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

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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.

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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).

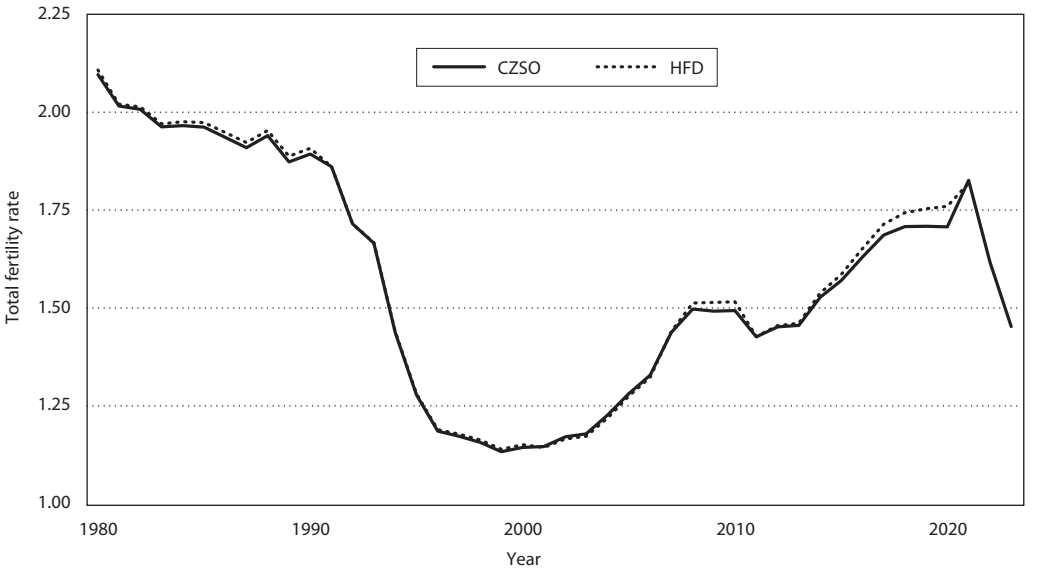
The main guideline for deriving future fertility development is the postponement of fertility to an older age. Predicting future fertility levels is currently quite difficult given the unclear development of fertility levels in the last years. Following the initial decline in fertility levels in the 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.

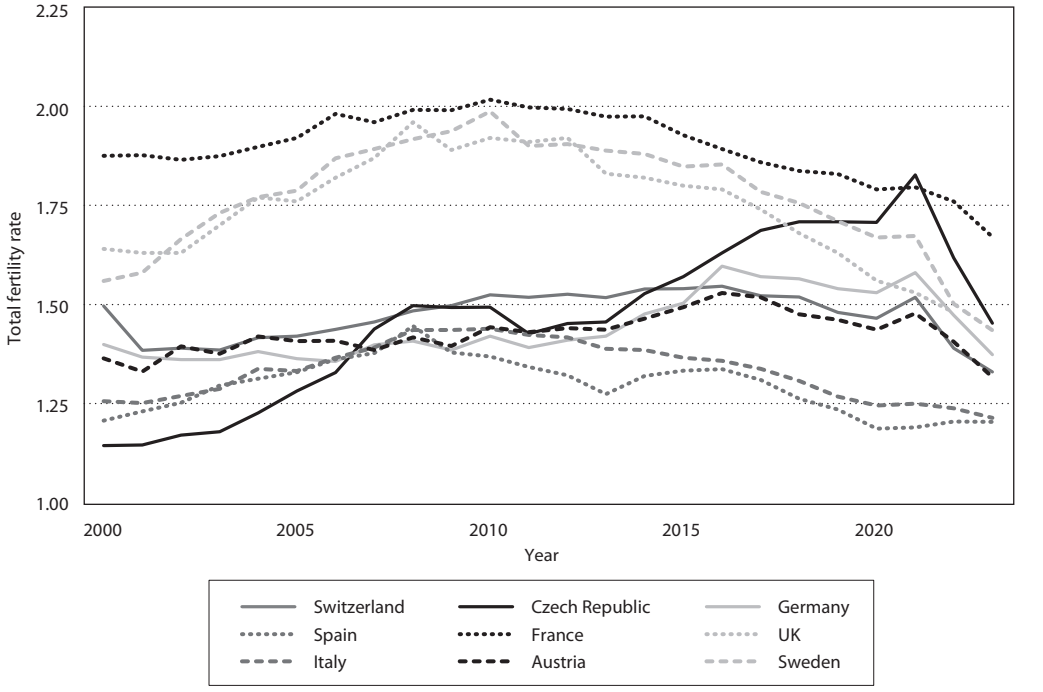
Given the fluctuations of the TFR in recent years and especially the sharp drops in 2022 (1.62) and 2023 (1.45; the official numbers for 2023 were not yet published when the projection was being prepared, but a preliminary analysis using quarterly and monthly data were already indicating a sudden drop), 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.

