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Association between the COVID-19 vaccination campaign and fertility trends: a population-level time series analysis for 22 countries

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ABSTRACT

Introduction At the turn of 2021–2022, monthly birth rates declined in many higher-income countries. We explore how the rollout of COVID-19 vaccination was associated with this decline.

Methods Using an interrupted time series design, we evaluate the impact of the onset of the COVID-19 pandemic and the start of COVID-19 vaccination on seasonally adjusted monthly total fertility rates in 22 high-income countries. We study the associations between COVID-19 vaccination and fertility by additionally controlling for youth unemployment, stringency index and vaccination coverage. Fertility data come from the Short-Term Fertility Fluctuations data series under the Human Fertility Database. Indicators used as control variables originate from Eurostat and OECD databases, Oxford COVID-19 Government Response Tracker and Our World in Data.

Results The start of the pandemic had an immediate effect on fertility in most countries, although the size and direction of level changes considerably varied across them. The impact of COVID-19 vaccination was likewise extensive. While a relatively pronounced negative association between the COVID-19 vaccine rollout and fertility 9 months later was found only for 10 out of 22 countries, indications of a negative fertility response were detected in the vast majority of countries. For several countries, the decline was preceded by fertility increase that took place after the onset of the pandemic. Only 4 out of 22 countries had post-vaccination fertility declines that resulted in fertility being on lower level than what the pre-pandemic trend predicted. Additional control variables changed the associations only a little.

Conclusions The COVID-19 vaccination campaign contributed to the variation in short-term fertility trends. Several countries experienced declines following the campaign, which often returned fertility closer to the pre-pandemic trend. Fertility appears to have responded in short run to vaccination, but only in few cases such that the long-term trajectory is below the pre-pandemic trend.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ COVID-19 vaccine rollouts have been often cited as having contributed to large short-term fertility declines, but this association is under-explored.

WHAT THIS STUDY ADDS

⇒ The study finds a negative association between the start of COVID-19 vaccination and fertility for 10 out of 22 studied countries. The post-vaccination decline mostly brought fertility back to its pre-pandemic trend. Only in few cases, fertility rates declined to a level below the predicted long-term trajectory.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Further research into causal mechanisms underlying fertility responses to COVID-19 vaccination is needed that enhances the understanding of short-term fertility processes and helps shape future policies aimed at supporting fertility decisions in times of epidemiological uncertainties.

INTRODUCTION

The COVID-19 pandemic was one of the most challenging global health emergencies experienced in decades. The outbreak of COVID-19 and unprecedented measures adopted by governments to contain infections caused significant disruptions in daily life.[1–3] The unforeseen situation, combining a health threat, increased risk of unemployment, increased financial vulnerability, reduced social contacts, and switch to teleworking, overwhelmingly impacted individuals, couples and families.[4] The shock and uncertainty brought by the pandemic forced changes and adjustments in all dimensions of life, including re-evaluating one's childbearing plans.

In line with past evidence on fertility dynamics in times of crisis and uncertainty,[5–7] monthly births sharply fell in many high- and middle-income countries in response to the COVID-19 outbreak and lockdowns.[8 9] The baby busts were short-term, however, and small and similarly momentary baby booms soon followed in many countries. These

swings marked the start of the pandemic's roller-coaster ride for fertility.[10] Upward and downward fertility shifts of varying sizes occurred synchronously in many countries. At the end of 2021 and in early 2022, many countries simultaneously experienced another marked drop in birth rates. The sudden decline was puzzling given the generally stable and relatively positive fertility dynamics during most of 2021 in many countries. Although some countries maintained the stability of fertility trajectory into 2022 (the USA, France, Belgium, the UK, Spain, South Korea and Japan) and even showed signs of improvement as compared with 2021 (eg, Portugal), there were countries where the decline in birth rates in early 2022 seemed more pronounced than the pandemic baby bust (eg, Hungary, Poland). Fertility fell sharply also in countries that had not experienced the pandemic baby bust (eg, Germany, Czechia and Sweden) as well as among those that had undergone remarkable fertility increases during 2021 (Denmark, Finland, the Netherlands and Norway).[11]

Multiple non-exclusive explanations for the abrupt fertility declines at the turn of 2021–2022 are possible. This study focuses on one potentially important aspect—the COVID-19 vaccination campaign, also recognised in other research.[10 12 13] The decline in births was linked with conceptions in spring-summer 2021, coinciding with the momentum of COVID-19 vaccination programmes.[14] The main goal of this study is to investigate immediate and sustained fertility changes in response to the start of COVID-19 vaccination among the general population in 17 European countries, the USA, Canada, Japan, South Korea and Israel.

