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Exploring associations between the Covid-19 vaccination campaign and fertility trends: A population-level analysis for 22 countries

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Abstract

Background

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.

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 countries. The impact of COVID-19 vaccination was less all-embracing. A negative association between the COVID-19 vaccine rollout and fertility nine months later was found for ten out of 22 countries. For several countries, the decline was preceded by fertility increase that took place after the onset of the pandemic. Only four of 22 countries had post-vaccination fertility declines that resulted in fertility being on a lower level than what the pre-pandemic trend predicted. Additional control variables changed the associations only little.

Conclusions

The COVID-19 vaccination campaign contributed to the variation in the short-term fertility trends. Several countries experienced declines following the campaign, however, this decline 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.

Keywords: COVID-19 pandemic, COVID-19 vaccination, birth rates, fertility trends, interrupted time series

Introduction

The COVID-19 pandemic was one of the most challenging global health emergencies experienced in decades. The outbreak of the coronavirus 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, overwhelming 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 coronavirus outbreak and lockdowns.[8,9] The baby bust was short-term, however, and a small and similarly momentary baby boom followed in most countries soon after. 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 United States, France, Belgium, the United Kingdom, Spain, South Korea, and Japan) and even showed signs of improvement as compared to 2021 (e.g., Portugal), there were countries where the decline in birth rates in early 2022 seemed more pronounced than the pandemic baby bust (e.g., Hungary, Poland). Fertility fell sharply also in countries that had not experienced the pandemic baby bust (e.g., Germany, Czechia, and Sweden) as well as among those that had undergone remarkable fertility increases during 2021 (Denmark, Finland, the Netherlands, and Norway).[11]

It is not simple to disentangle forces behind the abrupt fertility declines at the turn of 2021-2022. Multiple non-exclusive explanations are possible. This study focuses on one potentially important aspect – the COVID-19 vaccination campaign, also recognized in previous research.[10,12] The decline in births was linked with conceptions in spring-summer 2021, coinciding with the momentum of COVID-19 vaccination programmes.[13] 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 United States, Canada, Japan, South Korea, and Israel.

Methods

Study design and data

This ecological study employs an interrupted time series (ITS) approach based on generalized least squares modelling fitted by maximum likelihood. An ITS study design is widely used for evaluating the impact of various policy or other interventions within a defined period of time.[14] 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 (STFF) data series in the Human Fertility Database.[11,15] 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). As many countries used an age-based approach in administering the vaccine to the general population, typically starting from the oldest age groups and gradually expanding its eligibility to younger age groups, not all age groups of the age span 16-49 years became eligible for the vaccine at the same date in some countries. For these countries, the first month when any age group from 16 to 49-year-olds became eligible for the vaccine was used in the analysis (Supplementary Material 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 nine 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, changes the estimated immediate (level) and sustained (slope) effects following the start of vaccination.

The ITS generalized least squares models were fit using the *gls* function adapted from the *nlm*e R package with the method set to maximum likelihood (ML).[16,17] The modelling also accounts for autocorrelation by applying corARMA procedure and autoregression (AR) and moving average (MA) 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 socio-economic contexts without bypassing the Nordic social welfare states.[18,19] The exceptions are Portugal and Hungary, for which the pre-pandemic slope change is positive.

[TABLE 1 HERE]

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 United Kingdom, the United States, 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, 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 United Kingdom, Poland, and the United States, the positive slope 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 coefficients indicate that the positive immediate effect of the pandemic's start was sustained.

