Title

The Short-term Postponement of Fertility Related to Covid-19 Vaccination

Subtitle

Its Contribution to Czech Fertility Decline between 2021 and 2022

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Abstract

As with Northern European countries, Czechia experienced unexpected fertility developments during the Covid-19 pandemic. Fertility in Czechia increased between 2020 and 2021 from 1.76 children per woman to 1.83. However, between 2021 and 2022, fertility fell significantly to just 1.62 children per woman. The main change that occurred between 2020 and 2021, which predominantly affected fertility one year later, comprised vaccination against Covid-19. Based on the principle of indirect standardisation, we calculated the expected number of children for cases in which women who were vaccinated in a specific month decided against becoming pregnant in that month; hence, they postponed their fertility intentions by one month. The results of the analysis showed that considering vaccination as a reason to avoid becoming pregnant in the same month as vaccination is able to largely explain the fertility decline between 2021 and 2022 in Czechia.

Keywords: Fertility, vaccination, covid-19, short-term postponement; Ukrainian migrants

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1 Introduction

The total fertility rate (TFR) in Czechia experienced a gradual increase from 1.43 in 2011 to 1.83 in 2021 (CZSO, 2023a). Moreover, the Czech TFR in 2021 was one of the highest in Europe (VID, 2022), which was surprising in the context of the development of the Covid-19 pandemic during 2020. During the spring 2020 wave of the pandemic, Czechia had one of the lowest proportions of infected persons in Europe; however, conversely, during the autumn wave of 2020, Czechia had one of the highest proportions (Hasell et al., 2020; Hulíková Tesárková & Dzúrová, 2022; Mathieu et al., 2021). The most recent data, obtained from the Czech Statistical Office, reports a TFR of 1.62 in 2022 (Štyglerová & Němečková, 2023). However, this value reflects the fact that the population of women of reproductive age in Czechia increased significantly in 2022 with the inclusion in the statistics of Ukrainian refugees granted temporary protection[1]. If Ukrainian women with temporary protection and their children were not included in the calculation[2], the TFR would be 1.67 in 2022 (Štyglerová & Němečková, 2023). The difference of five-hundredths (1.67-1.62) can, therefore, be considered the consequence of the change in the Czech population structure.

While the first year of the pandemic (2020) did not apparently negatively affect fertility in 2021, the situation changed significantly in terms of the impact of the pandemic in 2021 on the fertility level in 2022. In addition to the direct effects of the pandemic on mortality, the indirect impacts on fertility were discussed (Aassve et al., 2020; Berrington et al., 2022; Wilde et al., 2020) from the outset of Covid-19. The various ways in which the pandemic affected fertility are discussed in detail in, for example, fertility projections in the UK (Berrington et al., 2022). The potential negative factors outweighed the positive considerations. The positive factors included the reduction of the opportunity costs of having children, more time spent with the partner due to the lockdown, and the facilitation of combining family and work life thanks to the expansion of home-office options. The negative factors included, for example, an increase in economic uncertainty, stress associated with higher demands for childcare services and health concerns (Berrington et al., 2022). The direct impacts of the Covid-19 pandemic on fertility in the context of the health and economic crises have been assessed by e.g. Cozzani et al. (2023), Lappegård et al. (2023), Matsushima et al. (2023) or Sobotka et al. (2021).

[1] The statistics published by the Czech Statistical Office in 2022 include in the Czech population all those refugees who applied for an extension to temporary protection beyond March 2023 and thus declared their intention to stay in Czechia for a prolonged period. A total of 330,000 persons were added to the Czech population via the migration balance in 2022, of which 293,000 were refugees (Štyglerová & Němečková, 2023).

[2] This concerns almost 1,500 live births (Štyglerová & Němečková, 2023).

The initial expectation concerning fertility trends in high-income countries was that the Covid-19 pandemic would comprise the main cause of fertility decline (Aassve et al., 2020). However, this was confirmed only in certain countries (Aassve et al., 2021; Sobotka et al., 2021). For example, regarding Northern European countries, no decline in fertility was observed directly following the outbreak of the Covid-19 pandemic (Bujard et al., 2022; Lappegård et al., 2023; Neyer et al., 2022; Nisén et al., 2022). However, at the beginning of 2022, a decline in fertility was observed in, e.g. Sweden (Bujard et al., 2022). Bujard and Andersson (2022) evaluated the association between the development of unemployment, infection rates, Covid-19 deaths and vaccination and fertility in Sweden and Germany. The only association they observed concerned that between fertility and the commencement of vaccination. While vaccination was considered by most people as facilitating the lifting of pandemic-related restrictions, in the early days of vaccination, concerns were raised about the safety of vaccination, mainly due to the spread of misinformation (Berkowitz & Jacobson Vann, 2023; Sajjadi et al., 2021). Moreover, such concerns were more frequently expressed by women who were breastfeeding, pregnant or planning to become pregnant (Januszek et al., 2021; Riad et al., 2021). The dominant argument used by disinformers was that vaccination causes infertility in both men and women, even to the extent that vaccinated individuals can spread their infertility to unvaccinated persons (Berkowitz & Jacobson Vann, 2023; Diaz et al., 2021). A study by Wesselink et al. (2022), however, demonstrated that vaccination did not result in a decrease in the fecundity of women in the subsequent 90 days (rather an increase in fecundity, which may have been the consequence of compensation for short-term delayed fertility due to vaccination) but, conversely, the fecundity of women decreased in the 90 days after experiencing Covid-19, which was most likely due to the overall weakening of the system, which is not the ideal state in which to conceive.