MATERIALS AND METHODS

Study design and data

This ecological study employs an interrupted time series (ITS) approach based on generalised least squares modelling fitted by maximum likelihood (ML). An ITS study design is widely used for evaluating the impact of various policies or other interventions within a defined period of time.[15] The dependent variables are country-specific monthly total fertility rates (TFRs) adjusted for seasonal and calendar variations. The seasonally and calendar-adjusted monthly TFRs come from the Short-Term Fertility Fluctuations data series in the Human Fertility Database.[11 16] The study's observation period extends from January 2017 to December 2022.

Two interventions are considered in the analysis: the onset of the COVID-19 pandemic and the start of COVID-19 vaccination among the general (non-risk) population of reproductive ages (16–49 years). Many countries used an age-based approach in administering the COVID-19 vaccine to the general population, typically starting from the oldest age groups and gradually expanding its eligibility to younger age groups. For these countries, the first month when any age group from 16 to 49 years old became eligible for the vaccine was used as the date for the start of vaccination (online supplemental table S1).

Country-specific models were fitted to estimate whether the monthly TFRs changed in response to (a) the start of COVID-19 pandemic (March 2020) and (b) the start of COVID-19 vaccination among the general population. Considering the natural delay of fertility response, these two time points were moved forward by 9 months (average length of pregnancy). Each country-specific ITS model includes the following terms: (a) pre-pandemic slope term accounting for a secular monthly fertility trend before the start of the pandemic; (b) immediate effect (a step change in the level of fertility) of the start of the pandemic; (c) additional slope change between the start of the pandemic and the start of vaccination; (d) immediate effect (a step change in the level of fertility) of the start of vaccination; and (e) additional slope change following the start of vaccination. We also tested whether additional controlling for selected variables, including youth unemployment, stringency index and vaccination coverage (for data sources, see online supplemental table S2), changes the estimated immediate (level) and sustained (slope) effects following the start of vaccination.

The ITS generalised least squares models were fit using the *gls* function adapted from the *nlme* R package with the method set to ML.[17 18] The modelling also accounts for autocorrelation by applying corARMA procedure and autoregression and moving average terms.

RESULTS

Pre-pandemic period and pandemic period before COVID-19 vaccination

For the pre-pandemic period, the slope coefficients are negative for most of the countries in the study (table 1). The downward fertility trends are also suggested by the visual representation of the ITS regression results (figure 1). These findings are consistent with the continual fertility decline, witnessed by many countries during the 2010s: fertility rates have fallen across various socioeconomic contexts without bypassing the Nordic social welfare states.[19 20] The exceptions are Portugal and Hungary, for which the pre-pandemic slope is positive.

Following the start of the COVID-19 pandemic, almost all the countries experienced an immediate change in the level of monthly fertility. The size and direction of the change considerably varied across countries. In the South European countries (Spain, Italy and Portugal), France, the UK, the USA and Poland, the COVID-19 outbreak prompted a drop in fertility, whereas in the Nordic countries (Norway, Denmark, Finland and Sweden), the German-speaking countries (Austria, Germany and Switzerland), the Netherlands, Czechia and South Korea, fertility increased.

