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The COVID-19 pandemic changed the socioeconomic composition of parents: A register-based study of 76.5 million live births in 12 countries

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Abstract

The COVID-19 pandemic continues to offer opportunities to study how in-utero and early life exposure to environmental changes can affect health and socioeconomic outcomes throughout the life course. However, inferences from such studies and resulting policies may be flawed if the pandemic has changed the socioeconomic composition of parents.

Using register data covering over 76.5 million live births from January 2015 to December 2021 from 12 countries (Americas: Brazil, Ecuador, Colombia, Mexico, the United States; and Europe: Austria, England, Finland, the Netherlands, Scotland, Spain, Wales) we estimated the pandemic's effect on the socioeconomic and demographic composition of the cohort born between December 2020 and December 2021.

In the United States and all included European countries, the December 2020-December 2021 birth cohort had a 0.6% (Netherlands) to 2.5% (Spain) higher proportion of babies born to socioeconomically advantaged parents compared with their counterfactual compositions. In Latin American countries, the proportion of babies born to advantaged parents was 0.3% (Mexico) to 3% (Ecuador) lower than their counterfactual proportions.

These compositional changes may cause between-cohort differences in life course outcomes that are affected by the socioeconomic position of parents even if in-utero or early life exposure to the pandemic had no direct effect on these outcomes. Cross-country differences in our results suggest that changes in a birth cohort's socioeconomic composition in response to macro-level shocks depend on how socioeconomic position relates to agency in fertility decisions.

Introduction

The Coronavirus Disease (COVID)-19 pandemic has created "a natural experiment of unprecedented proportions" [1]. As such, it is widely used as an exposure in a growing number of natural experimental study designs to uncover causal relationships of core interest in a range of scientific disciplines.[1]

These studies seek to use the unanticipated and sudden occurrence of a pandemic-induced temporary change in the environment humans live in as exogenous exposure. The relatively clear period of population-wide exposure combined with available measures of exposure intensity (e.g. number of new COVID-19 cases or stringency of policy response[2]), offer researchers opportunities to estimate causal effects of living in a suddenly changed world regarding many outcomes. Potentially, the most severe caveat of such study designs is that the COVID-19 pandemic has abruptly changed human environment and behaviour simultaneously, making it difficult to isolate the effect of a single pandemic-related exposure on an outcome.[3]

Research interested in the reproductive health effects of in-utero and early life exposures on pregnancy has already used the COVID-19 pandemic as a natural experiment to study pregnancy and birth outcomes[4–6]. This research is often motivated by or interpreted through the 'foetal origins hypothesis'[7,8] which proposes that a foetus adapts to the maternal environment during gestation[7–9] and that so called foetal programming may have long-term effects on health, developmental, and socioeconomic outcomes throughout the life course.[7] As the cohorts born and conceived during the COVID-19 pandemic age, we expect this literature to expand rapidly across many outcomes like educational attainment, income, mental health, and mortality in later stages of the life course.

However, differences in outcomes between cohorts born and conceived before, during, or after the COVID-19 pandemic can only be causally attributed to in-utero or early life exposure to the pandemic if the exposed and unexposed cohorts are exchangeable[10]. That is, the cohorts born and conceived before (or after) the pandemic need to be a useful representation of what would have happened to the cohort that was conceived and born during the pandemic had the pandemic not occurred. More specifically, the difference between the average outcome of the exposed and the unexposed cohorts must not be confounded by another variable that causes the exposure and the outcome.

Intuitively, because the pandemic was an unanticipated population-wide event, it might seem safe to assume that there is no confounding variable that is associated with an outcome and caused in-utero or early life exposure to the pandemic. Indeed, numerous already published studies on how the pandemic affected outcomes during the earliest stages of the life course – during pregnancy and at birth –implicitly assume exposed and unexposed cohorts to be exchangeable.[11–13]

While not obvious, we believe that this assumption is likely violated when using the COVID-19 pandemic as an in-utero or early life exposure. For babies born and conceived during the pandemic, there are two main selection mechanisms which can violate the exchangeability assumption and potentially bias effect estimates of in-utero and early life exposure to the pandemic on life course outcomes.

First, for babies conceived before the pandemic but exposed to the pandemic in-utero, this bias can occur due to selection mechanisms while in utero[9,14] (e.g., through pregnancy loss, abortion, miscarriages, stillbirths) – also known as live birth bias[15] in perinatal epidemiology. For example, the pandemic environment may have led to an increase in abortions among pre-pandemic conceptions in the most disadvantaged population groups due to deteriorating economic circumstances, while the rate of abortions did not change (or less so) in advantaged groups[16] – assuming that there was equal access to safe abortions. Assuming increased barriers to safe abortions, the opposite scenario is also plausible.[17–19] For babies born shortly after the start of the pandemic such selection mechanisms are of little concern[20], but these pregnancies might have been affected by disruptions in perinatal health services.[12]

The second mechanism – selection into conceptions – is the focus of this paper. For babies conceived during the pandemic, the exchangeability assumption is violated if the pandemic changed the composition of conceptions and consequently the composition of live births in respect to parental characteristics that are associated with the outcomes of interest. We believe that such compositional changes in parental socioeconomic characteristics are especially likely in the context of the unequal impacts of the COVID-19 pandemic.[21–24] There are many plausible hypotheses why fertility responses to the pandemic might have differed across socioeconomic, or age groups.[25]

Socioeconomically advantaged groups were expected to adjust their fertility during the pandemic to positive changes in their work-life balance (e.g., working from home and reduced travel)[26]. At the same time, restricted access to assisted reproductive technology[27] (e.g. fertility clinics were closed during the lockdown) may have been a barrier for fertility – especially for those at higher reproductive ages. On the other hand, the pandemic may have led disadvantaged families to postpone pregnancies in the face of increased economic uncertainty and income losses.[25,26,28] Further, the fertility response of disadvantaged groups may be more sensitive to their access to contraception.[29] Importantly, explanations for pandemic-induced change in parental socioeconomic composition of births must also pay attention to context-specific reasons for pre-pandemic socioeconomic differences in fertility.[30]

Our directed acyclic graph (DAG) in Figure 1 illustrates how these potential violations of the exchangeability assumption can bias estimation of the effects of in-utero and early life exposure to the pandemic even if there is no confounding variable that causes the exposure and the life course outcome of interest directly. The problem arises because analysing the effect of exposure to the pandemic inevitably conditions on observing the outcome. Trivially, a life course outcome, like birth weight of an individual can only be observed if that individual was conceived and survived all subsequent selection mechanisms (e.g., conception, miscarriage, abortion, stillbirth) until live birth. Thus, any effect of in-utero or early life exposures is partially mediated through potential pandemic-induced changes in fertility behaviour and/or survival[14,15] until live birth. Because of this unavoidable conditioning on potential mediators, any variable (e.g., “Pre-pandemic Parental Characteristics” in Figure 1) that is associated with fertility behaviour and/or survival until live birth and the outcome will bias the estimate of the effect of in-utero or early life exposure to the pandemic even if this variable has no association with the exposure. This sort of bias is not entirely novel but contained in multiple well-known concepts: mediator-outcome confounding[31], selection bias[32], collider bias[32,33], immortal time bias, and survival bias[14,15].

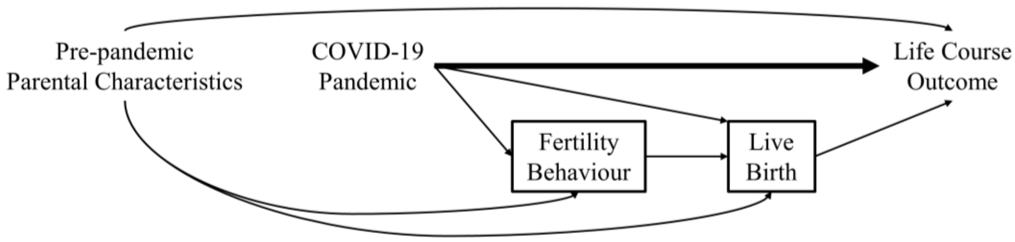

Figure 1: *Directed Acyclic Graph (DAG) showing how conditioning on “Fertility Behaviour” and “Live Birth” (indicated by boxes) introduces mediator-outcome confounding of the effect of the “COVID-19 Pandemic” (exposure) on “Life Course Outcome” (outcome) of cohorts born and conceived during the pandemic. “Pre-pandemic Parental Characteristics” confound the mediator-outcome relationship between the mediators “Fertility Behaviour” and “Live Birth” and the outcome “Life Course Outcome”.*

Based on previous literature in health and social sciences, we believe that the existence of this bias is highly plausible for two reasons. First, emerging evidence suggests that the effect of the COVID-19 pandemic on fertility was dependent on parental socioeconomic circumstances at birth in Scotland[26], Spain[27], Norway[28], the United States[34,35], Colombia[36], Brazil[36], Mexico[37], and Australia[38]. These socioeconomic differences in the pandemic’s effect on fertility may have caused a change in the parental socioeconomic composition of live births conceived during the COVID-19 pandemic.

Second, because there is robust evidence that parental socioeconomic circumstances are strongly associated with health, developmental, and socioeconomic outcomes throughout the life course[39,40], it is plausible that sudden changes in the parental socioeconomic composition of a birth cohort can cause population-level differences in outcomes between babies conceived during the pandemic and earlier and later cohorts. If the COVID-19 pandemic has led to sudden changes in the parental socioeconomic composition of the cohort born and conceived during the pandemic, research comparing (persons from) this birth cohort to other cohorts needs to take this into consideration. Not accounting for such compositional changes has led to erroneous conclusions in the social and health sciences before. Only in 2022, it has been shown that, in the United States, war-induced changes in socioeconomic composition of parents during the 1918 influenza pandemic explain why the 1919 birth cohort had lower adult socioeconomic status than earlier and later birth cohorts.[41] Previously, this difference was thought to be caused by in-utero exposure to the 1918 influenza pandemic.[7]

In this study, we used population-wide administrative data from 12 countries covering the period 2015-2021 to analyse changes in the parental socioeconomic composition of babies conceived during the COVID-19 pandemic (born between December 2020 and December 2021). Our selection of countries is based on differences in pre-pandemic social inequalities and differences in fertility trends, welfare regimes, pandemic mitigation policy, pandemic experiences, and data availability. We sought to estimate the difference in the absolute number of live births between observed and expected live births between December 2020 and December 2021 by available measures of parental socioeconomic circumstances (household income, area-level deprivation, or parental education) and by country. Finally, our goal was to quantify the differences in socioeconomic composition between the cohort of live births conceived during the COVID-19 pandemic and counterfactual cohorts had pre-pandemic trends continued. As maternal age and parity are also associated with life course outcomes such as birth weight or preterm birth[42,43], we additionally estimated potential pandemic-induced compositional changes in maternal age and parity.

Methods

Data

We used population-wide birth register data from 12 countries spanning the period 2015 to 2021. For Austria, Brazil, Colombia, Ecuador, Finland, Mexico, the Netherlands, and Spain, we had access to individual-level data. We used these data to create time series of the weekly or monthly number of live births by available indicators of parental socioeconomic circumstances (equivalised household income, maternal level of formal education, area-level deprivation). For England, Scotland, the United States, and Wales, we obtained aggregated monthly time series data on live births by available socioeconomic indicator. Where feasible, we created weekly time series of live births (Brazil, Ecuador, Finland, and Mexico). Otherwise, we used monthly time series data on the number of live births.

Indicators of parental socioeconomic circumstances

As primary indicators of parental socioeconomic circumstances, we used equivalised household income, pre-existing measures of (small) area-level deprivation, and maternal formal level education as available in population registers or on birth certificates. For equivalised household income (Finland, the Netherlands) and area-level deprivation (Brazil, Ecuador, England, Scotland, Wales), we used pre-pandemic measures, so that pandemic-induced effects on the parental socioeconomic composition cannot be driven by pandemic-induced changes in the income distribution or deprivation measure of an area. Live births were categorised into quintiles of equivalised household income and area-level deprivation. Maternal education at birth or in the year of birth was used for Austria, Colombia, Mexico, Spain, United States. For comparative visualisations, we grouped formal levels of education into primary and lower secondary (or compulsory), upper secondary, and post-secondary and tertiary education of the mother (except for Mexico due to availability, see suppl. material).

The availability and quality of data on indicators for parental socioeconomic circumstances varied across countries and it is important to note that the socioeconomic indicators are not directly comparable. For example, although we used area-level measures of deprivation for Brazil, Ecuador, England, Scotland, and Wales, their measurement varied. They are combining different indicators, being measured on different spatial levels, and using data from different years.

Missing data on socioeconomic indicators at birth varied across countries. Over the entire period, there were less than 1.5% live births without information on parental socioeconomic circumstances in Austria, Brazil, Ecuador, England, Finland, the United States, Scotland, Wales, and 1.8%, 2.6%, 3.9%, 6.6%, and 14.3% missing information on maternal education in Finland, the Netherlands, Colombia, Mexico, and Spain respectively. As educational levels in Spanish Vital Statistics are only assigned to people over 25, this was our target population for Spain (see suppl. material p.65 and onwards). In this group, 4.4% of live births between 2016 and 2021 had missing information on maternal education. For the United States and Spain, data on the number of live births by education only included data from 2016-2021 because not all United States reporting regions provided information on maternal education in 2015 and because Spain changed their collection of educational levels in 2015, so that levels are hardly comparable across time (see respective country profiles in suppl. material).

In sensitivity analyses, we used alternative or more detailed indicators of parental socioeconomic circumstances where available. For countries with maternal education as primary indicator, we also used the highest educational level of both parents (Austria, Colombia, Mexico, Spain) or paternal education (United States) in complementary analysis.

In our supplementary material, we describe the data sources, measurements and missingness in more detail for each country separately (see country profiles). We additionally present country-specific results on the compositional change in absolute and relative terms regarding alternative socioeconomic indicators, maternal age, and parity where available.

Birth cohort exposed to potential compositional change

For our included countries, strict lockdown measures to contain the spread of COVID-19 were introduced in mid-March 2020 as indicated by the Stringency Index (Oxford COVID-19 Government Response tracker[2], see figure 2). Although some babies conceived in the second half of March 2020 have been born before December 2020, we assume, based on the average gestational age at birth, that live births conceived during the pandemic will present a substantial share (~50%) of live births in the second half of December 2020. Therefore, we set the start of the exposed period to December 2020 for monthly time series and the start of the 51st week of 2020 for weekly time series (see Figure 2).

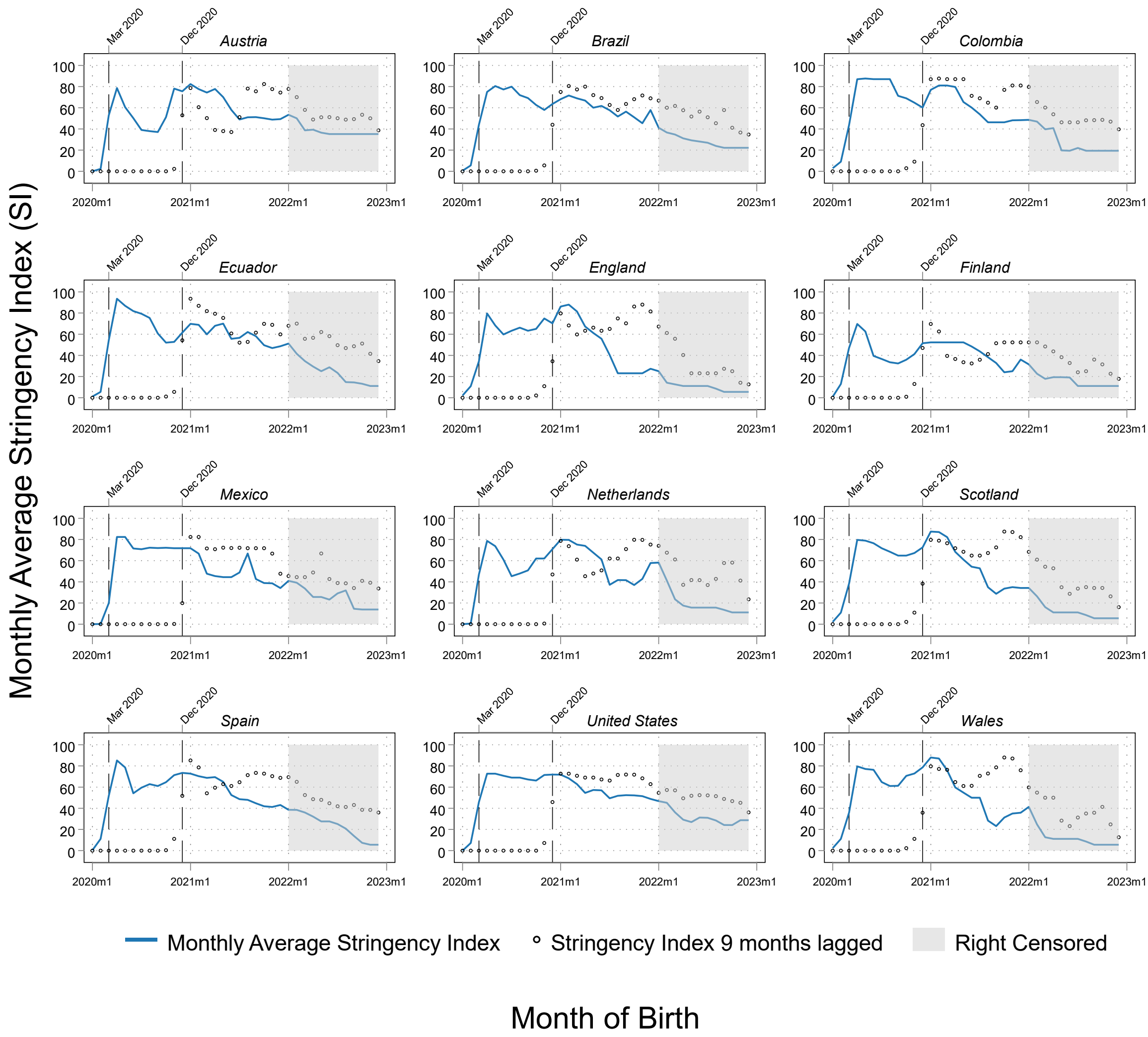

***Figure 2**: Monthly average Stringency Index (SI) of government's national lockdown policies for all included countries indicated by solid lines. Circles show the 9 months lagged SI value to indicate the SI level around conception (9 months prior to the month of birth). The grey shaded area highlights the SI levels during the months of birth and conception for live births not included in our data.*

Using birth cohorts over conception cohorts entails misclassification of births close to the start of our exposure period. There are babies born just after our cutoff (51st week of 2020 or December 2020) that have been conceived before the onset of lockdown measures in mid-March 2020. Because of anticipation, this group of births may have still been exposed to pandemic-induced changes in fertility. They mostly consist of full-term births because these pregnancies had to last at least from before the onset of lockdown measures (~11th week of 2020) to our chosen cutoff for the exposure period (51st week of 2020). This may select for maternal characteristics that are protective for preterm birth like maternal age[42] or more advantaged parental socioeconomic circumstances[40,44]. Conversely, there is an upper bound of gestational age (~39 weeks) for babies conceived just after the onset of lockdown measures and born just after our cutoff. This upper bound may select for parental characteristics that are associated with preterm birth. Further, there may have been direct effects of exposure to the pandemic on preterm births[20,45] possibly moderated by parental socioeconomic circumstances[20,46] and an indirect effect on preterm birth rates close to our cutoff through pandemic-induced drops in conceptions[13,27] which may have also been moderated by parental socioeconomic circumstances[13,26]. These could be other reasons for why our chosen cutoff is not accurately distinguishing between live births conceived before and after the onset of lockdown measures.

However, the period vulnerable to misclassification is short and the number of potentially misclassified births is low. Thus, we believe that the advantages of using birth cohorts (knowledge on exact birth date, no missing data on gestational age, and no between-country variation in measurement) outweigh the disadvantages described above.

Analytical strategy

Our main aim was to estimate compositional differences in parental socioeconomic circumstances between the cohorts conceived during the COVID-19 pandemic and their counterfactual compositions had the pandemic never occurred.

To obtain these, we first estimated the level changes in the number of live births between December 2020 and December 2021 by interrupted time series Poisson regression models. These models were estimated for each socioeconomic group (e.g., highest fifth of equivalised household income or post-secondary and tertiary maternal education) and country separately. We specified our models with linear and quadratic terms for time-trends and week/month of the year indicator variables to address for seasonality (January or the first week of the year as reference). For Brazil, Colombia, Mexico, and Ecuador we adjusted for the effect of the ZIKV epidemic on the number of births by including a binary variable indicating the period from August 2016 to December 2016 as informed by previous studies (for details, see country profiles in suppl. material).[47–49]

We used the parameters estimated by the models described above to estimate the sum of the group-specific number of births over the exposed period (December 2020 – December 2021) had the COVID-19 pandemic not happened and, counter to the fact, pre-pandemic trends continued instead.[50]

Next, to estimate the counterfactual compositions, we calculated each group-specific proportion of live births by dividing the obtained counterfactual group-specific number of births by the sum of all group-specific counterfactual numbers in each country using our point estimates. To calculate the percentage point differences in proportions of births, we subtracted the counterfactual proportions from their respective observed proportions.

To obtain 95% confidence intervals for these differences in composition, we used a three-step approach. First, we drew a random counterfactual number of live births from a normal distribution with the mean equal to our point estimate for the group-specific counterfactual number of live births and the standard deviation equal to our estimate's standard error. The random draws for each group are independent as we assumed that the absolute number of live births in one population group is independent of the number of live births in the other groups.

Second, we created a counterfactual cohort composition by dividing the randomly drawn group-specific numbers of live births by the sum of all group-specific random draws.

Third, we calculated the percentage point difference between the observed group-specific proportion of live births and the respective, randomly drawn, counterfactual group-specific proportion.

We repeated these three steps 10 000 times per country, to obtain 10 000 different counterfactual cohort compositions and their respective differences with the observed composition. The lower and upper bounds of our 95% confidence intervals for the group-specific differences between observed and counterfactual proportions of live births are then given by the 2.5th and 97.5th percentiles of each group-specific distribution.

Although selecting different modelling approaches for each country and parental characteristic could lead to slightly more accurate estimates when time series are non-linear and autoregressive beyond the accounted monthly and weekly seasonality, we prefer a simpler homogenous approach for the sake of comparison and interpretability.

The number of women in reproductive age in each level of our parental characteristics is unavailable in our data sources for most countries. Therefore, we were not able to include an exposure variable in these Poisson regression models. As we are not trying to estimate changes in fertility rates but the socioeconomic composition of live births, this limitation is tolerable.

Analyses were carried out in Stata v18[51] and all code for the statistical analysis is openly available at https://github.com/MoritzOberndorfer.

Results

The analysed data covered 76 580 516 live births across 12 countries born between 2015-2021 out of which over 10.7 million live births were conceived during the COVID-19 pandemic.

In Figure 3, we visualised the observed weekly/monthly proportions of live births by women living in households placed the highest 20% of the country-specific equivalised household income distribution (Finland, Netherlands), living in the 20% least deprived areas of their country (Brazil, Ecuador, England, Scotland, Wales), or by mothers who completed post-secondary or tertiary education at birth (Austria, Colombia, Mexico, Spain, the United States) in black solid lines – henceforth called the socioeconomically advantaged groups. Displayed by grey dashed lines, Figure 3 also shows the observed weekly/monthly proportions of live births by mothers living in households placed the poorest 20% of the country-specific household income distribution (Finland, Netherlands), living in the 20% most deprived areas of their country (Brazil, Ecuador, England, Scotland, Wales), or by mothers who had primary or lower secondary education at birth (Austria, Colombia, Mexico, Spain, United States) – henceforth called the socioeconomically disadvantaged groups. The vertical line depicts the start of the exposed period (51^{st} week of 2020 for Brazil, Ecuador, Finland, and Mexico; and December 2020 for Austria, Colombia, England, the Netherlands, Scotland, Spain, the United States, and Wales).