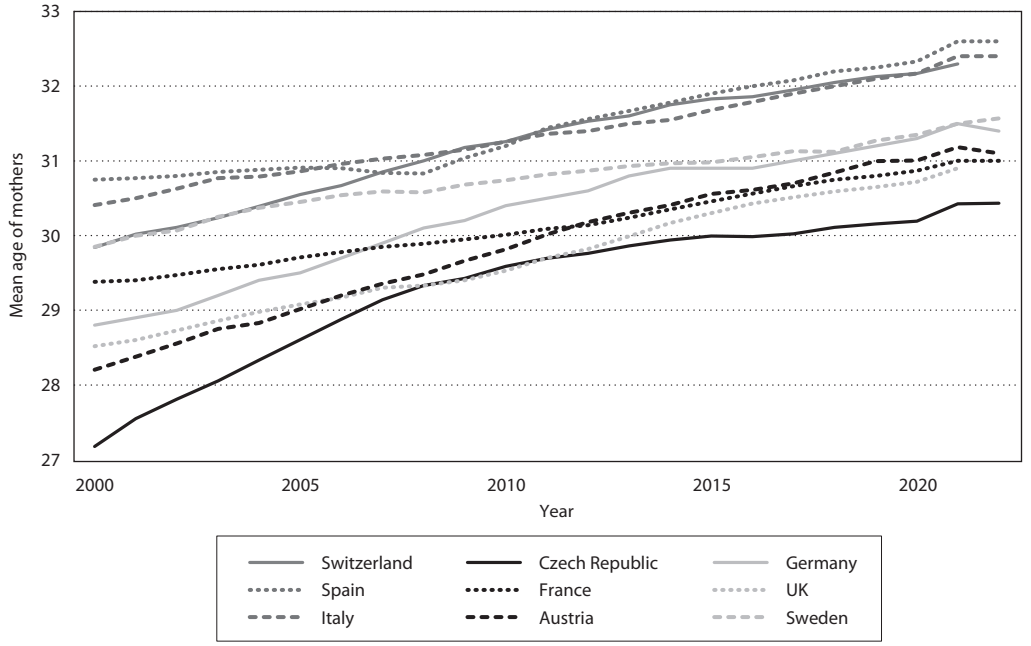
What is more clear, is the continuing increase in the age at which women have their first child and children generally. The mean age at first childbirth completely stagnated between 1970 and 1990 at 22.5 years. After 1990 it began to grow quickly and almost linearly every year by about 0.3 years of age 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