However, neither positive nor negative immediate effects of the start of the pandemic were sustained in most countries. A positive immediate fertility response in the Nordic countries, Austria, Switzerland, Germany

Table 1 Interrupted time series linear regression controlled for level (immediate effects) and slope (sustained effects) changes*

	Slope before pandemic	Immediate level change after start of pandemic	Slope change before vaccination	Immediate level change after start of vaccination	Slope change after vaccination
	January 2017–November 2020		December 2020–vaccination (+9 months)		Vaccination (+9 months)–December 2022
Sweden	−0.0034***	0.0333*	0.0001	−0.0807***	−0.0073*
Finland	−0.0032***	0.0916**	0.0042	−0.1159***	−0.0038
Denmark	−0.0022***	0.0577*	−0.0021	−0.0877*	−0.0023
Norway	−0.0040***	0.0929***	0.0015	−0.0903**	−0.0023
Austria	−0.0021***	0.0594**	−0.0005	−0.0046	−0.0015
Germany	−0.0014***	0.0869***	−0.0039*	−0.0529*	0.0057
Switzerland	−0.0019***	0.0740***	−0.0026	−0.0336	−0.0016
Netherlands	−0.0020***	0.0657***	0.0038**	−0.0964***	−0.0058*
UK	−0.0047***	−0.0571***	0.0108***	−0.0540**	−0.0090**
Belgium	−0.0018***	−0.0377	0.0083**	−0.0469	−0.0167**
France	−0.0019***	−0.0615*	0.0109***	0.0102	−0.0248***
Spain	−0.0029***	−0.1041***	0.0133***	−0.0201	−0.0124*
Italy	−0.0028***	−0.0186*	0.0068***	−0.0690**	0.0033
Portugal	0.0011*	−0.1586***	0.0081**	−0.0459	0.0073
Poland	−0.0018***	−0.0732***	0.0037*	−0.0565*	−0.0051*
Czechia	0.0004	0.0996***	−0.0021	−0.0533	−0.0076
Hungary	0.0022*	−0.0502	0.0039	−0.0450	−0.0036
Canada	−0.0037***	−0.0101	0.0090**	−0.0296	−0.0104*
USA	−0.0033***	−0.0467*	0.0105***	−0.0030	−0.0080*
Japan	−0.0028***	−0.0017	0.0003	−0.0301	0.0095
South Korea	−0.0058***	0.0255***	0.0022***	0.0155	0.0001
Israel	−0.0054***	−0.0738	0.0322***	−0.1314**	−0.0307***

***p<0.001; **p<0.01; *p<0.05.
*Unit for the slope coefficient is month.

and Czechia was not accompanied by an upturn in the trend. The opposite was happening in the countries where the start of the pandemic brought about an abrupt drop in fertility levels. In these countries, including the countries of Southern Europe, France, the UK, Poland and the USA, positive slope change coefficients suggest that the start of the pandemic either contributed to the reversal of the pre-pandemic downward fertility trend or, like in case of Portugal, did not break the prior positive trajectory. Israel and Belgium also show positive fertility dynamics during this pandemic period (before the start of vaccination).

The Netherlands and South Korea make exceptional cases among these turnarounds—positive slope change coefficients indicate that the positive immediate effect of the pandemic's start was sustained.

Pandemic period after COVID-19 vaccination

From the moment when the WHO on 11 March 2020 declared the COVID-19 outbreak to be a pandemic, enormous technological and scientific efforts were expended for the urgent development of COVID-19 vaccines. In early December 2020, the UK became the first country in the Western world to approve the use of COVID-19 vaccines and to begin their distribution. Shortly, it was joined by the USA and Israel, and by the end of December 2020, COVID-19 vaccines began to be administered and distributed in most of EU countries (in the Netherlands in January 2021).[14 21 22] In South Korea and Japan, the vaccination effort began in February 2021.[23 24] Although countries developed vaccination campaigns autonomously, based on their own epidemiological setting, they shared some mutual organisational characteristics. Due to the limited vaccine supply, the vaccine was administered using a phased approach in most countries, normally starting from population groups at the highest risk of exposure to COVID-19 (eg, healthcare workers), the elderly and those with high-risk comorbidities. The WHO identified pregnancy among conditions qualifying for prioritised access to COVID-19 vaccination.[25 26] As the COVID-19 vaccination campaigns started, many countries were recommending against COVID-19 vaccination in pregnancy, especially among low/middle-income countries. However, in the course of several months, the number of countries recommending or permitting