[FIGURE 1 HERE]

Pandemic period after COVID-19 vaccination

From the moment when the World Health Organization (WHO) on March 11, 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 United States 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).[13,20,21] In South Korea and Japan, the vaccination effort began in February 2021.[22,23] Although countries developed vaccination campaigns autonomously, based on their own epidemiological setting, they shared some mutual organizational characteristics. Due to the limited vaccine supply, the vaccine was administered using a phased approach in most countries, normally starting from population groups at highest risk of exposure to COVID-19 (e.g., health care workers), the elderly, and those with high-risk comorbidities. The WHO also identified pregnancy as a condition qualifying for prioritized access to COVID-19 vaccination.[24,25]

The speed of COVID-19 vaccination rollouts and how soon the COVID-19 vaccine became accessible to non-risk population groups varied across countries (Supplementary Material Table S1). Israel and the United States were among the leaders in this process. Israel opened vaccine eligibility to the population aged 16 and over in January-February 2021. In the United

States, 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.[13]

The results provide evidence of a reduction in fertility level following nine months after the COVID-19 vaccine rollout for ten out of 22 analysed countries, including the four Nordic countries, Germany, the Netherlands, the United Kingdom, Italy, Poland, and Israel (Table 1). Although 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, 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 (Figure 1). The slope coefficients are negative for Sweden, the Netherlands, Belgium, France, the United Kingdom, Spain, Poland, Canada, the United States, 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 (Table 1). 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: 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.[26] 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.[27] Some individuals are generally critical of vaccination.[28] 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 (Supplementary Material Table S2). 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 United Kingdom, 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. 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 United Kingdom. Level change coefficients persistently suggest negative immediate effects of COVID-19 vaccination for these countries. Regarding the sustained effects of COVID-19 vaccination, the slope coefficients for the United Kingdom, Belgium, France, and Israel remained negative, irrespective of added control variables. The United Kingdom 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 nine 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 may 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[29] and many professional medical organizations[30,31] recommend COVID-19 vaccination as safe and effective before and during pregnancy and beneficial (i.e., 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.[32] Likewise, in assisted reproduction clinics, fertility measures and pregnancy rates were found to be similar in vaccinated and unvaccinated patients.[33] Existing studies also offer no evidence for fertility impairment in men following COVID-19 vaccination.[34,35]

As the vaccination effort advanced, many women shared experiencing various menstrual disorders,[36,37] which could also influence the rate of conceptions. Menstrual changes are not uncommon outcomes of vaccination and were observed in response to other vaccines (e.g., against HPV[38]). COVID-19 vaccine-related menstrual disorders were short-lived in most cases, and the period returned to normal the following cycle.[35,39,40]

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.[29] 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.[41,42] During the pandemic, as evidence about SARS-CoV2 as a potential threat to maternal and fetal health started to emerge,[43-46] 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.[47] 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.

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 total fertility rates (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. The impact of the start of COVID-19 vaccination is less all-embracing. Negative immediate effects were found for ten out of 22 countries, including Sweden, Norway, Denmark, Finland, Germany, the Netherlands, the United Kingdom, 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.

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: 1) countries where vaccination pushed fertility back to the downward pre-pandemic trajectory (Finland, Norway, the Netherlands, Germany, Switzerland, the United Kingdom, Belgium, and France); 2) countries where fertility was pushed to a level below the pre-pandemic trajectory (Poland, Czechia, Sweden, and Denmark); 3) 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 United States, and Israel); and 4) countries where the impact of vaccination was limited or looks 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. 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.

Conclusions

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 realization of fertility intentions in times of epidemiological uncertainties.

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Data Availability

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 Supplementary Material Table S3. The entire dataset, including explanatory variables and R code used for analyses, will be shared on reasonable request to the corresponding author.

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TABLES AND FIGURES

Table 1. Interrupted time series linear regression controlled for level (immediate effects) and slope (sustained effects) changes [a]

	Slope before pandemic Jan 2017 - Nov 2020	**Immediate level change after start of pandemic**	**Slope before vaccination** Dec 2020 - Vaccination (+ 9 m.)	**Immediate level change after start of vaccination**	**Slope after vaccination** Vaccination (+ 9 m.) - Dec 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***
United Kingdom	**-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
S. 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*

[a] Unit for the slope coefficient is month.

