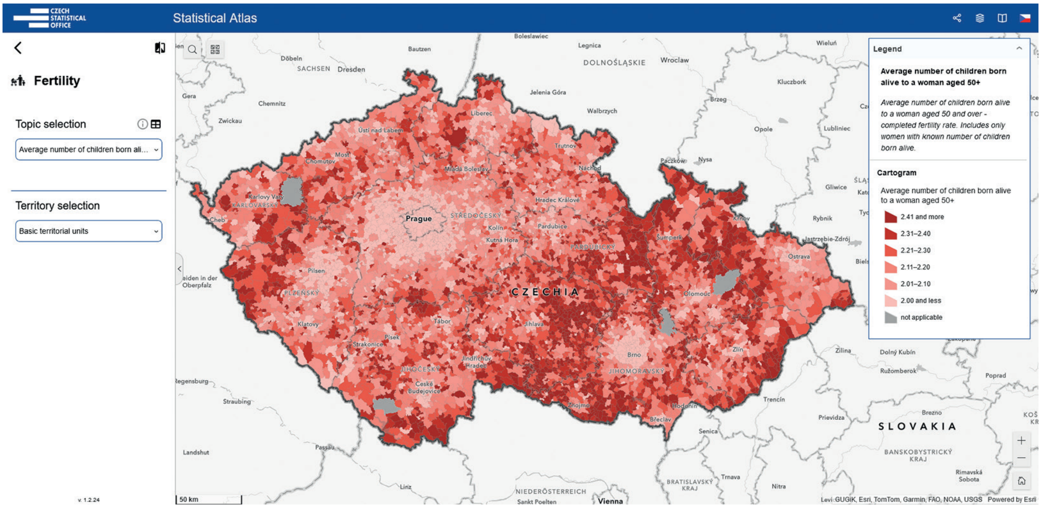
A second user application, **Mobility**, has also undergone a significant transformation over the last year in terms of its content and functions. The application was originally called '*Commuting*' and in the form of linear vectors it displayed the directions and intensity of public *commuting both to and from work and school* and the commuting balance between selected administrative and statistical territorial units. In May, however, the application's data content was enriched with the addition of matrices of *internal migration flows* for the year 2022, providing users with a unique opportunity to easily view on a map where people who had moved into their municipality, district, or region had come from or where their fellow citizens had moved to most in a given year. Users can also ask the app to display the number and share of in-migrants and out-migrants for the total population and according to sex or to three basic age groups (0–14, 15–64, 65+) at territorial levels ranging from municipalities to regions. In the 2021 Population and Housing Census data on commuting to and from work and school are generally available right down even to basic settlement units (and parts of settlements) and can be broken down into subpopulations according to age, sex, education, commute frequency, main mode of transport, and sector of economic activity. This means that it is possible for municipalities, cities, regions, and other interested parties to analyse, for example, the age and education structure of non-resident and resident commuters or find out where students at the secondary or post-secondary level are commuting to and from most frequently. In addition to commuting to and from work and school and internal migration, the application can also be used to visualise *international commuting for work* from Czechia abroad using data from the 2021 Population and Housing Census. There are five maps that can be selected to display the number and share of people commuting for work from Czechia to selected other countries around the world, from Czech regions to all the countries of Europe, and from districts, SO ORPs, and municipalities to four neighbouring countries. If users select a foreign country on the map instead of a territorial unit in Czechia, they will be presented with a unique picture of which areas of Czechia people commute from most to work in the selected country. There is no map depicting cross-border labour mobility balance, however, as the census does not measure the number of people who commute from abroad to work in Czechia. The Mobility app currently offers users the possibility to generate almost 600 maps with different content. Although the possibilities for further expanding the application's data content are much more limited than in the case of the Statistical Atlas because the content depends on the specific format of the input data (data matrices of the flows between the source and destination territorial units), the range of topics and maps that users will be able to choose from should continue to grow in the future. Internal migration flows for other calendar years will be added next year, and there are also plans to add attractive maps displaying arrival flows based on tourism statistics.

The third user application is **Statistical Georeports,** which offers experts and the general public the ability to generate outputs that clearly visualise aggregated statistical data on selected topics for a user-defined area (flooded areas, vehicular traffic accessibility zones, areas serviced by public infrastructure, or areas for potential customer acquisition, etc.). Statistical data are provided in the smallest possible territorial detail – 1 x 1 km cells (grids) – provided that the conditions of statistical confidentiality are fulfilled. The Statistical Georeports application currently offers a wide range of indicators from the 2021 Population and Housing Census. In addition to the indicators on *population* and *housing* originally available from the census, indicators for *households* will be added in the near future as well. Users will thus be able to discover the number and composition of households in the area they are interested in by household type and size, by the number of dependent children in the household, or by housing arrangements. Further gradual enhancements of the application's data content are planned but are largely limited by the need for input data to be available at the level of the kilometre grids or at the level of individual address points. Among official Czech statistics only the population census and some statistical registers (Business Register, Register of Census Districts and Buildings, and Register of Collective Accommodation Establishments) meet this condition. There is a goal to use the 2021 Population and Housing Census to add to the georeports high-demand data in various breakdowns of interest to users on *commuting to work and school*. Discussions are also taking place to expand accessible subjects to include *economic subjects* from the Business Register and *collective accommodation establishments* from the Register of Collective Accommodation Establishments.

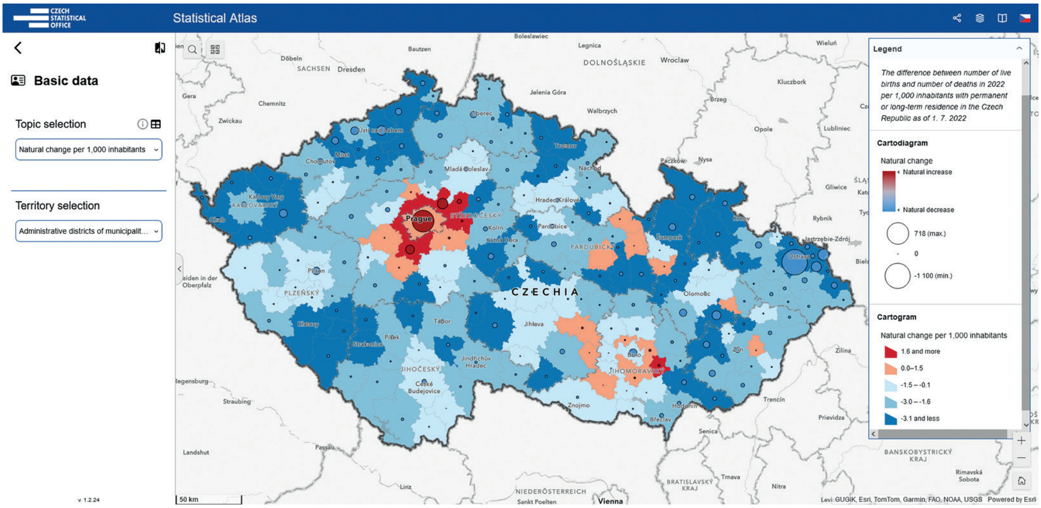
Alongside the many changes in the data content of user applications described above, visitors to the geoportal will also notice several innovations to the applications' user interfaces and functions that have been made in the past year. The most visible and biggest change has been the creation of an English version of the geoportal's content. Since the end of last year, English-speaking visitors to the website have been able to make full use of the Statistical Geoportal and its content is maximally intelligible to them. This past spring, a multilevel selection of sources, data sets, and topics similar to the Statistical Atlas was added to the panel on the left side of the Mobility application's user interface. For users who want to view their particular territorial unit in the Statistical Atlas through the lens of different topics and indicators, the way the application functions has been modified so that the last territorial level selected by the user is automatically displayed even when the selected indicator within a given topic is changed. During the summer, the basic GIS component of the geoportal, *ArcGIS Enterprise*, underwent an almost imperceptible upgrade to the latest version and the homepages of the geoportal and all user application pages migrated to the new CZSO subdomain *csu.gov.cz*. Over the next year there are plans to enhance the Statistical Geoportal with the addition of interactive thematic *story maps* and attractive *dashboards* combining visualisations of statistical data in interactive maps, graphs, tables, and more.

Štěpán Moravec, Petr Klauda

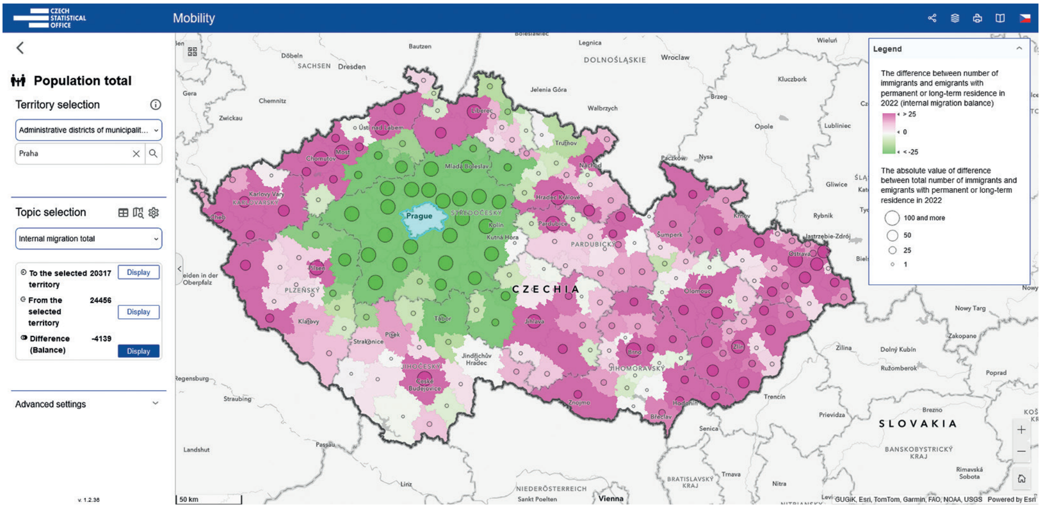
Map 1 **Average number of children born alive to a woman aged 50+ for basic territorial units**



