Associations between Covid-19 vaccination and fertility: interrupted time series analyses of birth rates for 22 countries

Aiva Jasilioniene[1], Domantas Jasilionis[1,3], Dmitri Jdanov[1], and Mikko Myrskylä[1,2,3]

[1] Max Planck Institute for Demographic Research (MPIDR), Rostock, Germany
[2] Population Research Unit, University of Helsinki, Helsinki, Finland
[3] Max Planck – University of Helsinki Center for Social Inequalities in Population Health, Rostock, Germany and Helsinki, Finland

Abstract

Fertility trends underwent strong fluctuations during the COVID-19 pandemic. Upward and downward fertility shifts, although of varying size, occurred quite synchronously in many higher-income countries. This study focuses on the sharp downturn in monthly birth rates observed at the turn of the years 2021-2022, which has been puzzling in the light of the relatively stable and positive fertility dynamics during most of 2021 in many countries. This decline in births is linked with conceptions in spring-summer 2021, which coincides in time with the COVID-19 vaccination effort gathering momentum. The central aim of this study is to explore whether the rollout of COVID-19 vaccination and the fall in monthly fertility are associated. Using an interrupted time series design, the impact of two interventions – the start of the COVID-19 pandemic in March 2020 and the start of COVID-19 vaccination– on the trends in seasonally- and calendar-adjusted monthly TFRs has been evaluated. The findings suggest that at least in some countries, the COVID-19 vaccination seemingly influenced childbearing behaviour and thus contributed to the decline in birth rates seen about nine months following the start of the effort. More in-depth and context-sensitive research is needed to further explore causal mechanisms underlying changes in childbearing decisions in response to COVID-19 vaccination.

Extended abstract

Introduction

The COVID-19 pandemic was one of the most challenging global health emergencies experienced in decades. The shock and uncertainty brought by the pandemic forced changes and adjustments in all dimensions of life, including re-evaluation of one's childbearing plans, which soon manifested in monthly birth trends. In line with the past evidence on fertility dynamics in times of crisis and uncertainty (Sobotka et al. 2011, Boberg-Fazlic et al. 2021, Wagner et al. 2020), a sharp decline in monthly number of births was observed in most high- and middle-income countries in response to the outbreak of the coronavirus and the lockdowns (for early cross-national comparisons, see Sobotka et al. 2021 and Aassve et al. 2021). The baby bust was short-lived, but it marked the start of the pandemic's roller-coaster ride for fertility (Sobotka et al. 2023)

It is not easy to disentangle the forces behind the abrupt fall in the short-term fertility trends observed in many higher-income countries in early 2022. Multiple non-exclusive explanations can be possible; however, this study aims to have a closer look at one potentially important aspect, which is related to COVID-19 vaccination and which has also been recognized in previous research (Bujard and Andersson 2022, Sobotka et al. 2023). The decline in births at the turn of 2021-2022 is associated with conceptions in spring-summer 2021, which coincides in time with the momentum of COVID-19 vaccination programmes (Our World in Data 2023). The main goal of this study is to identify immediate and sustained fertility changes in response to the start of COVID-19 vaccination among general population in 17 European countries, the United States, Canada, Japan, South Korea, and Israel.

Data and methods

This ecological study employs an interrupted time series (ITS) approach based on generalized least squares modelling fitted by maximum likelihood. Two interventions are considered in the analysis: the onset of the COVID-19 pandemic and the start of COVID-19 vaccination among general (non-risk) population of reproductive ages (16-49 years). The observation period in this study covers the period of time from January 2017 to December 2022. 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, recently integrated in the Human Fertility Database (HFD/STFF 2023, Jdanov et al. 2022). The ITS generalized least squares models were fit using *gls* function from the *nlm*e R package with the method set to maximum likelihood (ML). The modelling also accounts for autocorrelation by applying corARMA procedure and autoregression (AR) and moving average (MA) terms (Beard et al. 2019). These terms were chosen using the Akaike Information Criterions (AICs) for each model.

Country-specific models were fitted in order to estimate whether the seasonally- and calendar-adjusted TFRs have changed in response to a) the start of COVID-19 pandemic (March 2020) and b) the start of COVID-19 vaccination among general population. Considering the natural delay of fertility response (it is visible only about 9 months after conception), these two time points have been moved forward by 9 months. Each country-specific ITS model accounts for pre-pandemic slope term accounting for a secular monthly fertility trend before the start of the pandemic; immediate effects (level change) after a) the start of pandemic and b) the start of vaccination; additional slope changes following the start of vaccination.