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-adjusted monthly TFR trends, and vertical lines indicate periods (start of the pandemic and start of COVID-19 and vaccination, both lagged by 9 months)

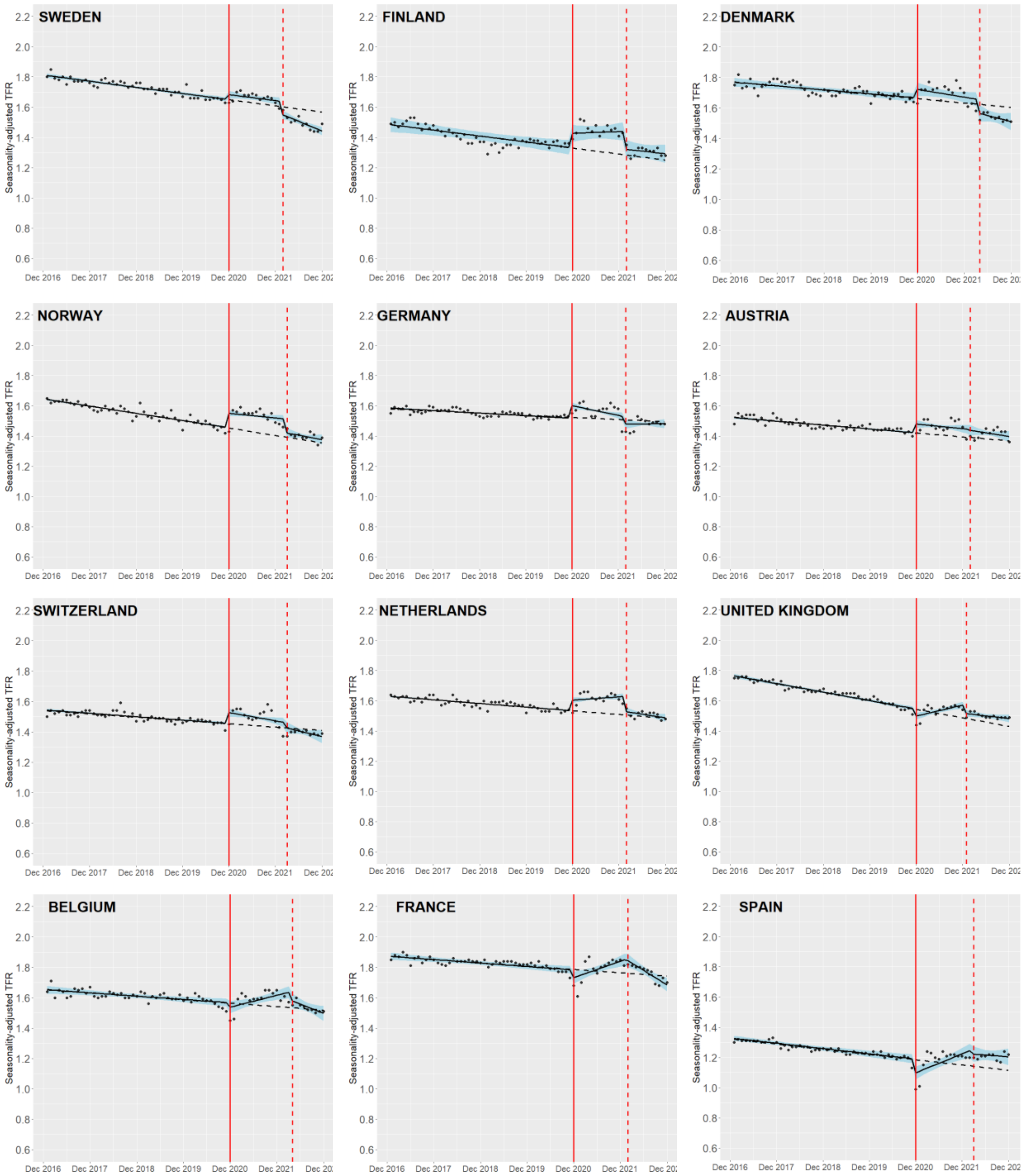
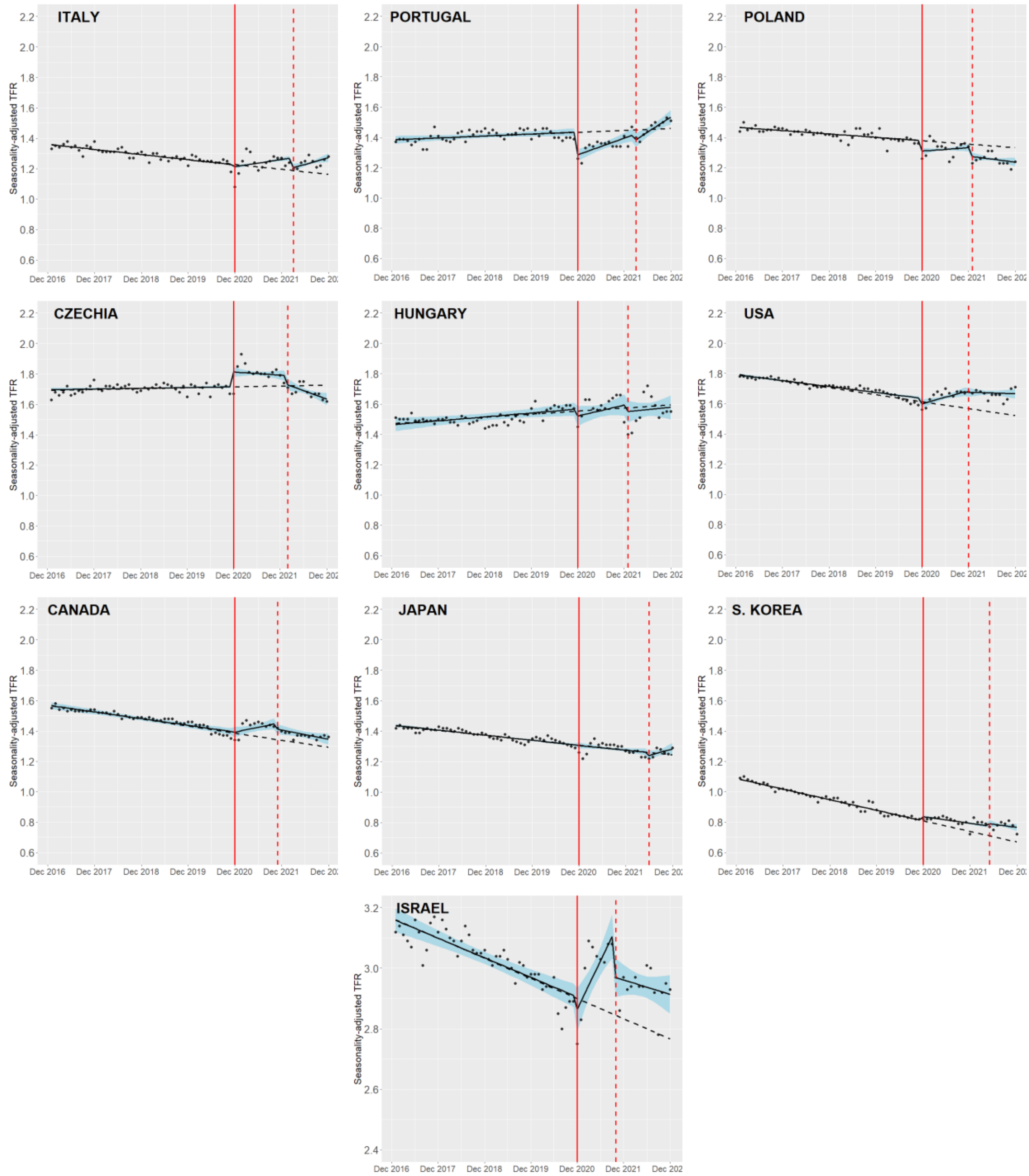