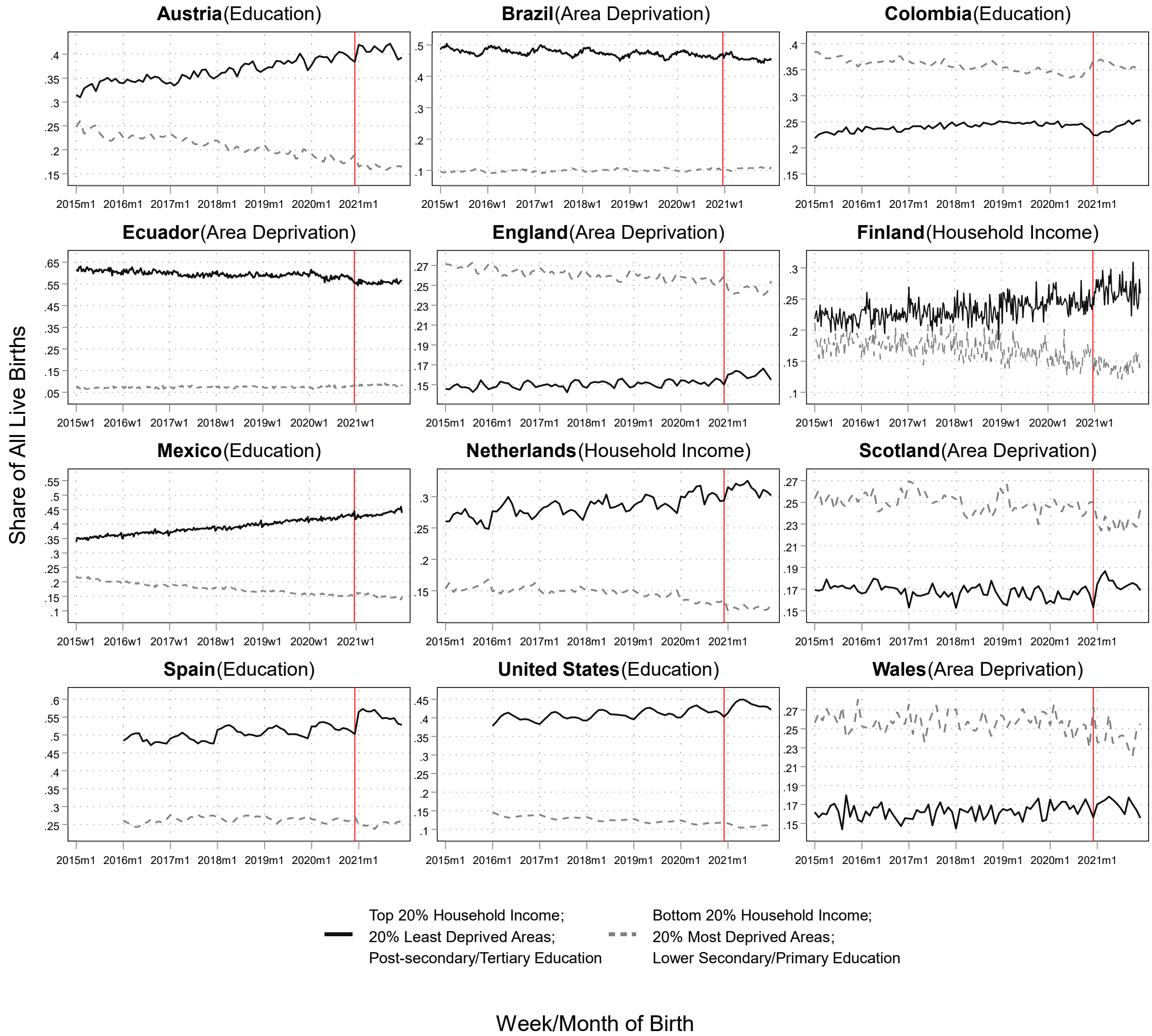

Figure 3: The proportion of live births by most (dashed grey lines) and least socioeconomically disadvantaged (solid black lines) groups. The solid vertical line marks the start of the exposed period. The indicator of socioeconomic circumstances used for each county is mentioned in parentheses next to the country name. Time series are weekly for Brazil, Ecuador, Finland, and Mexico and monthly for the other countries. Note that, for Mexico, due to data availability, the black solid line presents the share of live births by women with upper secondary education and the grey dashed line the share by women with elementary education. Also note that the y-axes are different which impairs visual comparability of changes between countries. For Spain, only births with maternal age over 25 are included (see methods and suppl. material)

In Austria, England, Finland, the Netherlands, Scotland, Spain, and Scotland the proportion of live births held by the socioeconomically advantaged groups climbed to its highest values at the start of the exposed period. In contrast, the proportions of the socioeconomically most disadvantaged groups increased in Colombia, Ecuador, and Mexico.

We visualised the observed numbers of weekly or monthly live births (dots), the estimated numbers (grey solid line), the deseasonalised estimates (solid black lines), and the counterfactual numbers (dashed black lines) born to the most socioeconomically advantaged groups in Figure 4 and these respective numbers for those born to the most socioeconomically disadvantaged groups in Figure 5. In Table 1, we compare the socioeconomic compositions of the observed cohorts conceived during the COVID-19 pandemic with their respective counterfactual compositions. Due to space, uncertainty estimates are provided visually in Figures 6,7 and in the supplementary material.

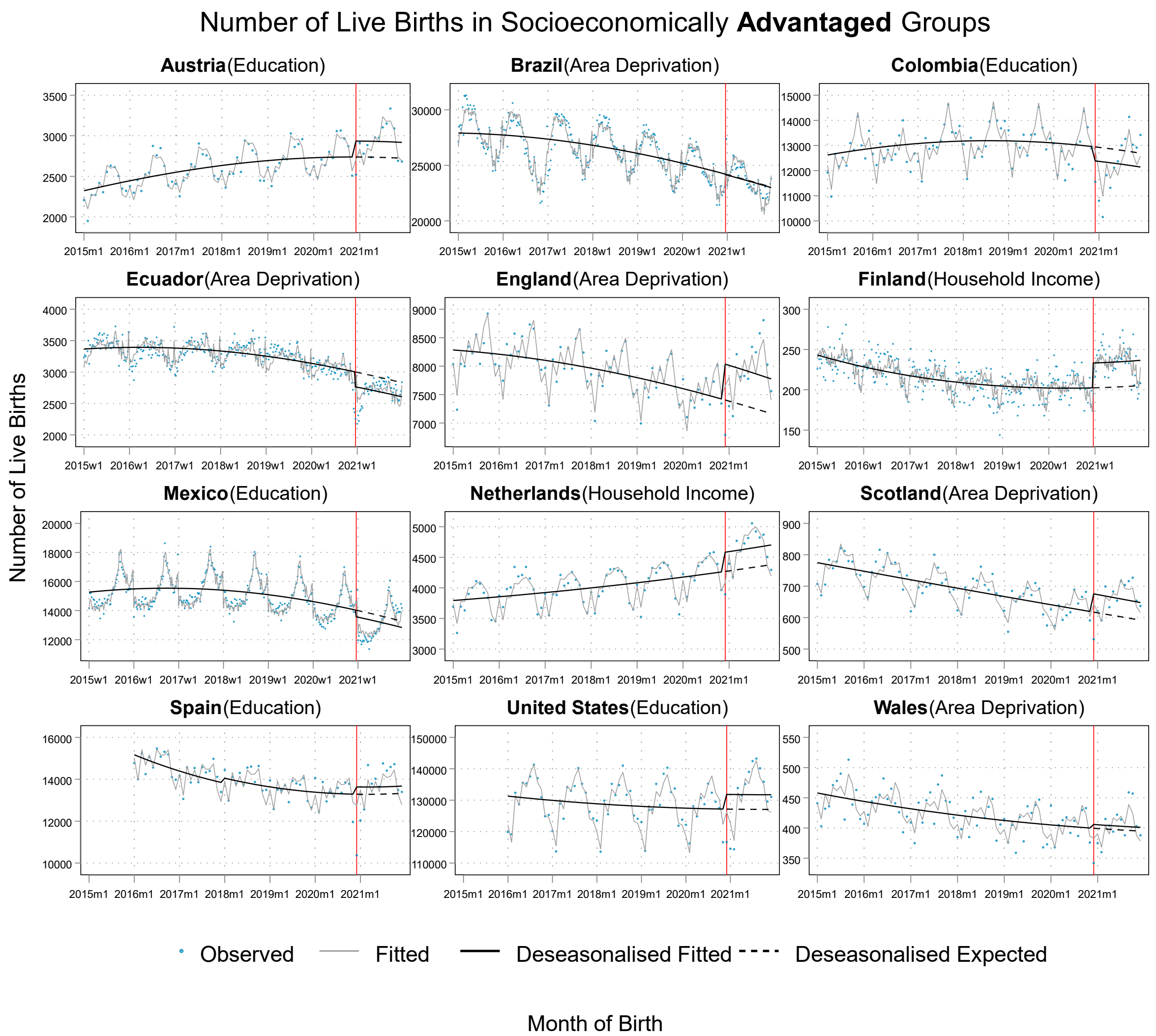

Figure 4: Number of live births 2015-2021 among socioeconomically advantaged population groups in all included countries. Blue dots indicate the observed number of live births. The solid vertical line marks the start of the exposed period. Grey solid lines indicate the number of live births estimated by group-specific Poisson regression modes on the full time series including an indicator variable for the exposed period to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week/month of live birth to capture potential non-linearities in the secular time trends; week/month of the year fixed effects to account for seasonality; an indicator variable for August 2016 to December 2016 for Brazil, Ecuador, Colombia, and Mexico to account for the Zika Virus epidemic; an indicator variable for 2016 and 2017 for Spain to account for changes in data collection. Black solid lines show the deseasonalised trends estimated from these models ignoring any level changes due to the Zika Virus epidemic. Black dashed lines show the estimated deseasonalised expected (counterfactual) number of live births had the COVID-19 pandemic never happened and pre-pandemic trends continued instead. Socioeconomic indicators used are shown in parentheses on top of each panel. For Spain, only births with maternal age over 25 are included (see methods and suppl. material)

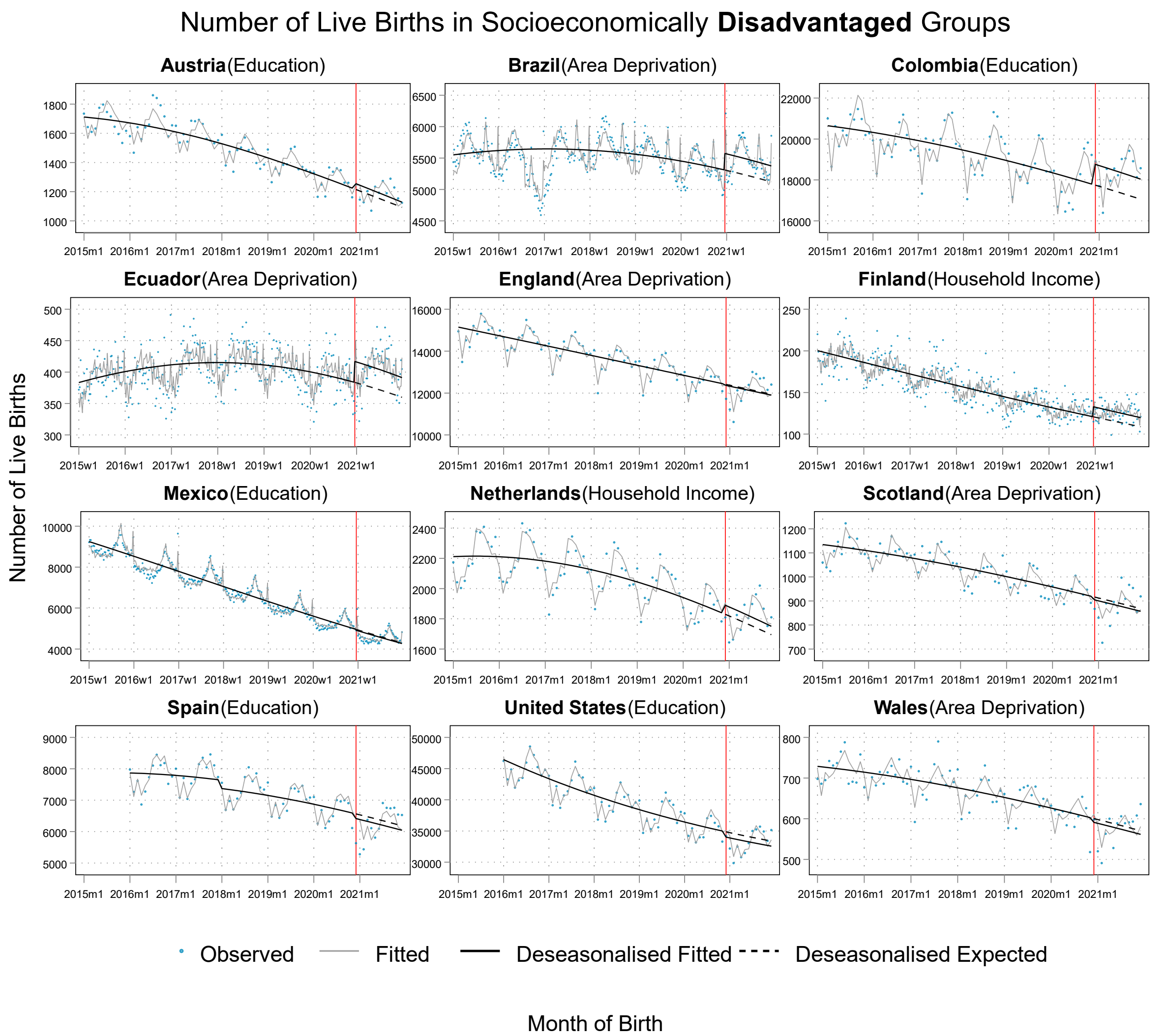

Figure 5: Number of live births 2015-2021 among socioeconomically disadvantaged population groups in all included countries. Blue dots indicate the observed number of live births. The solid vertical line marks the start of the exposed period. Grey solid lines indicate the number of live births estimated by group-specific Poisson regression modes on the full time series including an indicator variable for the exposed period to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week/month of live birth to capture potential non-linearities in the secular time trends; week/month of the year fixed effects to account for seasonality; an indicator variable for August 2016 to December 2016 for Brazil, Ecuador, Colombia, and Mexico to account for the Zika Virus epidemic; an indicator variable for 2016 and 2017 for Spain to account for changes in data collection. Black solid lines show the deseasonalised trends estimated from these models ignoring any level changes due to the Zika Virus epidemic. Black dashed lines show the estimated deseasonalised expected (counterfactual) number of live births had the COVID-19 pandemic never happened and pre-pandemic trends continued instead. Socioeconomic indicators used are shown in parentheses on top of each panel. For Spain, only births with maternal age over 25 are included (see methods and suppl. material)

In Austria, England, Finland, the Netherlands, Scotland, Spain, and the United States, the average number of weekly/monthly live births in the advantaged groups increased visibly between December 2020 and December 2021 (Figure 4). Relative to the counterfactual number of live births during this entire period, socioeconomically advantaged groups had 7.2% [95%CI: 5.2%; 9.2%] (Austria), 8.5% [95%CI: 7.3%; 9.7%] (England), 15.3% [95%CI: 11.7%; 19%] (Finland), 7.4% [95%CI: 5.8%; 9.0%]

(Netherlands), 9.4% [95%CI: 5.5%; 13.7%] (Scotland), 2.6% [95%CI: 1.6%; 3.6%] (Spain), and 3.7% [95%CI: 3.4%; 4.0%] (United States) more live births than expected based pre-pandemic trends (Figure 4, Table 1, Figure S1). In these countries, the disadvantaged groups either experienced small increases in the number of live births as well (Austria: 3.3% [95%CI: 0.6%; 6.0%], Netherlands: 3.3% [95%CI: 1.1%; 5.6%]) or small decreases (England: -0.4% [95%CI: -1.2%; 0.5%], Scotland: -1.3% [95%CI: -4.3%; 1.9%], Spain: -2.3% [95%CI: -3.6%; -1%], United States: -2.4% [95%CI: -3%; -1.9%]) compared to their counterfactual number of live births (Figure 5, Table 1, Figure S1). Finland is an exception, where the lowest household income group (10% [95%CI: 5.9%; 14.5%]) as well as all other income groups showed substantial increases in birth cohort size between 7.9% and 11.8% (Table 1, Figure S1).

In Colombia, Ecuador, and Mexico, the observed numbers of live births among the advantaged groups were lower than the counterfactual numbers (Figure 4). In Brazil and Wales, the observed and counterfactual trends differed only negligibly for advantaged groups. In Brazil, Colombia, and Ecuador, the number of live births born to the socioeconomically most disadvantaged was higher than their counterfactual between December 2020 and December 2021 (Figure 5). Relative to the counterfactual number of births, 5% [95%CI: 4.3%; 5.6%] more babies were born to women living in the most deprived municipalities of Brazil, 5.7% [95%CI: 5.0%; 6.5%] more babies were born to women with primary or lower secondary education in Colombia, and 8.7% [95%CI: 6.2%; 11.3%] more babies were born to women living in the most deprived cantons of Ecuador (Table 1, Figure S1).

The size of these effects was dominated by the initial effect of the pandemic on the number of births and the consequent recovery during 2021. Among socioeconomically advantaged and disadvantaged groups in Austria, Brazil, England, Finland, and the Netherlands, there was no decrease in the number of live births at the start of the exposed period (Figure 4, Figure 5). Except for Brazil, there was a subsequent increase in live births that resulted in a higher average weekly/monthly number of live births in these countries during the exposed period. There were fewer babies born to socioeconomically advantaged groups in Scotland, the United States, and especially Spain at the beginning of the exposed period (blue dots near the vertical line in Figure 4). However, the subsequent rebound in the number of births outweighed the initial drop.

In Figure 6, we show the percentage point differences between the observed and counterfactual proportions of live births held by the socioeconomically advantaged groups (left panel) and disadvantaged groups (right panel) for all included countries.

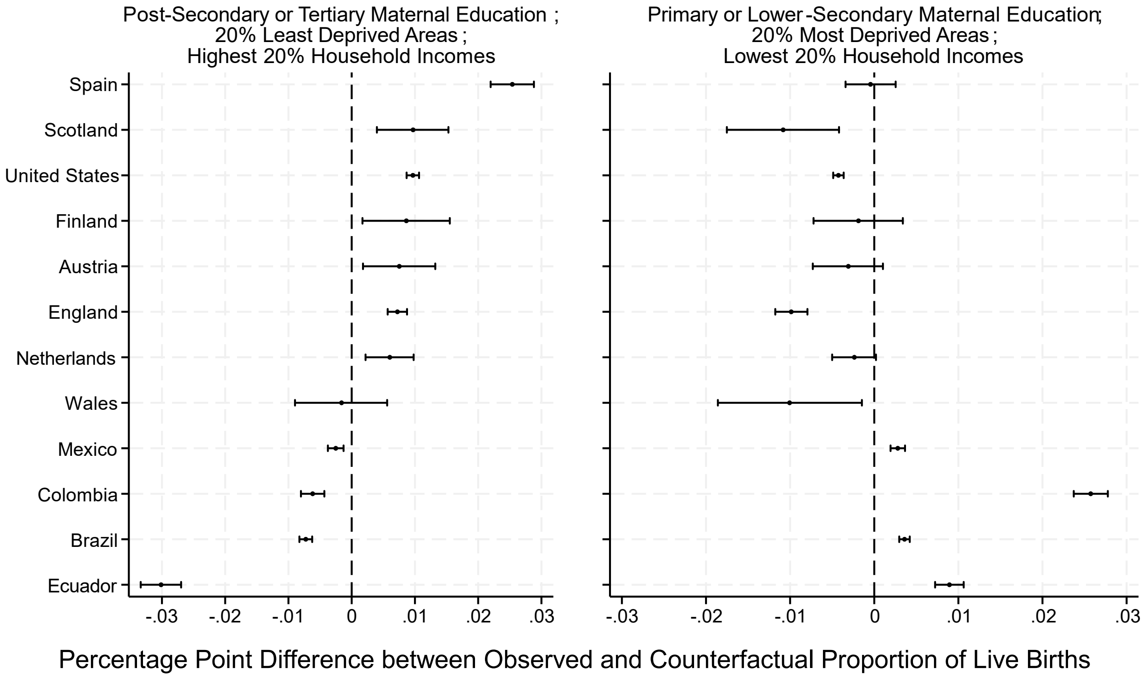

Figure 6: Percentage point differences in the observed and counterfactual proportions of live births by socioeconomically advantaged groups (left panel) and disadvantaged groups (right panel). The order of countries follows the size of differences estimated for the advantaged groups. For Finland and the Netherlands, parental socioeconomic circumstances are indicated by household income. For Brazil, Ecuador, England, Scotland, and Wales, parental socioeconomic circumstances are indicated by area-level deprivation. For the remaining countries, maternal formal educational level was used. For Spain, only births with maternal age over 25 are included (see methods and suppl. material). Countries are ordered by effect size for advantaged population groups (left panel). Point estimates are derived from interrupted time series Poisson regressions on the number of live births and 95% confidence intervals are estimated by a three-step approach (see method section).

In Spain, Scotland, the United States, Finland, Austria, England, and the Netherlands, the proportion of babies born to socioeconomically advantaged groups during December 2020 – December 2021 was higher compared with their counterfactual cohort composition. In Colombia, Mexico, Brazil, and Ecuador, the proportion of live births born to advantaged groups decreased (left panel, Figure 6). These were also the only included countries where the proportion of live births born to socioeconomically disadvantaged groups increased (right panel, Figure 6). In Wales, there was no change in the proportion of babies born to the advantaged groups but a decrease in the proportion of babies born to women living in the most disadvantaged areas (right panel, Figure 6). Compared with the socioeconomic composition of their counterfactual cohorts, Spain saw the largest percentage point increase in the share of live births born to women with post-secondary and tertiary education (2.5% [95%CI: 2.2%; 2.9%]). In contrast, the share of live births with unknown maternal education decreased by -2.6% [95%CI: -2.8%; -2.4%]) while the share of babies born to women with primary or lower secondary maternal education did not change (right panel, Figure 6).

In Figure 7 and Table 1, we show the differences between the socioeconomic composition of the observed cohort of live births conceived during the pandemic and their respective counterfactual compositions for each country.

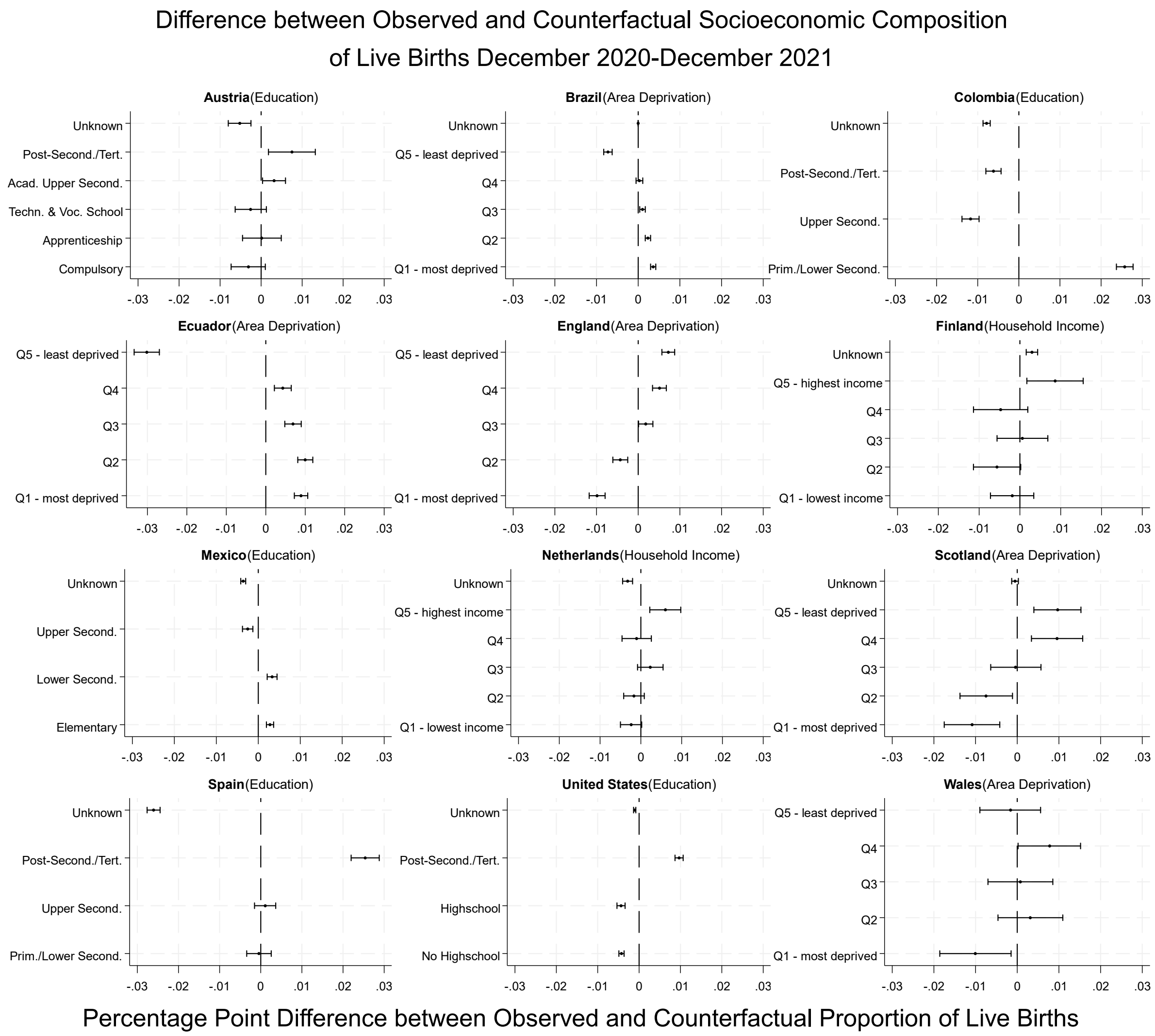

Figure 7: Percentage point differences between the observed and counterfactual socioeconomic composition of the December 2020 – December 2021 birth cohort. For Spain, only births with maternal age over 25 are included (see methods and suppl. material) Point estimates are derived from interrupted time series Poisson regressions on the number of live births and 95% confidence intervals are estimated by a three-step approach (see method section).