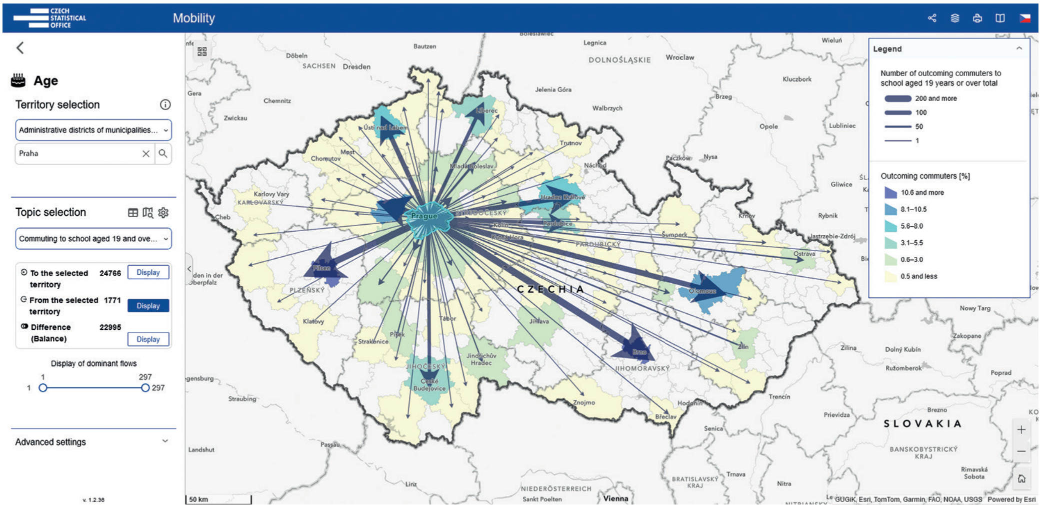
Map 2 **Natural change per 1,000 inhabitants in 2022 for administrative districts of municipalities with extended powers (SO ORP)**



Map 3 **Internal migration balance in 2022 for Prague at the level of administrative districts of municipalities with extended powers (SO ORP)**



Map 4 **Number of outcoming commuters to school aged 19 years or over from Prague at the level of administrative districts of municipalities with extended powers (SO ORP)**



THE FERTILITY ASSUMPTIONS FOR THE POPULATION PROJECTION OF THE CZECH REPUBLIC OF THE CZECH STATISTICAL OFFICE FROM 2023

Kryštof Zeman[1)]

Abstract
This paper introduces the methodology used to estimate the fertility parameters for the population projection of the Czech Republic for 2023–2050. Elements of methodology discussed here include the assumptions, input and output data, and the details of the computations and estimations. The analysis focus on the birth order dimension, cohort perspective, and high and low estimation variants. The paper further compares the estimated summary fertility indicators with past projections by the Czech Statistical Office, as well as with recent projections by other agencies.

Keywords: Population projection, Czech Republic, births, fertility, total fertility rate, cohort fertility, mean age of mothers
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INTRODUCTION

This paper introduces the methodology used to estimate the fertility rates that served as input parameters for the population projection of the Czech Republic that was published by the Czech Statistical Office (CZSO) in 2023 (*CZSO*, 2023a). It follows a similar article describing the population projection for 2018 (*Zeman*, 2019). The main methodological principles have not changed since the last projection, but the assumptions behind the projection have changed significantly, reflecting the rapid development in fertility in the last 5 years. The main changes are the lower expected level of fertility, and the higher target mean age of childbearing.

The CZSO 2023 population projection is based on classic deterministic principles and uses the cohort-component method. The input parameters of fertility are fertility rates at age 15–49, for the calendar years 2023–2050. In the subsequent period, 2051–2100, the rates are fixed at the values for the year 2050.

The next section introduces first the main principles of fertility projection and then the process used to derive the projection assumptions and parameters from past and recent demographic developments, including the low and high variants. Subsequent sections then show the results of the projection, concerning the levels and timing of period fertility, as well as the plausibility of the projections from the cohort fertility perspective. Finally, comparisons are made with past projections of the CZSO and other agencies.

1) Vienna Institute of Demography. Contact: Krystof.Zeman@oeaw.ac.at.

THE MAIN PRINCIPLES OF THE PROJECTION, PAST FERTILITY DEVELOPMENTS, AND THE PROCESS USED TO DERIVE PROJECTION ASSUMPTIONS AND PARAMETERS

For the fertility projection we use one-year age-specific fertility rates (age 15–49, age in completed years, or Lexis squares) by birth order (first, second, third and higher). As an input we use the age-specific fertility rates in 2022, taking into account fertility developments since the 1980s. The projection itself does not require parameters specified by birth order, but the model estimates each birth order separately in order to control the effect of projected fertility changes on cohort fertility and childlessness. The main results are also checked against past projections of the CZSO, as well as projections of other agencies. All calculations were done using the R programming language (*R Core Team*, 2024).

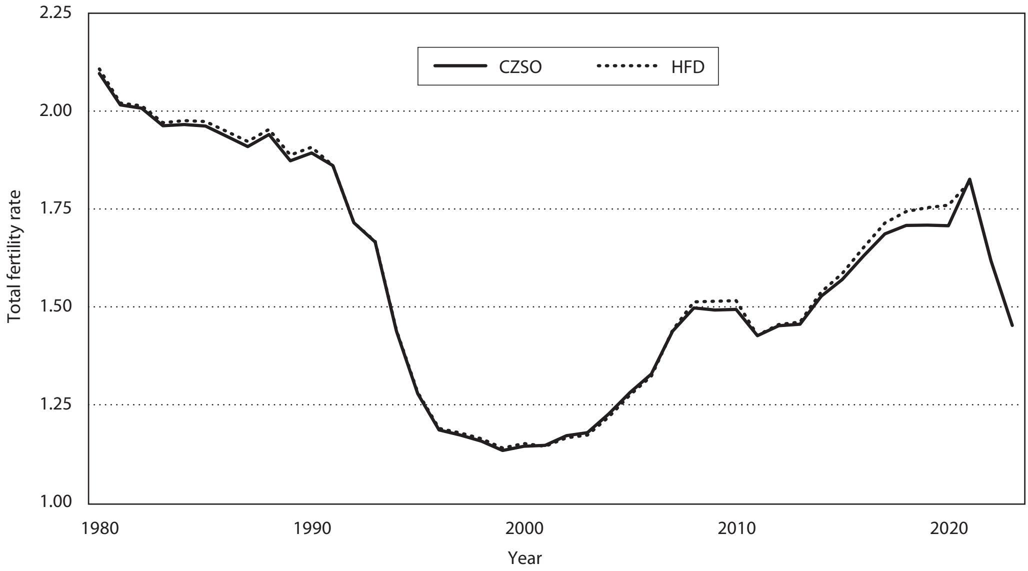
The main guideline for deriving future fertility development is the postponement of fertility to an older age. Predicting future fertility levels is currently quite difficult given the unclear development of fertility levels in the last years. Following the initial decline in fertility levels in the 1990s, the total fertility rate (TFR) reached a low of 1.13 in 1999 (Figure 1). Since that time, the TFR has been increasing and accelerated after 2014. The summary fertility of first births followed a similar pattern, first dropping from around 0.9 to 0.52 in 1996 and then slowly recovering to around 0.85. Among second births, a similar pattern occurred with a decline from around 0.7 to 0.43 in 2000 and with it then recovering to 0.6. The TFR of third- and higher-order births was more stable, declining from 0.3 and stabilising around 0.2

In the last couple of years (2020–2023), the TFR has shown sudden yearly changes and fluctuations that have been triggered mainly by three factors:

1) The COVID-19 pandemic caused a short-term drop in monthly births in many countries just nine months after the onset of the first wave in December 2020 and January 2021. This was not so in the Czech Republic, where the first wave of the pandemic was relatively mild (*Sobotka et al.*, 2023). A fertility decline came only in 2022 and 2023 (and continued in 2024), but then it was more severe (a decline of around minus 10 percent yearly).
2) The 2021 Population Census updated the population of the Czech Republic (with permanent residence status), reducing it by 207 thousand inhabitants, including about 73 thousand women aged 15–49 (*Šanda*, 2023). This contributed to a statistical increase in the 2021 TFR value of 0.07–0.08 (author's calculations). If the results of the census were not reflected in the demographic statistics, the TFR value in 2021 would have been 1.75 instead of 1.83. To show the effect of the change in the population structure, Figure 1 also shows data from the Human Fertility Database (HFD 2024), which uses its own population structures, estimated as a gradual interpolation between the two censuses (2011 and 2021 in this case).
3) The war in Ukraine triggered a wave of Ukrainian migrants – several hundred thousand refugees have settled in the Czech Republic. Thus, in 2022, 83 thousand women from Ukraine aged 15–49 were newly counted in the population. If these women had not been added, the TFR in 2022 would have been 1.66 instead of 1.62 (author's calculations), so the net effect of this wave statistically reduced the TFR by 0.04.

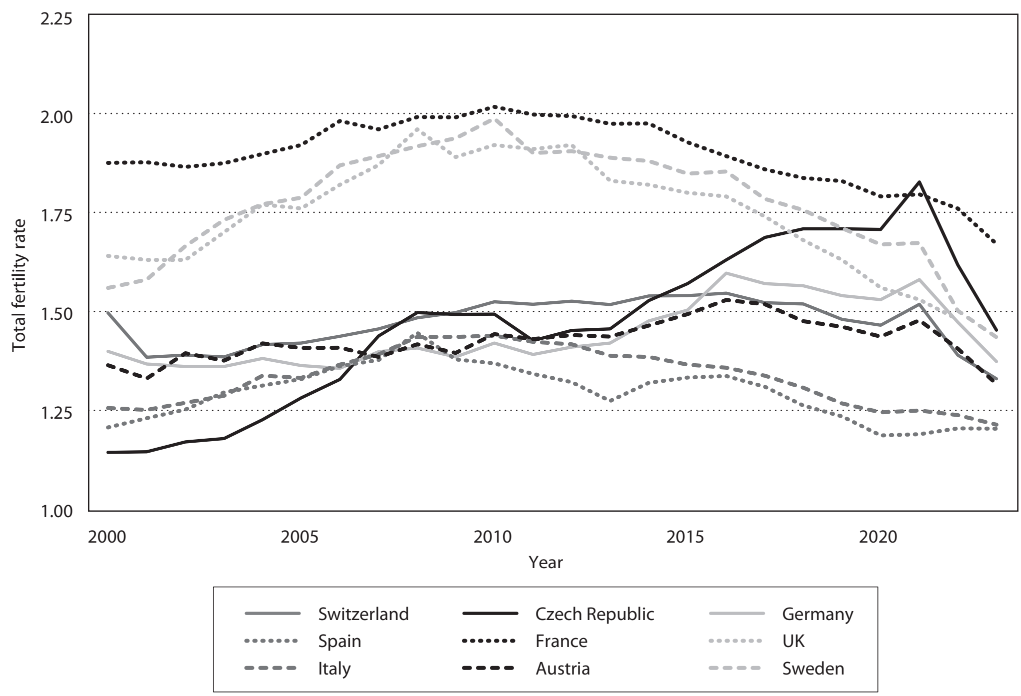
Given the fluctuations of the TFR in recent years and especially the sharp drops in 2022 (1.62) and 2023 (1.45; the official numbers for 2023 were not yet published when the projection was being prepared, but a preliminary analysis using quarterly and monthly data were already indicating a sudden drop), the future predictions of fertility levels are extremely uncertain. To assess the likely direction of the changes, we consulted recent fertility developments in a number of countries in Europe, looking at different regions of Western, Southern and Northern Europe, as well as German-speaking countries and the United Kingdom (UK). All these countries recently experienced significant drops in fertility levels (Figure 2). In many countries, where the fertility used to be higher than in the Czech Republic (like the UK, Sweden, and Switzerland), the TFR has now dropped below the Czech level and even below the level of 1.5, which is regarded as low fertility.