Similar trends to those in Sweden concerning fertility development in 2021 and 2022 were observed in Czechia. The question therefore arises to what extent the decline in fertility in Czechia between 2021 and 2022 can be attributed to vaccination. *This article aims to evaluate the maximum possible impact of vaccination against Covid-19 on the level of fertility in Czechia.* The main mechanism of the impact of vaccination on fertility monitored concerned the *short-term postponement of fertility* based on the assumption that women who decided to be vaccinated against Covid-19 also decided not to become pregnant in the same month as that in which they were vaccinated. The resulting hypothetical impact is then compared with the actual observed development of fertility in individual months; this is followed by a discussion of how vaccination may have contributed to the decrease in the TFR between 2021 and 2022.

2 The pandemic context in Czechia

In the European context, the impact of the first wave of the pandemic in Czechia (spring 2020) was very mild; at this time the number of persons infected was max. 25 per one million of the population (Figure 1). Despite this relatively low Covid-19 infection level (from today's perspective), strict measures were imposed from mid-March 2020 that significantly limited the free movement of people, the provision of services and the

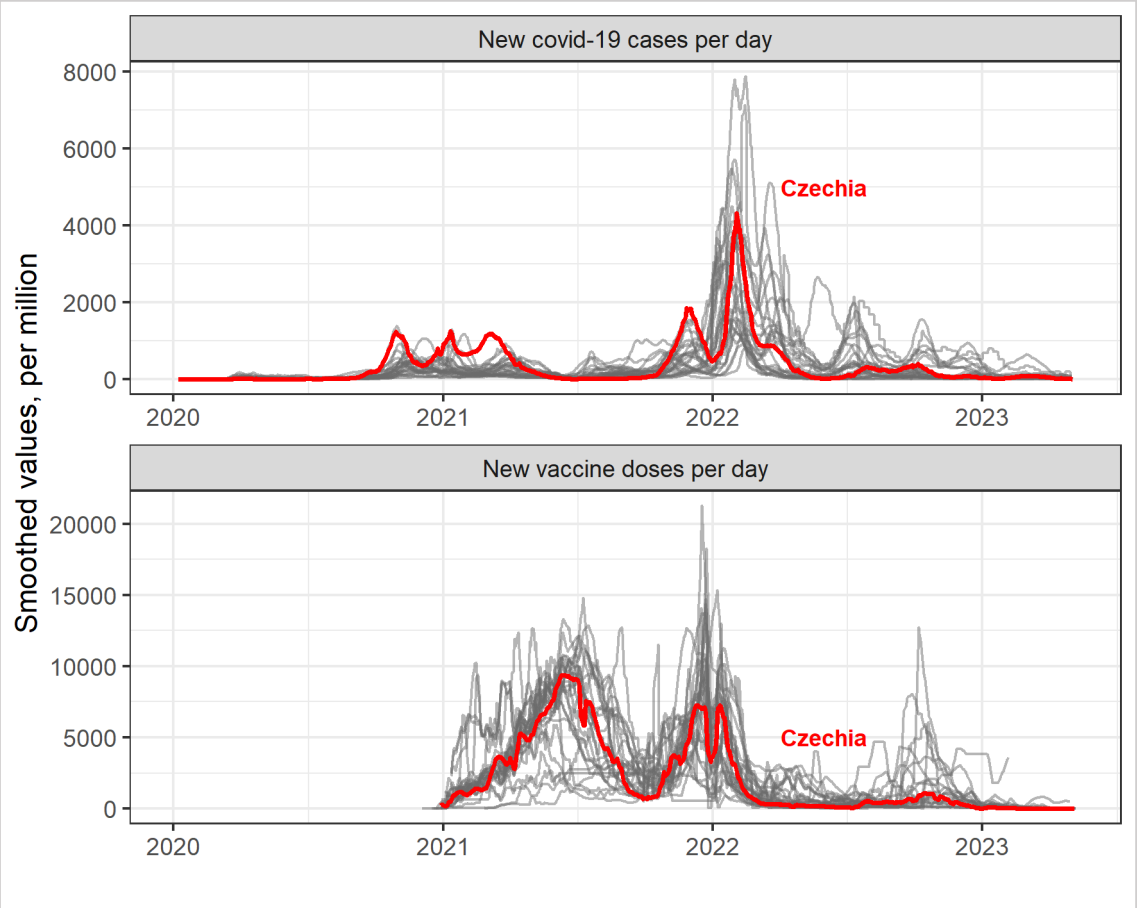
operation of educational facilities (Slabá, 2022). This affected, *inter alia*, the functioning of households (Höhne & Žáčková, 2023; Šťastná, 2023). The impact in Czechia of the second wave of the pandemic in autumn 2020 was much more serious than the first; indeed, Belgium was the only country in Europe with a higher infection rate (Figure 1). After a brief improvement at the end of 2020, a further worsening of the situation was observed, which culminated in the first half of April 2021. For the entire first quarter of 2021, Czechia evinced one of the highest relative increases in infected persons in Europe. Surveys were conducted in Czechia at the end of 2020 and following the end of the spring wave of 2021 that included questions on the reproductive plans of women and men over the following three years (Kreidl et al., 2021a; Kreidl et al., 2021b). It was evident that in the first year of the pandemic and even during the period of high infection rates in the spring of 2021, the declared reproductive intentions of Czech men and women were not significantly affected (Paloncyová, 2022). The main factors concerning reproductive intentions comprised the number of children in the family (a greater chance was evident of the planning of another child for respondents without children and those with one child than for respondents with multiple children) and the value orientations and attitudes towards parenthood of the respondents. In contrast, the financial situation was not seen to play a significant role in the formulation of reproductive plans; this was surprising for the author, who explained it by the relatively short duration of the pandemic at the time, which was not yet fully reflected in the economic situation of households (Paloncyová, 2022).