For Austria, the Netherlands, and especially England and Scotland, these differences in socioeconomic composition approximated a socioeconomic gradient: Starting with a decrease in the proportion of live births among the most socioeconomically disadvantaged, each step towards the least disadvantaged group was associated with a smaller decrease or higher increase. The opposite socioeconomic pattern was visible for Brazil and Ecuador. It is worth noting that the proportion of live births with missing information on socioeconomic circumstances also changed by at least half a percentage point for Austria (-0.5% [95%CI: -0.8%; -0.2%]), Colombia (-0.8% [95%CI: -0.9 %; -0.7%]), and Spain (-2.6% [95%CI: -2.8%; -2.4%]) (Figure 7, Table 1).

Table 1: Point estimates of differences between the observed and counterfactual socioeconomic composition of the December 2020 – December 2021 birth cohort. Counterfactual numbers of live births were estimated by interrupted time series Poisson regression models (see methods section). 95% confidence intervals for estimates are visually shown in Figures 6, 7, and S1. Data for Spain only includes births among women aged older than 25 due to availability of maternal education (see methods and suppl. material)

Country	Characteristic	Observed Number of Births	Counterfactual Number of Births	Observed - Counterfactual Number of Births	% More or Less Births Observed than Counterfactual	Observed Proportion of Births in %	Counterfactual Proportion of Births in %	Observed - Counterfactual Proportion in %
Austria	**Maternal Education**							
Austria	Compulsory School	15481	14991	490	3.3	16.7	17.0	-0.3
Austria	Apprenticeship	20347	19332	1015	5.2	21.9	21.9	0.0
Austria	Technical; Vocational School	11336	11004	332	3.0	12.2	12.5	-0.3
Austria	Academic Upper Secondary	6304	5713	591	10.3	6.8	6.5	0.3
Austria	Post-Secondary; Tertiary	37847	35318	2529	7.2	40.7	40.0	0.8
Austria	Unknown	1633	2012	-379	-18.8	1.8	2.3	-0.5
Austria	Total	92948	88371	4577	5.2	100.0	100.0	0.0
Brazil	**Area Deprivation**							
Brazil	Q1 - most deprived	295939	281980	13959	5.0	10.6	10.3	0.4
Brazil	Q2	323640	312788	10852	3.5	11.6	11.4	0.2
Brazil	Q3	334608	327174	7434	2.3	12.0	11.9	0.1
Brazil	Q4	557568	549166	8402	1.5	20.0	20.0	0.0
Brazil	Q5 - least deprived	1275824	1278324	-2500	-0.2	45.8	46.5	-0.7
Brazil	Unknown	801	813	-12	-1.5	0.0	0.0	0.0
Brazil	Total	2788380	2750247	38133	1.4	100.0	100.0	0.0
Colombia	**Maternal Education**							
Colombia	Primary/Lower Secondary	239433	226444	12989	5.7	35.8	33.3	2.6
Colombia	Upper Secondary	246595	259256	-12661	-4.9	36.9	38.1	-1.2
Colombia	Post-Secondary; Tertiary	159921	167149	-7228	-4.3	23.9	24.5	-0.6
Colombia	Unknown	22415	28176	-5761	-20.4	3.4	4.1	-0.8

Colombia	Total	668364	681025	-12661	-1.9	100.0	100.0	0.0
Ecuador	**Area Deprivation**							
Ecuador	Q1 - most deprived	21861	20113	1748	8.7	8.4	7.5	0.9
Ecuador	Q2	27866	26015	1851	7.1	10.7	9.7	1.0
Ecuador	Q3	33220	32359	861	2.7	12.7	12.0	0.7
Ecuador	Q4	32902	32728	174	0.5	12.6	12.2	0.4
Ecuador	Q5 - least deprived	145294	157756	-12462	-7.9	55.6	58.7	-3.0
Ecuador	Total	261143	268972	-7829	-2.9	0.0	0.0	0.0
England	**Area Deprivation**							
England	Q1 - most deprived	157752	158360	-608	-0.4	24.6	25.6	-1.0
England	Q2	140452	138217	2235	1.6	21.9	22.3	-0.4
England	Q3	125637	120142	5495	4.6	19.6	19.4	0.2
England	Q4	114553	107398	7155	6.7	17.9	17.4	0.5
England	Q5 - least deprived	102394	94354	8040	8.5	16.0	15.3	0.7
England	Total	640788	618472	22316	3.6	100.0	100.0	0.0
Finland	**Household Income**							
Finland	Lowest 20%	6809	6189	620	10.0	14.2	14.4	-0.2
Finland	Q2	8106	7514	592	7.9	16.9	17.5	-0.6
Finland	Q3	9083	8122	961	11.8	18.9	18.9	0.1
Finland	Q4	10720	9820	900	9.2	22.3	22.8	-0.5
Finland	Highest 20%	12642	10969	1673	15.3	26.3	25.5	0.9
Finland	Missing income information	624	432	192	44.4	1.3	1.0	0.3
Finland	Total	47984	43047	4937	11.5	100.0	100.0	0.0
Mexico	**Maternal Education**							
Mexico	Elementary	248081	250220	-2139	-0.9	15.1	14.8	0.3
Mexico	Lower Secondary	585510	596123	-10613	-1.8	35.7	35.3	0.3
Mexico	Upper Secondary	715098	739122	-24024	-3.3	43.5	43.8	-0.3
Mexico	Unknown	93635	102284	-8649	-8.5	5.7	6.1	-0.4
Mexico	Total	1642324	1687750	-45426	-2.7	100.0	100.0	0.0

Netherlands	**Household Income**							
Netherlands	Poorest 20%	23674	22919	755	3.3	12.3	12.5	-0.2
Netherlands	Q2	21178	20426	752	3.7	11.0	11.2	-0.2
Netherlands	Q3	34168	32033	2135	6.7	17.8	17.5	0.2
Netherlands	Q4	49488	47197	2291	4.9	25.7	25.8	-0.1
Netherlands	Richest 20%	59846	55745	4101	7.4	31.1	30.5	0.6
Netherlands	Missing income information	3955	4348	-393	-9.0	2.1	2.4	-0.3
Netherlands	Total	192309	182669	9640	5.3	100.0	100.0	0.0
Scotland	**Area Deprivation**							
Scotland	Q1 - most deprived	11455	11605	-150	-1.3	23.2	24.3	-1.1
Scotland	Q2	10119	10153	-34	-0.3	20.5	21.3	-0.7
Scotland	Q3	8965	8698	267	3.1	18.2	18.2	0.0
Scotland	Q4	10124	9344	780	8.4	20.5	19.6	1.0
Scotland	Q5 - least deprived	8566	7828	738	9.4	17.4	16.4	1.0
Scotland	Unknown	94	116	-22	-18.8	0.2	0.2	-0.1
Scotland	Total	49323	47745	1578	3.3	100.0	100.0	0.0
Spain	**Maternal Education**							
Spain	Primary/Lower Secondary	80993	82900	-1907	-2.3	25.2	25.3	0.0
Spain	Upper Secondary	55956	56812	-856	-1.5	17.4	17.3	0.1
Spain	Post-Secondary; Tertiary	176475	171982	4493	2.6	55.0	52.4	2.5
Spain	Unknown	7507	16213	-8706	-53.7	2.3	4.9	-2.6
Spain	Total	320931	327907	-6976	-2.1	100.0	100.0	0.0
United States	**Maternal Education**							
United States	No Highschool	433594	444395	-10801	-2.4	11.0	11.4	-0.4
United States	Highschool	1752085	1745654	6431	0.4	44.3	44.7	-0.4
United States	Post-Secondary; Tertiary	1707681	1647083	60598	3.7	43.2	42.2	1.0
United States	Unknown	60810	64144	-3334	-5.2	1.5	1.6	-0.1
United States	Total	3954170	3901276	52894	1.4	100.0	100.0	0.0
Wales	**Area Deprivation**							

Wales	Q1 - most deprived	7512	7631	-119	-1.6	24.3	25.3	-1.0
Wales	Q2	6437	6184	253	4.1	20.8	20.5	0.3
Wales	Q3	6064	5892	172	2.9	19.6	19.5	0.1
Wales	Q4	5735	5359	376	7.0	18.5	17.7	0.8
Wales	Q5 - least deprived	5221	5141	80	1.6	16.9	17.0	-0.2
Wales	Total	30969	30208	761	2.5	100.0	100.0	0.0

Complementary to differences between observed and counterfactual proportions in the main manuscript, we present the relative differences between the observed and counterfactual number of births by socioeconomic group and country in our supplementary material (Figure S1). There, we also present the results of our re-estimation using alternative socioeconomic indicators (Figure S2, S3) Additionally, we show these differences for the maternal age and parity composition in Figures S4 to S7 where these data were available to us. In Ecuador, Finland, the Netherlands, Scotland, Spain, and the United States, the observed cohorts tend to have older mothers than their counterfactual cohorts (Figure S4). In Brazil, Colombia, and Mexico, we observed the opposite. In Austria, there were no changes in the maternal age composition. The proportion of firstborns was lower than their counterfactual proportions in all countries except for Brazil (Figure S6, no data were available to us for England, Scotland, or Wales).

Discussion

Summary

In this comparative study, we used population-wide administrative data (2015-2021) from 12 countries to compare the observed country-specific socioeconomic compositions of live births between December 2020 and December 2021 with their counterfactual compositions estimated by assuming that pre-pandemic trends and seasonal patterns in the number of live births would have continued in the COVID-19 pandemic period. In total, our study covers data of over 76.5 million live births out of which over 10.7 million were conceived after the first lockdown measures were introduced in March 2020.

For all seven included European countries (Austria, England, Finland, Netherlands, Scotland, Spain, Wales) and the United States, we found that the COVID-19 pandemic produced a more socioeconomically advantaged birth cohort than expected had pre-pandemic trends continued. For all Latin American countries (Brazil, Colombia, Ecuador, Mexico) included in our analysis, we found the opposite: the composition of live births conceived during the pandemic changed towards more socioeconomically disadvantaged groups. The percentage point differences in the proportion of live births born to advantaged groups were between -1% and +1%, except for Spain (+2.5%) and Ecuador (-3%). Similarly, the percentage point differences in the proportion of babies born to disadvantaged groups were between -1% and +1%, except for Colombia (+2.6%).

Comparison with previous literature on socioeconomic differences in fertility during the COVID-19 pandemic

Socioeconomic differences in the fertility response to the pandemic have recently been confirmed in country-specific analyses of Spain[27], Norway[28], the United States[34,35], Colombia[36], and Brazil[36]. In Brazil and Colombia, fertility was found to have decreased for women with at least 8 years of schooling while this effect was null or positive for women with fewer years of education.[36] In Spain[27], Norway[28], and the United States[34], more babies than expected were born to women with tertiary education, and a decrease (Spain) or little to no change in live births among women with less formal education (Norway, United States). We add to this literature by focussing on changes in the socioeconomic composition of cohorts conceived and born during the COVID-19 pandemic. This focus is warranted by the potential effect of sudden compositional changes of births on population-level differences in outcomes that are associated with socioeconomic circumstances at birth and/or parental socioeconomic position.

Our analysis was motivated by the Lockdown Cohort (LoCo) – effect hypothesis[26], which suggests that COVID-19 pandemic-induced compositional changes in the sociodemographic composition of parents may produce differences in life course outcomes between the birth cohort conceived during the pandemic (the LoCo) and earlier and later birth cohorts – even if early life exposure to the COVID-19 pandemic had no direct effect on life course outcomes. Independent of how socioeconomic characteristics at (or before) birth were measured – by household income, area-level deprivation, or parental education – we indeed found that the birth cohort conceived during the pandemic has a different socioeconomic composition than expected in all twelve included countries. While this general prediction is in line with our results, the initial formulation of the LoCo-effect hypothesis only considered change towards a more socioeconomically advantaged birth cohort that potentially explains counterintuitive improvements in health outcomes at birth during the pandemic.[26] We show that shifts to a more socioeconomically advantaged birth cohort than expected were only observed in European countries and the United States. Our result of opposite changes in Latin American countries make it clear that considering national social contexts is essential for understanding changes in the socioeconomic composition of babies born and conceived during the COVID-19 pandemic.

To try to explain the differences in compositional change between the included Latin American countries, the European countries, and the United States, it is helpful to draw from quantitative and qualitative research on socioeconomic differences in fertility during the 2015-2016 ZIKV epidemic. In January 2016, several Latin American countries made official public recommendations to postpone pregnancy for 6 months to 2 years to avoid the risk of the Congenital Zika Syndrome.[52] Subsequent analyses of fertility using Brazilian data showed that, 9 months after the public recommendations to postpone pregnancies, declines in age-specific fertility rates were larger for women with higher educational levels compared with any other groups.[47] As an explanation for this pattern in Brazil, there are stark socioeconomic inequalities in women's ability to postpone pregnancy – even in the face of the ZIKV epidemic or the COVID-19 pandemic.[52–54] These inequalities are produced by sociocultural norms surrounding gender roles and motherhood, access to contraceptives and safe abortion procedures. As a consequence, women in more disadvantages socioeconomic positions have less fertility decision-making agency and a higher rate of unplanned pregnancies.[52–54] The 2015-2016 ZIKV epidemic might not only be useful as a comparison to the COVID-19 pandemic, but, in fact, may have contributed to the compositional changes we observed. In 2021, Marteleto and Dondero[54] reported that women in Brazil still have lively memory of the health risks associated with pregnancy during the ZIKV epidemic. In their sample, more than 75% of women cited "enormous amounts of fear and worry about COVID-19 and its health and economic consequences as reasons for wanting to delay or avoid pregnancy" in in-depth interviews. Furthermore, 90.2% of their survey participants think that women should not get pregnant during the COVID-19 pandemic (preliminary results).[54] Therefore, it is plausible that the ZIKV epidemic may have amplified any effects of the COVID-19 pandemic on the socioeconomic composition of birth cohorts in regions previously affected by the ZIKV epidemic.

Generalising the findings

To summarise, the direction of change in the socioeconomic composition induced by the COVID-19 pandemic, and potentially other macro-level shocks, crucially depend on how a socioeconomic position relates to agency in fertility decision making. To the extent that socioeconomic position is the moderator of the effect of macro-level shocks on fertility, agency in fertility decision making is the mediator of this moderation. Thus, in contexts, where women in socioeconomically disadvantaged positions have less control over their fertility decisions than women in more advantaged positions, macro-level shocks that exert a downward pressure on fertility across the population will cause compositional change towards a more disadvantaged birth cohort. The ZIKV epidemic in Brazil is a useful example of a population-wide downward pressure on fertility to which this mechanism applies. The COVID-19 outbreak in Latin American countries may have also produced population-wide downward pressure on fertility due to the heightened risk perception caused by the preceding ZIKV epidemic[54]. In the context of public health emergencies, this mechanism linking population-wide downward pressure on fertility and change in socioeconomic composition of birth cohorts holds even if there are no socioeconomic differences in risk aversion during pregnancy and even if there are no socioeconomic inequalities in the risk of harm.

In contexts of higher agency in fertility decisions and lower inequalities therein, fertility can be more responsive to public health emergencies or other macro-level shocks. Here, the socioeconomically unequal distribution of shock-induced adversities and/or benefits will lead to a more socioeconomically advantaged birth cohort as suggested by the LoCo-effect hypothesis. This assumes that shock-induced downward pressures on fertility outweigh upward pressures among disadvantaged groups and/or shock-induced upward pressures on fertility prevail among advantaged groups.[26] For a list of previously hypothesised potential upward and downward pressures of the COVID-19 pandemic on fertility and according theories, please see relevant papers focused on fertility[25,55–57].

Which groups are driving the compositional change during the COVID-19 pandemic?

For Brazil, Colombia, Ecuador, England, Scotland, Spain, the United States, and Wales, we found an effect on either the disadvantaged or advantaged groups and no effect on other groups. For Austria, Finland, Mexico, and the Netherlands, on the other hand, births in all socioeconomic groups either increased or decreased, but compositional changes were produced by differences in effect sizes. Among countries where the pandemic produced a socioeconomically more advantaged birth cohort than expected (except for Spain), this compositional change was driven by increases in the number of live births among advantaged groups rather than decreases in the number of live births among disadvantaged population groups. Put differently, compositional change in these countries was driven by advantaged groups having more babies than expected rather than disadvantaged groups having fewer babies than expected.

Are these compositional changes impactful?

To understand the potential impact of our results for life course outcomes, it may be helpful to interpret the size of these compositional changes in two ways.

First, we draw a comparison with prominent research that used a cross-cohort comparison strategy to show that in-utero exposure to the 1918 Influenza epidemic in the United States was associated with lower adult socioeconomic position and increased rates of physical disability in adult life compared with birth cohorts conceived before and after the 1918 Influenza epidemic.[7,58] In 2022, Beach et al.[41] published a study that used United States enlistment records during the First World War and census data including information on the parental characteristics of the birth cohort exposed to the 1918 Influenza epidemic in utero to investigate if often-cited effects[7,58] persist after controlling for potential compositional changes in parental characteristics. Beach et al. showed that fathers of the exposed 1919 birth cohort had, on average, a lower socioeconomic position compared with fathers of earlier and later cohorts. This difference in paternal socioeconomic composition between the 1918-1920 birth cohorts existed because men in higher socioeconomic positions were more likely to be drafted for military service during the first world war.[41] For example, fathers of the exposed 1919 birth cohort were composed of 91% literates while fathers of the 1918 birth cohort were composed of about 91.6% literates (see Figure 2 in Beach et al. 2022)[41].

The compositional changes we found for the proportion of babies born to the most socioeconomically advantaged and disadvantaged groups in the December 2020 - December 2021 birth cohort are comparable with and often exceed this 0.6% percentage point difference in literate fathers induced by the 1918 Influenza epidemic and the First World War in the United States. For example, we estimated that, in the United States, the birth cohort conceived during the COVID-19 pandemic is composed of 1% [95%CI: 0.9%; 1.1%] more babies born to women with post-secondary or tertiary education than their counterfactual cohort had pre-pandemic trends continued. Although the effect of paternal illiteracy on life course outcomes in the 1919 birth cohort might not be comparable to the effect of parental tertiary education in the December 2020 – December 2021 birth cohort, this puts our effect sizes for compositional change into perspective.

Importantly, the size of these compositional differences in the case of the 1918 Influenza epidemic was strong enough to substantially attenuate previously found effects of in-utero exposure on adult socioeconomic outcomes once parental characteristics were controlled for, rendering the effect of in-utero exposure statistically insignificant.[41] In other words, the differences in adult life socioeconomic position between the 1919 birth cohort and its adjacent birth cohorts were more likely attributable to differences in parental characteristics than to direct in-utero exposures. The size of compositional changes we found may therefore be large enough to significantly bias similar studies of early life exposure to the COVID-19 pandemic on life course outcomes.

Second, the extent to which compositional changes in parental socioeconomic position may produce differences in life course outcomes between the cohort conceived during the pandemic and surrounding birth cohorts is contingent on the strength of association between the socioeconomic positions of parents and the outcomes of interest. For example, although there are socioeconomic inequalities in birth outcomes like preterm birth or low birth weight[40,44], the size of currently observed inequalities in these outcomes together with observed compositional changes are unlikely to produce substantial differences in birth cohort averages. For life course outcomes with larger inequalities by parental socioeconomic position, like completion of tertiary education, the observed compositional changes might indeed produce detectable differences between birth cohorts like those found for the 1919 birth cohort conceived during the 1918 Influenza epidemic.[41,58]

Importantly, the effects of compositional changes and potential direct effects of in-utero or early life exposure to the pandemic on life course outcomes are not mutually exclusive. Still, it is plausible that parental composition did not only change in observable characteristics like, e.g., age at birth, parity, socioeconomic position, residential area, or ethnicity, but also in unobserved parental characteristics that might be associated with future outcomes of interest. Future studies using the COVID-19 pandemic as in-utero or early life exposure will have to carefully consider their analytical strategies to avoid bias associated with compositional change in observed and unobserved parental characteristics.

Strengths

Strengths of our study stem from the use of birth register data with almost complete coverage of births from 12 countries. Although the effect size of compositional changes varied across countries, the consistency of this pattern strongly suggests generalisable population-level mechanisms. These compositional changes were visible irrespective of whether we used maternal or parental education, household income, or area-level deprivation of the mother's residential area as an indicator of socioeconomic circumstances.

Limitations

In Austria, Colombia, Mexico, the Netherlands, and Spain the differences between the observed and counterfactual number of live births without information on socioeconomic circumstances were non-negligible when compared to differences in the number of births in the other population groups. Thus, increases or decreases in the number of births for population groups could be affected by missing data or misclassification of parental socioeconomic position. Another alternative explanation for observed compositional changes could be that the registration of births was drastically delayed for some population groups during the COVID-19 pandemic.

Although in Colombia, Mexico, the Netherlands, and Spain proportions of missing socioeconomic information ranged from 2.1% to 5.7%, these alternative explanations are unlikely, because in other included countries (Brazil, Ecuador, England, Scotland, and Wales) with very little missing information on area-level deprivation of mothers' residential areas, changes in socioeconomic composition showed an overall consistent pattern. Moreover, included countries with near complete population coverage for 2021 showed the same pattern in compositional changes as observed for countries with lower coverage and delayed birth registrations, e.g., Colombia, Ecuador, or Mexico. Lastly, the number of births with missing socioeconomic information was substantially reduced for Austria and Spain, once we used the highest available non-missing parental education instead of maternal education (see suppl. material). Using this alternative indicator of parental socioeconomic circumstances, percentage point differences between observed and counterfactual proportion of births with missing information shrank towards zero and the results reinforced compositional change towards a more socioeconomically advantaged birth cohort in Austria and Spain.

Naturally, we would have liked to have better comparable measures of socioeconomic circumstances of live births to make more valid cross-country comparisons of effect sizes. Having readily available and validated area-level material deprivation indices that can be linked to geographical information available in birth registers would be a simple way of increasing homogeneity of socioeconomic indicators in cross-country studies – especially in countries where socioeconomic information contained in population registers is of limited quality or cannot easily be linked to birth registers or other health-related data.

We do not take an intersectionality approach to trace how pre-existing social inequalities and evident intersectional inequalities in the COVID-19 pandemic's impact lead to compositional changes in the December 2020 - December 2021 birth cohort[22]. Such estimates will require careful country-specific studies with registers that contain reliable information on ethnicity.

We observed compositional change towards higher maternal age for Ecuador, Finland, the Netherlands, Scotland, Spain, and the United States. As higher socioeconomic position is associated with higher maternal age, this result is not surprising. Still, the differences between the socioeconomic composition of the observed and counterfactual December 2020 - December 2021 birth cohort persisted even among women aged 26 and older in Spain or in Austria where we observed compositional changes regarding socioeconomic circumstances but not regarding maternal age. Moreover, the December 2020 - December 2021 birth cohort is composed of fewer firstborns than expected in Austria, Colombia, Ecuador, Finland, Mexico, the Netherlands, Spain, and the United States. Future research that investigates to what extent this compositional change may be an artefact of compositional change towards higher maternal age or a result of pandemic-induced heightened uncertainty would be useful to better understand these compositional changes in parity.

Lastly, we lack the data to tell if compositional changes reverse in subsequent birth cohorts or if the COVID-19 pandemic led to a lasting change in birth cohort composition. First evidence from Spain suggests that fertility recuperation differs by age group and parity.[59] The finding that the birth deficit among women under 25 was still increasing in Spain by the end of 2021 might indicate that socioeconomically disadvantaged groups take longer to change their fertility intentions, or that (perceived) economic uncertainty has not yet improved for these groups.[59]

Conclusions & Implications

In all twelve included countries – Austria, Brazil, Colombia, Ecuador, England, Finland, Mexico, the Netherlands, Scotland, Spain, the United States, and Wales – we found evidence that the COVID-19 pandemic produced changes in the socioeconomic composition of the birth cohort (December 2020 – December 2021) conceived during the pandemic. Where material barriers and sociocultural norms make it more difficult for women in socioeconomically disadvantaged positions to postpone pregnancy in the face of adversity, we observed pandemic-induced compositional changes towards a more socioeconomically disadvantaged birth cohort. Conversely, in contexts with higher agency in fertility decision making, we observed pandemic-induced compositional changes towards a less socioeconomically disadvantaged cohort.