Figure 1 **Total fertility rate, Czech Republic 1980–2023**



Source: Czech Statistical Office; Human Fertility Database.

Figure 2 **Total fertility rate in the Czech Republic and in selected countries, 2000–2023**



Source: Czech Statistical Office; Human Fertility Database.

After discussions in the CZSO projection team, the decision was made to maintain a conservative approach and fix the TFR level at 1.50 for the whole period of 2023–2050.

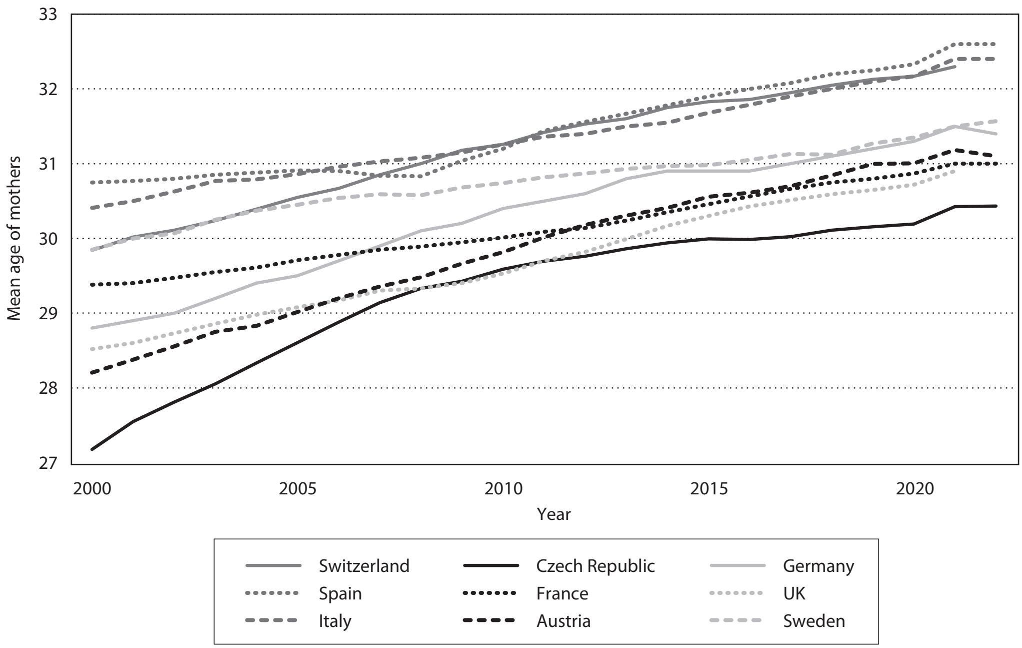
What is more clear, is the continuing increase in the age at which women have their first child and children generally. The mean age at first childbirth completely stagnated between 1970 and 1990 at 22.5 years. After 1990 it began to grow quickly and almost linearly every year by about 0.3 years of age until 2010 (27.6). In the following decade until 2023 (28.9) it increased at a slower pace of about 0.1 yearly. A similar increase was reported in the mean age of mothers, which is by about 1.5–2.5 years higher than the mean age at first birth. Figure 3 shows the mean age of mothers in the Czech Republic and selected European countries. While it is rising, it is still 1–2 years lower in the Czech Republic than in Western societies, and a further significant increase must be expected.

Looking at the age structure of fertility rates (Figure 4 and Figure 5), it is obvious that the biggest decline in fertility has been concentrated in the age group under 25. On the contrary, among women over age 28 the fertility level has increased. While until the 1980s the focus of fertility was on the very young age of 21–22 years, after 1990 it quickly moved towards older ages because of so-called fertility postponement. The shock of the 1990s first caused a quick drop in fertility across the age spectrum, gradually followed by increasing fertility among 'postponing' mothers at older ages. From the period perspective this caused extremely low fertility levels at the end of the 1990s and then a shift in maximum fertility towards the ages around 30.

ESTIMATED FERTILITY RATES FOR 2023–2050 – THE MEDIUM VARIANT

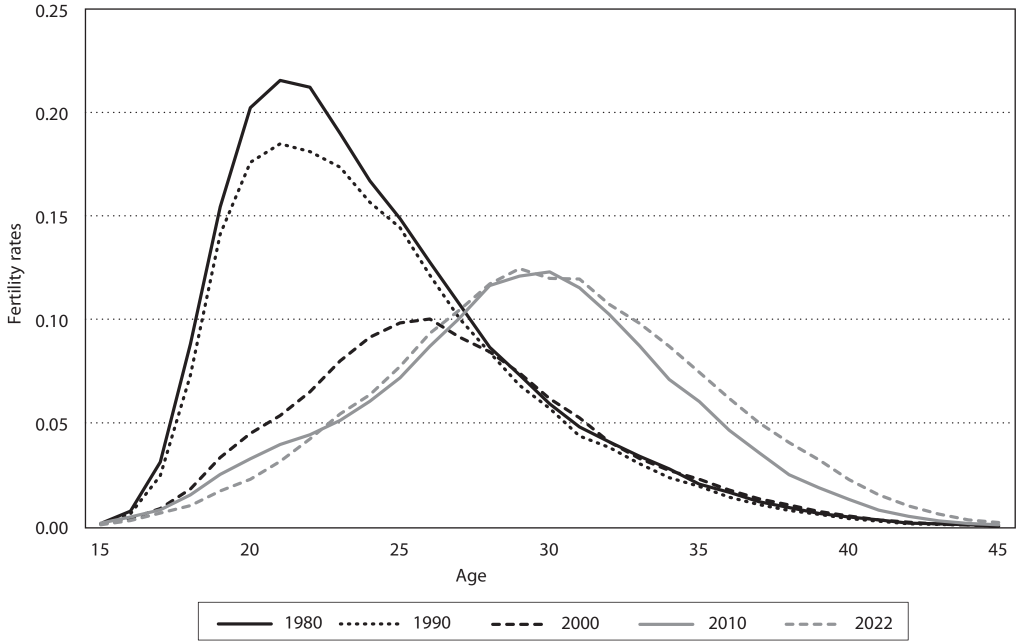
The projection of fertility parameters takes into account past trends as well as fertility developments in other European countries. Given that fertility levels have fluctuated considerably in recent years, as described above, the current projection is highly conservative and does not assume changes in the summary fertility level (TFR). However,

Figure 3 **Mean age of mothers in the Czech Republic and selected countries, 2000–2022**



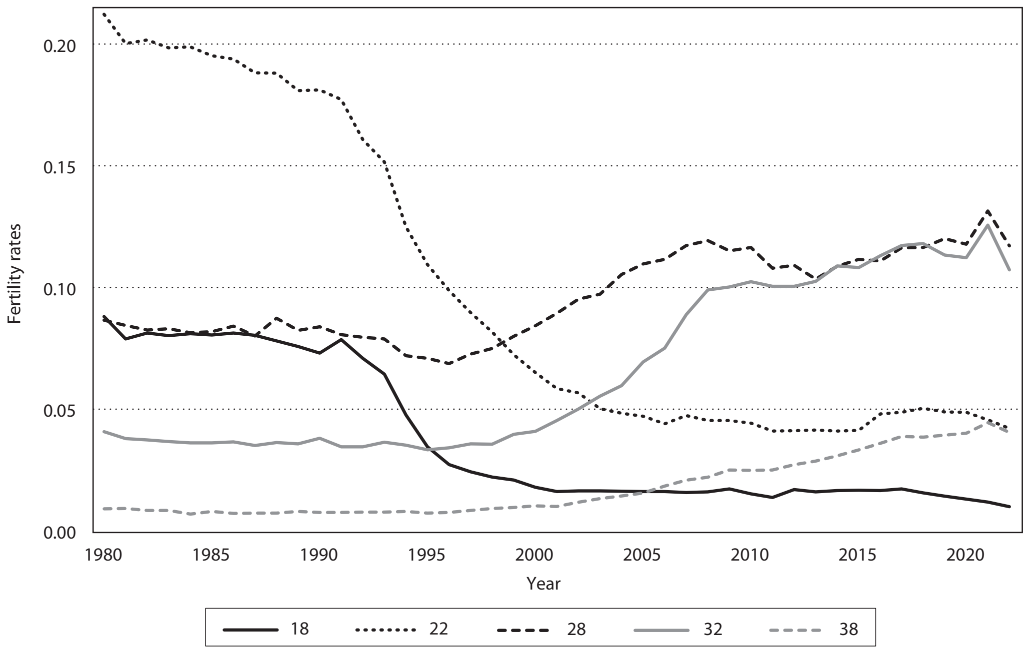
Source: Czech Statistical Office; Eurostat; Human Fertility Database.