Results

Following the start of the COVID-19 pandemic, almost all the countries experienced an immediate change in the level of monthly fertility, but the size and the direction of the change considerably varied across countries. In the South European countries (Spain, Italy, and Portugal) as well as in France, the United Kingdom, the United States, and Poland, the coefficients of level change are negative and indicate that the coronavirus outbreak and the introduced lockdowns induced an immediate decrease in fertility. At the same time, the Nordic countries (Norway, Denmark, Finland, and Sweden), the German-speaking countries (Austria, Germany, and Switzerland) as well as the Netherlands, Czechia, and South Korea display statistically significant positive effect, suggesting an upturn in monthly birth rates in these countries in response to the onset of the pandemic. However, the slope coefficients of the pandemic trend (before the start of the COVID-19 vaccine rollout) show that the effects (both positive and negative) produced by the start of the pandemic were not sustained in the majority of the studied countries. For example, in the Nordic countries, the positive immediate effect was not accompanied by a positive shift in the fertility trend. No statistically significant sustained effect of the start of the pandemic has been found for Austria, Switzerland, and Czechia either. Only the Netherlands and South Korea make exceptional cases in this context showing that the positive immediate effect of the start of the pandemic was sustained until the start of COVID-19 vaccination. The opposite was happening in the countries, in which the start of the pandemic brought about an abrupt drop in the level of fertility (countries of Southern Europe, France, the United Kingdom, Poland, and the United States). The start of the pandemic contributed to the reversal of the pre-pandemic downward fertility trend in these countries.

The most intriguing part of our analysis and the primary aim of this study was to investigate whether and how COVID-19 vaccination influenced fertility trends in the countries selected for the study.

The speed of COVID-19 vaccination rollouts and how soon COVID-19 vaccine became accessible to non-risk population groups varied across countries. Israel and the United States were among the leaders in this process. Israel opened vaccine eligibility to population aged 16 and over in January-February 2021, and in the Unites States, although there was some divergence across the states, it happened around March 2021. In the majority of other higher-income countries, vaccine eligibility to non-risk population aged 16 and over was granted between May and July. In the two East Asian countries covered in this study, it started a couple of months later: August 2021 in South Korea and September 2021 in Japan (Our World in Data 2023; Annex Table 1).

The results for the immediate level change suggest that the COVID-19 vaccine rollout was generally associated with a reduction in the level of fertility following nine months after its start (Table 1 and Annex Figure 1). However, a statistically significant immediate effect of COVID-19 vaccination has been established only among ten analysed countries: the start of vaccination is associated with a significant decline in fertility level in the four Nordic countries, Germany, the Netherlands, the United Kingdom, Italy, Poland, and Israel. With a few exceptions, fertility trends in most of the analysed countries, including those that previously experienced a temporary improvement, seem to have returned to the pre-pandemic downward trajectory. The slope coefficients for the last period are negative and statistically significant 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, seem to be among the least influenced by the start of COVID-19 vaccine roll-out both in terms of level and slope change as both of these coefficients are statistically insignificant for these countries. The obtained results suggest interesting differences between the three countries of Southern Europe: no effects of the COVID-19 vaccination have been 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 the fertility trend following the start of COVID-19 vaccination. Curiously, Hungary and Japan are the only countries in our analysis, for which neither the start of the pandemic nor the start of COVID-19 vaccination seem to be associated with level or slope change in monthly fertility.

We have also tested whether additional controlling for selected variables, including youth unemployment, stringency index, and vaccination coverage, may lead to changes of the estimated immediate (level) and sustained (slope) effects following the start of vaccination (Table 2). The most systematic effect is related to additional controlling for vaccination coverage. For the majority of the countries, which initially showed significant negative immediate effects of the start of COVID-19 vaccination, the level change coefficients have lost their statistical significance. After controlling for vaccination coverage, the immediate effects remain negative and significant only for Finland, the United Kingdom, and Poland.

As regards the sustained effects of the start of COVID-19 vaccination, a distinct group of countries has been identified, for which the slope coefficients remain negative and statistically significant irrespective of added control variables. This group of countries comprises the United Kingdom, Belgium, France, and Israel. Moreover, the United Kingdom is a unique country in the study while none of control variables could change the significance of negative immediate as well as negative sustained effects of the COVID-19 vaccination found for this country.