Socioeconomic position of parents and socioeconomic circumstances at birth are strong predictors of many important health, developmental, and socioeconomic outcomes throughout the life course.[39,40] Thus, observed pandemic-induced compositional changes may well produce between-cohort differences in life course outcomes with strong socioeconomic gradients such as educational attainment, income, health, or mortality. Researchers must keep these compositional changes in mind when interpreting such between-cohort differences and when aiming to estimate the effect of in-utero or early life exposure to the pandemic on life course outcomes. As cohorts conceived during the COVID-19 pandemic and surrounding birth cohorts age, their between-cohort differences in parental socioeconomic composition and life course outcomes will offer valuable opportunities to advance knowledge on how public health emergencies and other macro-level shocks affect human populations.

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SUPPLEMENTARY INFORMATION FOR:

The COVID-19 pandemic changed the socioeconomic composition of parents: A register-based study of 76.5 million live births in 12 countries

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Contents

Methods for Country Profiles

For all country profiles, we used the analytical strategy presented in the main manuscript. Thus, all results can be interpreted in the same way.

Every country profile contains information on the data source used as well as figures showing the difference between the observed and counterfactual number of live births for each subgroup of the main socioeconomic variable. In addition, we show the same results for available alternative socioeconomic parental characteristics (e.g., taking the highest education of parents instead of just maternal education), maternal age, and parity. As the availability and quality of these parental characteristics varies by country, the country profiles below include a different range of variables.

At the end of each country profile, we present a table that summarises differences between the observed and counterfactual cohort of babies born between December 2020 and December 2021 for each analysed parental characteristic.

Before we present the country profiles, we show comparative figures of i) the percentage point differences in the proportion of live births and ii) the relative difference in the number of live births between the observed and counterfactual birth cohort December 2020 – December 2021 for each subgroup within available parental characteristics (an alternative indicator for parental socioeconomic circumstances, maternal age, and parity). As the percentage point differences in the cohort composition for the primary indicator of parental socioeconomic circumstances is presented in the main manuscript, we only present the relative differences for this indicator below. For the relative differences, the group with missing information is omitted due to visual distortion but the results are presented in the tables of the country profiles. Note that our chosen model specification sometimes fails to capture the erratic behaviour in the weekly/monthly number of live births with missing information on parental characteristics. This yields a less plausible estimate of the counterfactual number of live births with missing information on parental characteristics. A careful interpretation is warranted.

A short description of these results is given in the main manuscript.

Analyses were carried out in Stata v18[1] and all code for the statistical analysis is openly available at https://github.com/MoritzOberndorfer.

Comparative Results of Socioeconomic, Age, and Parity Composition

Complementary to differences between observed and counterfactual proportions in the main manuscript, we show the relative differences between the observed and counterfactual number of births by socioeconomic group and country in supplementary Figure S1. The same differences in the proportions of live births can be the result of different underlying changes in the number of live births. Figure S1 shows that, for example, compositional differences in Brazil were driven by a socioeconomic gradient in the surplus in the number of live births whereby the least disadvantaged show no change and the more disadvantaged, the higher was the relative increase in the number of births (Figure S1).

In Figure S2, we show the differences in observed and counterfactual proportions of live births along alternative or more detailed indicators for parental socioeconomic circumstances available for 9 out of 12 countries. Here, compositional change is less evident for Brazil and Finland where we used maternal education instead of area deprivation and quintile of household income respectively (Figure S2). Conversely, compositional differences were larger for Austria and Spain where we used the highest parental education (and paternal education if maternal education was missing) instead of maternal education (Figure S2). Complementary we again show relative differences between observed and counterfactual number of live births by alternative socioeconomic indicators in Figure S3.

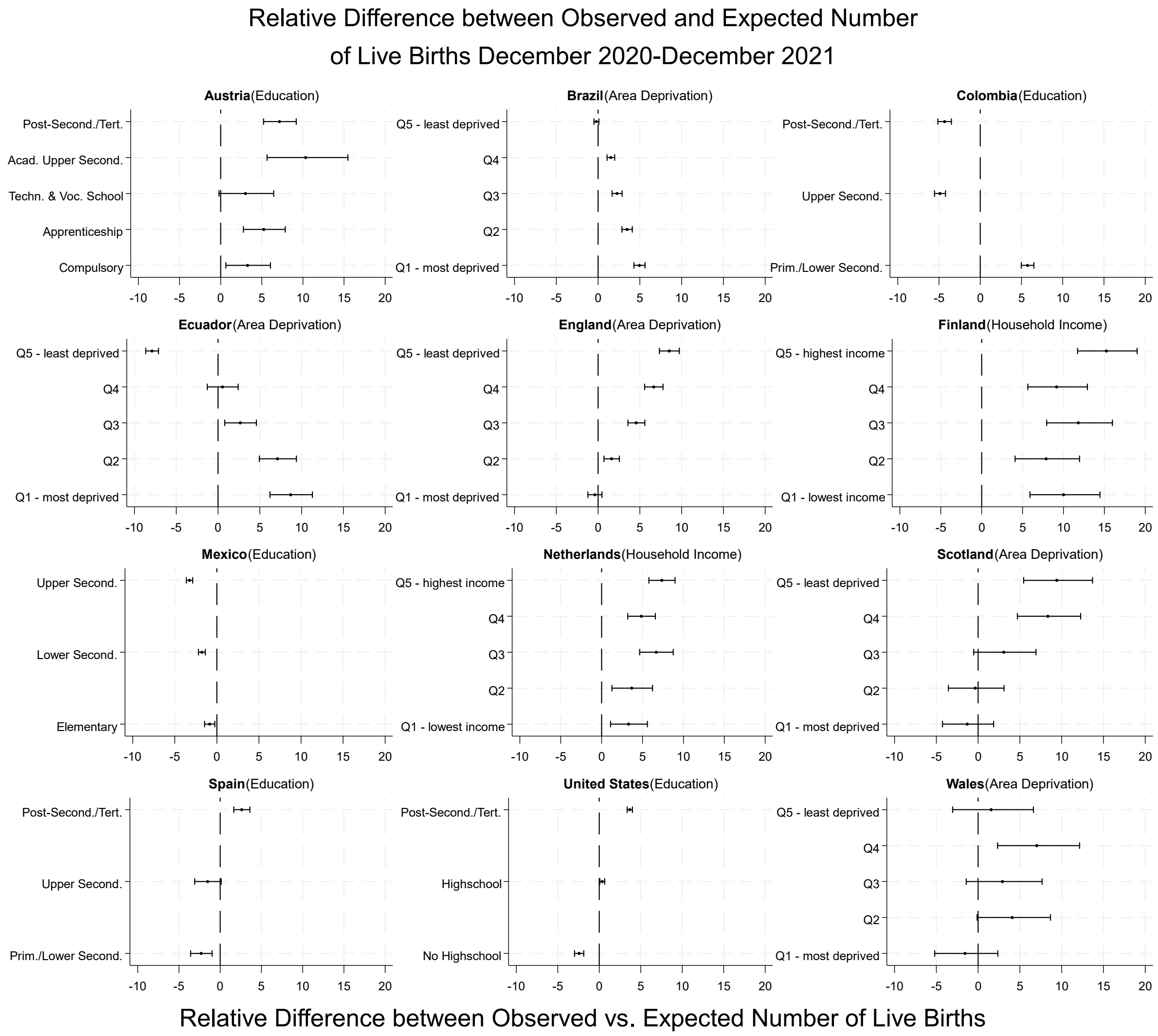


Figure S1: Relative differences in the number of live births between the observed and counterfactual birth cohort December 2020 – December 2021 by primary indicator of parental socioeconomic circumstances. Point estimates and 95% confidence intervals are estimated by taking the difference between the observed number of live births and the point estimates of the counterfactual number of live births (or upper and lower bounds of their 95% confidence intervals) divided by the respective counterfactual number of live births. For this visualisation, the relative difference is multiplied by 100.

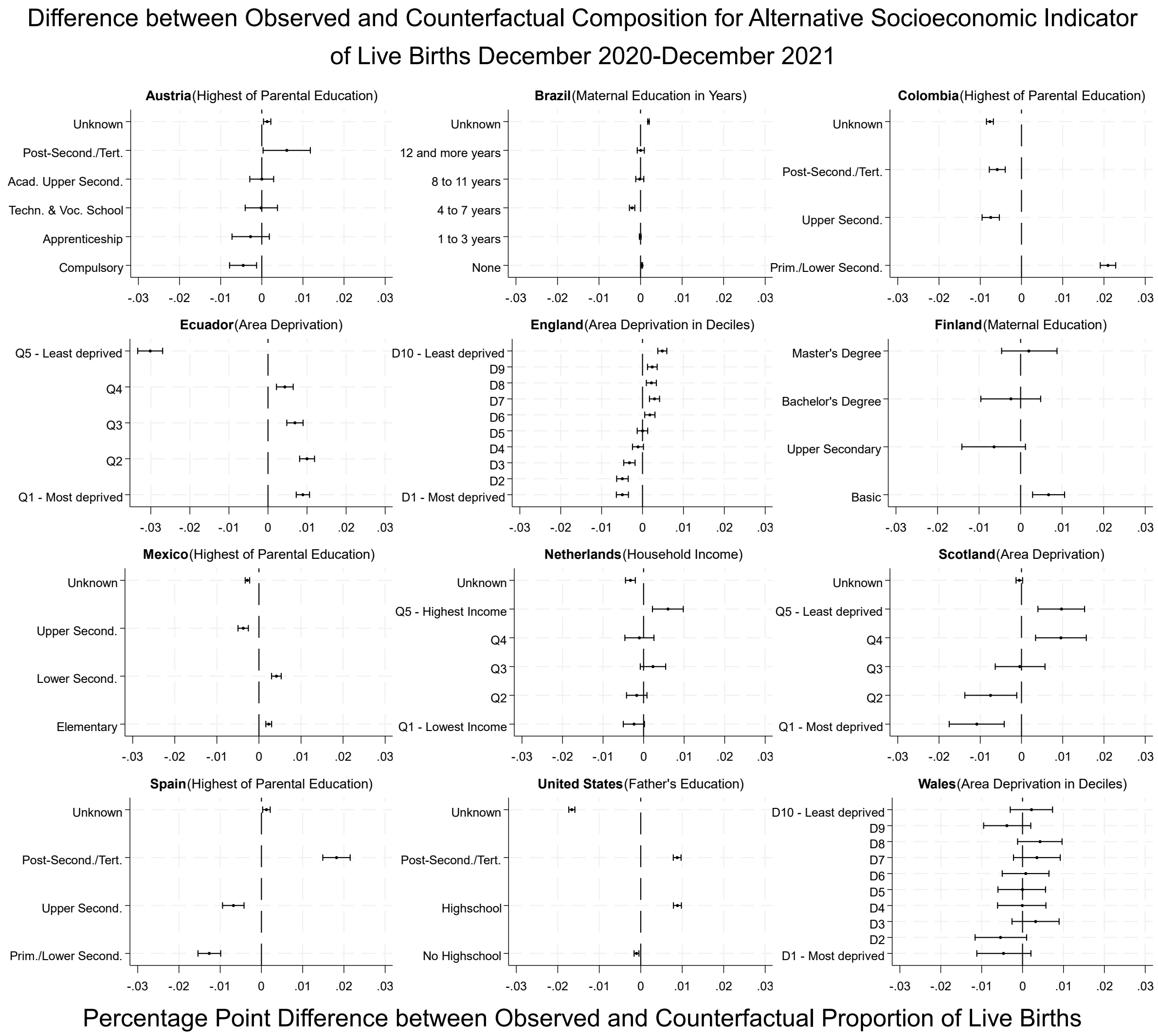


Figure S2: Percentage point differences in the socioeconomic composition of live births between the observed and counterfactual birth cohort December 2020 – December 2021. For all countries, except Ecuador, Scotland, and the Netherlands (for which we used the primary indicators), we used alternative or more detailed indicators of parental socioeconomic circumstances. The group with missing information ("unknown") is omitted when there were no or a negligible number of live births with missing information. Point estimates and 95% confidence intervals are estimated as described in the methods section of the main manuscript.

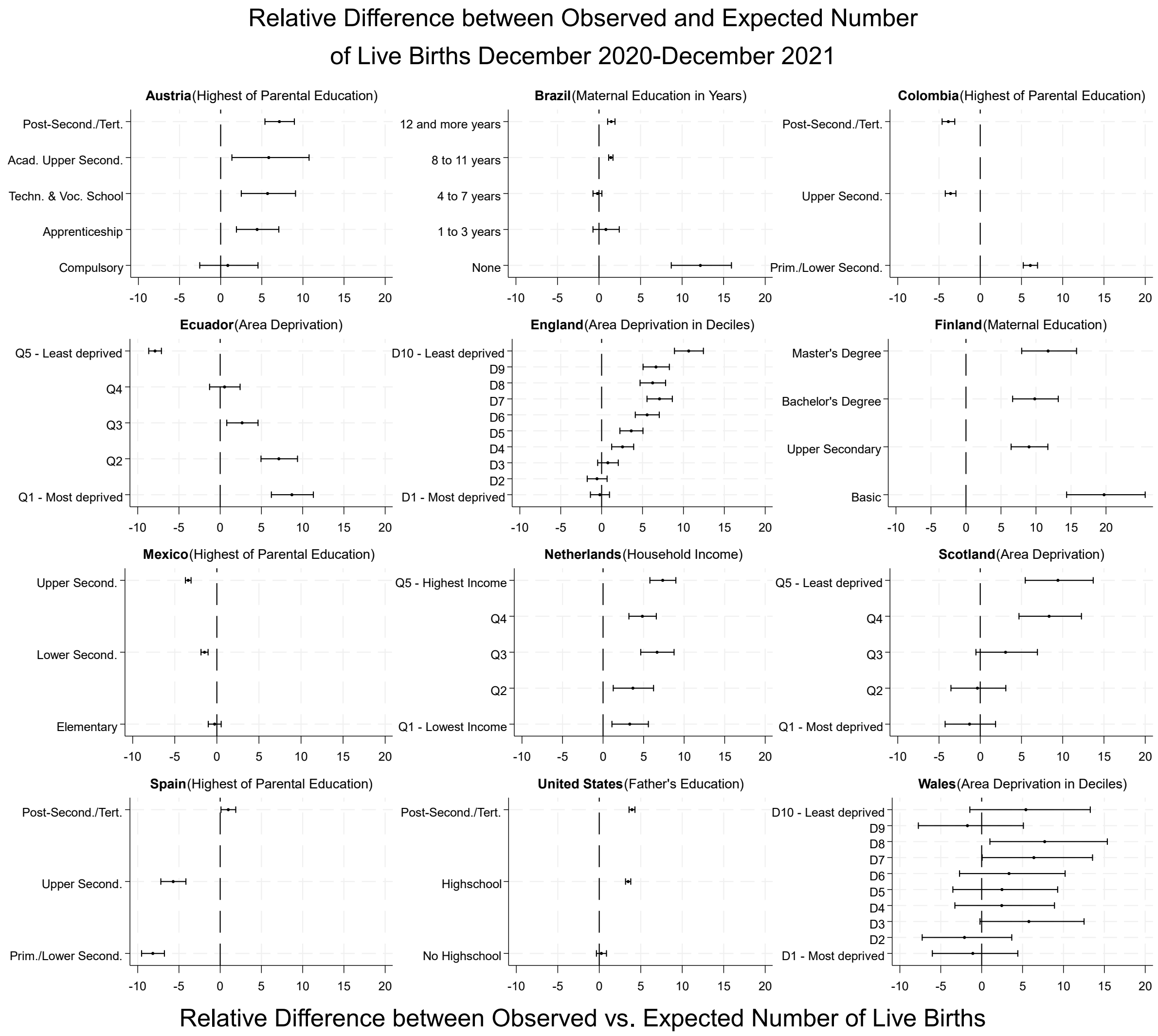


Figure S3: Relative differences in the number of live births between the observed and counterfactual birth cohort December 2020 – December 2021 by alternative indicator of parental socioeconomic circumstances. For all countries, except Ecuador, Scotland, and the Netherlands (for which we used the primary indicators), we used alternative or more detailed indicators of parental socioeconomic circumstances. Point estimates and 95% confidence intervals are estimated by taking the difference between the observed number of live births and the point estimates of the counterfactual number of live births (or upper and lower bounds of their 95% confidence intervals) divided by the respective counterfactual number of live births. For this visualisation, the relative difference is multiplied by 100.

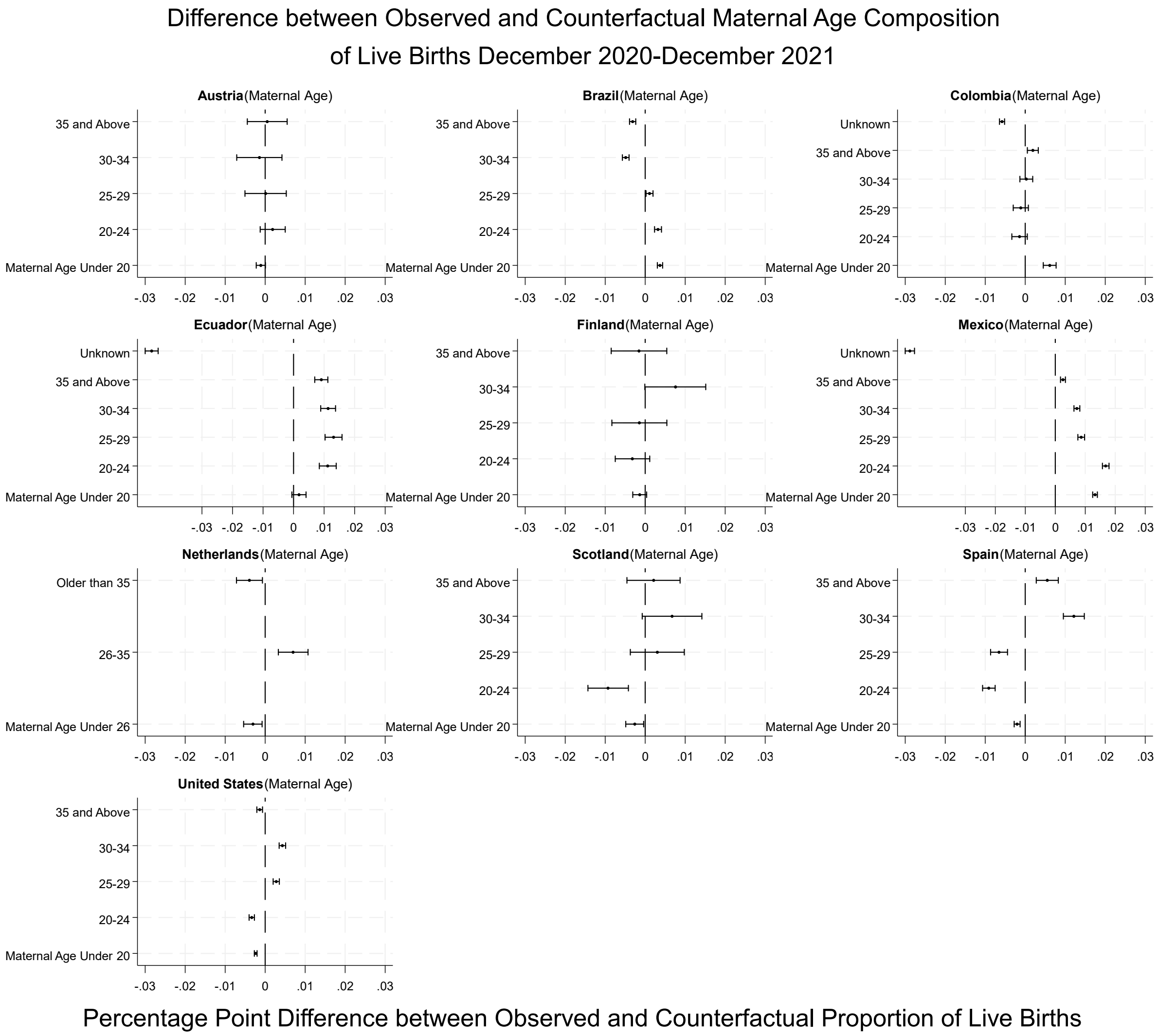


Figure S4: Percentage point differences in the maternal age composition of live births between the observed and counterfactual birth cohort December 2020 – December 2021. Point estimates and 95% confidence intervals are estimated as described in the methods section of the main manuscript. The group with missing information ("unknown") is omitted when there were no or a negligible number of live births with missing information.

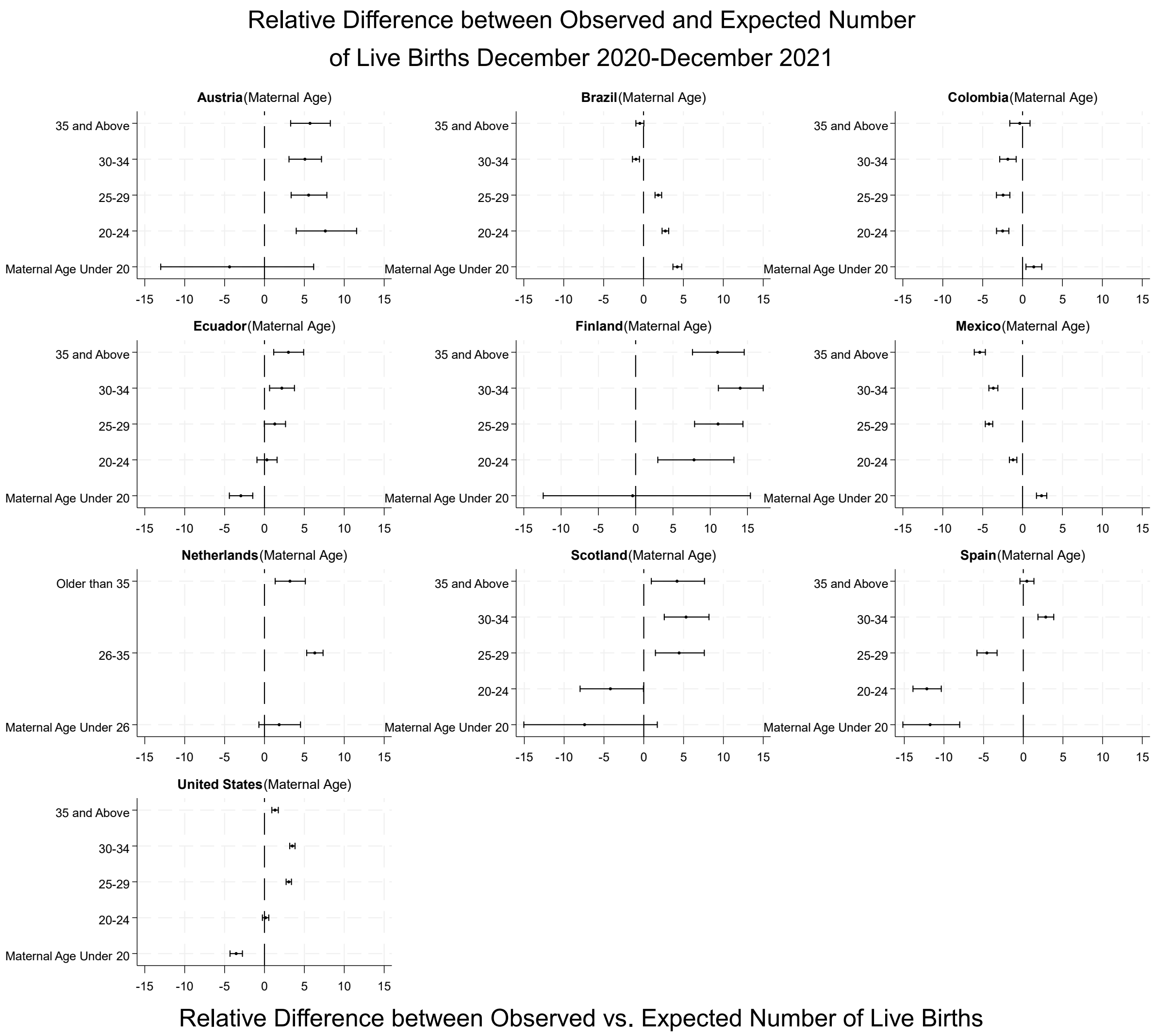


Figure S5: Relative differences in the number of live births between the observed and counterfactual birth cohort December 2020 – December 2021 by maternal age. Point estimates and 95% confidence intervals are estimated by taking the difference between the observed number of live births and the point estimates of the counterfactual number of live births (or upper and lower bounds of their 95% confidence intervals) divided by the respective counterfactual number of live births. For this visualisation, the relative difference is multiplied by 100.