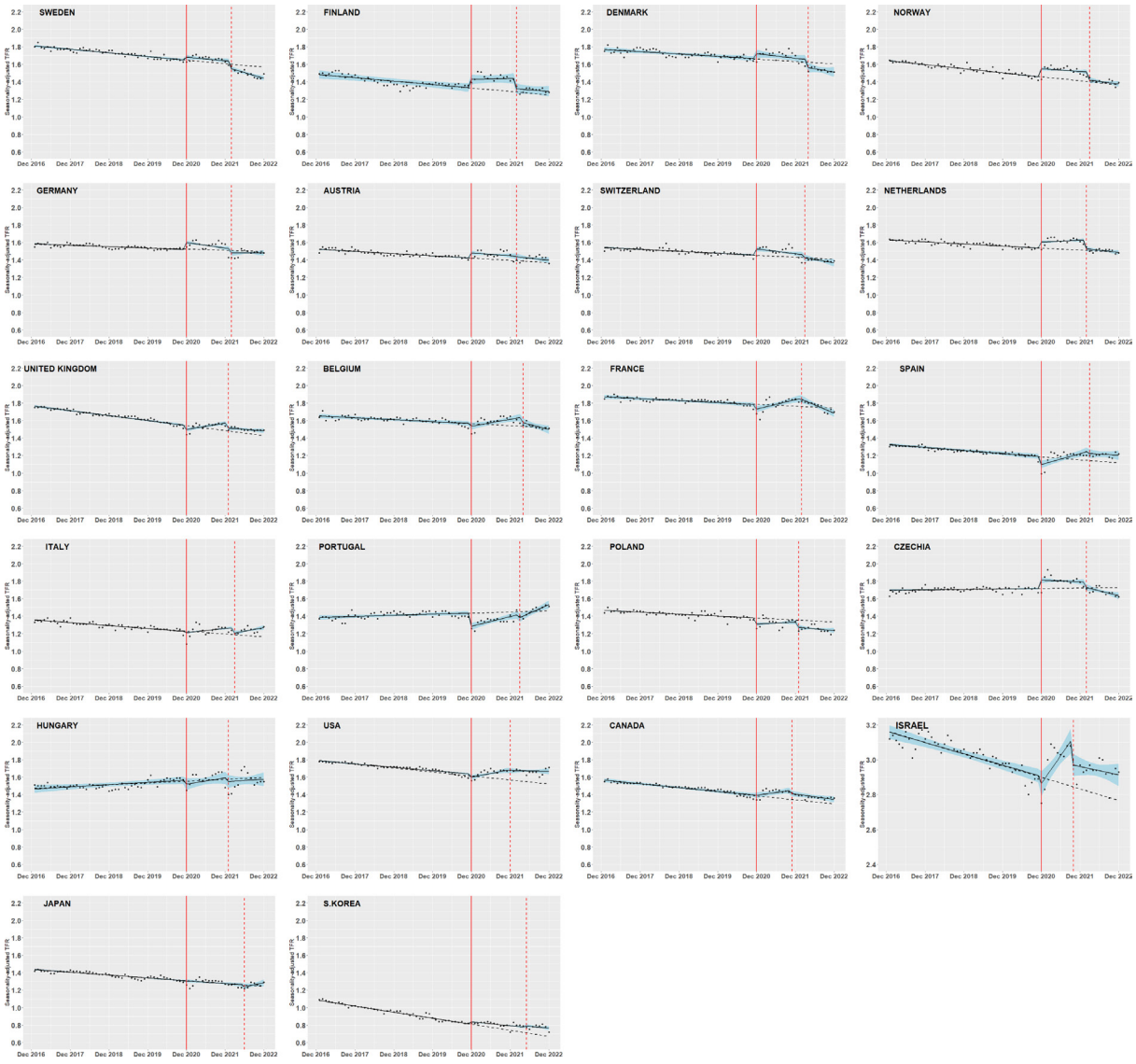

Figure 1 Trends in the seasonally and calendar-adjusted monthly TFRs, all countries. Dots represent observed data points, solid lines represent fitted values, dashed lines represent linear extrapolations of the pre-pandemic seasonally and calendar-adjusted monthly TFR trends and vertical lines indicate periods (start of the pandemic and start of COVID-19 vaccination, both lagged by 9 months). Israel has a different y-axis scale. TFR, total fertility rate.