Figure 1 (*continued*). Trends in the seasonally- and calendar-adjusted monthly TFRs, all countries. Dots represent observed data points, solid lines represent fitted values, dashed lines represent linear extrapolations of the pre-pandemic seasonally-adjusted monthly TFR trends, and vertical lines indicate periods (start of the pandemic and start of COVID-19 and vaccination, both lagged by 9 months)[a]



[a] Israel has a different y-axis scale.

Supplementary material

Table S1. Main dates related to COVID-19 vaccination

Country	Start of vaccination campaign	Vaccine opened to ages 16-49[1]	Age-based eligibility for vaccine
Sweden	December 2020	May 2021	Ages 16-44: June; ages 45-49: May 2021
Finland	December 2020	May 2021	Ages 16-34: June 2021; ages 35-49: May 2021
Denmark	December 2020	July 2021	
Norway	December 2020	June 2021	
Austria	December 2020	May 2021	
Germany	December 2020	May 2021	
Switzerland	December 2020	June 2021	
Netherlands	January 2021	May 2021	Ages 16-39: June 2021; ages 40-49: May 2021
United Kingdom	December 2020	April 2021	Ages 16-29: June 2021; ages 30-39: May 2021; ages 40-49: April 2021
Belgium	December 2020	July 2021	
France	December 2020	May 2021	
Spain	December 2020	June 2021	
Italy	December 2020	June 2021	
Portugal	December 2020	June 2021	Ages 16-29: August 2021; ages 30-49: June 2021
Poland	December 2020	April 2021	
Czechia	December 2020	May 2021	Ages 16-29: June 2021; ages 30-49: May 2021
Hungary	December 2020	April 2021	
Canada	December 2020	February 2021	
USA	December 2020	March 2021	
Japan	February 2021	September 2021	
S. Korea	February 2021	August 2021	
Israel	December 2020	January 2021	Ages 16-34: February 2021; ages 35-49: January 2021

[1] For countries, which applied a stepwise approach in vaccinating the general (non-risk) population, the first month when any age group from 16-49-year-olds became eligible for the vaccine was picked. Please see also the further information provide in the table regarding age-based eligibility for the vaccine.

Source: Oxford Covid-19 Government Response Tracker (https://www.bsg.ox.ac.uk/research/covid-19-government-response-tracker)

Table S2. Immediate effects and slope changes after vaccination without (Model A) and with controls for youth unemployment (Model B), stringency index (Model C), and vaccination coverage (cumulative percentage of vaccinated) (Model D)