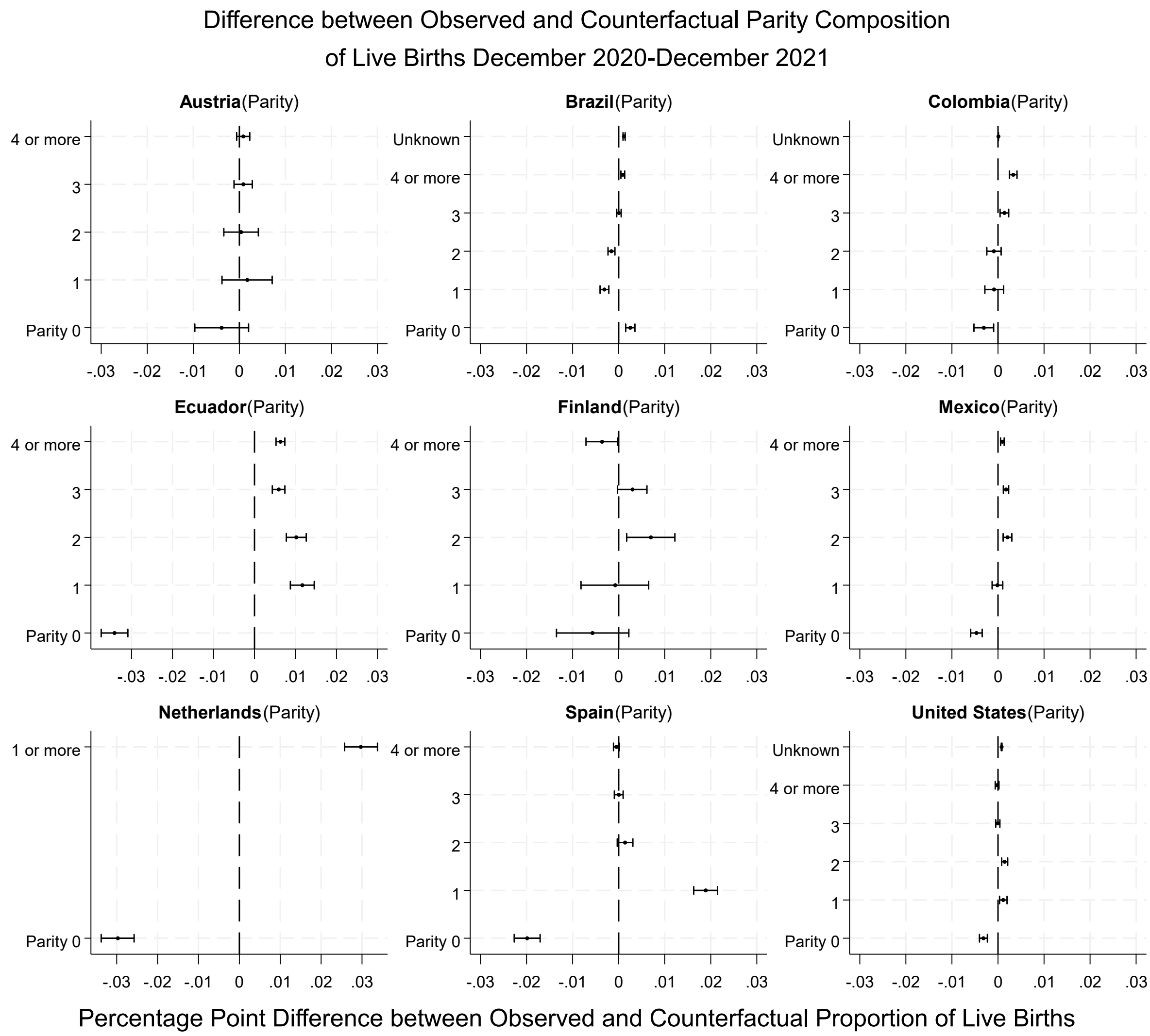


Figure S6: Percentage point differences in the parity composition of live births between the observed and counterfactual birth cohort December 2020 – December 2021. Point estimates and 95% confidence intervals are estimated as described in the methods section of the main manuscript. The group with missing information ("unknown") is omitted when there were no or a negligible number of live births with missing information.

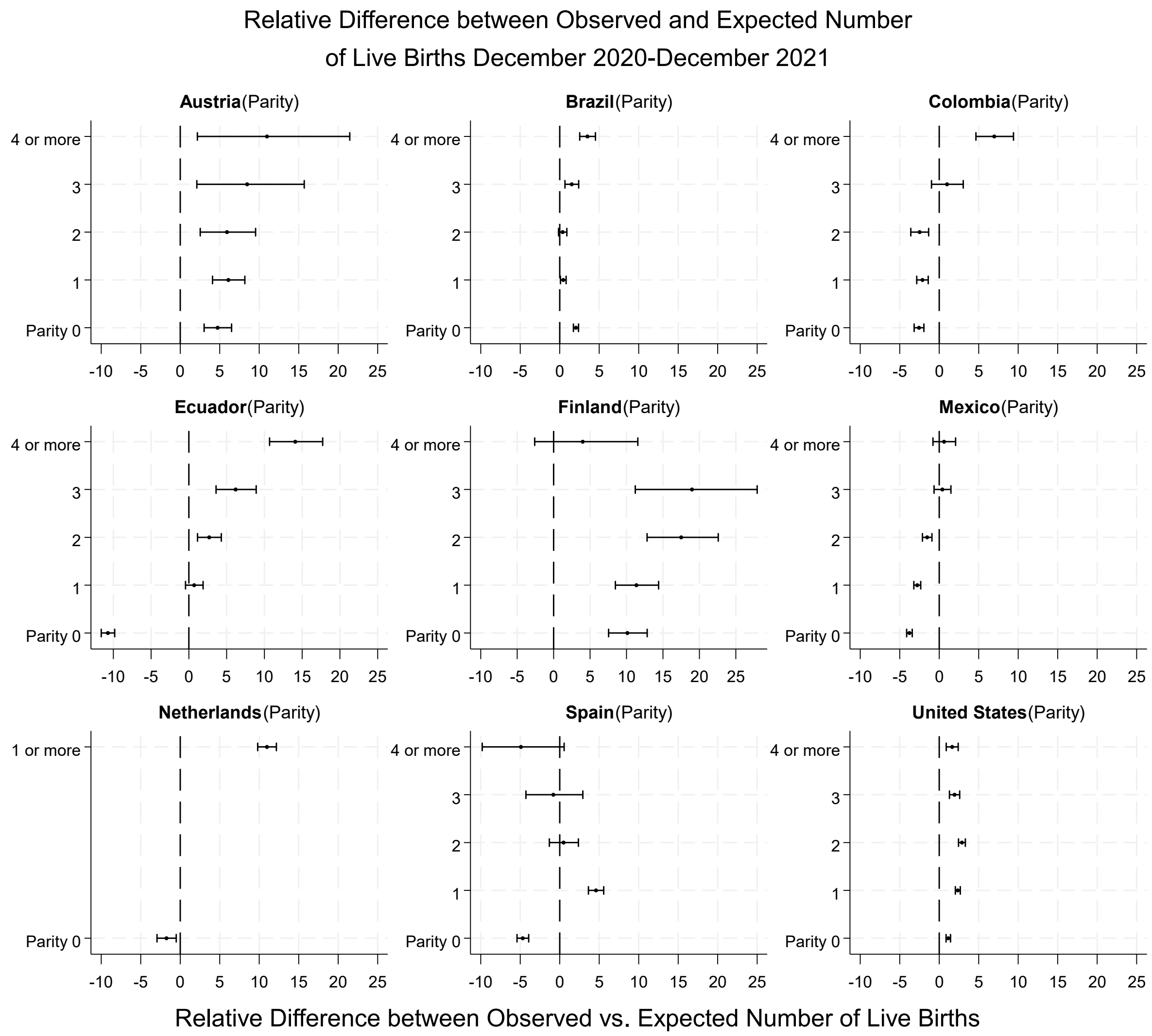


Figure S7: Relative differences in the number of live births between the observed and counterfactual birth cohort December 2020 – December 2021 by parity. Point estimates and 95% confidence intervals are estimated by taking the difference between the observed number of live births and the point estimates of the counterfactual number of live births (or upper and lower bounds of their 95% confidence intervals) divided by the respective counterfactual number of live births. For this visualisation, the relative difference is multiplied by 100.

Country Profiles

Austria

Data

For Austria, we used the birth register (2015-2021; n=601,886 live births) maintained by Statistics Austria. We used individual-level data and then aggregated to monthly time series by parental characteristics of interest. Available characteristics were maternal and paternal education at birth, maternal age, and parity.

Austria's educational system separates children at a young age. Therefore, we were reluctant to from an "upper secondary school" category and instead show the educational levels in more detail (Figure S8, S9). The missing values for maternal education increase in 2021 because they are obtained from population registers. The availability of these data is time lagged compared to the birth registers. The change in missing data through time is thus not induced by the COVID-19 pandemic but an artefact of the data collection.

Individual-level data used to create aggregated monthly time series was obtained by Thomas Waldhör through purchase of the data from Statistics Austria.

Results

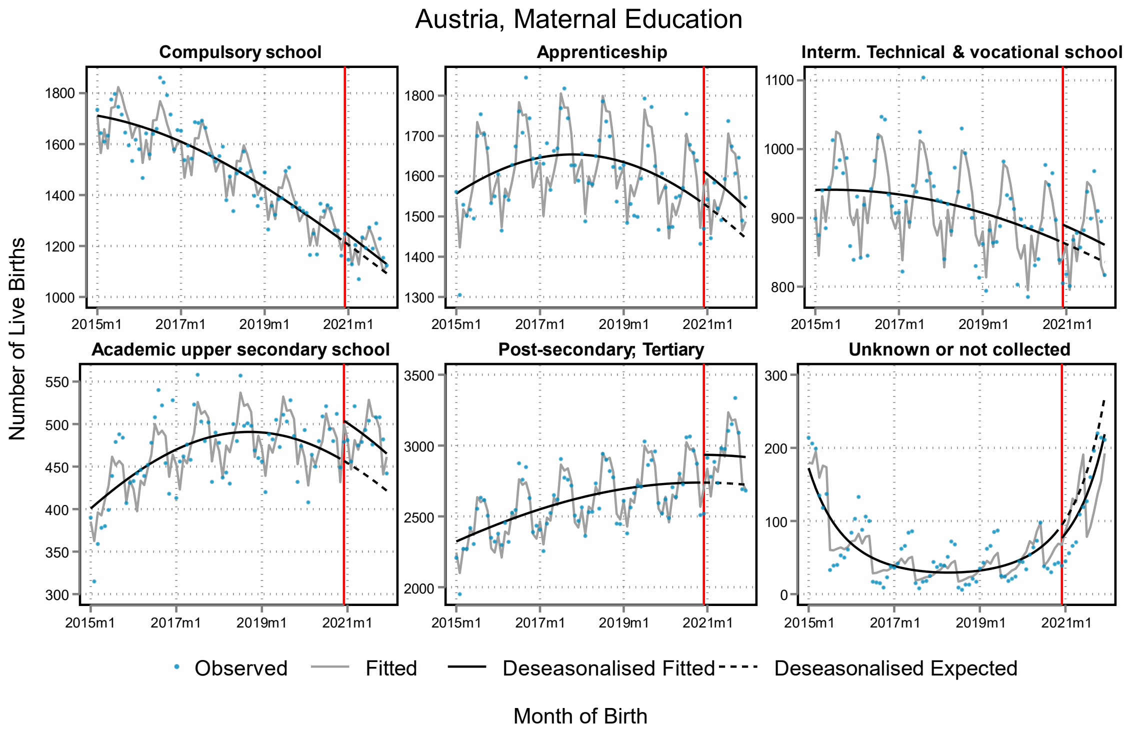


Figure S8: Observed and expected monthly number of live births in ***Austria*** *by primary socioeconomic indicator maternal education. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

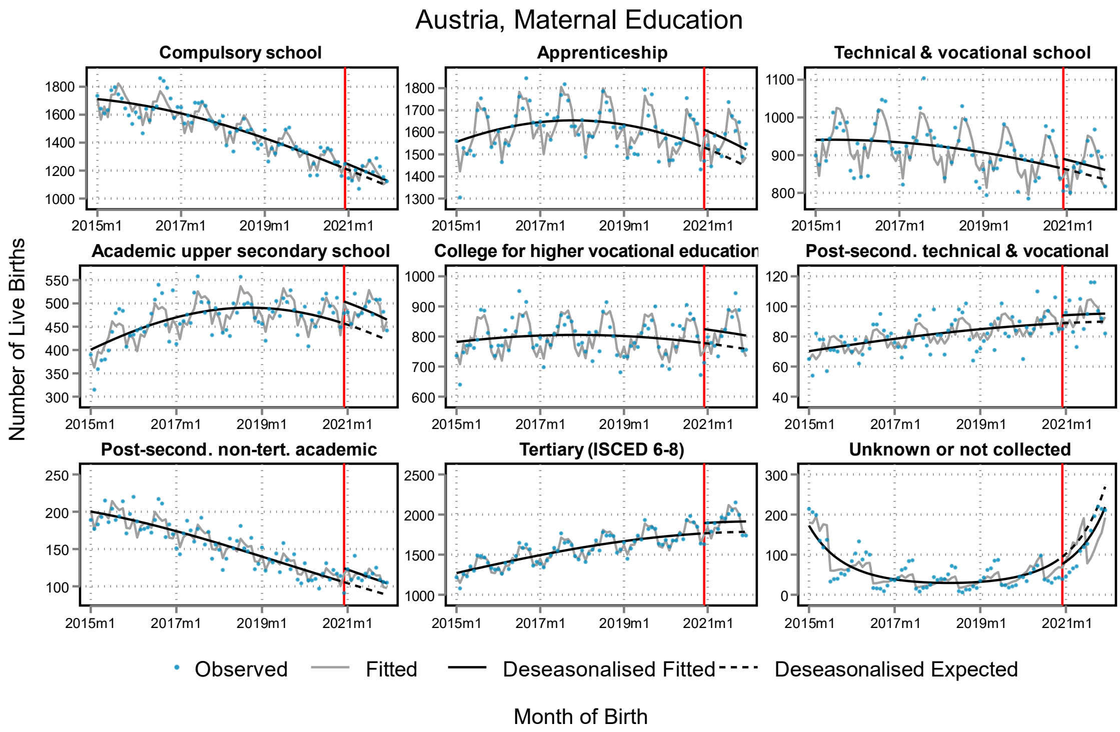


*Figure S9: Observed and expected monthly number of live births in **Austria** by maternal education in more detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

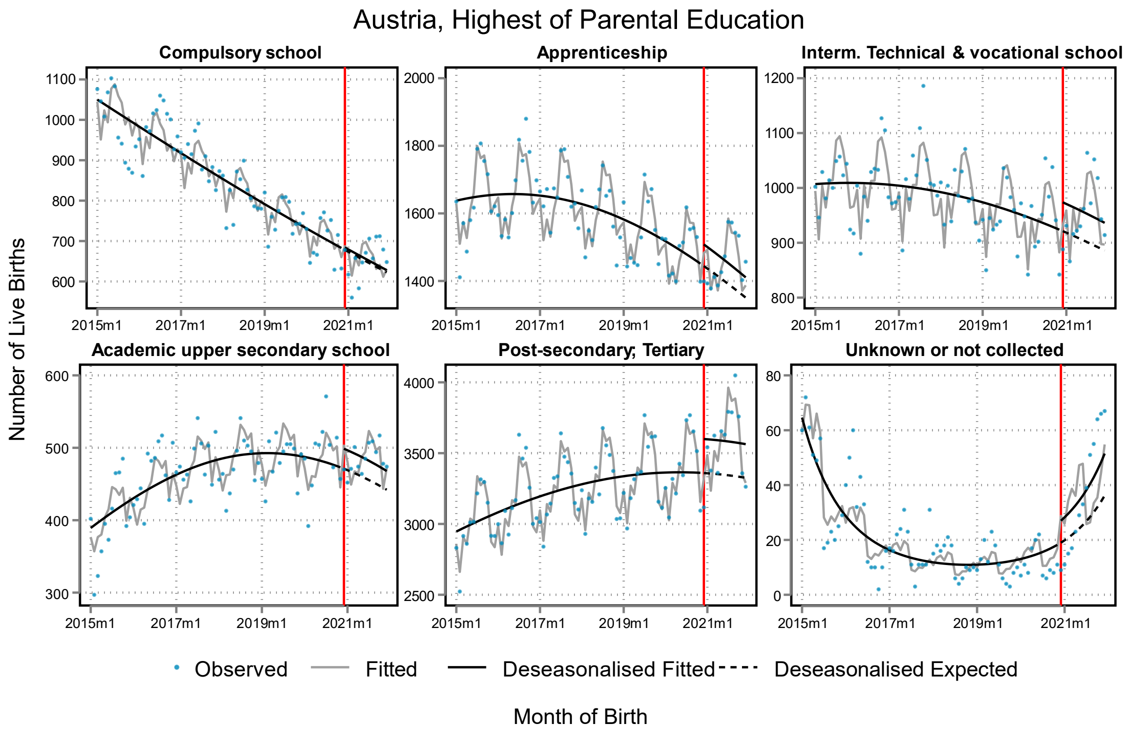


*Figure S10: Observed and expected monthly number of live births in **Austria** by highest education of both parents. If maternal education was missing and paternal was non-missing, we used paternal education. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

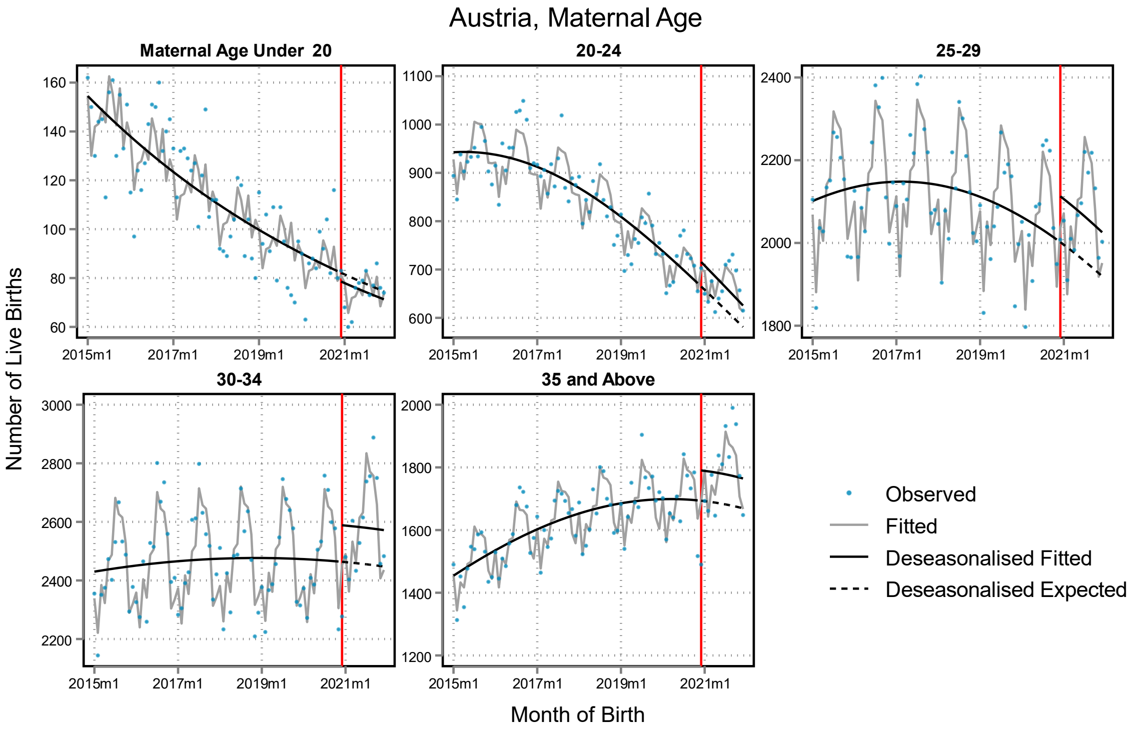


*Figure S11: Observed and expected monthly number of live births in **Austria** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

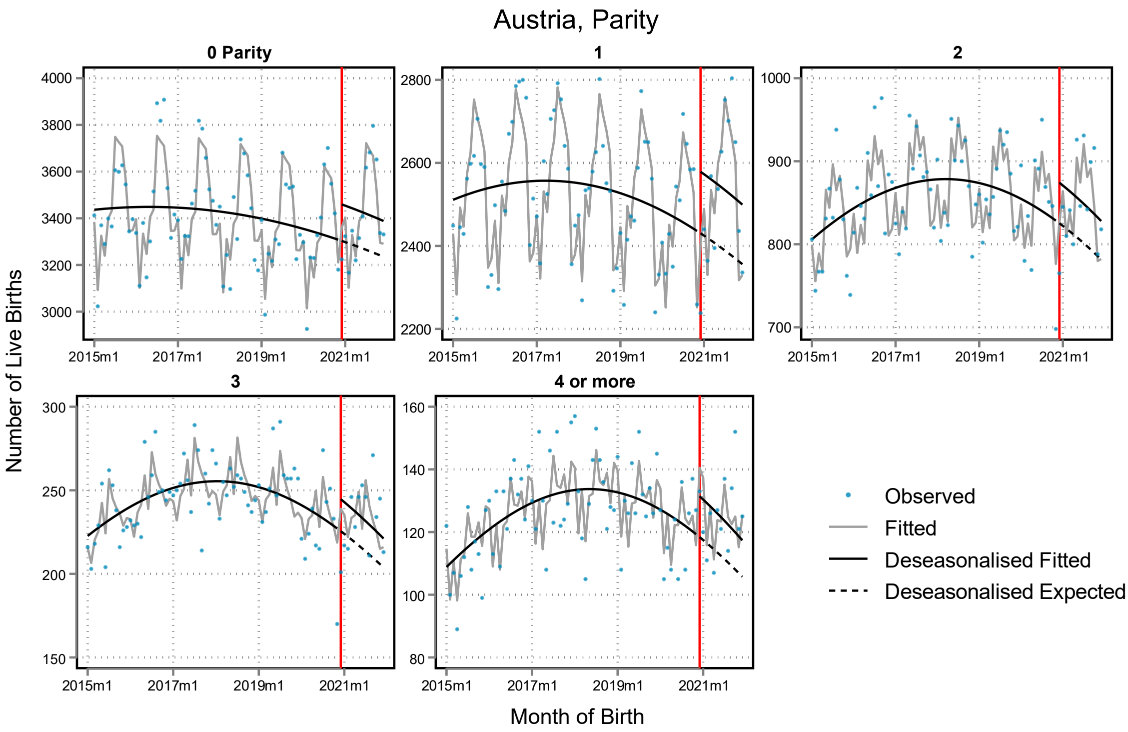


Figure S12: Observed and expected monthly number of live births in ***Austria*** *by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S1: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Austria. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	**Observed (OBS) Births**	**Counterfactual (CF) Births**	**95%CI: CF Births**	**OBS - CF Births**	**95%CI: OBS - CF Births**	**% more/less than CF**	**95%CI: % more/less than CF**	**OBS proportion in %**	**CF proportion in %**	**OBS - CF proportion**	**95%CI: OBS - CF proportion**
Maternal education detailed											
Compulsory	15481	14991	(14598; 15384)	490	(28; 953)	3.3	(0.6; 6.0)	16.7	17.0	-0.3	(-0.7; 0.1)
Apprenticeship	20347	19332	(18865; 19800)	1015	(470; 1560)	5.2	(2.8; 7.9)	21.9	21.9	0.0	(-0.5; 0.5)
Technical & Vocational School	11336	11004	(10649; 11359)	332	(-80; 744)	3.0	(-0.2; 6.4)	12.2	12.5	-0.3	(-0.6; 0.1)
Academic Upper Secondary School	6304	5713	(5459; 5967)	591	(293; 889)	10.3	(5.6; 15.5)	6.8	6.5	0.3	(0.0; 0.6)
College for Higher Vocational Education	10512	9922	(9583; 10261)	590	(196; 984)	5.9	(2.4; 9.7)	11.3	11.2	0.1	(-0.3; 0.4)
Post-secondary technical & vocational	1229	1161	(1040; 1281)	68	(-71; 207)	5.9	(-4.1; 18.2)	1.3	1.3	0.0	(-0.1; 0.1)
Post-secondary non-tertiary academic	1475	1254	(1148; 1361)	221	(90; 351)	17.6	(8.4; 28.5)	1.6	1.4	0.2	(0.0; 0.3)
Tertiary (ISCED 6-8)	24631	22963	(22424; 23502)	1668	(1047; 2288)	7.3	(4.8; 9.8)	26.5	26.0	0.5	(-0.0; 1.0)
Unknown	1633	2012	(1765; 2259)	-379	(-638; -120)	-18.8	(-27.7; -7.5)	1.8	2.3	-0.5	(-0.8; -0.3)
total	92948	88353		4595		0.1		100.0	100.0	0.0	
Highest Parental Education											
Compulsory	8527	8453	(8157; 8750)	74	(-274; 421)	0.9	(-2.5; 4.5)	9.2	9.6	-0.5	(-0.8; -0.1)
Apprenticeship	18953	18149	(17701; 18596)	804	(282; 1327)	4.4	(1.9; 7.1)	20.4	20.7	-0.3	(-0.7; 0.2)
Interim. Technical & Vocational School	12378	11710	(11345; 12075)	668	(243; 1093)	5.7	(2.5; 9.1)	13.3	13.3	0.0	(-0.4; 0.4)
Academic Upper Secondary School	6296	5948	(5685; 6211)	348	(42; 654)	5.8	(1.4; 10.7)	6.8	6.8	0.0	(-0.3; 0.3)
Post-secondary; Tertiary	46315	43227	(42506; 43949)	3088	(2252; 3923)	7.1	(5.4; 9.0)	49.8	49.2	0.6	(0.0; 1.2)
Unknown	479	337	(259; 415)	142	(53; 231)	42.2	(15.5; 85.0)	0.5	0.4	0.1	(0.0; 0.2)

total	92948	87824		5124		0.1		100.0	100.0	0.0	
Maternal age											
Below 20	975	1020	(918; 1121)	-45	(-163; 74)	-4.4	(-13.0; 6.2)	1.0	1.2	-0.1	(-0.2; 0.0)
20-24	8698	8081	(7798; 8365)	617	(279; 954)	7.6	(4.0; 11.5)	9.4	9.2	0.2	(-0.1; 0.5)
25-29	26835	25428	(24889; 25967)	1407	(780; 2034)	5.5	(3.3; 7.8)	28.9	28.9	0.0	(-0.5; 0.5)
30-34	33412	31800	(31184; 32415)	1612	(900; 2324)	5.1	(3.1; 7.1)	35.9	36.1	-0.1	(-0.7; 0.4)
Above 34	23028	21785	(21273; 22297)	1243	(651; 1835)	5.7	(3.3; 8.3)	24.8	24.7	0.1	(-0.4; 0.6)
total	92948	88114		4834		0.1		100.0	100.0	0.0	
Parity											
0	44419	42411	(41708; 43115)	2008	(1192; 2824)	4.7	(3.0; 6.5)	47.8	48.2	-0.4	(-1.0; 0.2)
1	32848	30961	(30363; 31558)	1887	(1192; 2582)	6.1	(4.1; 8.2)	35.3	35.2	0.2	(-0.4; 0.7)
2	11027	10411	(10067; 10755)	616	(215; 1017)	5.9	(2.5; 9.5)	11.9	11.8	0.0	(-0.3; 0.4)
3	3026	2790	(2615; 2964)	236	(32; 441)	8.5	(2.1; 15.7)	3.3	3.2	0.1	(-0.1; 0.3)
4 or more	1628	1467	(1340; 1593)	161	(12; 310)	11.0	(2.2; 21.5)	1.8	1.7	0.1	(-0.1; 0.2)
total	92948	88039		4909		0.1		100.0	100.0	0.0	