Figure 4 **Age-specific fertility rates, Czech Republic 1980, 1990, 2000, 2010, 2022**



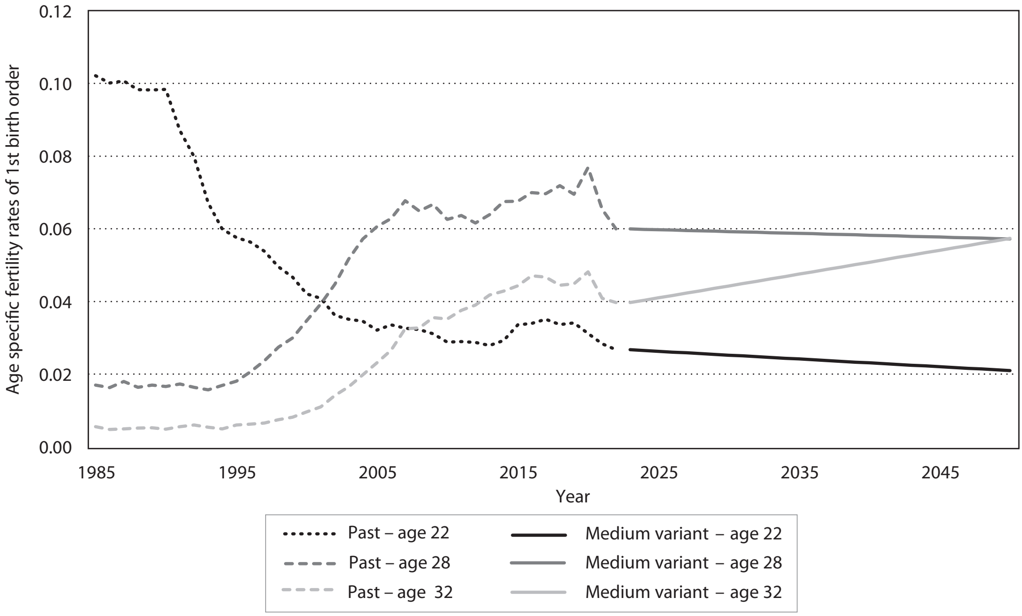
Source: Czech Statistical Office.

Figure 5 **Fertility rates at selected exact ages, Czech Republic 1980–2022**



Source: Czech Statistical Office.

Figure 6 **Estimation of the future development of the fertility rates of first-order births at age 22, 28, and 32 in 2023–2050 based on given values in 2023 and 2050 and previous development in 1985–2022**



Source: Czech Statistical Office; authors' calculations.

it assumes a further increase in the age of women at childbirth, changes in the structure of age-specific fertility rates, and changes in fertility rates by birth order.

Future fertility rates are estimated using a simple linear interpolation between the age-and-parity specific fertility rate in 2023 and an arbitrarily chosen rate in 2050. For each age x and birth order i the fertility rates $f_{x,i}$ in calendar time t are estimated as:

$$f^*_{x,i,t} = \frac{t-2023}{2050-2023} f^*_{x,i,2050} + \frac{2050-t}{2050-2023} f^*_{x,i,2023}$$

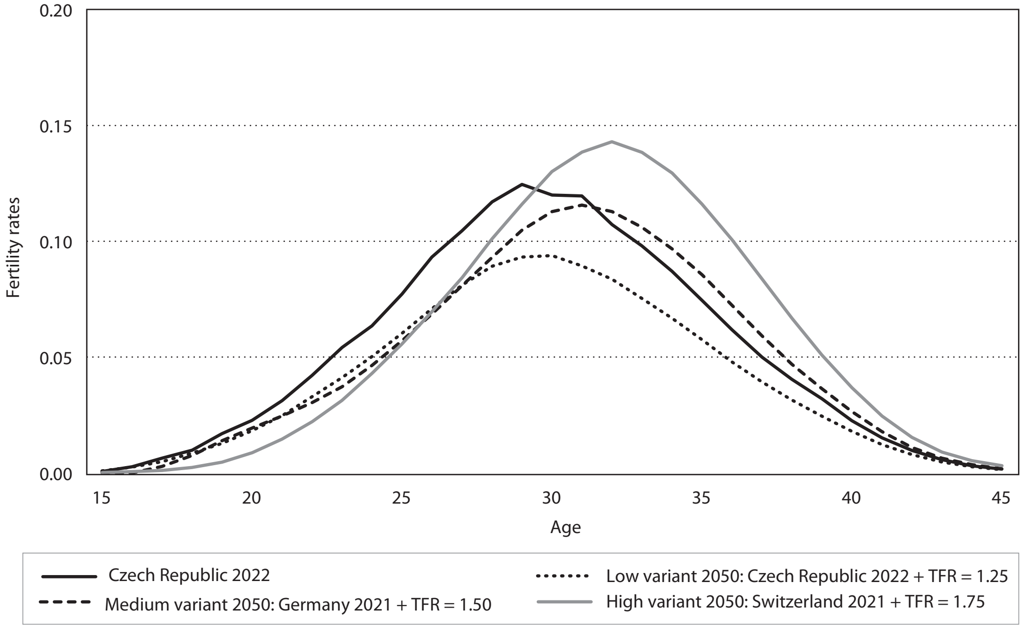
The values of and were determined expertly after discussions among the authors of the projection. The initial estimated fertility schedule retains the age structure (by birth order) used in the 2022 schedule but with smoothed age fluctuations (using a three-year moving average) and with a proportional reduction from a TFR of 1.62 in 2022 to an estimated 1.50 in 2023. The estimated TFR by birth order 1/2/3+ is thus 0.724/0.564/0.212 in 2023 (down from 0.781/0.608/0.228 in 2022). In contrast, the target fertility curve is estimated based on the fertility schedule of culturally and socially similar Germany in 2021, again with smoothed fluctuations and again reduced to 1.50. Germany has witnessed a significant increase in fertility around the age of 35, but at the same time fertility rates at young ages are not too low and are rather similar to the current levels in the Czech Republic. The TFR by birth order in 2050 is estimated at 0.800/0.520/0.180.

The process of deriving age-specific fertility rates is illustrated in Figure 6 using the example of first-order fertility measures at the exact ages of 22, 28, and 32. The fertility rates are further summed by birth order and then by age to the total fertility rates. All the rates evolve until 2050, after which all values are fixed at 2050 levels.

THE LOW AND HIGH VARIANTS OF FERTILITY PROJECTION

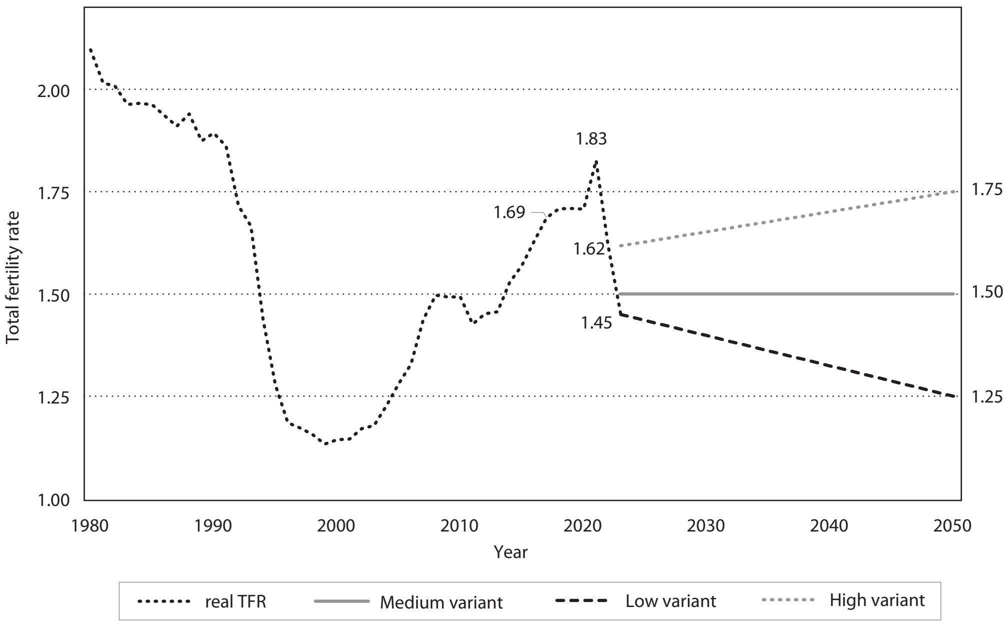
In addition to the medium variant, which is used to calculate the main variant of the population projection, which will be the most utilised output of the CZSO projection, low and high variants of future fertility were also estimated (see Figure 7 and Figure 8).

Figure 7 **Target age-specific profiles of fertility rates for 2050 compared to 2022 – medium, low, and high variants**



Source: Czech Statistical Office; author's calculations.

Figure 8 **Total fertility rate according to the low, medium, and high variants (2023–2050) and compared to previous trends (1980–2023)**



Source: Czech Statistical Office; author's calculations.

In the low and high variants, a more pronounced departure from the medium variant is deliberately forecasted in as early as 2023, capturing the uncertainty of current fluctuations.

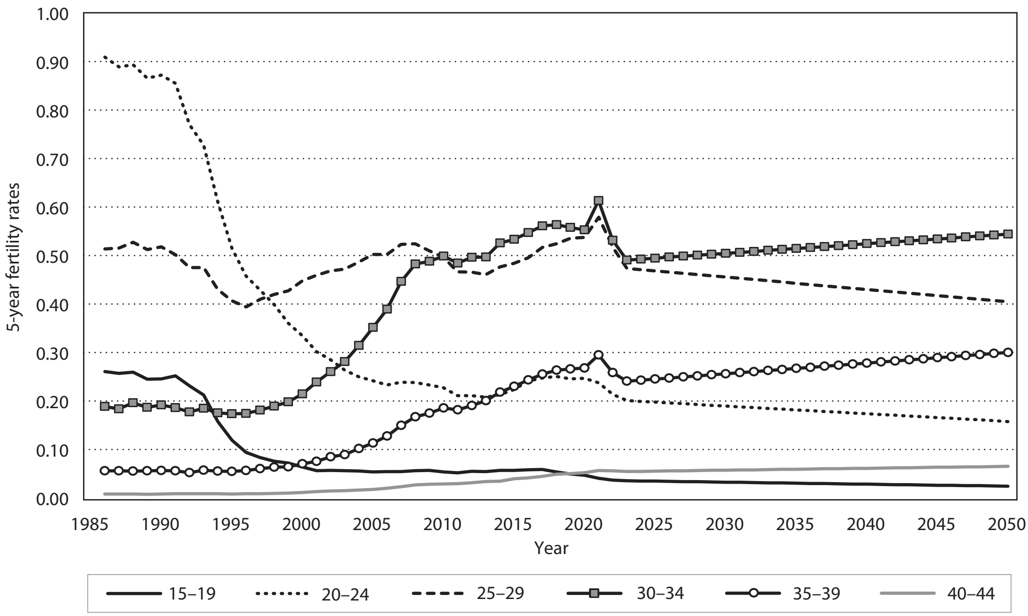
The high variant is held at the 2022 value of 1.62 in 2023. The high variant assumes a further acceleration of fertility ageing, taking the age-specific fertility pattern in Switzerland in 2021 (smoothed by a three-year moving average) as a model schedule for 2050. At the same time, it assumes a linear increase in the level of aggregate fertility to a threshold of 1.75 in 2050. Switzerland is even more advanced (than Germany, chosen as the target age structure in the medium variant) in the process of postponing motherhood to older ages. Here, fertility increases significantly in ages 32–45 and at the same time declines more sharply at young ages.