At the turn of 2020/2021, registration for vaccination against Covid-19 was introduced in Czechia. Older persons and those working in at-risk professions were prioritised (Slabá, 2022). The availability of vaccines was limited in the early days of vaccination; hence, it was unclear when registration would open for women of reproductive age. At the end of January 2021, a lack of vaccines for already-registered seniors, which led to the cancellation of appointments, was reported intensively in the media, and only during February 2021 was a government campaign launched to promote vaccination aimed at reversing the generally negative attitude of Czechs to vaccination. Despite the delays, all those interested were promised that vaccination would be possible by the summer of the same year. In mid-April 2021, it was announced that those over 40 could register for vaccination at the end of June. Finally, vaccination registration for those over 45 years of age commenced on 10th May and for those over 40 on 17th May. Registration was opened to those aged 35 and over on 24th May and for those over 30 on 26th May. From 4th June, vaccination was possible for all persons over 16 (Slabá, 2022). Aimed at encouraging vaccination, a change was introduced regarding the recognition of non-infectiousness; from November 2021, the PCR test was no longer recognised and only completed vaccination was considered in this respect (Slabá, 2022).

Figure 1 shows that the relative vaccination coverage of the Czech population was slightly below the average of other European countries. The number of new vaccinations increased steadily up to June 2021. The beginning of autumn 2021 saw a decline in vaccinations, which was followed at the turn of 2021/2022 by an increase, which related to booster doses (mainly the third dose). The overall vaccination rate of the Czech population reached 66% at the end of 2022 (Mathieu et al., 2021).

Vaccination rates as at 11th April 2023 for men and women according to age were as follows: 18-29 years 65%, 30-34 years 62%, 35-39 years 64%, 40-44 years 67% and 45-49 years 76% (Czech Ministry of Health, 2023b).

Figure 1: Development of Covid-19 cases and vaccination doses in selected European countries focusing on Czechia



Data source: Hasell et al. 2023; Mathieu et al. 2021
Note: The grey lines represent those European states with populations larger than 5 million inhabitants.

It is possible that with the prospect of vaccination against Covid-19, some women decided to postpone their short-term reproductive intentions. The question is, however, whether they did so as early as at the end of 2020 when the outlook concerning vaccination for the respective age categories was unclear, or at the time when registration became available. Moreover, it is necessary to consider that attitudes to vaccination in Czechia were, initially, far from positive, especially among younger age groups (STEM, 2021; Life during the pandemic, 2023), despite vaccination being strongly recommended by experts (Markert et al., 2021; Pratama et al., 2022) even for pregnant and breastfeeding women. However, the official expert opinion that supported vaccination for pregnant and breastfeeding women was not published until 3rd June 2021 (Česká vaccinologická společnost, 2021). Nevertheless, it was recommended that pregnant women be vaccinated only after the 12th week of pregnancy. It is noteworthy that even one year following the initiation of vaccination, some doctors expressed the opposite opinion and recommended that pregnant women should not be vaccinated (Hamplová, 2022). Moreover, the Czech media drew attention to the fact that some

hospitals insisted that those interested in vaccination provided their signed informed consent which stated that Covid-19 vaccination was not suitable for pregnant and breastfeeding women (Novinky.cz, 2021). In addition, research revealed that pregnant women were less willing to be vaccinated than the general population since additional factors had to be considered in the decision-making process (Januszek et al., 2021). Moreover, it is possible that women preferred to postpone conception until after vaccination, as suggested by Bujard and Andersson (2022). This assumption is supported by the fact that involvement in social activities was conditional upon vaccination, and employers of required proof of being infection-free. Further, state-funded Covid-19 testing was strictly limited once vaccination was possible for the whole of the adult population.

3 Studied scenarios

Vaccination against Covid-19 was unprecedented in modern times in terms of its scope and the short period of time in which it was introduced. Aimed at contributing to the understanding of the fertility decrease between 2021 and 2022, scenarios were constructed that reflect the maximum possible impact of vaccination on the number of live births, assuming that women of reproductive age made the rational decision not to conceive a child in the month in which they were vaccinated. Both of the scenarios presented below assumed that there was no change in the intensity of fertility between 2021 and 2022, and the only consequence of vaccination during the pandemic regarding fertility concerned short-term fertility postponement by one month for the period following vaccination, i.e. a decrease in the absolute number of women who conceived in a given calendar month. Further, we assumed that women who were interested in vaccination had the same level of fertility as those women who refused to be vaccinated (either temporarily or permanently). The following scenarios thus assess the maximum possible hypothetical impact following the reactions of women at the time of vaccination.