Brazil

Data

For Brazil (2015-2021, n=20,000,327 live births), we used openly available individual-level data from SINASC (Sistema de Informações sobre Nascidos Vivos) (https://opendatasus.saude.gov.br/dataset/sistema-de-informacao-sobre-nascidos-vivos-sinasc). SINASC contains national records of live births, and it covers close to 100% of all live births in Brazil.[2] We used individual-level data and then aggregated to weekly time series by parental characteristics of interest. To measure relative material deprivation of mothers' residential area, we used the BrazDep small-area deprivation index.[3] This index is created from the 2010 Brazilian Population Census data and combines i) the percent of household with per capita income smaller than 50% of the minimum wage, ii) percent of people not literate (older than 7), and iii) average percent of people with inadequate access to sewage, water, garbage, collection and no toilet and bath/shower. The BrazDep is developed for the smallest geographical level (310,120 census sectors; average population size ~615 residents in 2010) and was validated against health outcomes (see report by Allik et al. 2020). As the smallest geographical level available in SINASC is municipality (5565 municipalities; average population size ~34,100 in 2010), we needed to aggregate the BrazDep small-area deprivation measure to the municipality level. We did this by creating an average of the values of census sectors within municipalities weighted by the share of the population of each census sectors. Note that the BrazDep small-area deprivation measure uses data from 2010. One the one hand, this means that the COVID-19 pandemic had no impact on the deprivation measure we use. On the other, this time lag in the deprivation measure will probably induce measurement error. As areas have been shown to change their relative material positions only slowly (if at all)[4], we do not believe that the number of areas which drastically changed in their material deprivation is big enough to cause serious misclassification in quintiles of deprivation. Another advantage of the area-level measure is that information on municipality of maternal residence is far more complete than information on maternal education.

As secondary measure of socioeconomic circumstances, we used maternal education available in the SINASC data. Additionally, we estimated compositional change for maternal age and parity.

Results

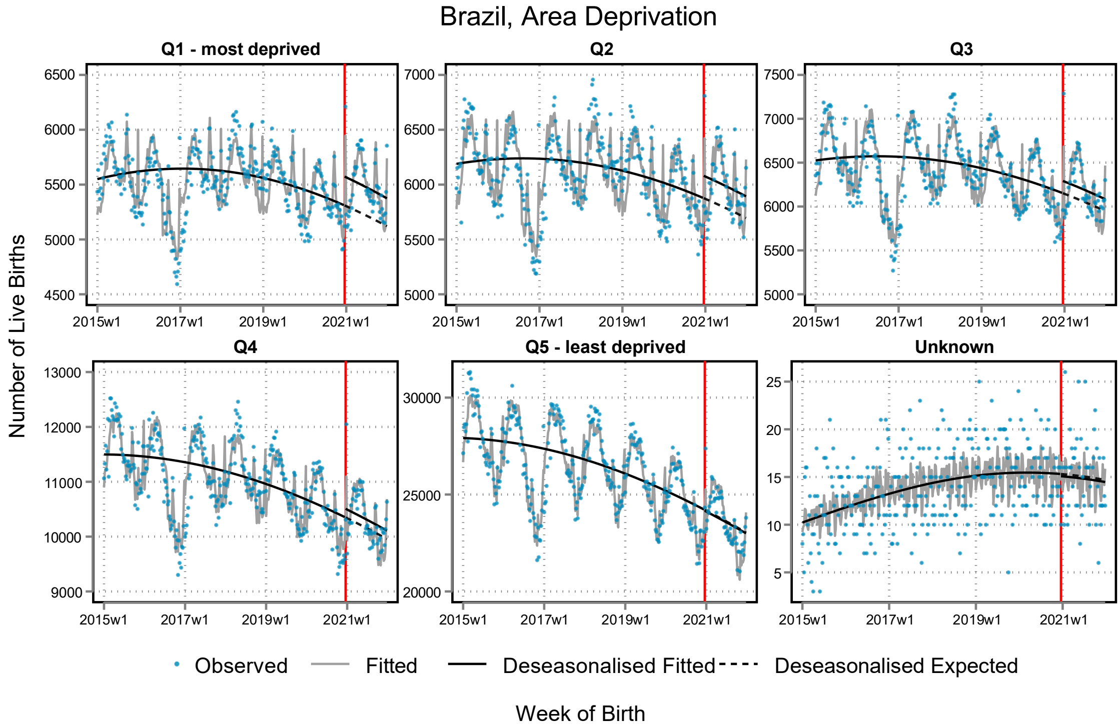


*Figure S13: Observed and expected weekly number of live births in **Brazil** by primary measure of socioeconomic circumstances (quintile of area level deprivation). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

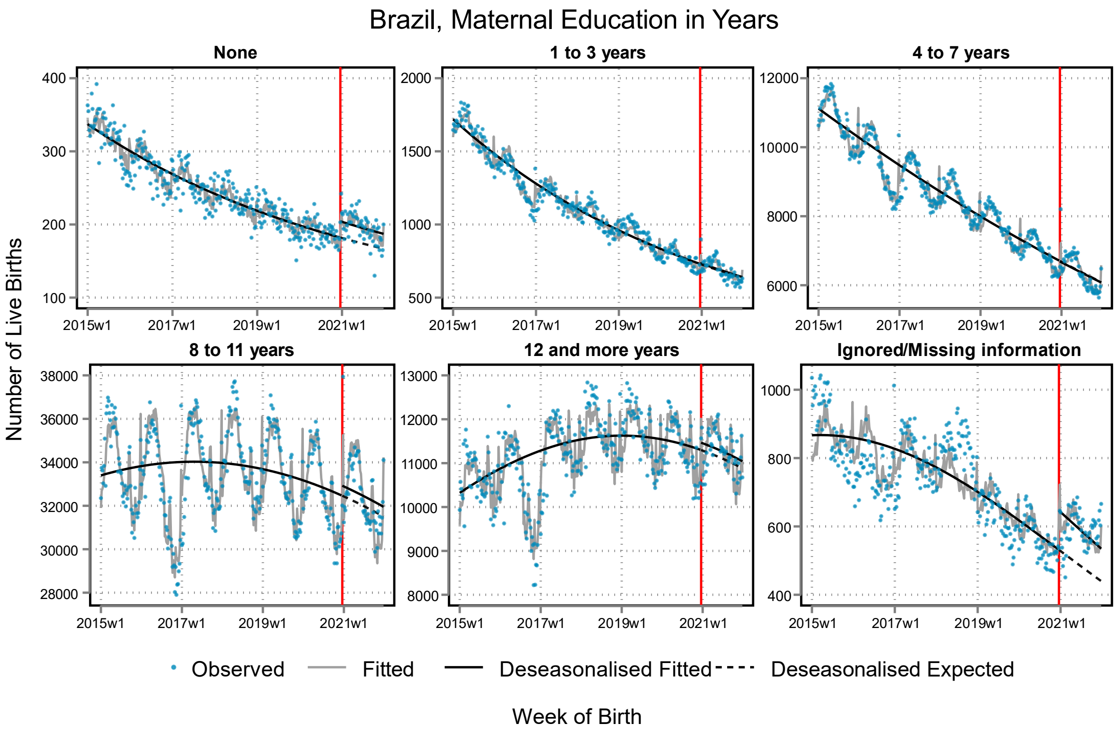


*Figure S14: Observed and expected weekly number of live births in **Brazil** by secondary measure of socioeconomic circumstances (maternal education). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic*

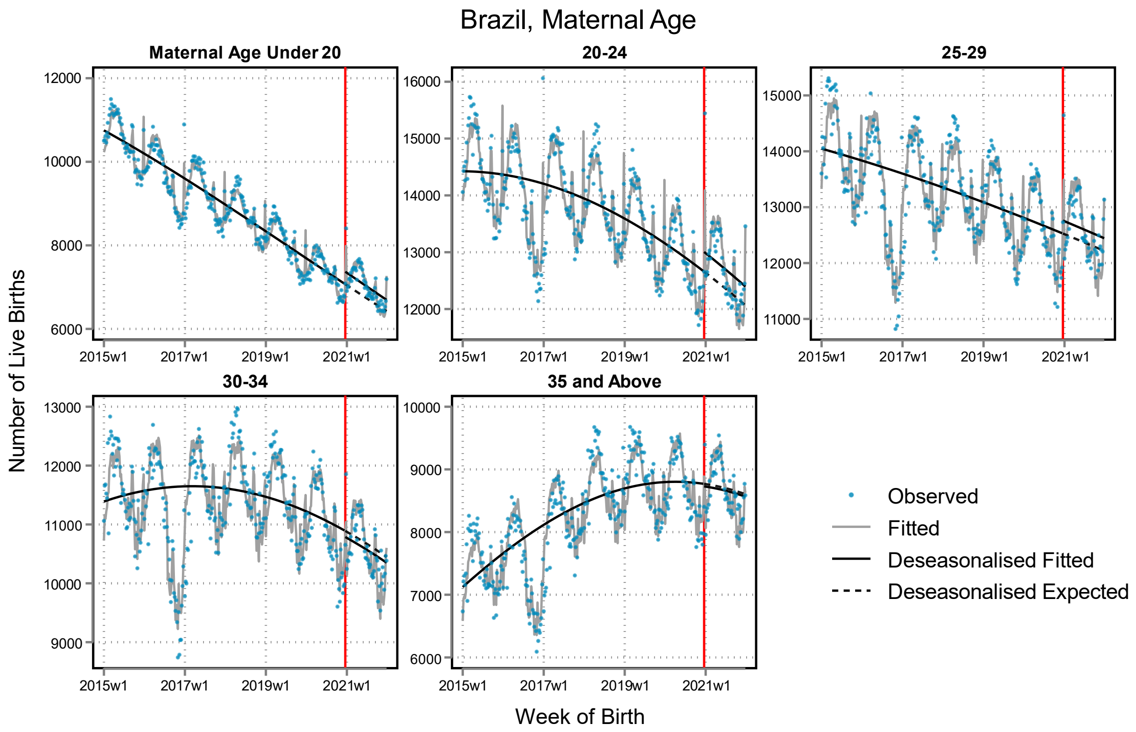


*Figure S15: Observed and expected weekly number of live births in **Brazil** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

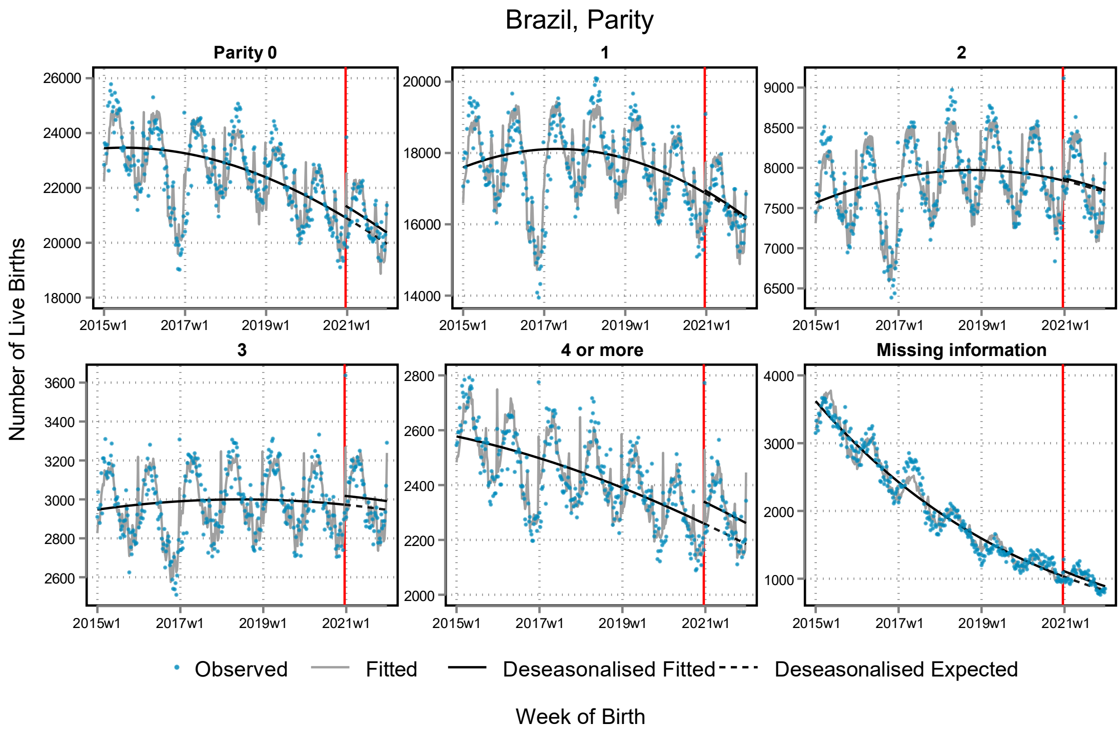


Figure S16: Observed and expected weekly number of live births in ***Brazil*** *by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

Table S2: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Brazil. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal education in years											
None	10559	9411	(9108; 9714)	1148	(784; 1512)	12.2	(8.7; 15.9)	0.4	0.3	0.0	(0.0; 0.0)
1-3 years	37136	36831	(36254; 37408)	305	(-385; 995)	0.8	(-0.7; 2.4)	1.3	1.3	0.0	(-0.0; 0.0)
4-7 years	345098	345759	(343905; 347613)	-661	(-2844; 1522)	-0.2	(-0.7; 0.3)	12.4	12.6	-0.2	(-0.3; -0.1)
8-11 years	1754767	1730192	(1725759; 1734624)	24575	(19438; 29712)	1.4	(1.2; 1.7)	62.9	63.0	0.0	(-0.1; 0.1)
12 years and more	608863	599998	(597376; 602620)	8865	(5829; 11901)	1.5	(1.0; 1.9)	21.8	21.8	0.0	(-0.1; 0.1)
Unknown	31957	26278	(25791; 26765)	5679	(5079; 6279)	21.6	(19.4; 23.9)	1.1	1.0	0.2	(0.2; 0.2)
total	2788380	2748468		39912		0.0		100.0	100.0	0.0	
Maternal age											
Below 20	380232	364793	(362879; 366708)	15439	(13175; 17703)	4.2	(3.7; 4.8)	13.6	13.3	0.4	(0.3; 0.4)
20-24	687112	668808	(666097; 671518)	18304	(15144; 21464)	2.7	(2.3; 3.2)	24.6	24.3	0.3	(0.2; 0.4)
25-29	681519	669110	(666364; 671855)	12409	(9222; 15596)	1.9	(1.4; 2.3)	24.4	24.3	0.1	(0.0; 0.2)
30-34	571615	577081	(574537; 579625)	-5466	(-8410; -2522)	-0.9	(-1.4; -0.5)	20.5	21.0	-0.5	(-0.6; -0.4)
Above 34	467840	469983	(467620; 472347)	-2143	(-4861; 574)	-0.5	(-1.0; 0.0)	16.8	17.1	-0.3	(-0.4; -0.2)
total	2788318	2749775		38543		0.0		100.0	100.0	0.0	
Parity											
0	1128507	1105785	(1102293; 1109277)	22722	(18656; 26788)	2.1	(1.7; 2.4)	40.5	40.2	0.3	(0.2; 0.4)
1	897185	893176	(890017; 896335)	4009	(345; 7673)	0.4	(0.1; 0.8)	32.2	32.5	-0.3	(-0.4; -0.2)
2	421817	420243	(418037; 422449)	1574	(-973; 4121)	0.4	(-0.1; 0.9)	15.1	15.3	-0.2	(-0.2; -0.1)
3	162545	160108	(158742; 161474)	2437	(859; 4015)	1.5	(0.7; 2.4)	5.8	5.8	0.0	(-0.0; 0.1)
4 or more	124373	120147	(118991; 121304)	4226	(2879; 5573)	3.5	(2.5; 4.5)	4.5	4.4	0.1	(0.0; 0.1)
Unknown	53953	49954	(49331; 50577)	3999	(3227; 4770)	8.0	(6.7; 9.4)	1.9	1.8	0.1	(0.1; 0.1)
total	2788380	2749413		38967		0.0		100.0	100.0	0.0	

Colombia

Data

For Colombia (2015-2021, n=4,503,315 live births), we used openly available individual-level vital statistics from DANE (Departamento Administrativo Nacional De Estatdistica) (https://microdatos.dane.gov.co/index.php/catalog/DEM-Microdatos#_r=1700214975152&collection=&country=&dtype=&from=2015&page=1&ps=&sid=&sk=&sort_by=title&sort_order=&to=2023&topic=&view=s&vk=). Close to 100% of births in Colombia are covered by these data as survey research found that the proportion of unregistered children under age 5 was 2% at highest in the regions with the lowest coverage (Caribbean, Eastern, Pacific).[5]

We aggregated the data to monthly time series of the number of live births by parental characteristics. The thirteen levels of parental education were translated to more comparable ISCED (International Standard Classification of Education) categories using OECD's profile of Colombia's educational system (https://gpseducation.oecd.org/CountryProfile?primaryCountry=COL&treshold=5&topic=EO). Having non, pre-school, primary school, and lower secondary school was grouped together as primary or lower secondary education (all qualifications up to ISCED 2). ISCED 3 level qualifications were grouped together as upper secondary and ISCED 4 to ISCED 8 were grouped together as post-secondary non-tertiary and tertiary education.

As secondary measure of socioeconomic circumstances, we used the highest education of mother or father and father's education if maternal education was not available. Additionally, we estimated compositional change for maternal education in more detail, maternal age, and parity.

Results

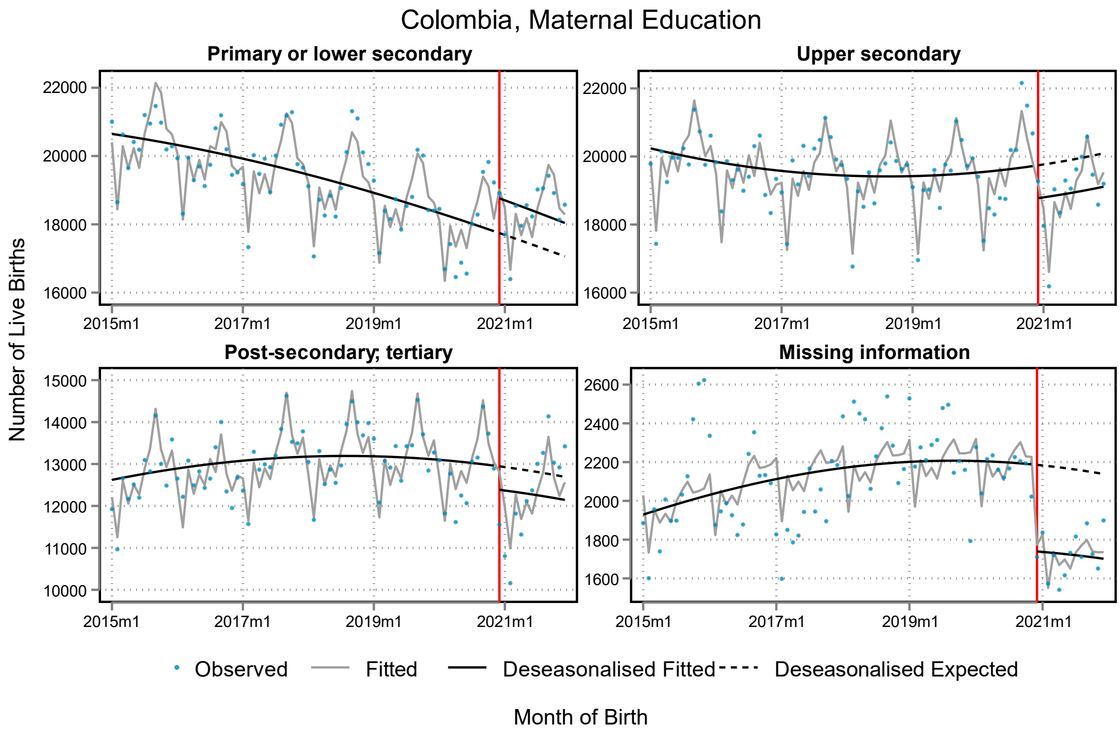


*Figure S17: Observed and expected monthly number of live births in **Colombia** by primary indicator of socioeconomic circumstances (maternal education). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

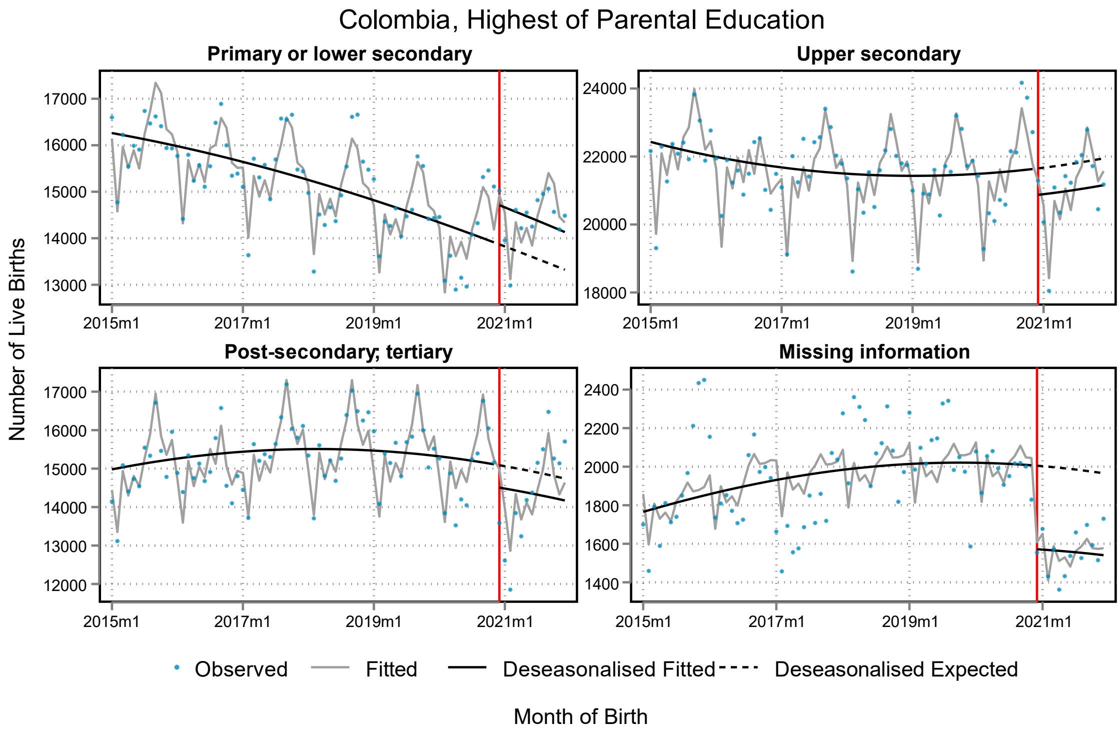


Figure S18: Observed and expected monthly number of live births in ***Colombia*** *by highest of parental education. We used paternal education if maternal education was missing. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