Discussion and conclusions

The study findings suggest that the outbreak of coronavirus and the introduced strict countermeasures had an immediate and significant effect on the level of short-term fertility in a large majority of the countries covered in the study. At the same time, in consistence with previous research (Sobotka et al. 2023), it has been found that the magnitude and the direction of fertility changes prompted by the pandemic differed across countries. The impact of opening the COVID-19 vaccine eligibility to general population aged 16 and over on the short-term fertility dynamics is less clear-cut. A statistically significant negative immediate effect has been established for ten out of 22 studied countries, including the four Nordic countries, Germany, the Netherlands, the United Kingdom, Italy, Poland, and Israel, suggesting that the start of COVID-19 vaccination is associated with a decline in birth rates observed in these countries. There were certainly also other factors at play, which influenced childbearing decision-making at the time and contributed to the subsequent fertility downturn. In this analysis, vaccination coverage (share of fully vaccinated population) appeared to have the strongest influence from all the selected control variables and altered the immediate effect of vaccination to non-significant in all the countries, except for Finland, the United Kingdom, and Poland.

Due to inherent limitations of aggregated data, the current study provides only a glimpse into a complex relationship between the COVID-19 vaccination campaign and fertility. In order to delve deeper into causal mechanisms linking the COVID-19 vaccination and reproductive decisions and behaviours, more detailed individual-level data, allowing a more nuanced analysis, are required. Two potential causal mechanisms underlying the link between the COVID-19 vaccination and fertility – biological and behavioural – could be considered. Biologically, COVID-19 vaccines may be associated with a decline in births both directly, through adverse side effects on human reproduction system, and indirectly, by negatively influencing coital frequency. From the behavioural perspective, individuals and couples plan their families and adjust reproductive behaviour in response to changing conditions. Past research shows that in times of crisis and uncertainty, most couples tend to revise their fertility intentions and to delay childbearing for more favourable circumstances (Sobotka et al. 2011, Boberg-Fazlic et al. 2021, Wagner et al. 2020). Such a reaction was witnessed also in response to the outbreak of the coronavirus pandemic, when many couples decided to postpone or even forgo their childbearing plans (Luppi et al. 2022, Malicka et al. 2021). During the pandemic, 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 a lot of uncertainty regarding vaccination of this population group (Speed 2021). It is likely that due to lack of evidence-based knowledge about the novel COVID-19 vaccines, also women who generally trusted vaccines reconsidered timing of pregnancy and deliberately avoided getting pregnant around the time of getting vaccinated.

This study provides an indication that being as massive as it was, the COVID-19 vaccination campaign, at least in some countries, did play a role in shaping childbearing plans and reproductive behaviour and thus likely contributed to the decline in the short-term fertility trends observed about nine months following its onset. Further, more in-depth, and context-sensitive research is needed to explore causal mechanisms underlying changes in childbearing decisions in response to COVID-19 vaccination. An enhanced knowledge of the character of the relationship between reproductive and COVID-19 vaccine decision-making could contribute not only to better understanding of short-term fertility processes and patterns but also to facilitating policy efforts aimed at supporting realization of fertility intentions in the times of epidemiological uncertainties.