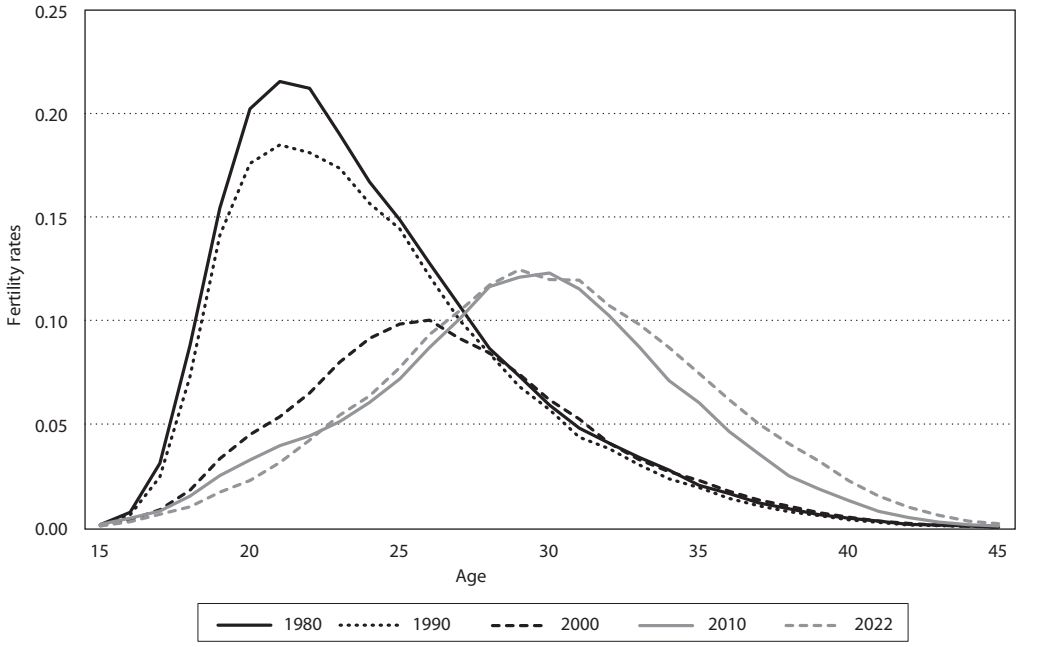
The projection of fertility parameters takes into account past trends as well as fertility developments in other European countries. Given that fertility levels have fluctuated considerably in recent years, as described above, the current projection is highly conservative and does not assume changes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

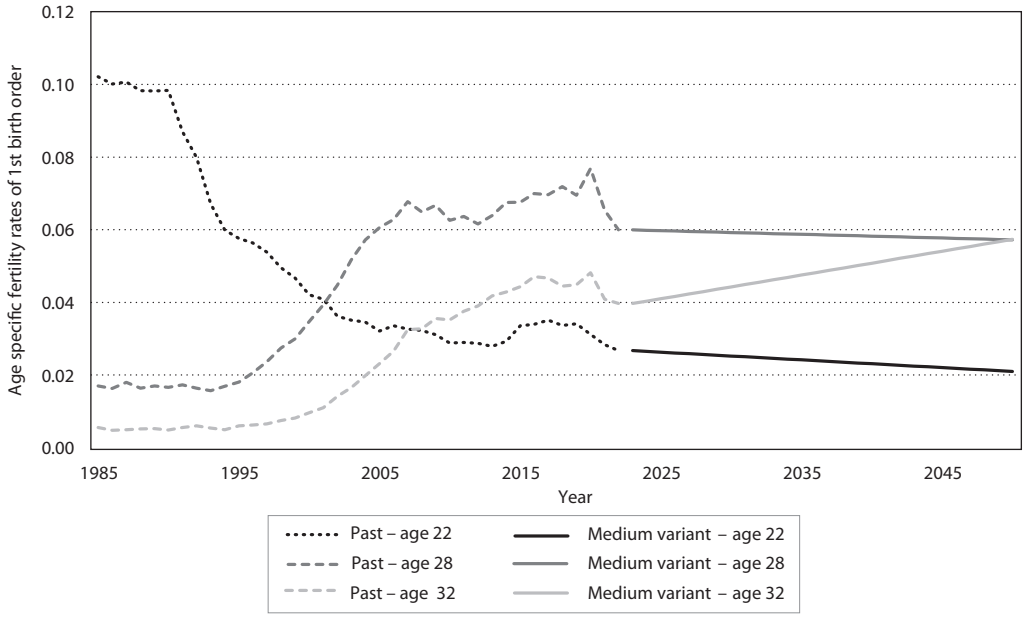


Source: Czech Statistical Office.