The low variant is based on the assumption of a continuation of the current trend of declining fertility levels and the suspension of the postponement of births to older ages. The age-specific fertility profile (smoothed by a three-year moving average) is fixed on 2022 levels. The low variant TFR is set at 1.45 children per woman in 2023 and cumulative fertility further declines linearly to 1.25 in 2050. The low and high variant are estimated for the total birth order, i.e. not by birth order as in the medium variant.

RESULTS – FERTILITY LEVELS IN 2023–2050

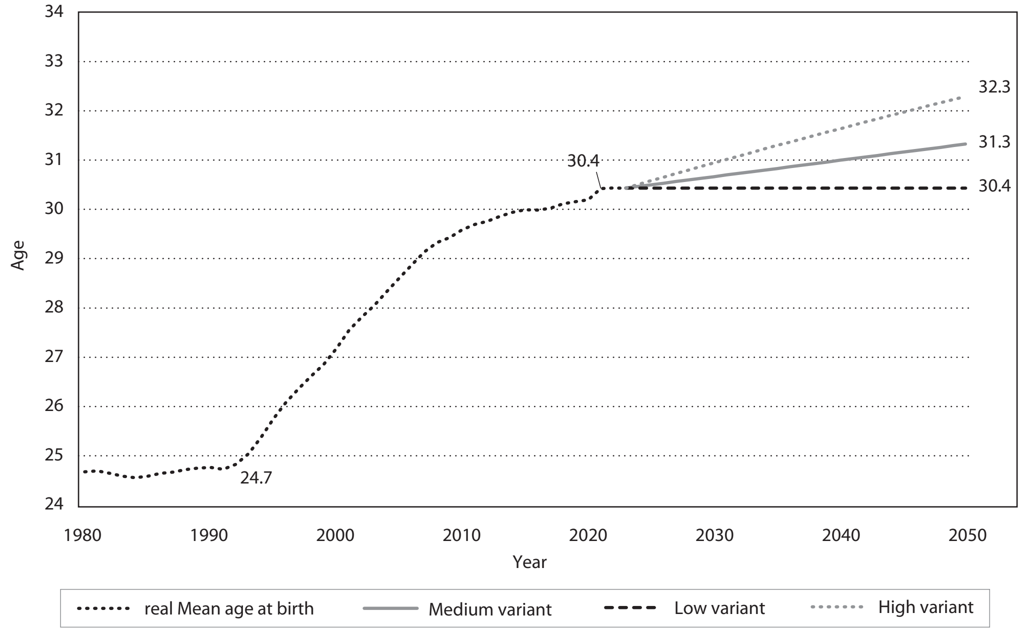
The total fertility level (TFR) was addressed in the preceding section. This section discusses the age and birth order components of fertility change. The fertility of the youngest age groups 15–19 and 20–24 will further decline (Figure 9). The 25–29 and 30–34 age groups, which recently levelled out, will continue to go in opposite directions: while the fertility of women in the late twenties will slightly diminish, women aged 30–34 will become the dominant group with the highest fertility and their fertility will continue to rise. There will also be a significant increase in the fertility of women in their late thirties. The number of women becoming mothers at age 40+ will increase, but their

Figure 9 **Fertility rates for five-year age groups, past developments (1986–2022), and the projection – medium variant (2023–2050)**



Source: Czech Statistical Office; author's calculations.

Figure 10 **Mean age at birth according to the low, medium, and high variants (2023–2050), and in comparison to previous trends (1980–2022)**



Source: Czech Statistical Office; author's calculations.

share on overall fertility will remain marginal, unless significant changes in the technologies of artificial fertilisation occur (which is beyond scope of this projection).

The mean age of mothers (Figure 10) should slowly increase to 31.3 in the medium variant. In the high variant with more postponement, the mean age should increase to 32.3, which corresponds to the current level in Switzerland. The low variant keeps the constant mean age at a level of 30.4 from definition. In the medium variant the mean age at first birth will increase from 28.8 to 30.2, among second births it will go from 31.4 to 32.2, and among third and higher births it will rise from 33.4 to 33.7.

RESULTS – COHORT FERTILITY

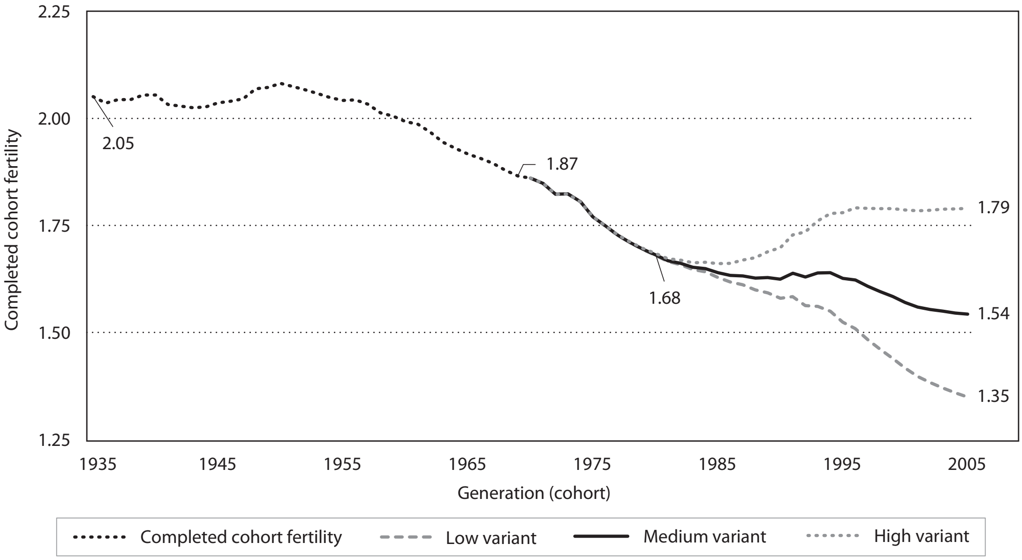
For the internal coherence of the model, it is important that the estimated fertility indicators are plausible and meaningful also from a cohort perspective. Therefore, the period fertility rates were transformed to cohort fertility rates and summed up according to the mother's year of birth (cohort). The transformation from Lexis squares (age in completed years *X*) to Lexis vertical parallelograms (age reached during year) was estimated by averaging the rates in neighbouring ages. The summary indicator of completed cohort fertility (CFR) is then calculated as the sum of such fertility rates for the given cohort *T*:

$$f_{X,i,t} = \frac{\left(f_{x-1,i,t} + f_{x,i,t}\right)}{2}$$

$$CFR_T = \sum_X f_{X,T} = \sum_X f_{X,\,t=T+X}$$

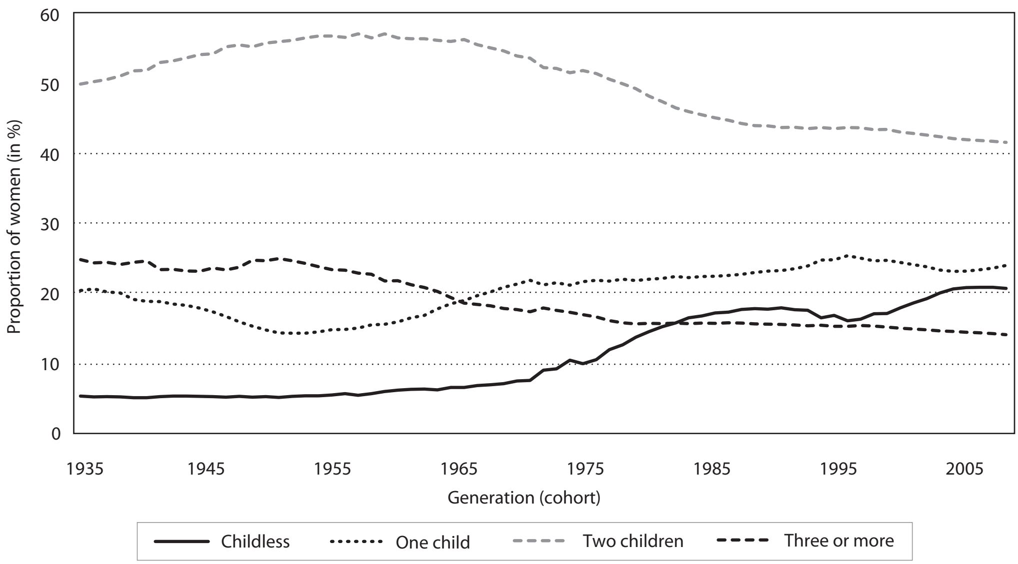
The resulting CFR for advanced generations (estimated up to cohort 2005) converges at the predicted level of the period fertility rate (Figure 11). The plausibility checks were focused on cohorts that recently passed their fertile age. The 'baby boom' generation born in 1974, which in 2024 will reach the age of 50, has completed its fertility at the level of 1.8 children per woman on average, with a childlessness rate of 10 percent. Women ten years younger, born in 1984, will have on average only 1.65 children and a childlessness rate of 17 percent. With subsequent cohorts, fertility is likely to decline even further and to ultimately converge at 1.5. At the same time, the childlessness will increase further and reach 20 percent (Figure 12). The prevalent two-child model will remain dominate, but the share of women with two children will gradually decline from 50–60 percent

Figure 11 **The completed fertility of cohorts born between 1935 and 2005 in the Czech Republic**



Source: Czech Statistical Office; author's calculations.

Figure 12 **Distribution of women by parity, Czech Republic, cohorts born between 1935 and 2005, medium variant**



Source: Czech Statistical Office; author's calculations.

to about 40 percent, while the share of women with just one child will slightly increase from 15–20 to 20–25 percent. The share of women with three or more children will stabilise at around 15 percent.