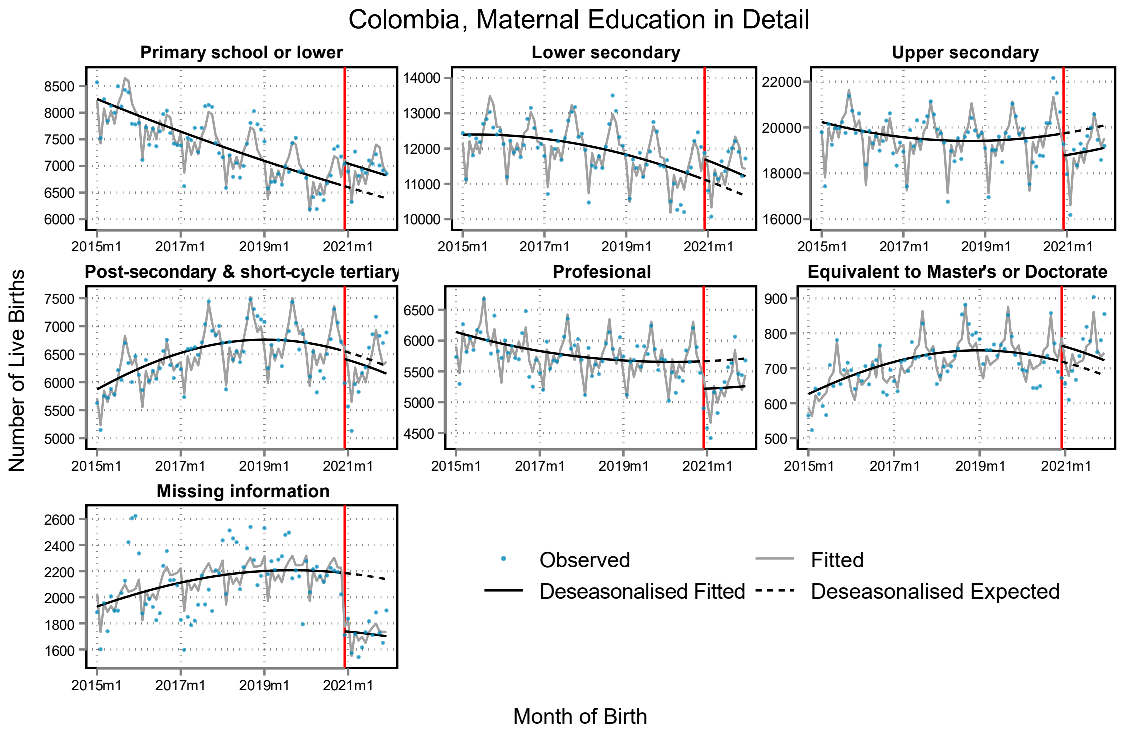


*Figure S19: Observed and expected monthly number of live births in **Colombia** by maternal education in detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

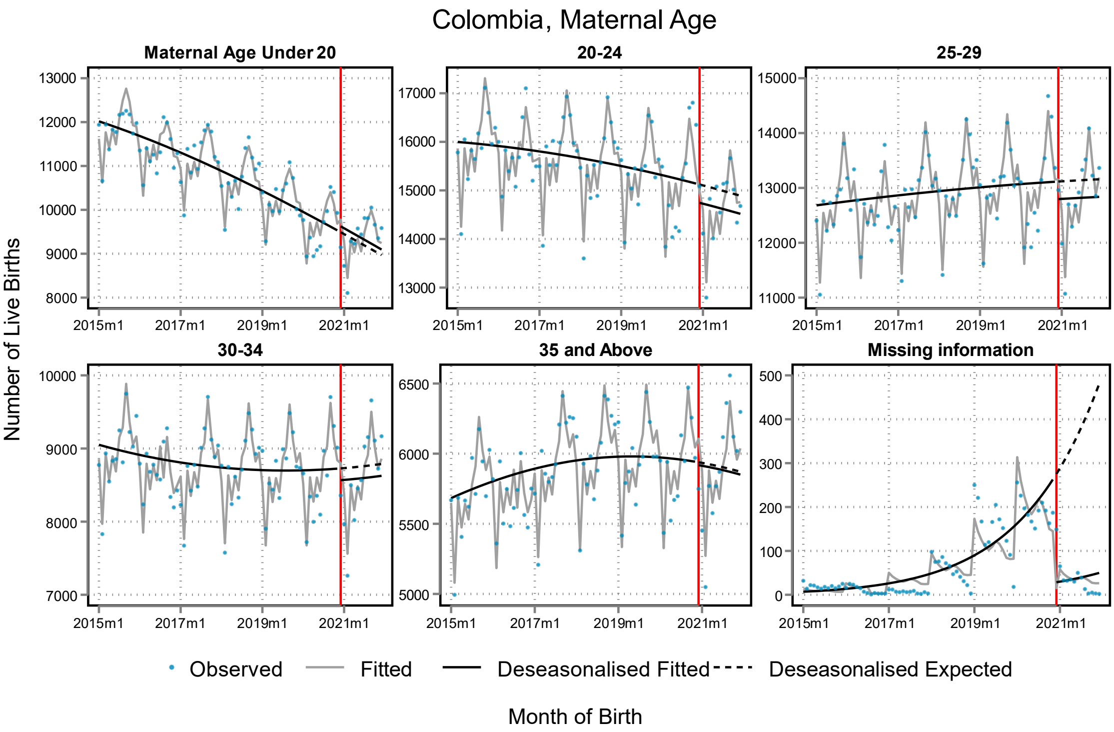


Figure S20: Observed and expected monthly number of live births in ***Colombia*** *by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

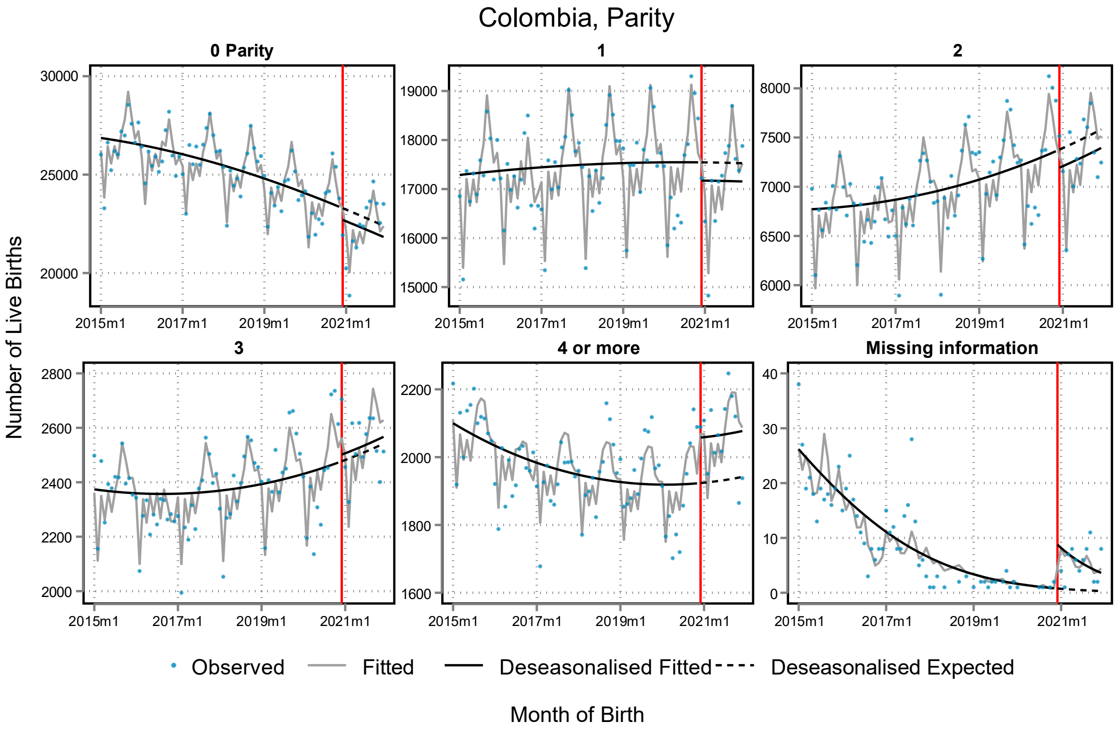


*Figure S21: Observed and expected monthly number of live births in **Colombia** by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

Table S3: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Colombia. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Highest Parental Education											
Primary or Lower Secondary	187661	176912	(175472; 178352)	10749	(9077; 12421)	6.1	(5.2; 6.9)	28.1	26.0	2.1	(1.9; 2.3)
Upper Secondary	273500	283706	(281808; 285603)	-10206	(-12362; -8049)	-3.6	(-4.2; -2.9)	40.9	41.7	-0.7	(-1.0; -0.5)
Post-secondary; Tertiary	186918	194430	(192882; 195979)	-7512	(-9278; -5747)	-3.9	(-4.6; -3.1)	28.0	28.6	-0.6	(-0.8; -0.4)
Unknown	20285	25880	(25306; 26454)	-5595	(-6233; -4956)	-21.6	(-23.3; -19.8)	3.0	3.8	-0.8	(-0.8; -0.7)
total	668364	680928		-12564		0.0		100.0	100.0	0.0	
Highest Parental Education in Detail											
Primary School or Lower	90285	84584	(83591; 85577)	5701	(4546; 6855)	6.7	(5.5; 8.0)	13.5	12.4	1.1	(0.9; 1.2)
Lower Secondary	149148	141790	(140496; 143083)	7358	(5859; 8857)	5.2	(4.2; 6.2)	22.3	20.8	1.5	(1.3; 1.7)
Upper Secondary	246595	259256	(257435; 261076)	-12661	(-14725; -10596)	-4.9	(-5.5; -4.2)	36.9	38.1	-1.2	(-1.4; -1.0)
Post-secondary; short tertiary	81957	83741	(82727; 84754)	-1784	(-2942; -625)	-2.1	(-3.3; -0.9)	12.3	12.3	0.0	(-0.2; 0.1)
"Profesional"	68265	74102	(73135; 75069)	-5837	(-6931; -4743)	-7.9	(-9.1; -6.7)	10.2	10.9	-0.7	(-0.8; -0.5)
Master's or Doctorate Equivalent	9699	9123	(8791; 9455)	576	(192; 960)	6.3	(2.6; 10.3)	1.5	1.3	0.1	(0.1; 0.2)
Unknown	22415	28176	(27578; 28774)	-5761	(-6427; -5095)	-20.4	(-22.1; -18.7)	3.4	4.1	-0.8	(-0.9; -0.7)
total	668364	680771		-12407		0.0		100.0	100.0	0.0	
Maternal age											
Below 20	121783	120095	(118921; 121268)	1688	(330; 3046)	1.4	(0.4; 2.4)	18.2	17.6	0.6	(0.5; 0.8)
20-24	190463	195335	(193786; 196883)	-4872	(-6641; -3103)	-2.5	(-3.3; -1.7)	28.5	28.6	-0.1	(-0.3; 0.1)

	25-29	166979	171158	(169685; 172632)	-4179	(-5856; -2502)	-2.4	(-3.3; -1.6)	25.0	25.1	-0.1	(-0.3; 0.1)
	30-34	111970	114075	(112876; 115273)	-2105	(-3471; -738)	-1.8	(-2.9; -0.8)	16.8	16.7	0.0	(-0.1; 0.2)
	Above 34	76710	76979	(75998; 77960)	-269	(-1390; 853)	-0.3	(-1.6; 0.9)	11.5	11.3	0.2	(0.1; 0.3)
	Unknown	459	4420	(3989; 4851)	-3961	(-4394; -3528)	-89.6	(-90.5; -88.5)	0.1	0.6	-0.6	(-0.6; -0.5)
	total	668364	682061		-13697		0.0		100.0	100.0	0.0	
Parity												
	0	289982	297607	(295729; 299486)	-7625	(-9780; -5470)	-2.6	(-3.2; -1.9)	43.4	43.7	-0.3	(-0.5; -0.1)
	1	223514	228359	(226664; 230054)	-4845	(-6777; -2913)	-2.1	(-2.8; -1.4)	33.4	33.5	-0.1	(-0.3; 0.1)
	2	94929	97346	(96219; 98474)	-2417	(-3697; -1138)	-2.5	(-3.6; -1.3)	14.2	14.3	-0.1	(-0.2; 0.1)
	3	32998	32674	(32024; 33324)	324	(-417; 1065)	1.0	(-1.0; 3.0)	4.9	4.8	0.1	(0.0; 0.2)
	4 or more	26874	25123	(24564; 25681)	1751	(1107; 2396)	7.0	(4.6; 9.4)	4.0	3.7	0.3	(0.3; 0.4)
	Unknown	67	6	(1; 11)	61	(44; 78)	1020.5	(532.9; 4783.4)	0.0	0.0	0.0	(0.0; 0.0)
	total	668364	681116		-12752		0.0		100.0	100.0	0.0	

Ecuador

Data

For Ecuador (2015-2021; n=1,966,277 live births), we used openly available individual-level vital statistics from INEC (Instituto Nacional de Estadística y Censos) (https://aplicaciones3.ecuadorencifras.gob.ec/BIINEC-war/index.xhtml). We used the most recent data (2015-2022), to include births that occurred in 2021 but were registered in 2022. The number of births registered two years after the year of birth has been continuously declining in recent years (https://www.ecuadorencifras.gob.ec/nacidos-vivos-y-defunciones-fetales/). Therefore, the analysed number of live births in 2021 might not be definitive but will be close to the definitive number of live births. For our analysis, results will only be biased by incomplete coverage if the propensity to registration two or more years after birth is associated with parental characteristics. As late registrations will be more likely to happen in remote areas and for births outside hospitals, we believe that, if anything, our estimates for differences in socioeconomic composition will be underestimates.

Data on maternal education available in the vital statistics were inconsistently collected through time and thus not used in our analysis. Instead, we used a deprivation index created to study geographical inequalities in health outcomes.[6] This deprivation index on the canton level (n=221, population size ranges from1,760 to 2,350,278 (median 23,820)) was created using data from the National Population Census 2010 and the National Living Conditions Survey 2013-2014 and comprises 17 indicators in total. We created quintiles of this index and linked them to the canton of maternal residence.

Additionally, we estimated compositional change for maternal age and the number of living children as a measure of parity.

The Zika virus epidemic had two waves in Ecuador (https://www3.paho.org/hq/dmdocuments/2017/2017-phe-zika-situation-report-ecu.pdf). We thus estimated our models once with variables indicating the start of the epidemic in Brazil that coincided with public recommendations to postpone pregnancies in many Latin American countries. Here, we assumed that not the actual ZIKV cases are driving behaviour change, but the spillover of information from other countries and the official recommendations. We then re-estimated our models with variables indicating the 40-weeks lagged period after the two ZIKV waves (1st wave in summer 2016 and 2nd wave in the first half of 2017).

After visual inspection of our results, we decided that the former model specification captured the drop in live births (in some time series clearly visible in the second half of 2016) while the latter specification did not. (An exception is the time series for live births with missing information on maternal age, where the second option fitted the data better). This is not a definitive answer to whether pregnancies were postponed due to the number of national cases or in response to cases in other Latin American countries. While this would warrant a different study, the conclusion for our estimands of interest are not affected by this choice of model specification (results not shown here but unconditionally available upon request to the first author).

Results

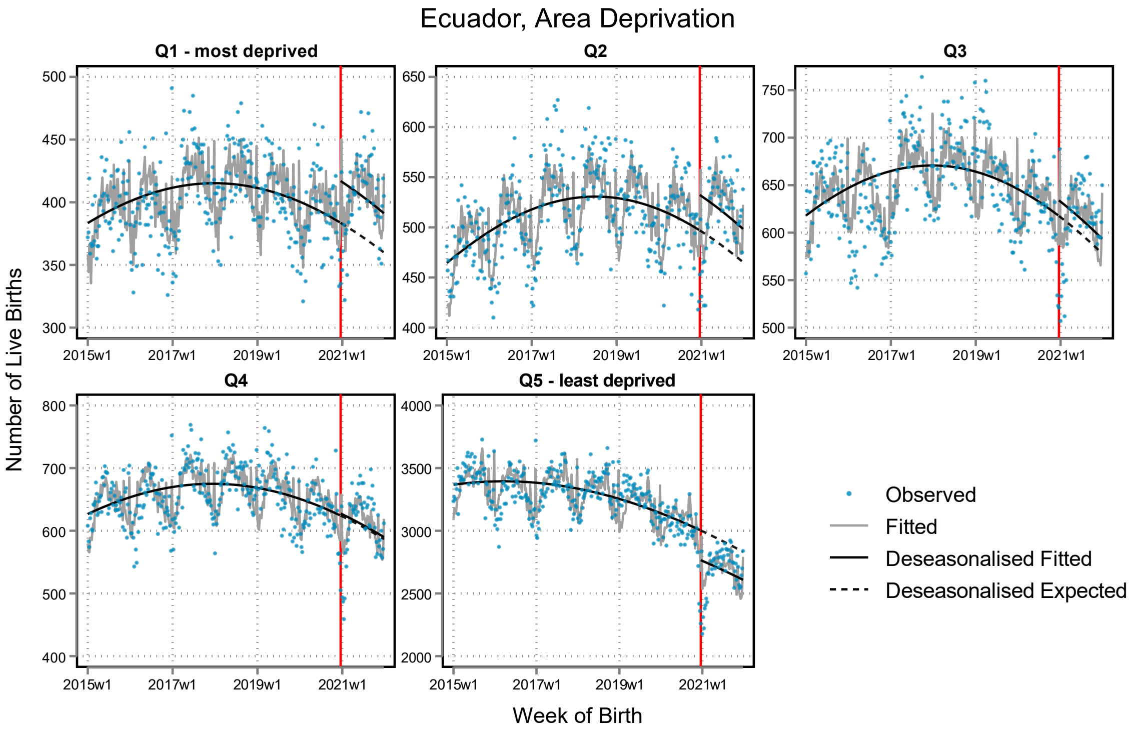


*Figure S22: Observed and expected weekly number of live births in **Ecuador** by primary indicator of socioeconomic circumstances (area deprivation in canton of maternal residence). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

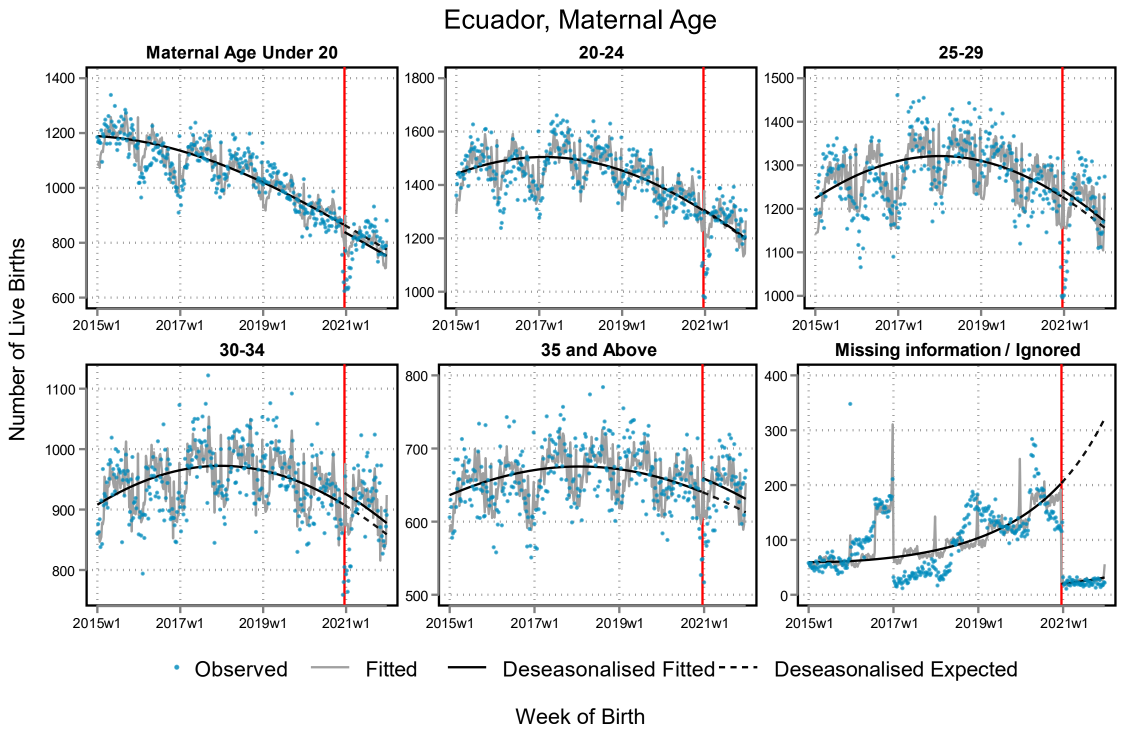


*Figure S23: Observed and expected weekly number of live births in **Ecuador** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

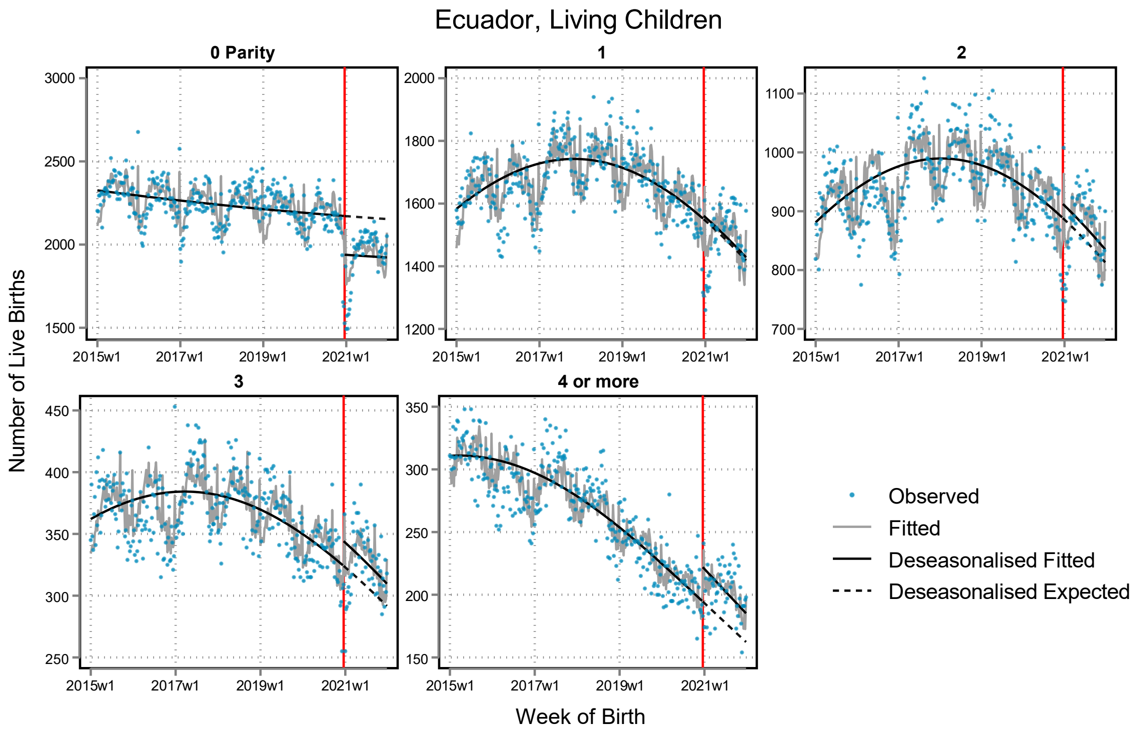


*Figure S24: Observed and expected weekly number of live births in **Ecuador** by number of living children (before focal birth). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

Table S4: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Ecuador. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal age											
Below 20	42974	44284	(43615; 44953)	-1310	(-2092; -527)	-3.0	(-4.4; -1.5)	16.5	16.3	0.2	(-0.1; 0.4)
20-24	67789	67584	(66736; 68433)	205	(-785; 1194)	0.3	(-0.9; 1.6)	26.0	24.8	1.1	(0.8; 1.4)
25-29	65310	64477	(63632; 65323)	833	(-150; 1816)	1.3	(0.0; 2.6)	25.0	23.7	1.3	(1.0; 1.6)
30-34	48797	47759	(47030; 48487)	1038	(191; 1886)	2.2	(0.6; 3.8)	18.7	17.6	1.1	(0.9; 1.4)
Above 34	34893	33876	(33259; 34493)	1017	(299; 1735)	3.0	(1.2; 4.9)	13.4	12.5	0.9	(0.7; 1.1)
Unknown	1383	14086	(13491; 14681)	-12703	(-13303; -12104)	-90.2	(-90.6; -89.7)	0.5	5.2	-4.6	(-4.9; -4.4)
total	261146	272066		-10920		0.0		100.0	100.0	0.0	
Parity											
0	104357	116884	(115718; 118049)	-12527	(-13853; -11200)	-10.7	(-11.6; -9.8)	40.0	43.4	-3.4	(-3.7; -3.1)
1	80878	80310	(79381; 81239)	568	(-515; 1651)	0.7	(-0.4; 1.9)	31.0	29.8	1.2	(0.9; 1.5)
2	47243	46003	(45299; 46707)	1240	(417; 2063)	2.7	(1.1; 4.3)	18.1	17.1	1.0	(0.8; 1.3)
3	17681	16650	(16234; 17066)	1031	(540; 1522)	6.2	(3.6; 8.9)	6.8	6.2	0.6	(0.4; 0.7)
4 or more	10987	9630	(9333; 9926)	1357	(997; 1718)	14.1	(10.7; 17.7)	4.2	3.6	0.6	(0.5; 0.7)
total	261146	269477		-8331		0.0		100.0	100.0	0.0	

England

Data

For England (2015-2021; n=4,391,999 live births), we purchased monthly time series (2015-2022) of the number of live births by deciles of the Index for Multiple Deprivation (IMD) from the Office for National Statistics. These data are now openly available due to our purchase.