use of COVID-19 vaccines for pregnant women rapidly increased.[27 28]

The speed of COVID-19 vaccination rollouts and how soon the COVID-19 vaccine became accessible to non-risk population groups varied across countries (online supplemental table S1). Israel and the USA were among the leaders in this process. Israel opened vaccine eligibility to the population aged 16 and over in January–February 2021. In the USA, with some divergence across the states, it happened around March 2021. In most other high-income countries, vaccine eligibility to non-risk populations aged 16 and over was granted between May and July. In the two East Asian countries, it started a few months later: August 2021 in South Korea and September 2021 in Japan.[14]

The results provide evidence suggesting an immediate reduction in fertility level following 9 months after the COVID-19 vaccine rollout in all countries but France and South Korea, although a pronounced negative association was found only for 10 out of 22 analysed countries, including the four Nordic countries, Germany, the Netherlands, the UK, Italy, Poland and Israel (table 1). The time series of the available monthly TFRs is too short to make robust inferences about fertility trends in the period after the start of COVID-19 vaccination, however, the findings hint that with the availability of COVID-19 vaccines, the circumstances that had shaped people's reproductive behaviour during the prior phases of the pandemic faded away. With a few exceptions, fertility trends in most analysed countries, including those that previously experienced a temporary improvement, seemingly returned to the pre-pandemic downward trajectory. Slope change coefficients are negative for Sweden, the Netherlands, Belgium, France, the UK, Spain, Poland,

Canada, the USA and Israel. The two East Asian countries, Japan and South Korea, appear among the least influenced by the start of vaccination both in terms of level and slope changes. Interesting differences were discovered among the countries of Southern Europe: no effects of vaccination were found for Portugal; there is an immediate negative effect but no sustained effect for Italy; and for Spain, there is no immediate effect, but there is a sustained effect, suggesting a downward shift in fertility trend following the start of COVID-19 vaccination. Finally, Hungary and Japan are the only countries for which neither the start of the pandemic nor the start of COVID-19 vaccination seem to be associated with level or slope changes in monthly fertility.

Effects of selected explanatory factors

We tested the robustness of the association between COVID-19 vaccination and fertility using three control variables lagged by 9 months: youth unemployment, stringency index and vaccination coverage. Stringency index produced by the University of Oxford measures the strictness of government anti-pandemic policies and allows gauging for the level of the pandemic's severity and constraints on people's behaviour. Youth unemployment is used to account for economic security and certainty. The pandemic had different adverse effects on economic conditions. In some countries, especially those of Southern Europe where already pre-pandemic youth unemployment levels were high, youth unemployment increased to record highs after the COVID-19 outbreak.[29] Estimates of COVID-19 vaccination coverage not only present the level of vaccine uptake but also mirror its acceptance by the population, which is again influenced by contextual and personal factors.[30] Some individuals are generally critical of vaccination.[31] Because of their novelty and development speed, COVID-19 vaccines were subject to particular uncertainty.

Additional control for vaccination coverage produced the most systematic influence (online supplemental table S3). For most countries, which initially showed negative immediate effects of vaccination on fertility, this association disappeared. These countries include Sweden, Denmark, Norway, Germany, the Netherlands, Italy and Israel. Negative immediate effects remained only for Finland, the UK and Poland. In many cases, adjustment for youth unemployment either weakened the immediate effect of vaccination (for Norway, the Netherlands and Italy) or cancelled it (Denmark and Germany). The opposite outcome was observed for Portugal and countries of Central Europe (Poland, Czechia and Hungary), where adding youth unemployment enhanced the immediate (negative) effect. We also conducted a sensitivity analysis using monthly inflation rate (consumer price index, with 2015 as the base year) as an alternative economic indicator. Controlling for CPI modified the magnitude of the immediate effect of COVID-19 vaccination in a few cases but not the general direction of the effect (online supplemental table S4). The impact of stringency index was relatively modest. However, for Belgium and Spain, only the model with control for stringency index showed (negative) level change in response to vaccination. None of the three control variables changed the initial results for Finland and the UK. Level change coefficients persistently suggest negative immediate effects of COVID-19 vaccination for these countries. Regarding the sustained effects of COVID-19 vaccination, slope change coefficients for the UK, Belgium, France and Israel remained negative, irrespective of added control variables. The UK is a unique instance as all the level change and slope change models indicate a negative impact of COVID-19 vaccination on fertility in this country.