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TABLES AND FIGURES

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

	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

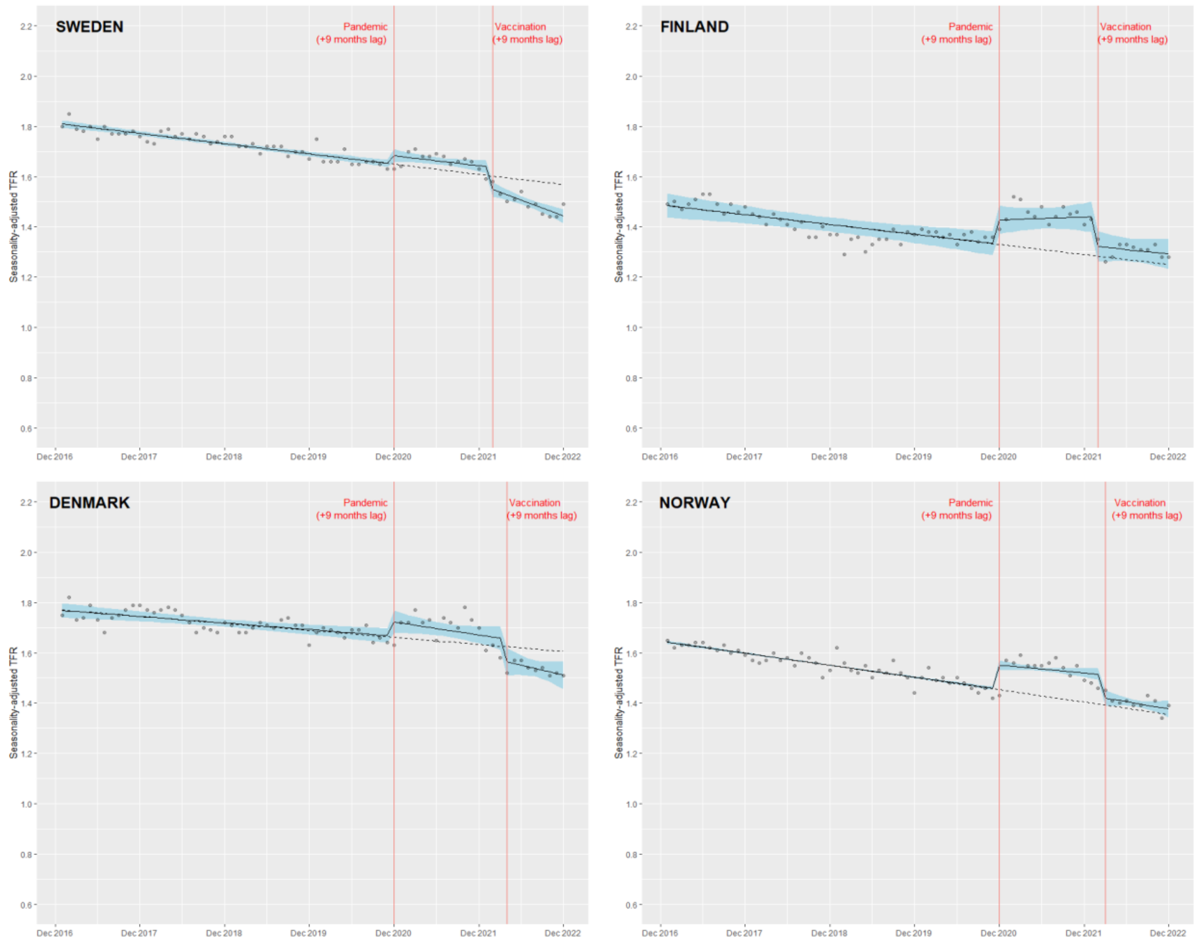
Table 2. Immediate effects and slope changes after vaccination without (Model A) and with controls for youth unemployment (Model B), stringency index (Model C), and vaccination coverage (cumulative percentage of vaccinated) (Model D)

	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

Annex Figure 1. Trends in the seasonally- and calendar-adjusted monthly TFRs. Dots represent observed data points, solid lines represent fitted values (including the confidence interval), dashed lines represent linear extrapolations of the pre-pandemic TFR trends, and vertical lines indicate periods analysed in regression models