A COMPARISON WITH PREVIOUS PROJECTIONS OF THE CZSO AND OTHER AGENCIES

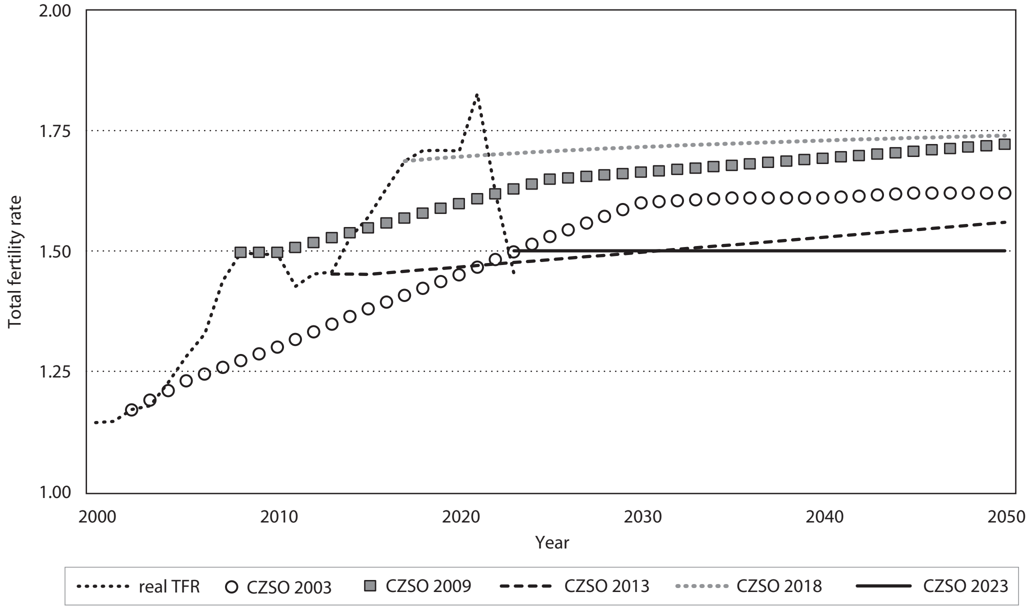
The Czech Statistical Office publishes population projections in five-year intervals – the last five projections were published in 1999, 2003, 2009, 2013, and 2018 (*CZSO*, 2019). In the 1990s the projections were issued every two years. In order to get feedback from past projections and to compare their estimates to real values later reached, this section analyses the medium variants of past projections from 2003, 2009, 2013, and 2018 (Figure 13).

It is clear that the respective predictions of future fertility were based on the fertility trends that existed when the predictions were made. Thus, the projection published in 2003, when the TFR started to increase from the low it had reached, accordingly predicted the TFR would increase to 1.6 by 2030 and beyond. The projection from 2009 estimated an increase that would be less steep but even higher, to 1.7, and the 2018 projection confirmed this. Only the 2013 projection, published at the time of a fertility recession, was less optimistic, estimating the TFR would stagnate at 1.45–1.55. The current 2023 projection follows this logic, projecting stagnation at 1.5.

To capture the complex nature of future developments, the projections use low and high variants. While in the 2009 projection, the variants for the year 2050 estimated low and high levels of 1.55 and 1.85, the 2013 projection used narrow variants with 2050 target levels of 1.45 and 1.61. The higher variant estimate for 2050 was then already outperformed by 2016. In order to avoid such a mistake, the 2018 projection used the variants' broader limits, 1.4 and 1.9, while current estimates put the variants at 1.25 and 1.75.

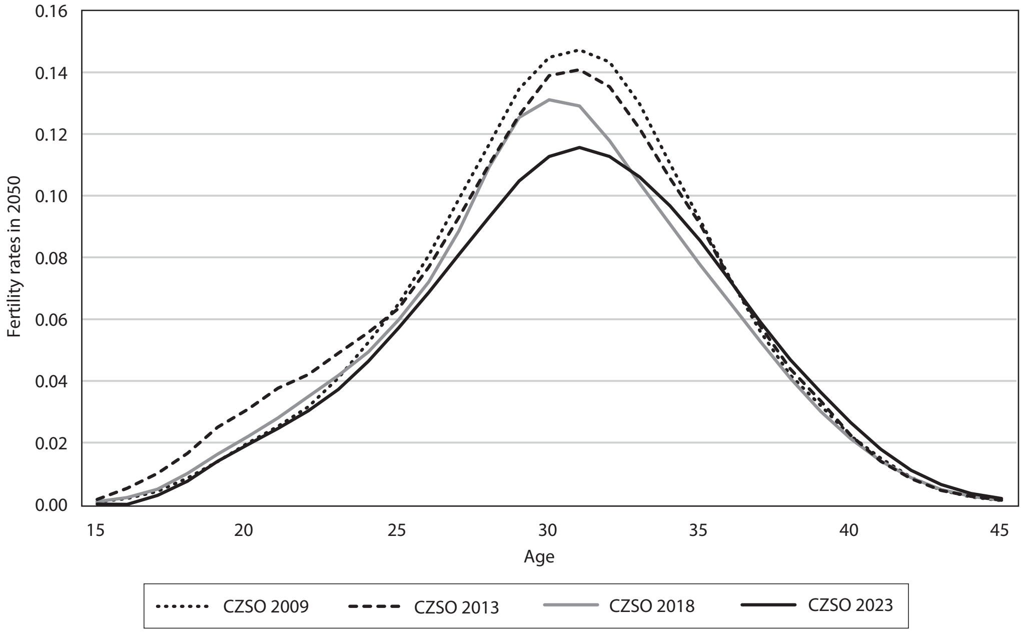
Figure 14 compares the age specific fertility rates estimated for 2050 in the last four projections. The

Figure 13 **A comparison of TFR estimates in the CZSO projections of 2003, 2009, 2013, and 2018, medium variants**



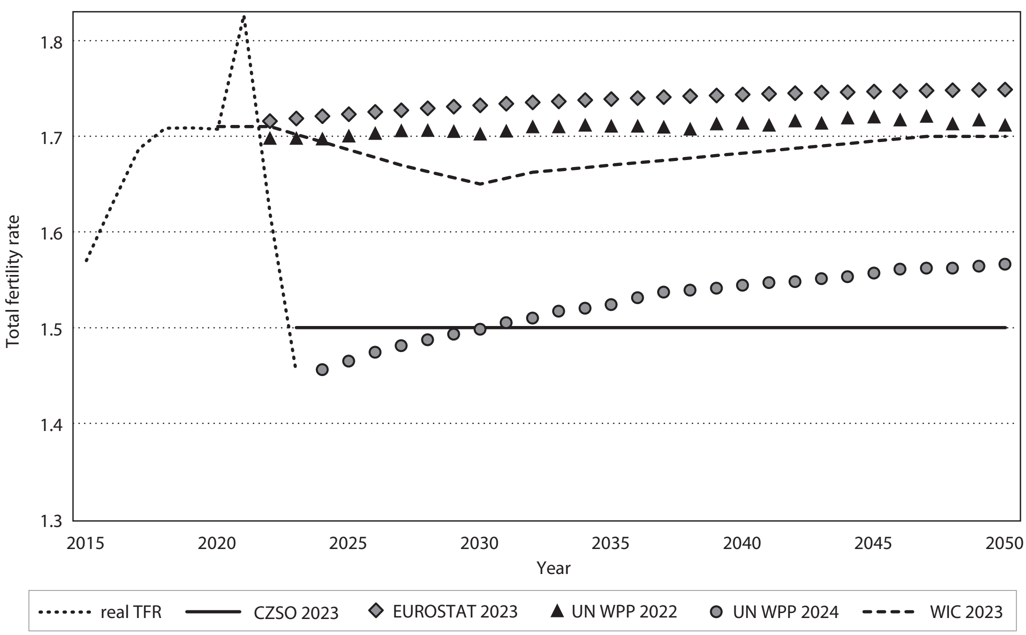
Source: Czech Statistical Office; author's calculations; Zeman (2019).

Figure 14 **A comparison of projected fertility rates for 2050 with the CZSO projections in 2009, 2013, and 2018, medium variants**



Source: Czech Statistical Office; author's calculations; Zeman (2019).

Figure 15 **A comparison of TFRs in alternative projections for the Czech Republic**



Source: Czech Statistical Office; author's calculations; Zeman (2019).

curve is always shifting to older ages, with a maximum at around 30–31 years and just different values for the maximums. The mean age of mothers is similar across the projections: 31.0 in the 2009 projection; 30.8 in the 2013 projection, 30.6 in the 2018 projection; and 31.3 in current projection.

Figure 15 also compares recent fertility projections for the Czech Republic from other agencies: the United Nations Population Division, Eurostat, and the Wittgenstein Centre for Demography and Global Human Capital. The older projections published in 2022 or 2023 all estimate the TFR at around 1.7–1.8 in 2050. However, the new projection from the UN has already taken into account the recent drop in fertility and revised its projections downward (compare UN WPP 2022 and 2024), estimating the TFR in 2030 at 1.5 and in 2050 at 1.57.

CONCLUSION

The projection of fertility rates for the Czech Republic in 2023–2050 followed two main trends: The first is the increasing age at childbirth and postponement of fertility timing, and the second is the fixed fertility level under the recent uncertainty of fertility shifts. The age of maximum fertility will move to the 30–34 age group, and the fertility level will be fixed at the total fertility rate of 1.50. At the same time, the projection variants are sufficiently wide to capture unpredictable fertility shifts in the future. Deep-rooted family patterns and models will change only slightly, while the two-child family model will remain dominant, but the share of ultimately childless women will also significantly increase.

The resulting population projection for the Czech Republic (*CZSO*, 2023a) incorporates components of this fertility projection, as well as projections of mortality and migration, each of which addresses the issue of uncertainty. One of the outcomes of the projection is the legally required 'Report on the expected development of mortality, fertility and migration in the Czech Republic' (*CZSO*, 2023b), which will be used by the Czech government for the much-needed reform of the pension system, as well as for other government measures in the social, pension, and health areas.