	Immediate level change after vaccination				**Slope after vaccination**			
	Model A (level and slope only)	Model B (A + youth unemployment)	Model C (A + stringency index)	Model D (A + fully vaccinated)	Model A (level and slope only)	Model B (A+youth unemployment)	Model C (A+stringency index)	Model D (A+fully vaccinated)
Sweden	**-0.0807*** **	**-0.0809*** **	**-0.0768*** **	-0.0498	**-0.0073** **	-0.0061	-0.0049	0.0004
Finland	**-0.1159*** **	**-0.1120*** **	**-0.1157*** **	**-0.1247*** **	-0.0038	-0.0032	-0.0033	-0.0117
Denmark	**-0.0877***	-0.0664	-0.0697	0.0019	-0.0023	-0.0033	0.0022	0.0041
Norway	**-0.0903** **	**-0.0838** **	**-0.0812** **	-0.0292	-0.0023	-0.0016	-0.0008	0.0066
Austria	-0.0046	-0.0070	-0.0046	0.0142	-0.0015	0.0001	-0.0015	0.0033
Germany	**-0.0529***	-0.0062	-0.0456	0.0127	0.0057	**0.0128** **	0.0086	**0.0185** **
Switzerland	-0.0336	-0.0313	-0.0315	0.0547	-0.0016	-0.0013	0.0030	**0.0130** **
Netherlands	**-0.0964*** **	**-0.0663** **	**-0.0874** **	-0.0523	**-0.0058***	-0.0004	**-0.0072***	0.0000
United Kingdom	**-0.0540** **	**-0.0653*** **	**-0.0682*** **	**-0.0539***	**-0.0090** **	**-0.0109** **	**-0.0119*** **	**-0.0090***
Belgium	-0.0469	-0.0465	**-0.0685***	0.0677	**-0.0167** **	**-0.0156***	**-0.0211** **	**-0.0141** **
France	0.0102	-0.0085	-0.0270	0.0232	**-0.0248*** **	**-0.0302*** **	**-0.0314*** **	**-0.0203***
Spain	-0.0201	-0.0322	**-0.0507***	0.0109	**-0.0124***	-0.0083	**-0.0131***	0.0033
Italy	**-0.0690** **	**-0.0565***	**-0.0691*** **	-0.0447	0.0033	0.0057	0.0013	0.0059
Portugal	-0.0459	**-0.0774***	-0.0468	-0.0805	0.0073	-0.0036	-0.0060	0.0030
Poland	**-0.0565***	**-0.1225*** **	-0.0476	**-0.0940** **	**-0.0051***	-0.0005	-0.0066	**-0.0144** **
Czechia	-0.0533	**-0.0719***	**-0.0661***	-0.0512	-0.0076	**-0.0082***	-0.0081	-0.0072
Hungary	-0.0450	**-0.1498*** **	-0.0337	-0.0225	-0.0036	**0.0159*** **	0.0010	0.0001
USA	-0.0296	-0.0037	-0.0053	0.0184	**-0.0104***	**-0.0083***	-0.0098	-0.0031
Canada	-0.0030	0.0093	-0.0293	-0.0312	**-0.0080***	**-0.0128***	**-0.0107***	-0.0086
Japan	-0.0301	-0.0292	-0.0268	-0.0171	0.0095	0.0101	0.0062	**0.0165***
S. Korea	0.0155	0.0373	0.0150	-0.0369	0.0001	-0.0021	0.0001	-0.0085
Israel	**-0.1314** **	**-0.0314** **	**-0.1314** **	-0.0863	**-0.0307*** **	**-0.0305** **	**-0.0307*** **	**-0.0281** **

****P<0.001; **P<0.01; *P<0.05.* Note: unit for the slope coefficient is month.

Table S3. Overview of the data and their sources

Data/Indicator	**Data source**
Monthly total fertility rates (TFRs) adjusted for seasonal and calendar variations	The Short-Term Fertility Fluctuations (STFF) data series (https://www.humanfertility.org/Data/STFF), which is part of the Human Fertility Database (https://www.humanfertility.org).
Starting date of vaccination programme	The Oxford Covid-19 Government Response Tracker (https://www.bsg.ox.ac.uk/research/ covid-19-government-response-tracker)
Date when COVID-19 vaccines became available to general population aged 16-49 years	The Oxford Covid-19 Government Response Tracker (https://www.bsg.ox.ac.uk/research/covid-19-government-response-tracker)
Stringency index	The Oxford Covid-19 Government Response Tracker (https://www.bsg.ox.ac.uk/research/covid-19-government-response-tracker)
Share of people who received all doses prescribed by the initial vaccination protocol (fully vaccinated)	Our World in Data (https://ourworldindata.org/covid-vaccinations)
Youth unemployment (under 25 years)	EUROSTAT database (https://ec.europa.eu/eurostat/databrowser/ view/EI_LMHR_M__custom_5475348/ default/table) and OECD database (for Switzerland, United Kingdom, Canada, South Korea and Israel) (https://data.oecd.org/unemp/youth-unemployment-rate.htm)