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:

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

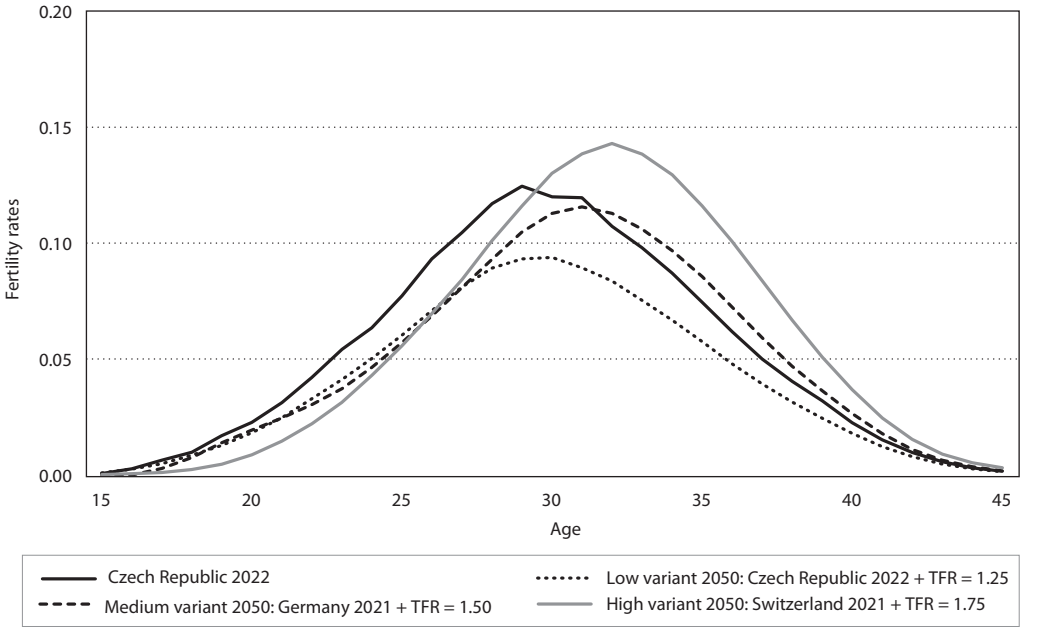
The values of and were determined expertly after discussions among the authors of the projection. The initial estimated fertility schedule retains the age structure (by birth order) used in the 2022 schedule but with smoothed age fluctuations (using a three-year moving average) and with a proportional 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

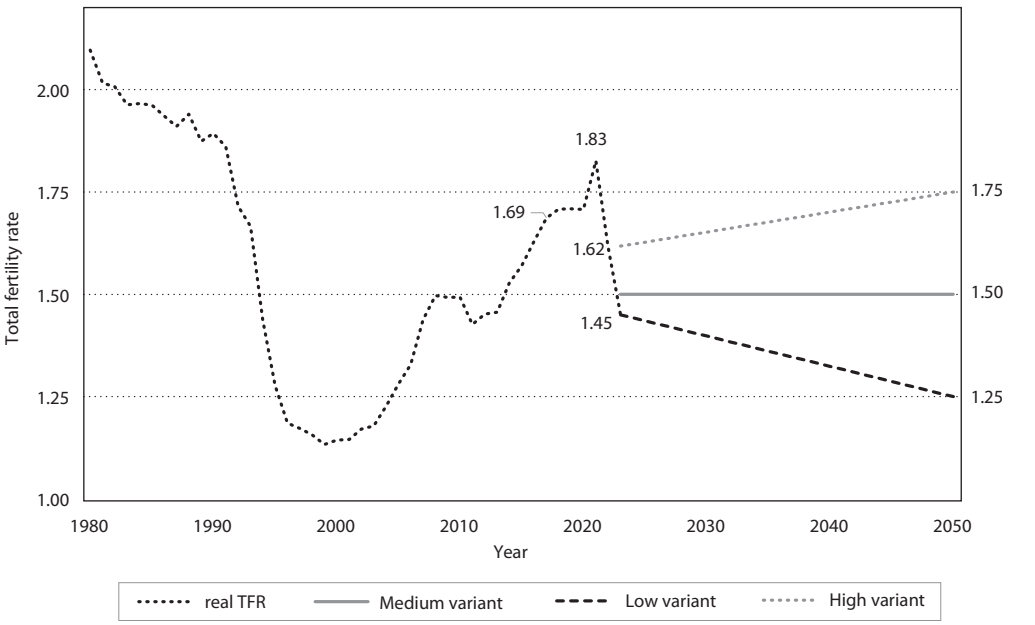
In addition to the medium variant, which is used to calculate the main variant of the population projection, which will be the most utilised output of the CZSO projection, low and high variants of future fertility were also estimated (see Figure 7 and Figure 8).