Nordic countries



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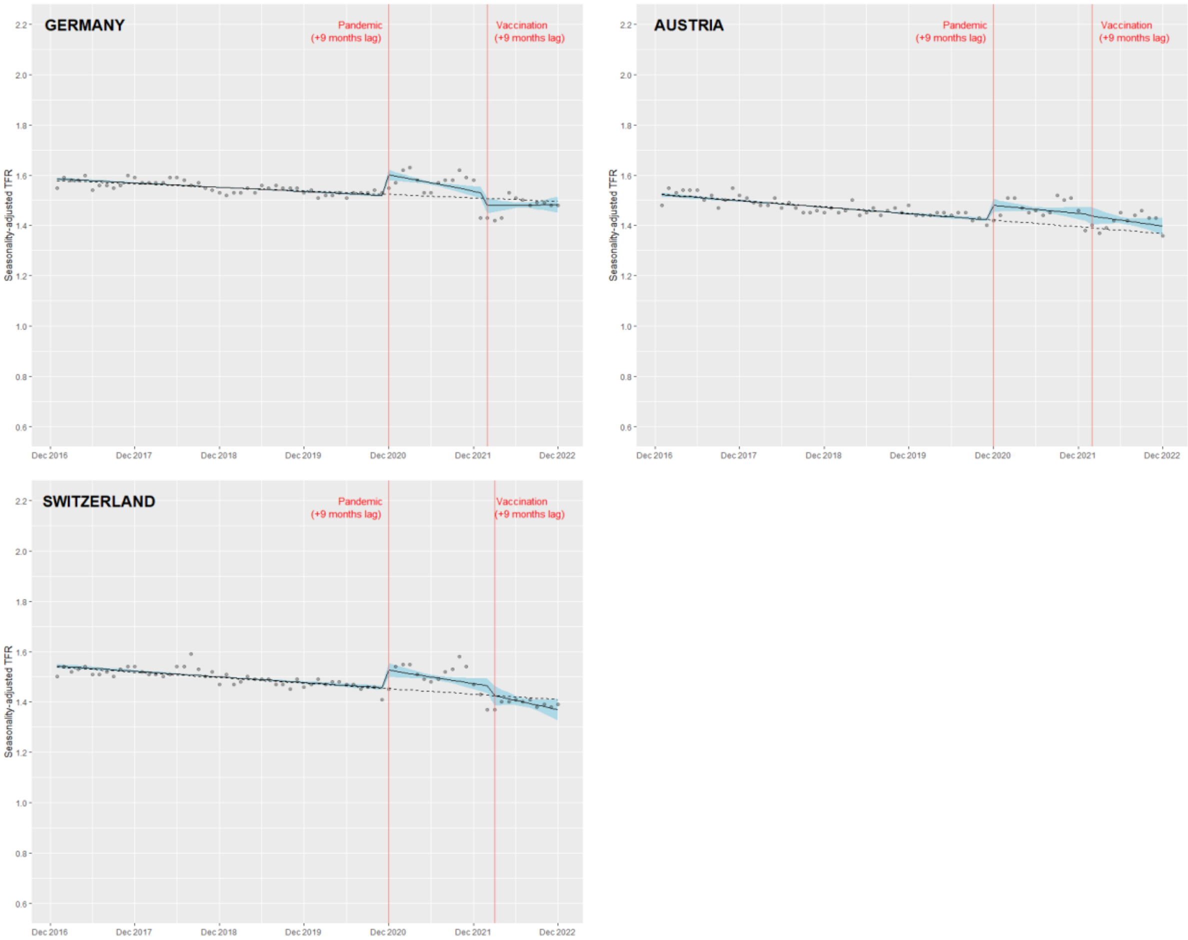
German-speaking countries