Scenario 1: The woman is concerned about vaccination and decides not to try to conceive a child in the respective month. However, she is worried only for the first vaccination dose.

Scenario 2: The woman is concerned about receiving each vaccination dose; hence, she decides not to conceive a child in the respective month and postpones potential conception until after vaccination.

4 Data and Methods

The study proceeded via three analytical steps: 1) the calculation of the monthly age-specific vaccination rates of women in Czechia in the period from the introduction of vaccination against Covid-19 from December 2020 to April 2023; 2) the calculation of the hypothetical (expected) number of live births per month for the period October 2021 to December 2022 based on the two scenarios defined above; 3) the calculation of the total fertility rate in 2022 based on the hypothetical (expected) number of live births.

The first step employed the data on vaccinated persons available on the Czech Ministry of Health website to calculate the monthly age-specific vaccination rates. The information on vaccinations included gender, age group (the relevant age groups were 18-24, 25-29, 30-34, 35-39, 40-44 and 45-49 years), date of vaccination, the order of the vaccination dose and the type of vaccine (Czech Ministry of Health, 2023a). The numbers of women vaccinated in the selected age groups were then related per individual calendar month to the female population exposure in the given age group in 2021, which resulted in the determination of monthly age-specific vaccination rates. The female population exposure in the various age groups was calculated from the population of women of 1st July 2021 for age units, as published on the Czech Statistical Office website (CZSO, 2022).

Table 1: Live births, female population exposure and age-specific fertility rates in Czechia in 2021 in vaccination-defined age groups

Age group	Live Births 2021	Women, 1 July 2021	Fertility rates 2021	Proportion of the age group of fertility
18-24	12,357	323,529	0.0382	15%
25-29	33,325	283,481	0.1176	32%
30-34	40,478	330,333	0.1225	34%
35-39	20,268	345,370	0.0587	16%
40-44	4,469	409,949	0.0109	3%
45-49	348	429,232	0.0008	0%

Source: Czech Statistical Office 2022: Demographic Yearbook 2021, Table D.04 and I.01

The second step comprised the calculation of the hypothetical monthly number of live births according to the above scenarios. This calculation is based on age specific fertility rates (ASFR) for the studied age groups in 2021, as calculated from vital statistics (Table 1).

Table 2: Average relative distribution of live births per calendar year from 2012 to 2021, monthly distribution

Delivery month (t)	Relative share	Delivery month (t)	Relative share	Delivery month (t)	Relative share
January	0.0828	May	0.0847	September	0.0862
February	0.0759	June	0.0867	October	0.0832
March	0.0830	July	0.0921	November	0.0771
April	0.0813	August	0.0888	December	0.0782

Source: Human Fertility Database

Based on the indirect standardisation principle, the expected number of live births at age group x and month t ($_tB_x^{exp}$) was calculated as follows (Formula 1): The ASFR in 2021 were applied to the changing female population exposure ($_{1.7.2021}P_x^f$). For each observed calendar month, we had information on the number of women in a given age group *(x)* who were vaccinated (first/any dose). The numbers of vaccinated women at a given age group in a specific calendar month *t-9* (conception month) were subtracted from the age group of women on 1st July 2021. The ASFR 2021 was then applied to the reduced female population exposure to obtain the expected number of live births to given age groups of women over one calendar year. This number was subsequently

multiplied by the relative share of the number of live births in month t (delivery month) (see Table 2). Subsequently (Formula 2), the total expected number of live births in the delivery month *(t)* was determined as the sum of expected life births of all the age groups of women.

(1)

$$ {}_tB_x^{exp} = ({}_{1.7.2021}P_x^f - {}_{t-9}Vaccinated_x^f) * {}_{2021}ASFR_x * {}_tRelative\ share $$

(2)

$$ {}_tB^{exp} = \sum_{18-24}^{45-49} {}_tB_x^{exp} $$

The calculation worked with the assumption that pregnancy lasted for 40 weeks; hence, the result was interpreted as the expected number of live births in the month that followed nine months following conception (*t+9*, i.e. the delivery month).

An illustration is provided below of the calculation of the expected number of live births in May 2022 to women aged 30 to 34 years in the case that the exposed population is reduced by the number of vaccinated women in August 2021 (N = 12,250), i.e. in the potential month of conception (Formula 3):

(3)

$$ {}_{V/22}B_{30-34}^{exp} = \left({}_{1.7.2021}P_{30-34}^f - {}_{VIII/21}Vaccinated_{30-34}^f\right) * {}_{2021}ASFR_{30-34} * {}_VRelative\ share $$

$$ = (330\,333 - 12\,250) * 0.1225 * 0.0847 \ = 3\,300 $$

The expected monthly number of live births was compared with registered monthly live births in 2021 and 2022. The data on the registered number of live births for 2021 was obtained from the Human Fertility database, while the data for 2022 was taken from the preliminary results provided by the Czech Statistical Office since they represented the most recent data source, which also included data on October, November and December 2022 (CZSO, 2023c).