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.

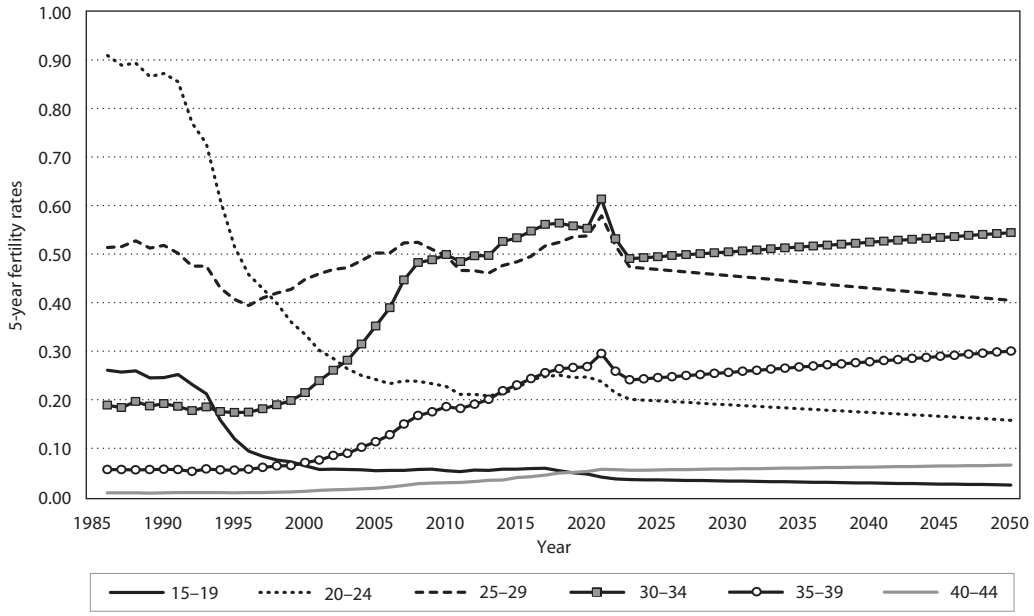
The high variant is held at the 2022 value of 1.62 in 2023. The high variant assumes a further acceleration of fertility ageing, taking the age-specific fertility pattern in Switzerland in 2021 (smoothed by a three-year moving average) as a model schedule for 2050. At the same time, it assumes a linear 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

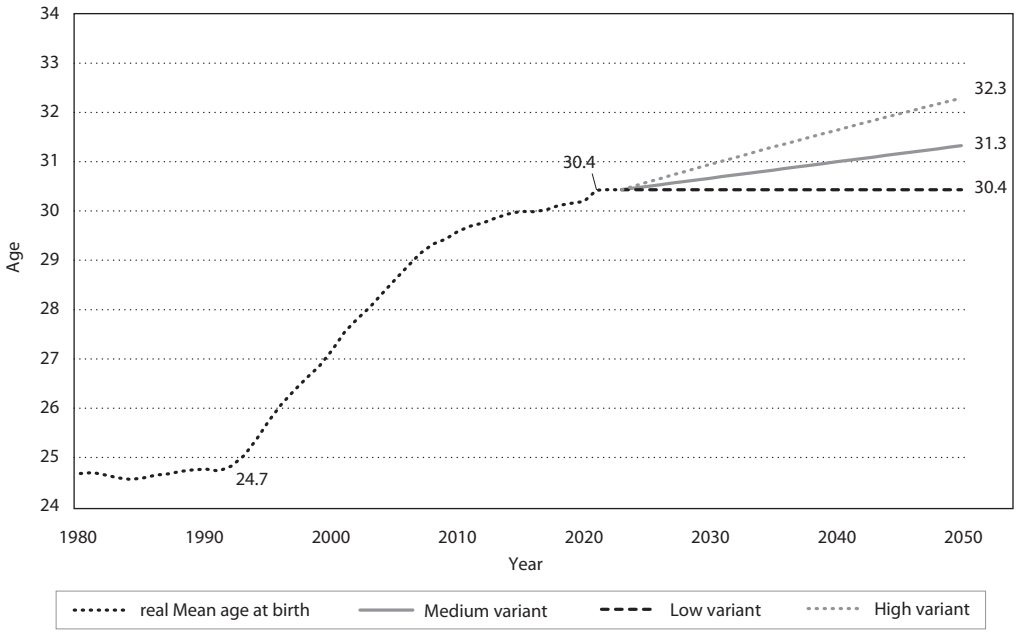
The total fertility level (TFR) was addressed in the preceding section. This section discusses the age and birth order components of fertility change. The fertility of the youngest age groups 15–19 and 20–24 will further decline (Figure 9). The 25–29 and 30–34 age groups, which recently levelled out, 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:

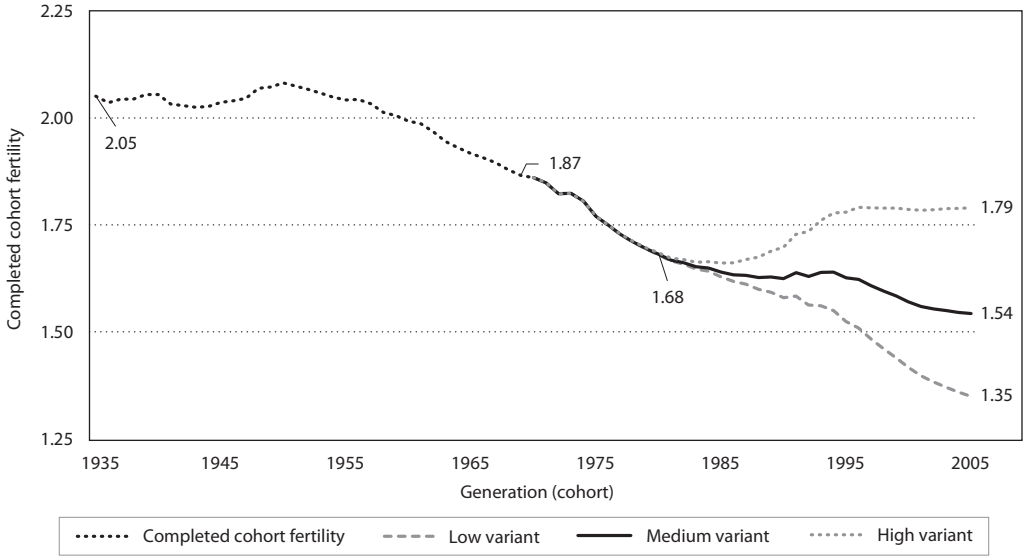
$$f_{X,i,t} = \frac{\left(f_{x-1,i,t} + f_{x,i,t}\right)}{2}$$