DISCUSSION

The central aim of this study was to investigate how the roll-out of COVID-19 vaccination was associated with the unexpected fall in birth rates, recorded across various contexts about 9 months after eligibility to COVID-19 vaccines had been opened to non-risk population. Two types of causal mechanisms underlying the link between COVID-19 vaccination and the decline in fertility could be considered: biological and behavioural.

Biologically, COVID-19 vaccines could lead to a decline in births directly, through adverse side effects on the human reproduction system, and indirectly, by negatively influencing coital frequency. Knowledge about the impact of COVID-19 vaccines on fecundity and pregnancy has been growing. Currently, the WHO[32] and many professional medical organisations[33 34] recommend COVID-19 vaccination as safe and effective before and during pregnancy and beneficial (ie, outweighing any potential risks) to both the pregnant woman and the baby. No significant differences were found in the rate of unintended pregnancies and pregnancy outcomes between vaccinated and control groups of people.[35] Likewise, in assisted reproduction clinics, fertility measures and pregnancy rates were found to be similar in vaccinated and unvaccinated patients.[36] Existing studies also offer no evidence for fertility impairment in men following COVID-19 vaccination.[37 38]

As the vaccination effort advanced, many women shared experiencing various menstrual disorders,[39 40] which could also influence the rate of conceptions. Menstrual changes are not uncommon outcomes of vaccination and were observed in response to other vaccines (eg, against HPV[41]). COVID-19 vaccine-related menstrual disorders were short-lived in most cases, and the period returned to normal the following cycle.[38 42 43]

Such relatively common reactions to COVID-19 vaccines as having a sore arm from the injection, headache, muscle ache, fever and other mild flu-like symptoms are not directly connected to human fecundity but may prevent conception indirectly.[32] Sickness is likely to diminish coital frequency for a few days, leading to a reduced likelihood of conception.

From the behavioural perspective, individuals and couples plan their families and adjust reproductive behaviour in response to changing conditions. In times of crisis and uncertainty, couples tend to revise their fertility intentions and to delay childbearing for more favourable circumstances.[5–7] This was witnessed also in response to the COVID-19 outbreak when many couples decided to postpone or even forgo their childbearing plans.[44 45] During the pandemic, as evidence about SARS-CoV-2 as a potential threat to maternal and fetal health started to emerge,[46–49] the COVID-19 vaccine was awaited as the only remedy against the virus. However, since clinical trials did not include pregnant women and the evidence about COVID-19 vaccines' safety for pregnant women and their unborn babies was very limited, there was much uncertainty regarding vaccination of this population group. Many unfounded rumours and false messages that COVID-19 vaccines may harm fecundity were circulating. Young women were hesitant to accept the vaccine because they feared it may leave them infertile.[50] It is likely that due to the lack of evidence-based knowledge about the novel COVID-19 vaccines, also women who generally trusted vaccines deliberately avoided getting pregnant around the time of getting vaccinated and postponed it until they were fully vaccinated.

The start of vaccinations marked a crucial turning point in the battle against the pandemic and spurred the anticipation of its end. It is possible that the changed perspective influenced childbearing behaviour. It would explain why post-pandemic fertility trends went back to pre-pandemic levels in some countries. Aside from the rollout of COVID-19 vaccination, there were clearly also other factors that played a role in the 2022 fertility downturn. Together with the gradual lifting of containment measures, life was returning to normal following the onset of vaccinations. Active social and work life was resumed again, and the 'cocooning effect',[12] that is, unique conditions created by the pandemic which some couples found favourable for procreation,[51 52] came to an end. Limited possibilities of establishing and maintaining romantic relationships during the pre-vaccination phases of the pandemic could also have depressed family formation.[10] In addition, recent research suggests that an increase in inflation in 2021 also contributed to fertility decline in 2022.[13]