The third step consisted of the calculation of the hypothetical (expected) total fertility rate in 2022. By summing up the expected number of live births for each month of 2022, we obtained the annual expected number of live births in 2022 for given age group x (Formula 4). For the expected TFR 2022 (Formula 5), the expected number of live births in 2022 was related to the female population in a given age group on 1st July 2022. The expected total fertility thus takes into account the shorter reproductive interval of 18-49 years. Information on the age structure of women in 2022 was obtained from Czech Statistical Office (CZSO, 2023d) data for units of age; this was then aggregated to the analysed age groups. As mentioned previously, this population structure included Ukrainian refugees granted long-term protection; thus it reported higher numbers than in 2022.

(4)

$$ {}_{2022}B_x^{exp} = \sum_{I/2022}^{XII/2022} {}_tB_x^{exp} $$

(5)

$$ {}_{2022}TFR_x^{exp} = \sum_{18-24}^{45-49} \frac{{}_{2022}B_x^{exp}}{{}_{1.7.2022}P_x^f} $$

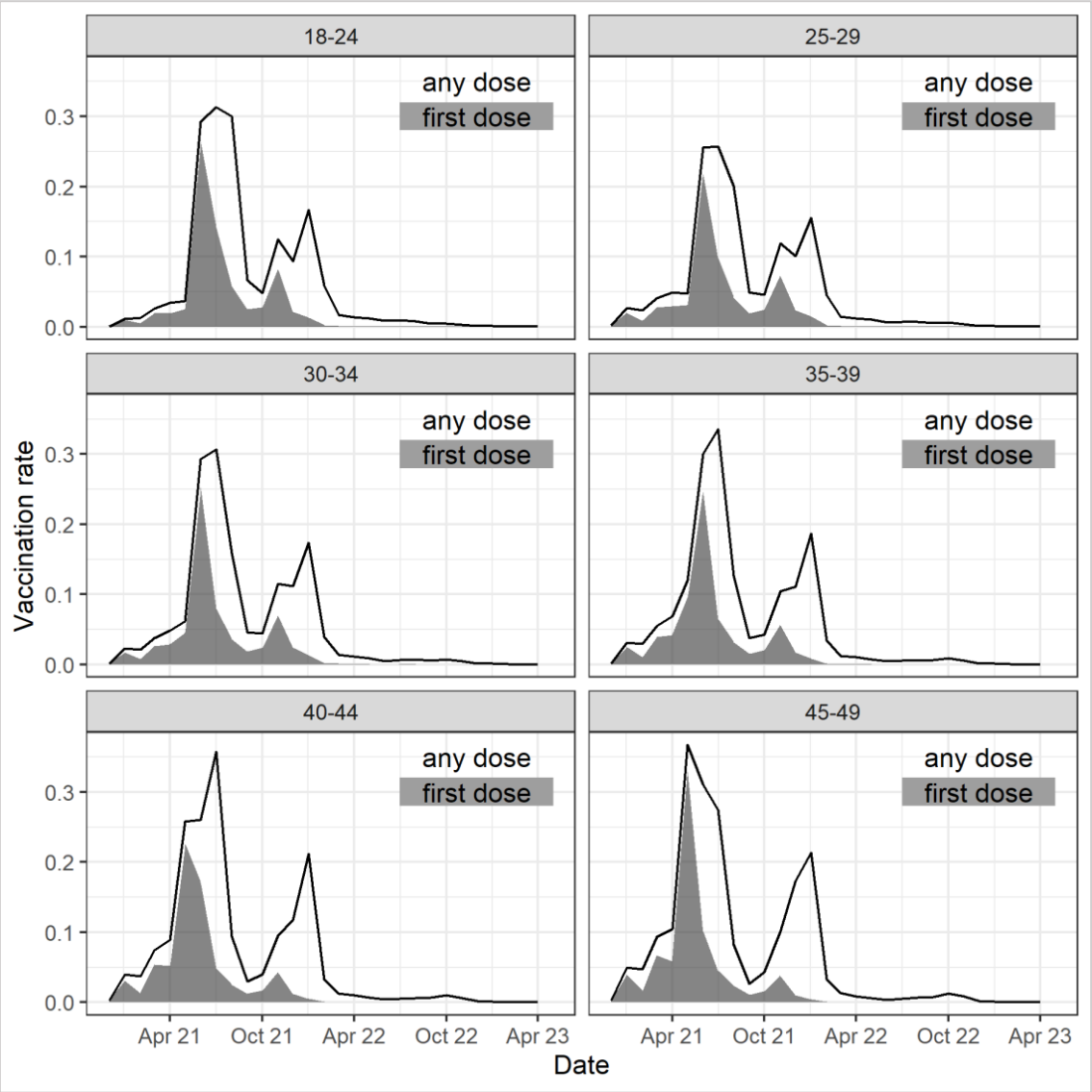
5 Results and discussion

5.1 Development of the intensity of vaccination in the various age groups

Figure 2 shows the development of the monthly vaccination rates of women in the fertility-related age groups. Figure 2 shows that the dominant level of interest in vaccination related to immediately following the commencement of registration, i.e. in May 2021 for the 40-44 and 45-49 age groups and in June 2021 for the 18-12, 25-29, 30-34 and 35-39 age groups. Comirnaty was the dominant vaccine in Czechia, concerning which the interval between the first and second doses was initially 42 days, and from mid-July 2021 just 21 days. Doses of all orders were thus administered most intensively during June, July and August 2021.