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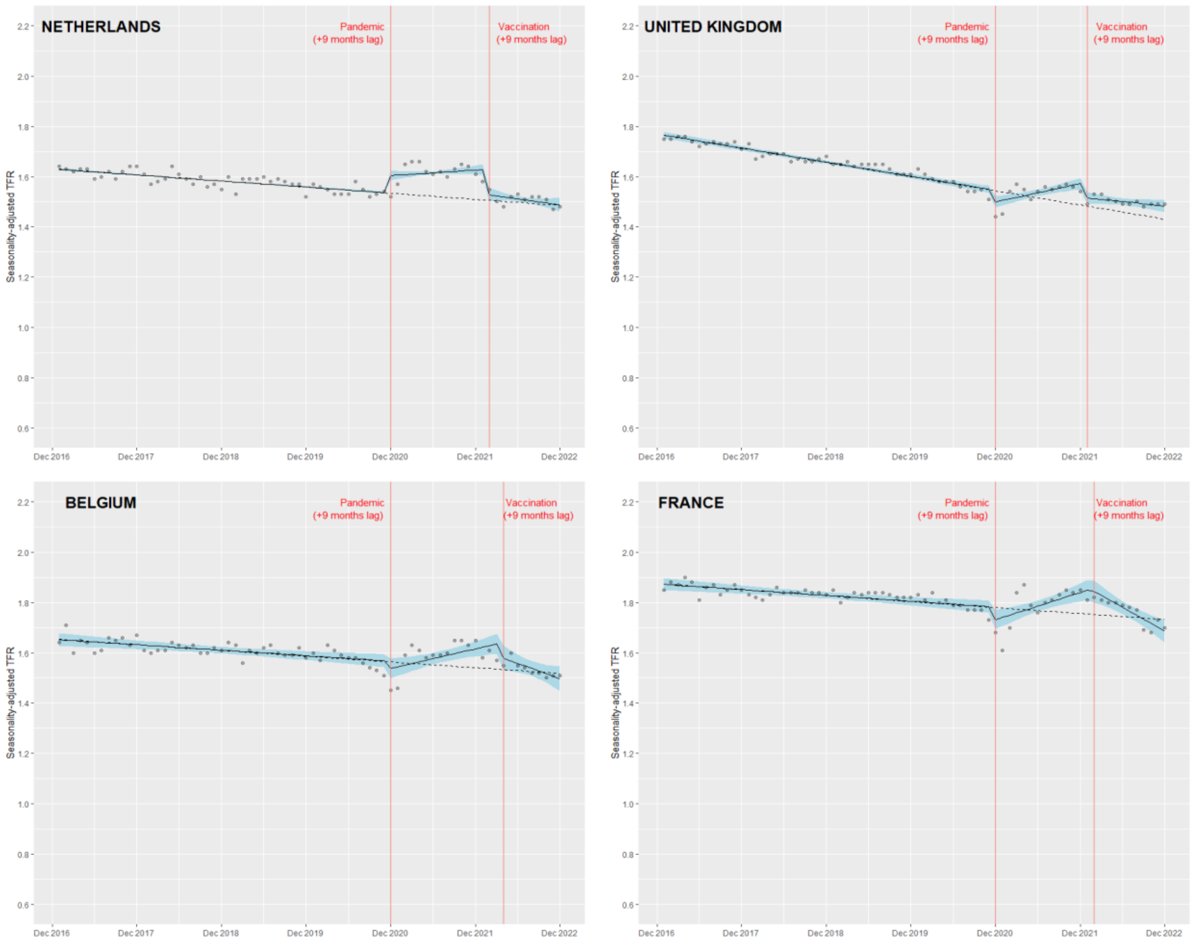
Western Europe



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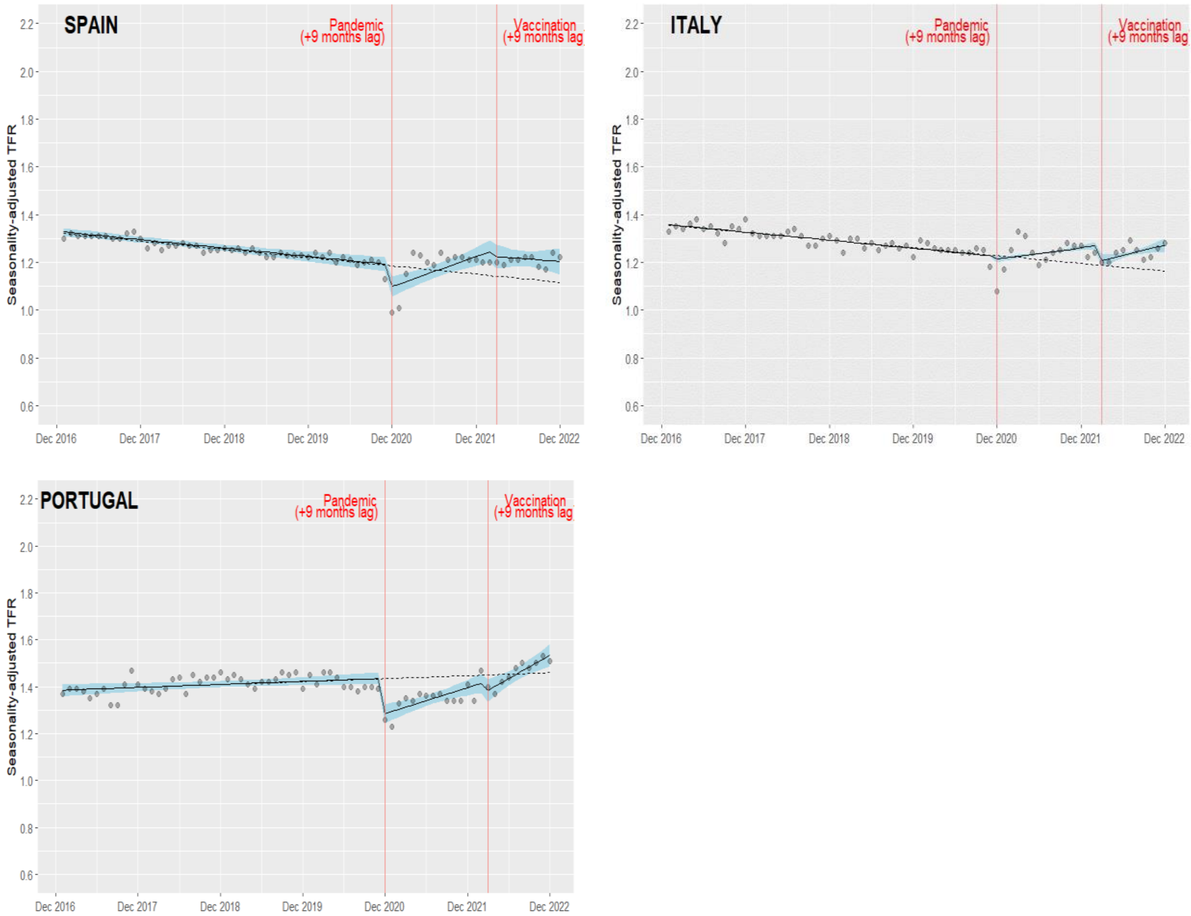
Southern Europe