In this study, we used the ITS design to evaluate the impact of two interventions—the start of the COVID-19 pandemic and the start of COVID-19 vaccination among the general population aged 16–49 years—on the seasonally and calendar-adjusted monthly TFRs. In agreement with previous research,[10] immediate effects of the onset of the pandemic were found for a large majority of the studied countries, although with a considerable cross-country variation in the magnitude and direction of the prompted fertility level changes. With respect to the impact of the start of COVID-19 vaccination, pronounced negative immediate effects were found for 10 out of 22 countries, including Sweden, Norway, Denmark, Finland, Germany, the Netherlands, the UK, Italy, Poland and Israel, suggesting that the COVID-19 vaccination was potentially associated with the downturn in birth rates in these countries. Additional control variables changed the associations only little. At the same time, it is noteworthy that the level change coefficients were negative for all countries, except for France and South Korea (table 1).

We performed a sensitivity analyses where the effect of COVID-19 vaccination was assessed six, instead of nine, months following its start. The findings suggest that in some countries, including Austria, Germany, Switzerland, Denmark, Norway, Netherlands, Belgium, Italy, Spain and Israel, women responded to the forthcoming vaccination earlier, that is, they started avoiding/postponing pregnancy before they became eligible for the COVID-19 vaccine (online supplemental table S5).

The findings also show that the COVID-19 vaccination campaign contributed to the variation in the short-term fertility trends (figure 1). Based on the visual inspection of the ITS results, four groups of countries could be roughly distinguished concerning the impact of COVID-19 vaccination on the longer-term fertility trajectory: (a) countries where fertility returned to the downward pre-pandemic trajectory (Finland, Norway, the Netherlands, Germany, Switzerland, the UK, Belgium and France); (b) countries where fertility was pushed to a level below the pre-pandemic trajectory (Poland, Czechia, Sweden and Denmark); (c) countries where (often notwithstanding the negative immediate effect of vaccination) fertility likely settled at a level above the pre-pandemic trajectory (Italy, Portugal, Spain, Canada, the USA and Israel); and (d) countries where the impact of vaccination on the post-vaccination fertility trends was limited or ambiguous (Austria, Hungary, Japan and South Korea).

Due to the inherent limitations of aggregated population-level data, the study provides only a glimpse into the complex relationship between COVID-19 vaccination and fertility. The descriptive analysis based on cross-sectional aggregated data provides no possibility of establishing causality. In order to delve deeper into causal mechanisms linking COVID-19 vaccination and reproductive decisions and behaviours, more detailed individual-level data, allowing a more nuanced analysis, are needed. Our analyses of possible explanatory variables are limited and cannot fully account for possible confounding effects of other unobserved factors or for possible multidirectional associations. This remaining evidence gap should be addressed by future more in-depth studies relying on more comprehensive data and methods.

CONCLUSIONS

Given the descriptive design of the study, no causality inferences can be made. However, the study provides an important evidence that the COVID-19 vaccination campaign likely influenced reproductive behaviour and contributed to the decline in birth rates at the turn of

2021–2022. While the declines in fertility following COVID-19 vaccination were sharp in many countries, they often took place in contexts where fertility had increased above the trend during the pandemic, and the post-vaccination decline pushed it closer to the pre-pandemic trend. More in-depth research is needed to explore causal mechanisms underlying fertility responses to COVID-19 vaccination. An enhanced knowledge of the relationship between reproductive and COVID-19 vaccine decision-making could contribute not only to a better understanding of short-term fertility processes but also to facilitating policy efforts aimed at supporting the realisation of fertility intentions in times of epidemiological uncertainties.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval The research project does not require ethics approval as it uses only population-level data that are freely available online.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. The fertility data underlying this article are freely available in the Human Fertility Database (HFD) at https://www.humanfertility.org/Data/STFF. The other indicators were also downloaded from freely accessible online sources listed in online supplemental file table S2. The entire dataset, including explanatory variables and R code used for analyses, will be shared upon reasonable request to the corresponding author.

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