In autumn 2021, a slight increase in first-order vaccination rates is evident following changes to the recognition of being infection-free, as is an increase in any-dose vaccination rates at the turn of 2021/2022 due to the introduction of the booster dose.

Figure 2: Trends in monthly vaccination rates by selected age groups, women, Czechia, 12/2020 to 04/2023



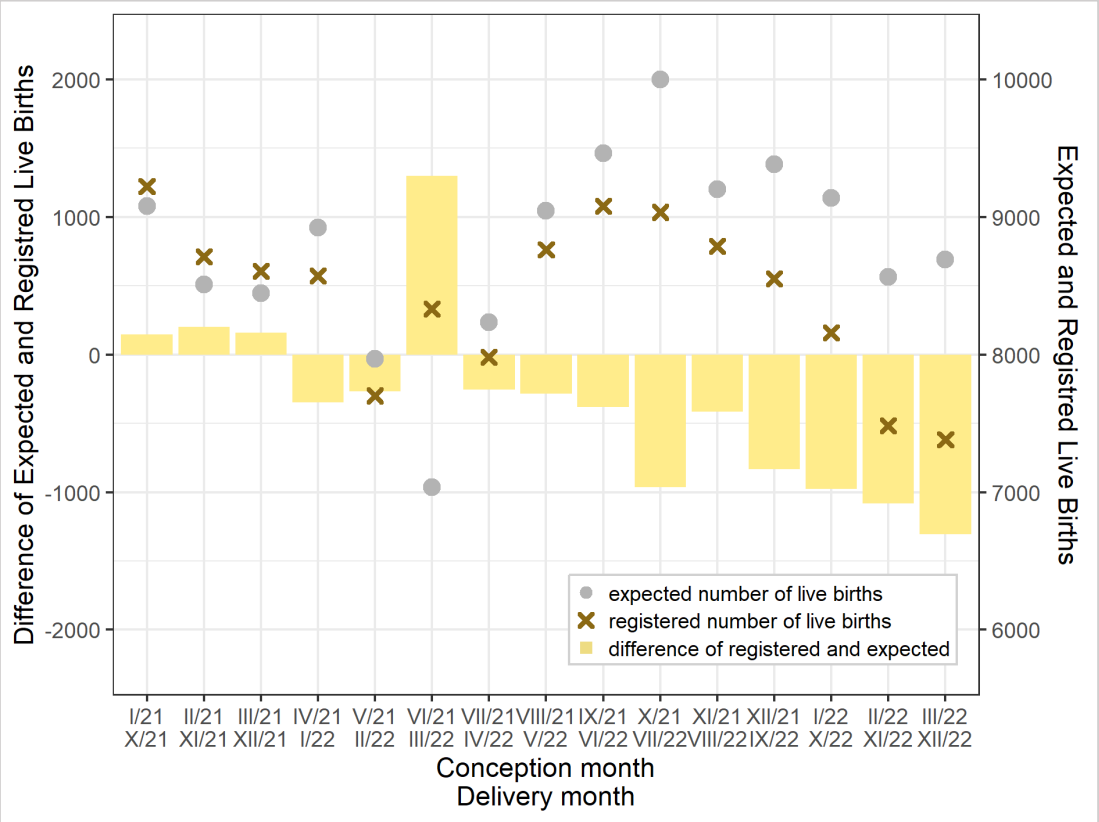
Source: Czech Ministry of Health 2023a (vaccination doses); Czech Statistical Office 2022 (population)

5.2 Scenario 1: the short-term postponement of fertility due to the first vaccination dose

The results in Figure 3 revealed that the hypothesis concerning the possible influence of the first dose of vaccination on the short-term postponement of conception is more relevant for the first half of the monitored period (births in October 2021 to May 2022). The numbers of expected and registered live births in the period October 2021 to February 2022 are relatively balanced, with the expected numbers being slightly lower than the registered numbers in the first three months (October to December 2021). Conversely, in the following two months (January and February 2022), the expected number of births is slightly higher; thus, it is possible that the planned commencement of vaccination led to the postponement of conception for some women by even more than the one month considered in the scenario. One possible explanation is that women of reproductive age already expected vaccination to become available and decided to temporarily postpone their reproductive intentions during April and May 2021.

First-dose vaccination was most intense in June 2021 (Figure 2), especially for women in those age categories that most contribute to fertility (Table 1). The expected postponement of conception in this month was reflected in a significant decrease in the expected number of live births during March 2022, while the registered values for live births significantly exceeded this estimate, i.e. by more than 1,000 live births (Figure 3). However, this concerns the maximum possible estimate of the decline in conception taking all vaccinated women into account. It can be expected that some women did not consider the timing of conception according to vaccination, or conception may have occurred after vaccination within the given month. With concern to the conception period from July 2021 to March 2022, a lower number of registered live births than expected is evident. One possible explanation is that the decrease was caused by subsequent vaccinations, as considered by the scenario 2 (see Figure 4).

Figure 3: Registered and expected monthly live births after excluding women who received the first dose of vaccine from the exposed population.