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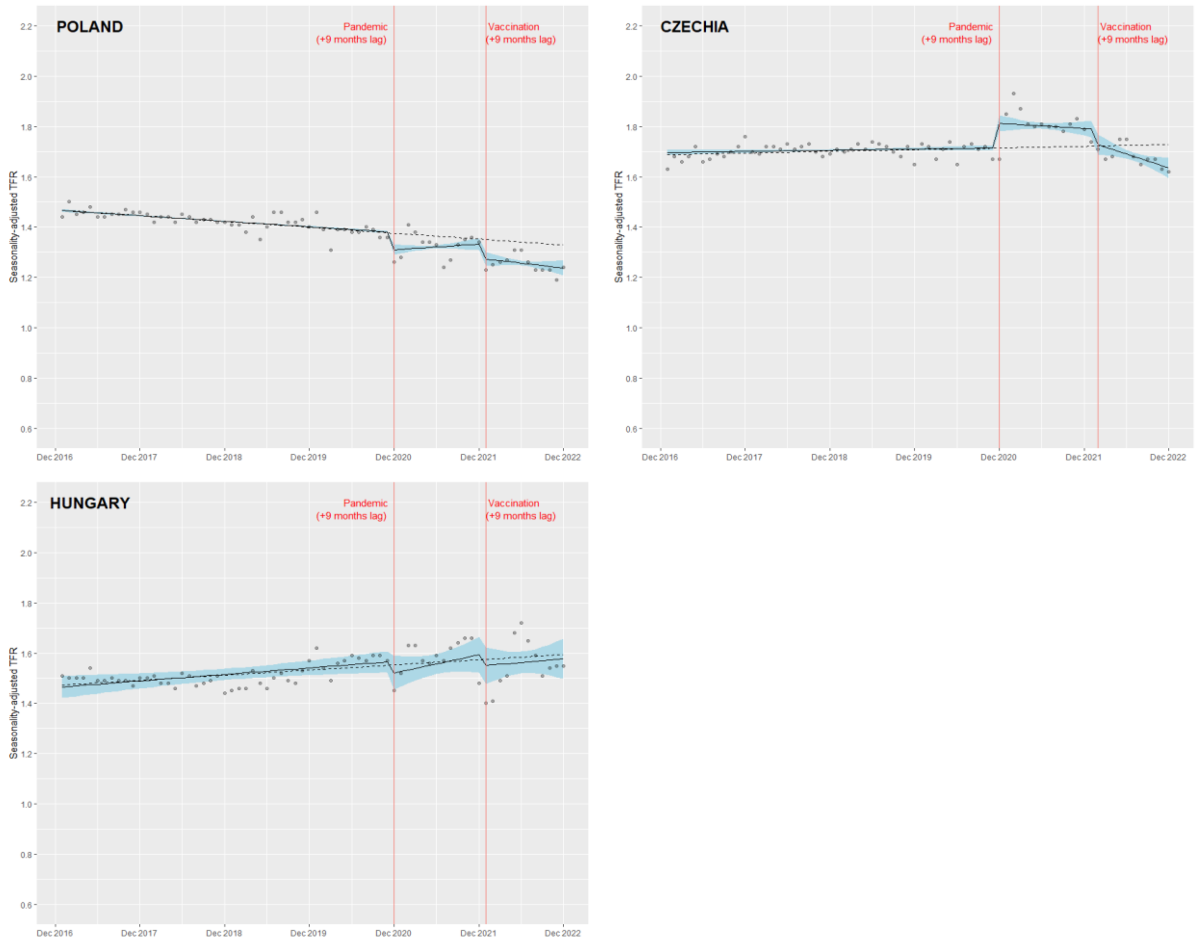
Central Europe