References

- Czech Statistical Office. 2019. Projekce obyvatelstva České republiky - 2018 – 2100 [Population projection of the Czech Republic - 2018 – 2100]. Prague: CZSO. Available at: https://www.czso.cz/csu/czso/projekce-obyvatelstva-ceske-republiky-2018-2100.
- Czech Statistical Office. 2023a. Projekce obyvatelstva České republiky - 2023 – 2100 [Population projection of the Czech Republic - 2023 – 2100]. Prague: CZSO. Available at: https://www.czso.cz/csu/czso/projekce-obyvatelstva-ceske-republiky-2023-2100.
- Czech Statistical Office. 2023b. Zpráva o očekávaném vývoji úmrtnosti, plodnosti a migrace v České republice. [Report on the expected development of mortality, fertility and migration in the Czech Republic]. Prague: CZSO. Available at: https://csu.gov.cz/zprava-o-ocekavanem-vyvoji-umrtnosti-plodnosti-a-migrace-v-ceske-republice.
- EUROSTAT. 2023. *Assumptions for fertility rates by age and type of projection.* EUROPOP2023 - Population projections at national level (2022-2100). Eurostat. Data available at: https://ec.europa.eu/eurostat/databrowser/view/proj_23naasfr.
- Human Fertility Database. 2024. Max Planck Institute for Demographic Research and Vienna Institute of Demography. https://www.humanfertility.org.
- K.C., S. – Dhakad, M. – Potancokova, M. – Adhikari, S. – Yildiz, D. – Mamolo, M. – Sobotka, T. – Zeman, K. – Abel, G. – Lutz, W. – and Goujon, A. 2024. *Updating the Shared Socioeconomic Pathways (SSPs) Global Population and Human Capital Projections*. IIASA Working Paper. Laxenburg, Austria: WP-24-003. https://pure.iiasa.ac.at/19487. Data available at: https://dataexplorer.wittgensteincentre.org/wcde-v3/.
- R Core Team. 2024. *R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing.* Vienna, Austria. https://www.R-project.org.
- Sobotka, T. – Zeman, K. – Jasilioniene, A. – Winkler-Dworak, M. – Brzozowska, Z. – Alustiza-Galarza, A. – Németh, L. – Jdanov, D. 2023. Pandemic roller- coaster? Birth trends in higher-income countries during the COVID-19 pandemic. *Population and Development Review*, 50(S1), pp. 23–58. https://doi.org/10.111/padr.12544.

- Šanda, R. 2023. Využití administrativních zdrojů dat při vymezení obyvatelstva ve Sčítání lidu 2021 v Česku. [The use of administrative data sources in the 2021 population census in Czechia]. *Demografie*, 65(3), pp. 120–135. https://doi.org/10.54694/dem.0323.
- UN WPP. 2024. *World Population Prospects. United Nations Population Division*. Available at: https://population.un.org/wpp/.
- Zeman, K. 2019. Fertility assumptions in the population projection of the Czech Republic of Czech Statistical Office 2018–2100. *Demografie*, 61(4), pp. 249–260.

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Population and Vital Statistics of the Czech Republic: Cohesion Regions and Regions in 2023

Cohesion region (NUTS 2), region (NUTS 3)	Population 1 July	Population 31 December	Marriages	Divorces	Live births	Abortions	Deaths			Increase (decrease)			Marriages	Divorces	Live births	Deaths	Total increase
							Total	Within 1 year	Within 28 days	Natural	Net migration	Total	per 1,000 inhabitants				
Czech Republic	*10,878,042*	*10,900,555*	*48,268*	*19,453*	*91,149*	*24,940*	*112,795*	*200*	*125*	*–21,646*	*94,672*	*73,026*	*4.4*	*1.8*	*8.4*	*10.4*	*6.7*
Praha	*1,374,334*	*1,384,732*	*6,393*	*2,288*	*12,575*	*2,820*	*12,212*	*20*	*9*	*363*	*27,043*	*27,406*	*4.7*	*1.7*	*9.1*	*8.9*	*19.9*
Střední Čechy	*1,450,379*	*1,455,940*	*6,181*	*2,758*	*12,249*	*3,206*	*13,765*	*29*	*19*	*–1,516*	*18,065*	*16,549*	*4.3*	*1.9*	*8.4*	*9.5*	*11.4*
Jihozápad	*1,264,226*	*1,267,879*	*5,620*	*2,307*	*10,291*	*2,795*	*13,050*	*22*	*15*	*–2,759*	*12,947*	*10,188*	*4.4*	*1.8*	*8.1*	*10.3*	*8.1*
Severozápad	*1,107,740*	*1,106,246*	*5,007*	*2,180*	*8,463*	*3,280*	*12,863*	*23*	*12*	*–4,400*	*4,714*	*314*	*4.5*	*2.0*	*7.6*	*11.6*	*0.3*
Severovýchod	*1,537,321*	*1,538,237*	*6,614*	*2,754*	*12,614*	*3,453*	*16,181*	*25*	*17*	*–3,567*	*8,599*	*5,032*	*4.3*	*1.8*	*8.2*	*10.5*	*3.3*
Jihovýchod	*1,740,143*	*1,744,709*	*7,762*	*2,918*	*15,145*	*3,348*	*17,792*	*30*	*23*	*–2,647*	*15,379*	*12,732*	*4.5*	*1.7*	*8.7*	*10.2*	*7.3*
Střední Morava	*1,213,756*	*1,213,608*	*5,197*	*2,069*	*10,183*	*2,878*	*13,257*	*29*	*18*	*–3,074*	*4,349*	*1,275*	*4.3*	*1.7*	*8.4*	*10.9*	*1.1*
Moravskoslezsko	*1,190,143*	*1,189,204*	*5,494*	*2,179*	*9,629*	*3,160*	*13,675*	*22*	*12*	*–4,046*	*3,576*	*–470*	*4.6*	*1.8*	*8.1*	*11.5*	*–0.4*
Hlavní město Praha	*1,374,334*	*1,384,732*	*6,393*	*2,288*	*12,575*	*2,820*	*12,212*	*20*	*9*	*363*	*27,043*	*27,406*	*4.7*	*1.7*	*9.1*	*8.9*	*19.9*
Středočeský kraj	*1,450,379*	*1,455,940*	*6,181*	*2,758*	*12,249*	*3,206*	*13,765*	*29*	*19*	*–1,516*	*18,065*	*16,549*	*4.3*	*1.9*	*8.4*	*9.5*	*11.4*
Jihočeský kraj	*654,078*	*654,505*	*2,990*	*1,201*	*5,349*	*1,637*	*6,939*	*13*	*10*	*–1,590*	*3,792*	*2,202*	*4.6*	*1.8*	*8.2*	*10.6*	*3.4*
Plzeňský kraj	*610,148*	*613,374*	*2,630*	*1,106*	*4,942*	*1,158*	*6,111*	*9*	*5*	*–1,169*	*9,155*	*7,986*	*4.3*	*1.8*	*8.1*	*10.0*	*13.1*
Karlovarský kraj	*294,964*	*295,077*	*1,304*	*589*	*2,131*	*717*	*3,346*	*3*	*2*	*–1,215*	*2,697*	*1,482*	*4.4*	*2.0*	*7.2*	*11.3*	*5.0*
Ústecký kraj	*812,776*	*811,169*	*3,703*	*1,591*	*6,332*	*2,563*	*9,517*	*20*	*10*	*–3,185*	*2,017*	*–1,168*	*4.6*	*2.0*	*7.8*	*11.7*	*–1.4*
Liberecký kraj	*450,450*	*450,728*	*1,939*	*890*	*3,549*	*1,289*	*4,735*	*10*	*4*	*–1,186*	*2,737*	*1,551*	*4.3*	*2.0*	*7.9*	*10.5*	*3.4*
Královéhradecký k.	*556,633*	*556,949*	*2,444*	*957*	*4,549*	*1,131*	*6,019*	*6*	*5*	*–1,470*	*3,152*	*1,682*	*4.4*	*1.7*	*8.2*	*10.8*	*3.0*
Pardubický kraj	*530,238*	*530,560*	*2,231*	*907*	*4,516*	*1,033*	*5,427*	*9*	*8*	*–911*	*2,710*	*1,799*	*4.2*	*1.7*	*8.5*	*10.2*	*3.4*
Kraj Vysočina	*517,019*	*517,960*	*2,184*	*835*	*4,476*	*955*	*5,466*	*9*	*6*	*–990*	*4,173*	*3,183*	*4.2*	*1.6*	*8.7*	*10.6*	*6.2*
Jihomoravský kraj	*1,223,124*	*1,226,749*	*5,578*	*2,083*	*10,669*	*2,393*	*12,326*	*21*	*17*	*–1,657*	*11,206*	*9,549*	*4.6*	*1.7*	*8.7*	*10.1*	*7.8*
Olomoucký kraj	*632,790*	*632,864*	*2,774*	*1,121*	*5,322*	*1,544*	*6,981*	*15*	*8*	*–1,659*	*2,721*	*1,062*	*4.4*	*1.8*	*8.4*	*11.0*	*1.7*
Zlínský kraj	*580,966*	*580,744*	*2,423*	*948*	*4,861*	*1,334*	*6,276*	*14*	*10*	*–1,415*	*1,628*	*213*	*4.2*	*1.6*	*8.4*	*10.8*	*0.4*
Moravskoslezský k.	*1,190,143*	*1,189,204*	*5,494*	*2,179*	*9,629*	*3,160*	*13,675*	*22*	*12*	*–4,046*	*3,576*	*–470*	*4.6*	*1.8*	*8.1*	*11.5*	*–0.4*

Radek Havel

Population and Vital Statistics of the Czech Republic in Towns with a Population above 50,000 in 2023