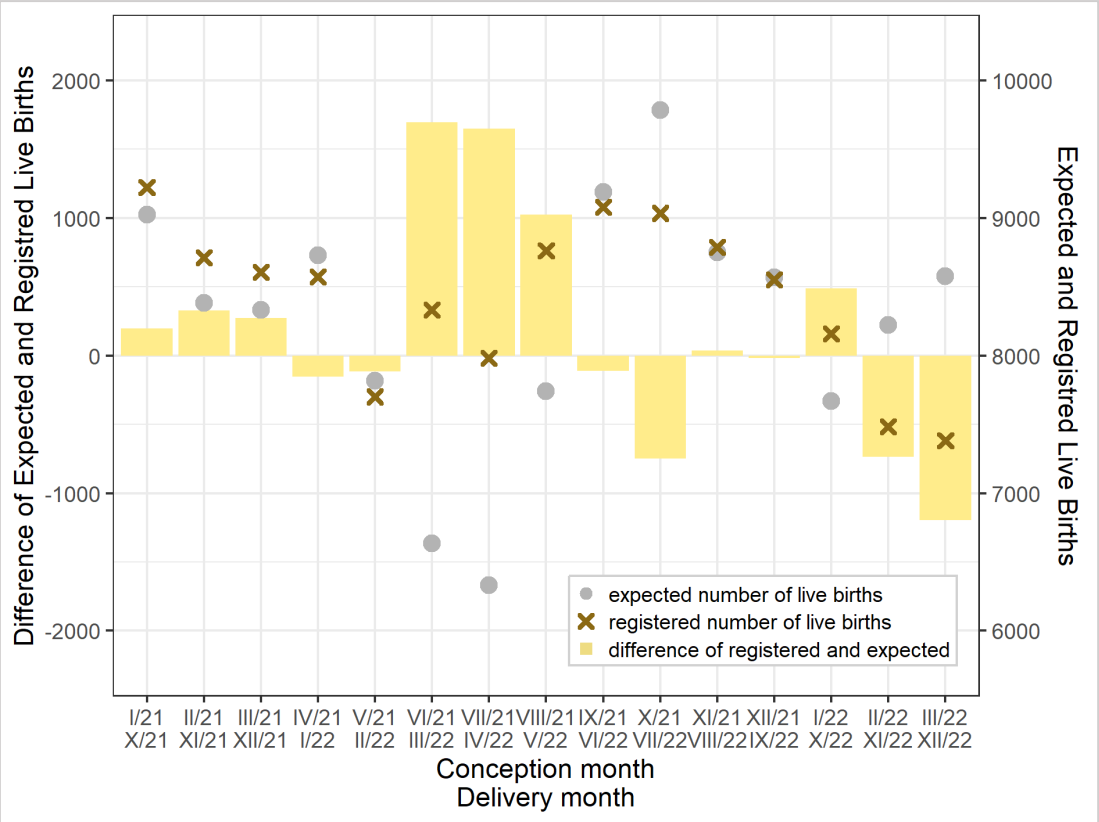
Note: The observed number of live births for the months of 2022 were taken from CZSO preliminary results (2023c).

5.3 Scenario 2: the short-term postponement of fertility due to all vaccination doses

Figure 4 shows that when all vaccination doses are considered as a potential reason for the short-term postponement of conception, the results for the expected number of live births to February 2022 (conception in May 2021) are similar to those of the single dose scenario since this scenario is also dominated by the first dose at this time (Figure 3). Concerning subsequent conceptions, i.e., June to August 2021, the registered numbers of births exceed the expected numbers. These are the months in which the first and second vaccinations were administered with the greatest intensity (Figure 2) for women

in the age categories that contribute most to fertility (Table 1). Moreover, this is the period in which Covid-19 restrictions were significantly relaxed both in Czechia (Slabá, 2022) and internationally, and thanks to vaccination, the prospects for the end of the pandemic seemed realistic and the influence of other negative factors that potentially prevented conception during the pandemic were limited. Concerning the conception period from September 2021 to December 2021, at the end of which booster doses dominated, the situation was balanced and the numbers of registered births basically correspond to those expected according to scenario 2. Only in January 2022 do we observe approx. 500 live births more than expected. However, concerning conceptions in February and March 2022, an increasing underestimation of registered live births is evident compared to expected births. Here we offer explanations other than a direct connection with vaccination, which had already been terminated due to the weakening of the pandemic (Figure 2). Firstly, from the beginning of 2022, the worsening economic situation of Czech households was increasingly apparent due to rapidly increasing inflation, which was observed in Czechia as early as in autumn 2021 (CZSO, 2023b). Secondly, the Russian-Ukrainian conflict broke out at the end of February 2022, which, in addition to the security threat, exacerbated the potential for the onset of an economic crisis and was accompanied by the arrival of a significant number of refugees in Czechia. Both these factors probably influenced the fertility drop via a decrease in conceptions from around 2022; the societal impact was further exacerbated in 2022 by the energy crisis and the macroeconomic impacts thereof.

Figure 4: Registered and expected monthly live births after excluding women who received the first and more doses of vaccine from the exposed population.



Note: The observed number of live births for the months of 2022 were taken from CZSO preliminary results (2023c).