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

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

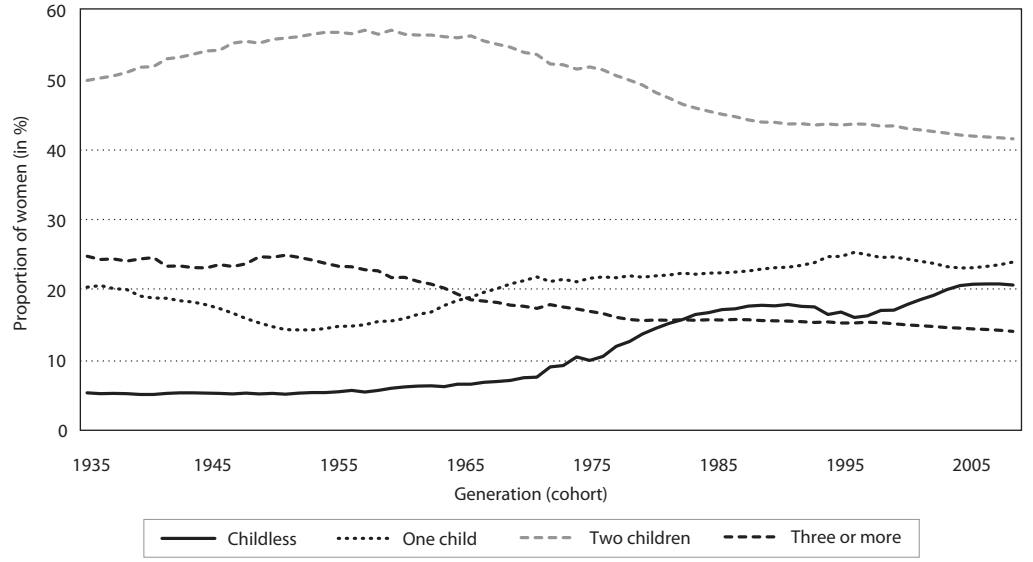
younger, born in 1984, will have on average only 1.65 children and a childlessness rate of 17 percent. With subsequent cohorts, fertility is likely to decline even further and to ultimately converge at 1.5. At the same time, the childlessness will increase further and reach 20 percent (Figure 12). The 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

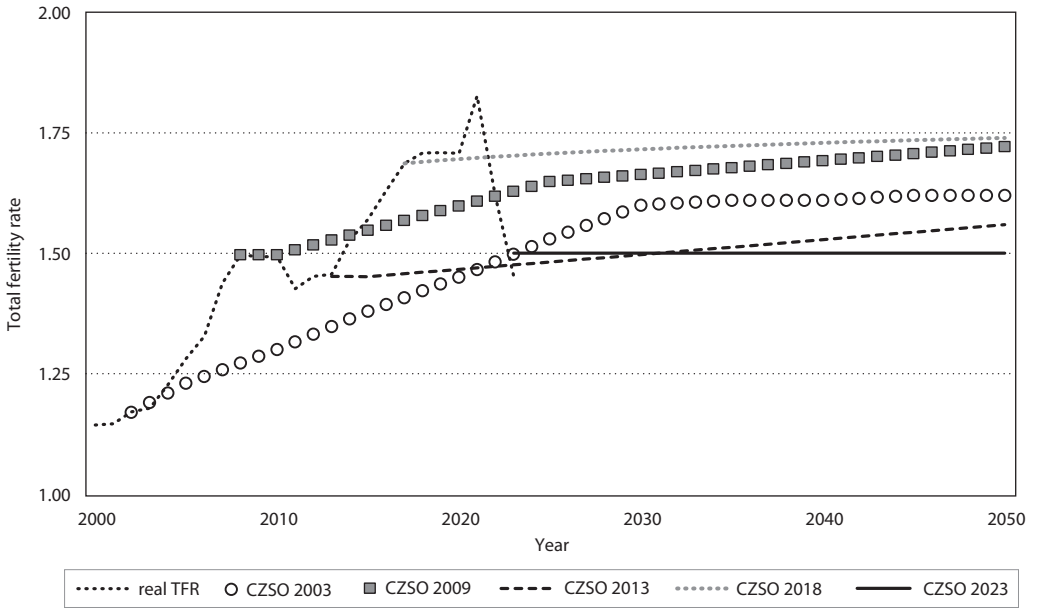
The Czech Statistical Office publishes population projections in five-year intervals – the last five projections were published in 1999, 2003, 2009, 2013, and 2018 (*CZSO*, 2019). In the 1990s the projections were issued every two years. In order to get feedback from past projections and to compare their 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.