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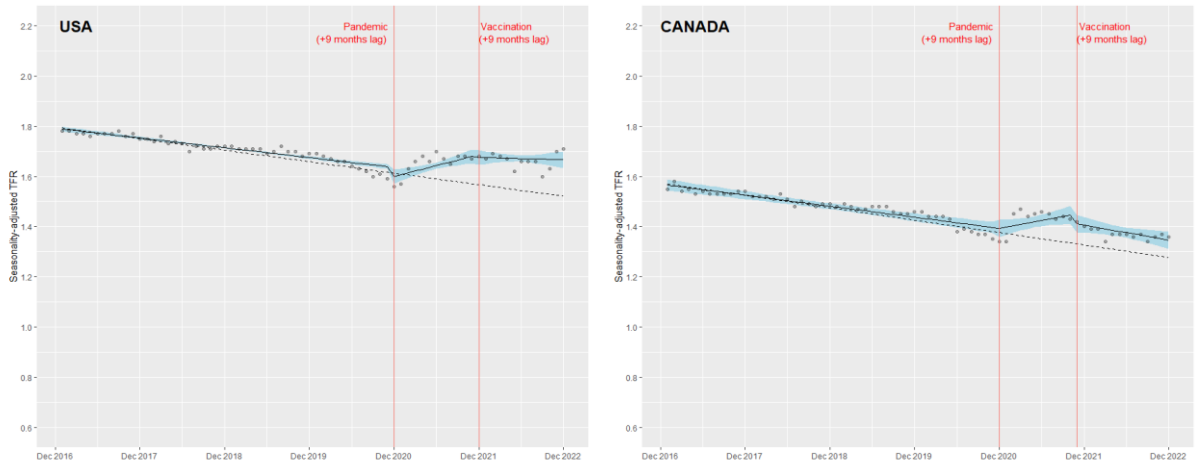
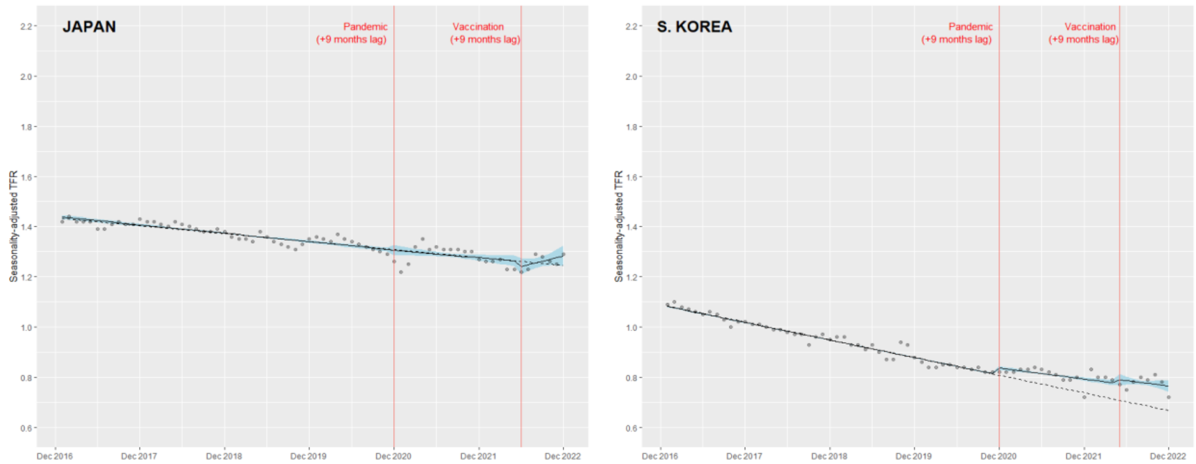
North America



East Asia



Other