Town	Population 1 July	Population 31 December	Marriages	Divorces	Live births	Abortions	Deaths	Increase (decrease)			Marriages	Divorces	Live births	Deaths	Total increase
								Natural	Net migration	Total	per 1.000 inhabitants				
Praha	1,374,334	1,384,732	6,393	2,288	12,575	2,820	12,212	363	27,043	27,406	4.7	1.7	9.1	8.9	19.9
Brno	398,688	400,566	1,921	627	3,828	788	4,041	−213	4,678	4,465	4.8	1.6	9.6	10.1	11.2
Ostrava	284,468	284,765	1,316	462	2,381	1,080	3,426	−1,045	2,306	1,261	4.6	1.6	8.4	12.0	4.4
Plzeň	183,722	185,599	789	301	1,536	356	1,782	−246	4,605	4,359	4.3	1.6	8.4	9.7	23.7
Liberec	107,663	107,982	450	211	841	314	1,055	−214	807	593	4.2	2.0	7.8	9.8	5.5
Olomouc	102,167	102,293	478	188	936	319	1,056	−120	588	468	4.7	1.8	9.2	10.3	4.6
České Budějovice	96,993	97,377	476	199	886	277	1,126	−240	1,200	960	4.9	2.1	9.1	11.6	9.9
Hradec Králové	93,737	93,906	398	159	758	150	1,035	−277	677	400	4.2	1.7	8.1	11.0	4.3
Pardubice	92,418	92,362	417	176	817	220	1,009	−192	405	213	4.5	1.9	8.8	10.9	2.3
Ústí nad Labem	91,637	91,342	395	182	749	283	1,089	−340	−281	−621	4.3	2.0	8.2	11.9	−6.8
Zlín	74,221	74,255	293	141	550	162	835	−285	349	64	3.9	1.9	7.4	11.3	0.9
Havířov	70,093	69,694	344	153	501	198	930	−429	−122	−551	4.9	2.2	7.1	13.3	−7.9
Kladno	68,851	69,078	284	132	549	234	808	−259	901	642	4.1	1.9	8.0	11.7	9.3
Most	64,131	63,882	288	112	541	215	760	−219	245	26	4.5	1.7	8.4	11.9	0.4
Opava	55,548	55,600	250	112	432	139	605	−173	261	88	4.5	2.0	7.8	10.9	1.6
Jihlava	53,468	53,986	225	89	457	95	551	−94	1,532	1,438	4.2	1.7	8.5	10.3	26.9
Frýdek-Místek	54,078	53,938	282	91	446	113	671	−225	−25	−250	5.2	1.7	8.2	12.4	−4.6
Teplice	50,933	50,959	240	88	391	144	564	−173	289	116	4.7	1.7	7.7	11.1	2.3
Karviná	50,060	49,724	227	68	374	103	751	−377	−71	−448	4.5	1.4	7.5	15.0	−8.9

Radek Havel

Abstracts of Articles Published in the Journal *Demografie* in 2024 (Nos. 1–3)

Marcela Káčerová – Dagmar Kusendová – Iveta Stankovičová

VIACROZMERNÁ ANALÝZA POPULAČNÉHO STARNUTIA V OKRESOCH SLOVENSKA V ROKOCH 2011 A 2021

Population ageing is a typical feature of population development in the majority of countries in the world. In each population, this process is specific –whether in terms of the timing of its onset or the factors that modify the process of population ageing. The main aim of this article is to identify the processes of population ageing in the districts of Slovakia. A regional analysis of this process focused on population ageing in Slovak districts in the years 2011 and 2021 using cluster analysis. The results of the cluster analysis of population ageing identified northern and eastern Slovakia as districts whose populations have a younger age structure. The western and southwestern districts of Slovakia have populations with an old age structure. In 2021, this age polarity began to change the territory of Slovakia. The suburbanised region of the capital, Bratislava, is becoming significant, as the population in the districts there is getting younger.

Keywords: population ageing, districts, evaluation of ageing, cluster analysis, Slovakia
https://doi.org/10.54694/dem.0328 **Demografie,** 2024, **66(1): 4–23**

Bety Ukolova – Boris Burcin

ANALÝZA FAKTORŮ ASOCIOVANÝCH S VÍCEČETNÝMI PŘÍČINAMI SMRTI V ČESKU V ROCE 2018 POMOCÍ XGBOOST REGRESE A METODY SHAP

This study focuses on the factors that are associated with recording multiple causes as the cause of death in Czechia. An XGBoost multiple regression is used in the analysis and its results are interpreted with SHAP values. The most significant factors associated with the number of causes of death, ranked in order of importance, are the place of death, the region, and the underlying cause of death. Age and autopsy also contribute, albeit to a lesser extent. Several important interactions were identified as well.

Keywords: multiple causes of death, death certificate, mortality, Czechia **Demografie,** 2024, **66(1): 24–38**
https://doi.org/10.54694/dem.0331

Štěpánka Lehmann – Jana Barvíková

DYNAMIKA VYJEDNÁVÁNÍ O USPOŘÁDÁNÍ PÉČE O DĚTI PO ROZCHODU ČI ROZVODU RODIČŮ

Based on data from a questionnaire survey and in-depth qualitative interviews with parents who have separated, the text describes the dynamics of the negotiations relating to physical custody of a child. When negotiating a custody arrangement, parents develop their strategies in relation to the prevailing model in Czech society of granting mothers sole custody. Most women prefer to maintain this arrangement, while fathers more often seek to move towards an equal division of care. When fathers are granted sole custody it is not usually on the basis of a consensual agreement being reached between parents. Custody arrangements enforced without parental consent are potentially conflictual and unstable.

Keywords: physical custody of a child, preferences, parental conflict, court proceeding, dynamics
https://doi.org/10.54694/dem.0333 **Demografie,** 2024, **66(1): 39–57**

Anne Herm – Allan Puur – Michel Poulain

LIVING ARRANGEMENTS AS AN INDICATOR OF THE INTEGRATION OF OLDER ETHNIC RUSSIAN IMMIGRANTS IN ESTONIA

This study is about living arrangements of older ethnic Russians living in Estonia most of whom are long-term immigrants. Studies involving immigrant populations have suggested that the integration process would decrease their differences with the host population, including their living arrangement preferences. Our investigation shows that despite long-term residence in country, living arrangements' pattern of ethnic Russians in Estonia is rather different from that of Estonians and that can be explained by low integration. The study is based on the microdata of the Estonian 2011 population and housing census and the 5% sample of the Russian 2010 census from the IPUMS database. In the first part of the analysis, we employ origin-destination perspective to comparing living arrangements of Russians in Estonia with Estonians and Russians in Russia. In the second part, we use binary logistic regression to study the association between living arrangements, migration background and integration to host society.

Keywords: older persons, living arrangements, integration, immigrants, ethnic group, education, marital status, Estonia
https://doi.org/10.54694/dem.0338 **Demografie,** 2024, **66(2): 113–129**

Jitka Slabá – Barbora Janáková Kuprová

THE MARITAL FERTILITY OF MEN AND WOMEN IN CZECHIA BEFORE THE FIRST DEMOGRAPHIC TRANSITION AND IN THE CURRENT POPULATION

The aim of this study is to analyse the changes in the marital fertility of men and women in Czechia before the first demographic transition (data obtained by excerpting the parish registers of Škvorec manor in the years 1760–1839) and in the current population (data from the Czech GGS II based on interviews between 2020 and 2022) using a unified methodology. The results confirm previous findings on historical and modern marital fertility – determining the overall intensity of marital fertility by the duration of marriage in the historical population, the decrease in marital fertility by the decrease in the number of higher-order births in the modern population, etc. The results show that the timing of the first childbirth in marriage is similar in both (the historical and the modern) populations. Historical marriages with the same number of children have a much shorter reproductive window than modern marriages, with no differences at the beginning of the reproductive period, but with differences especially at the end. The timing of reproduction (median age at birth of the first child) does not differ for first marriage in modern and historical populations. In the historical population, women's fertility was limited at a lower age than men's fertility. In the modern population, the intensity of fertility by sex does not differ. In both populations the median duration of the reproductive window does not differ according to either sex or marriage order.

Keywords: marital fertility, first and second demographic transition, female and male fertility
https://doi.org/10.54694/dem.0339 **Demografie,** 2024, **66(2): 130–153**

Filip Čábela – Luděk Šídlo

DEMOGRAFICKÉ STÁRNUTÍ V ČESKU MEZI LETY 2012–2022 PROSTŘEDNICTVÍM VYBRANÝCH RETROSPEKTIVNÍCH A PROSPEKTIVNÍCH UKAZATELŮ

Demographic ageing is considered a significant phenomenon and one of the most important population issues of the 21st century. It is a process that has no parallel in human history but is completely natural. The ageing of the population itself is a consequence of the changing quality of life, a new approach to lifestyle, and improvements in the health status of the population, all of which lead to improvements in the level of mortality, especially at old age. The concept of prospective age is not based on the number of years that a given person has already lived, but on the number of years that people probably have left to live. This paper presents the concept of prospective age and the development of prospective indicators using the example of Czechia between 2012 and 2022, focusing on a comparison of retrospective indicators with prospective ones. The paper also reveals the effect of the Covid-19 pandemic on demographic ageing indicators.

Keywords: demographic ageing, prospective age, retrospective and prospective indicators, Covid-19, Czechia
https://doi.org/10.54694/dem.0341 **Demografie,** 2024, **66(2): 154–165**

Branislav Šprocha

OSOBY RÓMSKEJ NÁRODNOSTI PODĽA TYPU CENZOVEJ DOMÁCNOSTI NA SLOVENSKU VO VÝSLEDKOCH SČÍTANIA OBYVATEĽOV 2021

The aim of the article was to analyse the census households of persons of Roma nationality in Slovakia according to the results of the Population and Household Census 2021. Moreover, we also tried to point out some factors that could influence possible differences between the structure of the census households of the Roma and non-Roma population.

Our results show that people of Roma nationality more often live in complete family households with dependent children and form their family at a younger age. Cohabiting couples also make up a significant portion of households. In the context of high non-marital fertility, single parent households are probably also a very important social group. Conversely, households of individuals are less common compared in the Roma than in the non-Roma population. A specific feature of Roma households is also the more frequent presence of men and women living in multi-person non-family households.

Keywords: Roma population, census households, complete family, cohabitation, single parent household, multi-person non-family household, Slovakia

https://doi.org/10.54694/dem.0347 **Demografie,** 2024, **66(3): 181–196**

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– *Potraty*. 2005. Prague: Ústav zdravotnických informací a statistiky.

Articles in periodicals

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Daly, M. 2004. 'Family Policy in European Countries.' In *Perspectives on Family Policy in the Czech Republic*, pp. 62–71. Prague: MPSV ČR.

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Syrovátka, A. 1962b. 'Child Mortality from Automobile Accidents in the Czech Lands.' *Czech Medical Journal*, 101, pp. 1513–1517.

In-text references

(*Srb*, 2004); (*Srb*, 2004: pp. 36–37); (*Syrovátka et al.*, 1984).

Table and figure headings

Table 1: Population and vital statistics, 1990–2010
Figure 1: Relative age distribution of foreigners and total population of CR, 31 Dec 2009

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