5.4 Assessment of the 2022 total fertility rate

The 2022 hypothetical total fertility rate was calculated based on the expected number of live births, the calculation of which was based on the assumption that being vaccinated would lead to the short-term postponement of female fertility. The official CZSO estimate indicated a TFR of 1.62 in 2022 based on the 15-49 age group (Štyglerová & Němečková, 2023). If we consider the reduced numbers of live births due to the first vaccination, the TFR of the 18 to 49 age group would be 1.69 children per woman. If we consider the reduced numbers of live births due to the first and more vaccinations, the TFR of the 18 to 49 age group would be 1.57 children.

Table 3: Estimated and hypothetical total fertility rate under the considered conditions

Age	Details	TFR
18-49	**Hypothetical TFR Scenario 1 =** Expected Live Births 2022 when the exposed population is reduced by those who received the 1st dose of vaccine, 1st July 2022	**1.687**
18-49	**Hypothetical TFR Scenario 2 =** Expected Live Births 2022 when the exposed population is reduced by those who received the 1st and more doses of vaccine, 1st July 2022	**1.566**
15-49	TFR 2022 according to the Czech Statistical Office (Štyglerová & Němečková, 2023)	**1.62**

6 Concluding remarks

Our study shows that the decrease in the TFR from 1.83 to 1.62 between 2021 and 2022 in Czechia can, partly, be explained by the short-term postponement of conception due to vaccination against Covid-19. We proceeded from the assumption that vaccination potentially led some women to temporarily avoid pregnancy due to fears of side effects and the potential negative impact of vaccination on fecundity (Bujard et al., 2022). The results show that if we consider the short-term absence of women from reproduction due to fertility postponement in the vaccination month, then the TFR for 2022 (1.69) would approximate to the value actually recorded (1.62). The consideration of the first and more doses of vaccination led to a significantly lower TFR (1.57) than actually observed (1.62). It can, therefore, be assumed that the short-term delay modelled in the analysis contributed to the decrease rather than any significant year-on-year change in the fertility intensity of women resident in Czechia.

There are two significant discrepancies between the registered and the expected number of live births in the observed period. During March to May 2022, the most intensive vaccination period with conception in June to August 2021, registered live births were significantly higher than expected. This may have reduced the difference between the hypothetical (1.57) and registered TFR (1.62). The difference may have been a consequence of not all women sharing the same concerns and behaving according to our assumption; thus, we emphasize that the results represent the maximum possible estimate of the decrease in conceptions, considering all women who were vaccinated. However, the opposite situation was apparent in November and December 2022. The lower numbers of registered live births at this time originated from conceptions in February and March 2022, when it can be assumed that the negative effects of other

factors prevailed, e.g. further increases in inflation accelerated by the security threat from Ukraine. Thus, the drop in the number of live births cannot be wholly attributed to vaccination concerns.

Finally, it is necessary to mention possible limitations, which are difficult to quantify within the model. The analysis assumed that women may have been concerned about side effects and the potential negative impact of vaccination on fecundity in the month of vaccination. Nevertheless, the results indicate that the postponement of conception due to the first vaccination refers both to the month of vaccination and the period before, i.e. when it became clear that vaccination would be available for women in the relevant age groups in the near future. Finally, when considering one dose and more, it is necessary to consider that following the shortening of the interval between the first and second doses to 21 days, some women were potentially vaccinated twice within one calendar month and were, therefore, subtracted twice from the exposed population. This situation applies mostly to conceptions in the summer of 2022, when the observed numbers of subsequently born children significantly exceeded the expected numbers.

This study presented scenarios of the hypothetical maximum possible direct effect of vaccination on the decrease in the fertility intensity of women in Czechia. However, it should be stated that the decline in the fertility level between 2021 and 2022 in Czechia was undoubtedly the result of several factors. The negative effect was due both to vaccination concerns and the fact that the gradual easing of the pandemic restrictions led to a return to work and social activities, i.e. people again became involved in their non-family lives (Sobotka et al., 2023). Subsequently, the increase in overall life insecurity due to the negative effects of the pandemic on economic development and the European security crisis became increasingly reflected in a decline in fertility. A further factor concerned the change in the age composition of the female population. The comparison of the female population in 2021 and 2022 revealed a significant increase in the reproductive age (18 to 49 years); the average annual one-year age group (e.g. between women aged 18 in 2021 and women aged 19 in 2022) increase was more than 2500 women. The increase consisted mainly of Ukrainian women with long-term protection status. The comparison of the data provided by the CZSO revealed that the change in the female population due to Ukrainian war refugees led to a difference of 0.05 in the TFR (Štyglerová & Němečková, 2023). Finally, the decrease in fertility in 2022 can be seen as compensating for the increase in fertility one year earlier, i.e. between 2020 and 2021 (from 1.76 to 1.83). This increase may have been the result of the acceleration of reproductive intentions by part of the population, for whom the pandemic strengthened the priority of the family over other aspects of life. These women already planned to have children, but decided to take advantage of the pandemic situation to have their children earlier, thus potentially reducing the number of people who planned a child in the following or subsequent years and, thus, reducing the fertility level. Moreover, the increase in the TFR between 2020 and 2021 was also partially due to the refinement of information on the number of women of reproductive age based on the 2021 census (Koukalová, 2022).

In conclusion, apart from the beginning of 2022, the number of vaccinated women had fallen to such low numbers (see Figure 1) that it was unnecessary to extend the analysis further; it can be expected that in the future there will be no negative impact of vaccination as studied herein on the development of fertility.

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