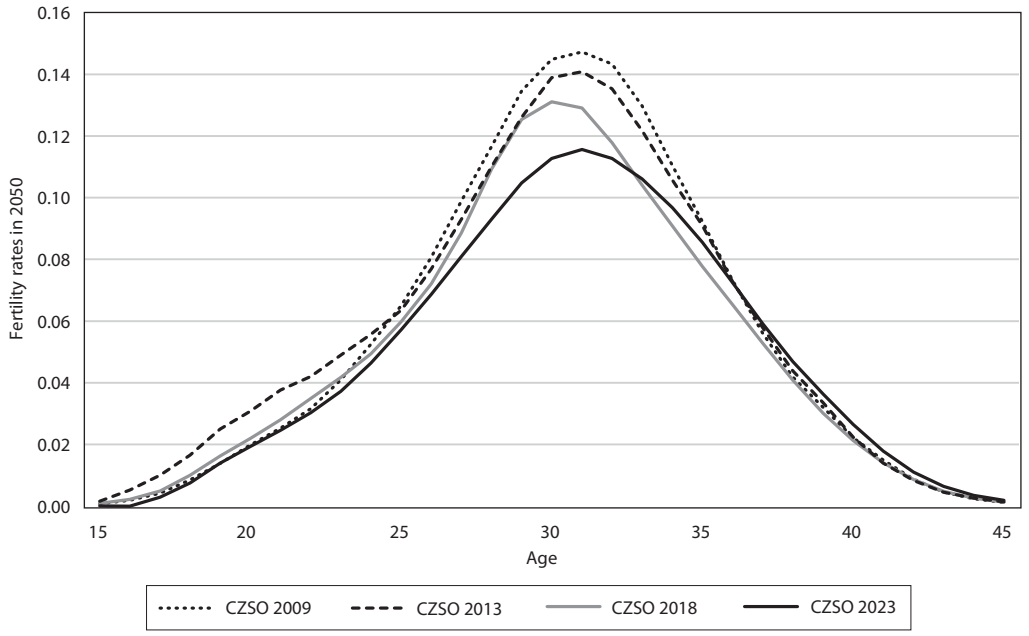
Figure 14 compares the age specific fertility rates estimated for 2050 in the last four projections. The

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



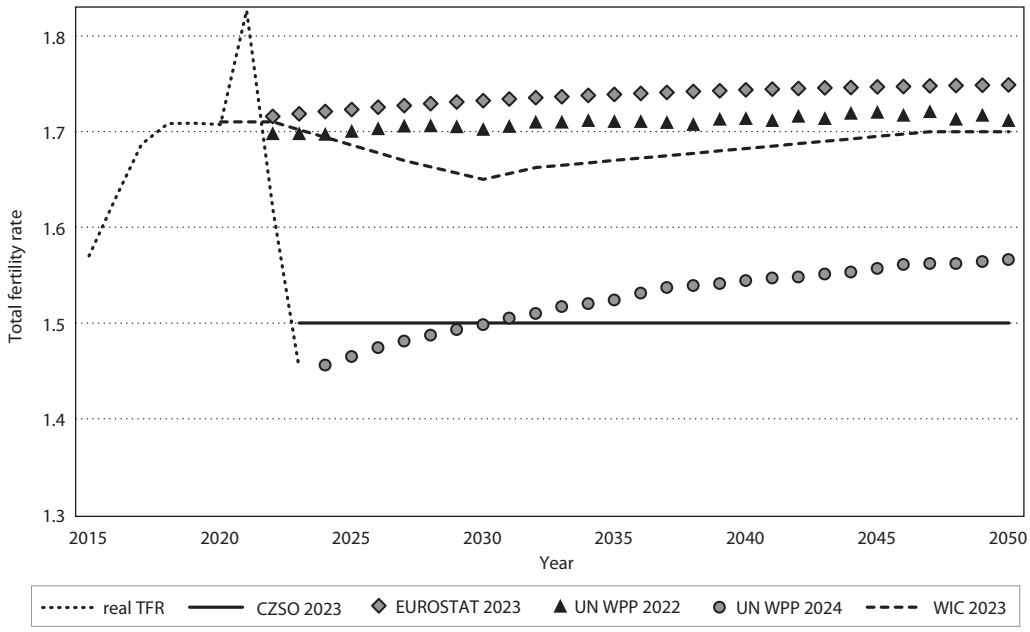
Source: Czech Statistical Office; author's calculations; Zeman (2019).

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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