(https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/adhocs/1703livebirthsbymonthofoccurrenceandimddecileenglandandwales2015to2022)

These data are considered to cover 100% of live births and there are only a low number of late registrations which, for 2021, are already captured in our data.

The IMD is created for Lower Super Output Areas (LSOAs) of mothers' residence. IMD deciles for 2015 are based on 2015 census data and IMD deciles for 2016-2022 are based on 2019 census data.

We use quintiles of the IMD as primary indicator of socioeconomic circumstances but show results also for deciles.

Results

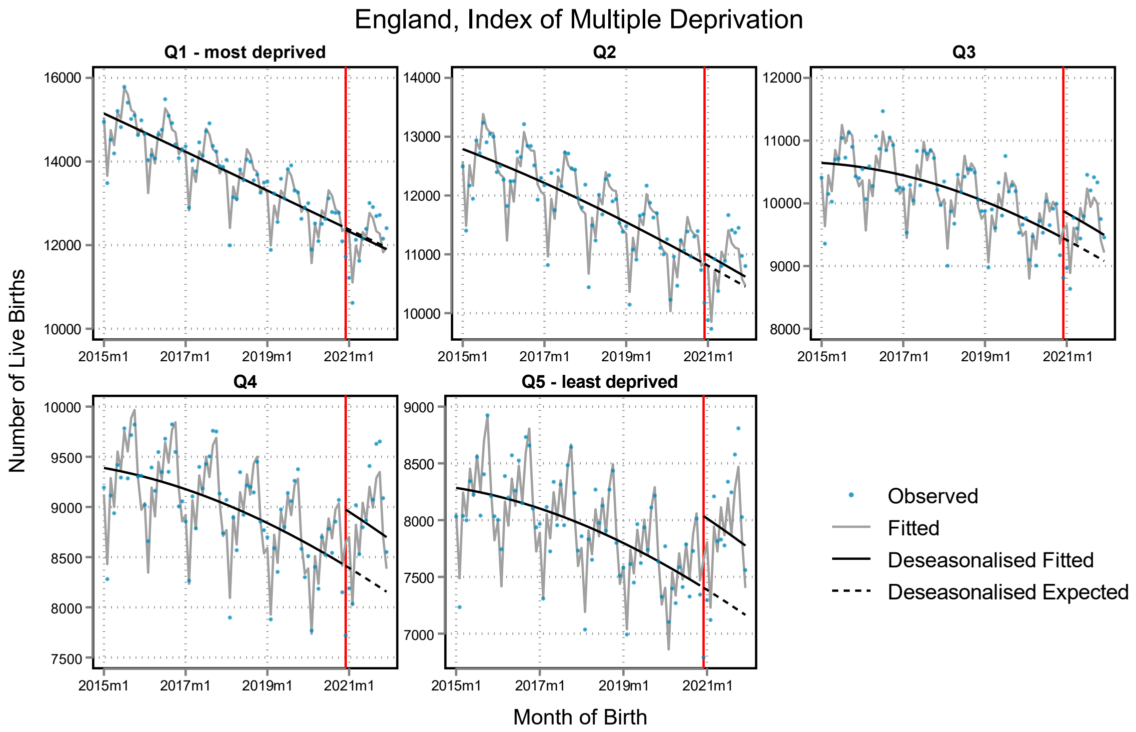


*Figure S25: Observed and expected monthly number of live births in **England** by primary indicator of socioeconomic circumstances (area deprivation in Lower Super Output Areas of maternal residence). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

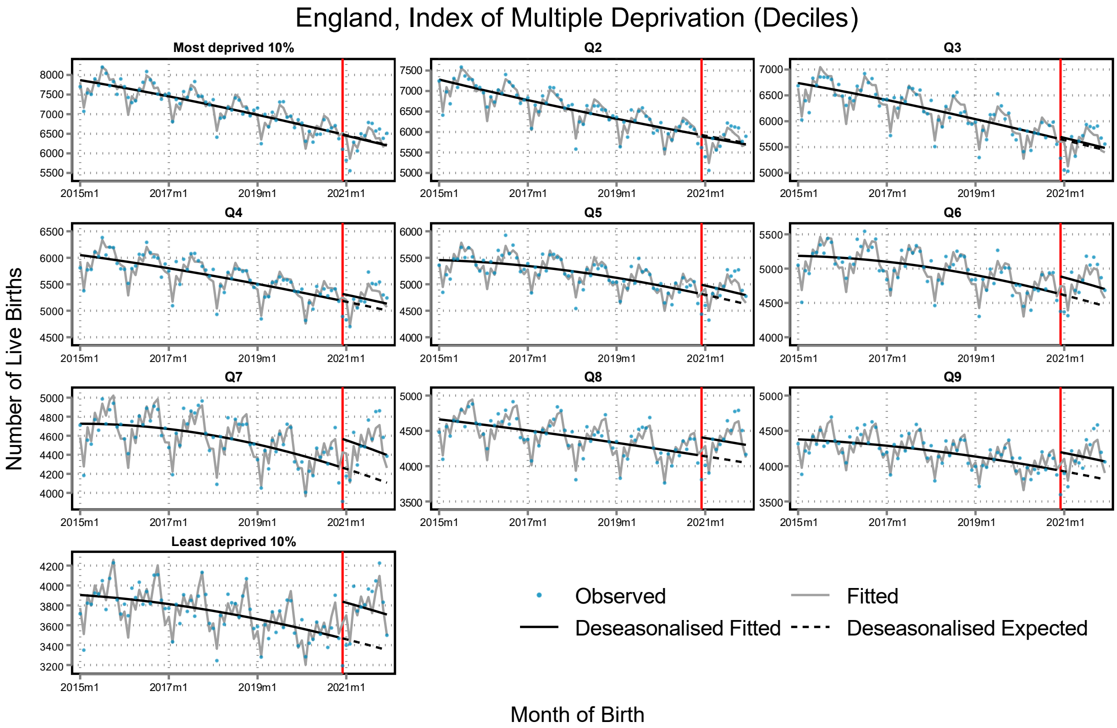


*Figure S26: Observed and expected monthly number of live births in **England** by decile of the index of multiple deprivation of Lower Super Output Areas of maternal residence. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S5: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in England. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	**Observed (OBS) Births**	**Counterfactual (CF) Births**	**95%CI: CF Births**	**OBS - CF Births**	**95%CI: OBS - CF Births**	**% more/less than CF**	**95%CI: % more/less than CF**	**OBS proportion**	**CF proportion**	**OBS - CF proportion**	**95%CI: OBS - CF proportion**
Index of Multiple Deprivation											
D1 - Most Deprived	82428	82610	(81646; 83574)	-182	(-1298; 934)	-0.2	(-1.4; 1.0)	12.9	13.4	-0.5	(-0.6; -0.3)
D2	75324	75750	(74824; 76676)	-426	(-1497; 645)	-0.6	(-1.8; 0.7)	11.8	12.2	-0.5	(-0.6; -0.4)
D3	72583	72036	(71134; 72938)	547	(-498; 1592)	0.8	(-0.5; 2.0)	11.3	11.6	-0.3	(-0.5; -0.2)
D4	67869	66179	(65312; 67046)	1690	(684; 2696)	2.6	(1.2; 3.9)	10.6	10.7	-0.1	(-0.2; 0.0)
D5	63451	61232	(60400; 62064)	2219	(1251; 3187)	3.6	(2.2; 5.1)	9.9	9.9	0.0	(-0.1; 0.1)
D6	62186	58909	(58091; 59726)	3277	(2325; 4230)	5.6	(4.1; 7.0)	9.7	9.5	0.2	(0.1; 0.3)
D7	58135	54293	(53508; 55078)	3842	(2926; 4758)	7.1	(5.6; 8.6)	9.1	8.8	0.3	(0.2; 0.4)
D8	56418	53106	(52326; 53886)	3312	(2403; 4220)	6.2	(4.7; 7.8)	8.8	8.6	0.2	(0.1; 0.3)
D9	53562	50222	(49466; 50979)	3340	(2458; 4222)	6.6	(5.1; 8.3)	8.4	8.1	0.2	(0.1; 0.4)
D10 - Least Deprived	48832	44133	(43427; 44839)	4699	(3871; 5527)	10.6	(8.9; 12.4)	7.6	7.1	0.5	(0.4; 0.6)
total	640788	618470		22318		0.0		100.0	100.0	0.0	

Finland

Data

For Finland (2015-2021; n= 336,494 live births), we used individual-level data from the medical birth register and linked parental characteristics (household income, education, maternal age, parity) via population registers and aggregated the data to weekly time series (access permit: TK/1170/07.03.00/2023 and THL/6303/14.06.00/2023). Quintiles of household incomes are based on the household income distribution of women aged 15-49 and are lagged by two years before the year of birth. This lag in household income avoids that our estimated compositional change is driven by pandemic-induced change in the income distribution (due to, e.g., income losses) instead of pandemic-induced change in fertility behaviour. To protect anonymity in line with data providers' policies, we set the number of weekly births to 5 if it was below 5.

The mother's highest completed formal education was grouped into primary education, upper secondary education, bachelor's degree, and master's and Doctoral degree and was lagged by one year before birth due to data availability.

We additionally estimated compositional change along maternal age and parity.

Results

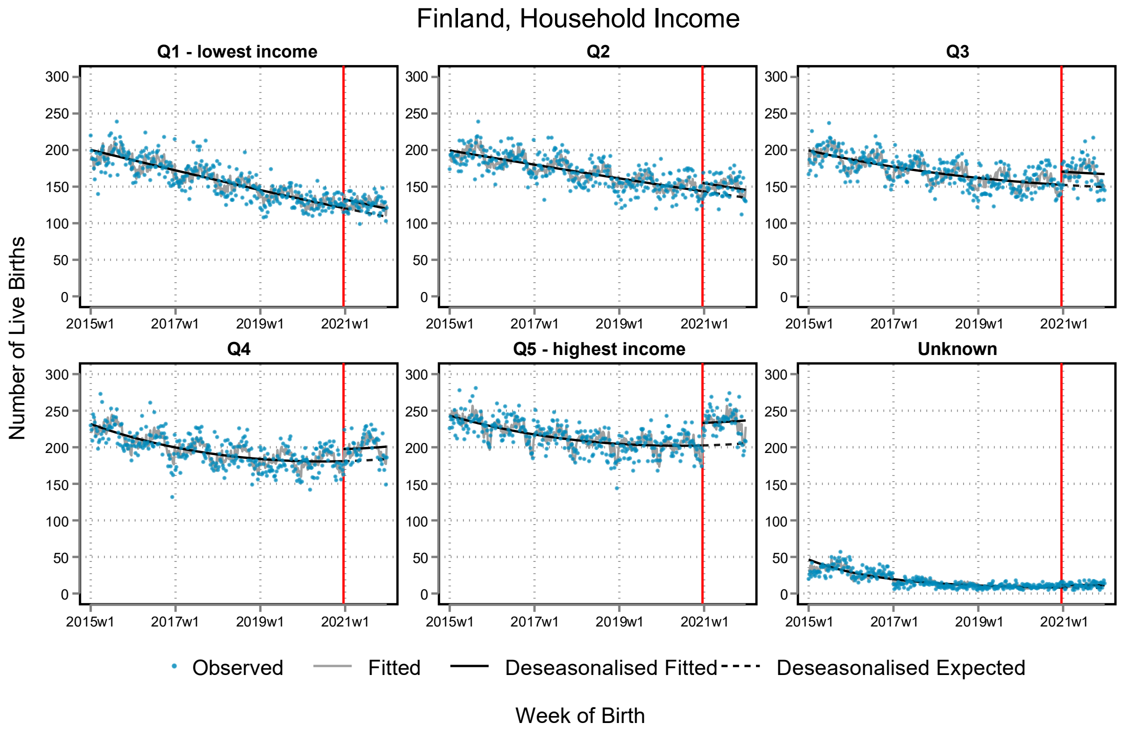


Figure S27: Observed and expected weekly number of live births in ***Finland*** *by quintile of equivalised disposable household income among women aged 15-49. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality. Weekly counts below 5 were set to 5 to protect anonymity (bottom right panel).*

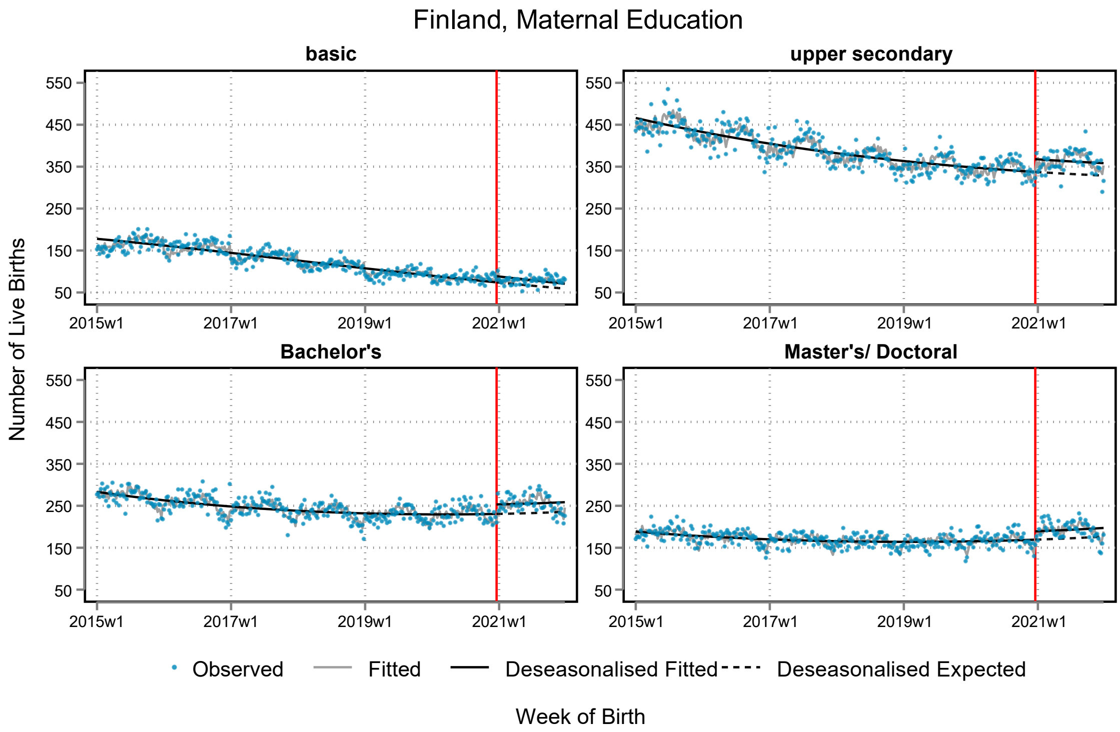


*Figure S28: Observed and expected weekly number of live births in **Finland** by formal maternal education. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality.*

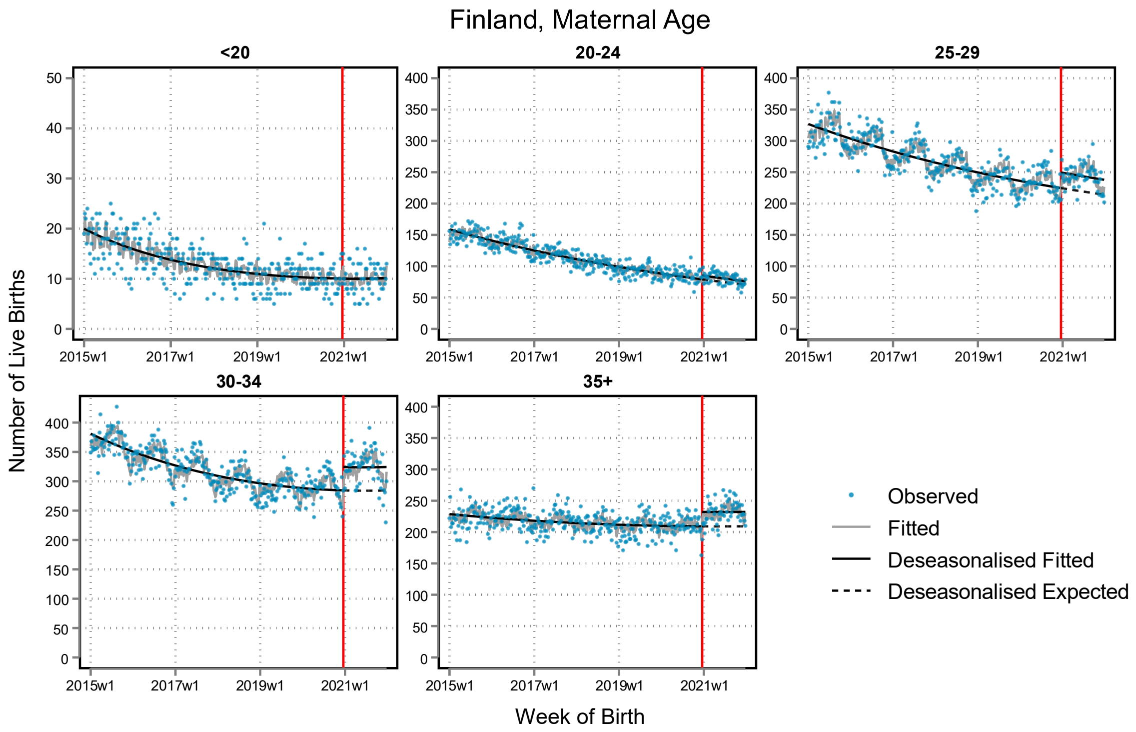


*Figure S29: Observed and expected weekly number of live births in **Finland** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality. Weekly counts below 5 were set to 5 to protect anonymity.*

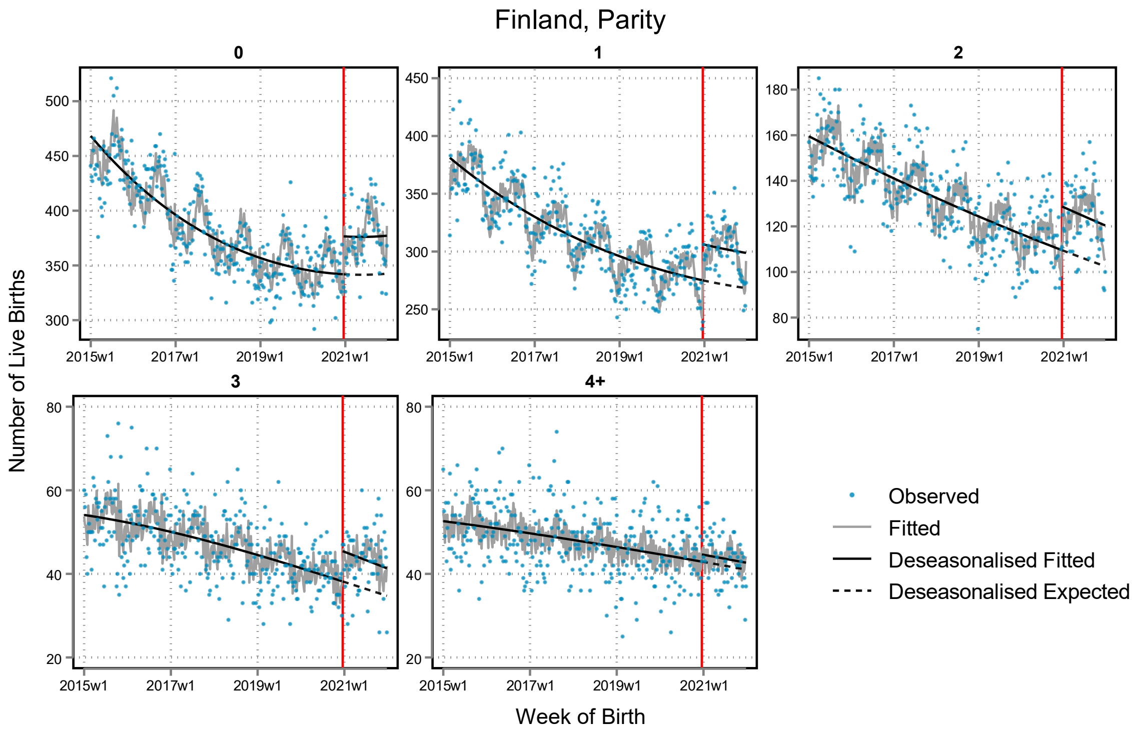


*Figure S30: Observed and expected weekly number of live births in **Finland** by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality.*

Table S6: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Finland. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal Education											
Compulsory	4298	3590	(3422; 3758)	708	(497; 919)	19.7	(14.4; 25.6)	9.0	8.3	0.7	(0.3; 1.1)
Upper Secondary	19563	17947	(17516; 18378)	1616	(1105; 2127)	9.0	(6.4; 11.7)	40.8	41.4	-0.6	(-1.4; 0.1)
Bachelor's Degree	13747	12517	(12146; 12889)	1230	(793; 1666)	9.8	(6.7; 13.2)	28.6	28.9	-0.2	(-1.0; 0.5)
Master's / Doctorate	10376	9286	(8961; 9611)	1090	(708; 1471)	11.7	(8.0; 15.8)	21.6	21.4	0.2	(-0.5; 0.9)
total	47984	43341		4643		0.1		100.0	100.0	0.0	
Maternal age											
Below 20	544	546	(471; 621)	-2	(-90; 85)	-0.4	(-12.4; 15.4)	1.1	1.3	-0.1	(-0.3; 0.0)
20-24	4352	4036	(3845; 4227)	316	(86; 546)	7.8	(3.0; 13.2)	9.1	9.4	-0.3	(-0.7; 0.1)
25-29	13119	11814	(11469; 12158)	1305	(894; 1717)	11.0	(7.9; 14.4)	27.3	27.5	-0.1	(-0.8; 0.5)
30-34	17453	15307	(14904; 15711)	2146	(1666; 2625)	14.0	(11.1; 17.1)	36.4	35.6	0.8	(-0.0; 1.5)
Above 34	12516	11278	(10926; 11629)	1238	(824; 1653)	11.0	(7.6; 14.6)	26.1	26.2	-0.2	(-0.8; 0.5)
total	47984	42981		5003		0.1		100.0	100.0	0.0	
Parity											
0	20304	18437	(17994; 18880)	1867	(1343; 2391)	10.1	(7.5; 12.8)	42.3	42.9	-0.6	(-1.4; 0.2)
1	16286	14624	(14235; 15014)	1662	(1199; 2124)	11.4	(8.5; 14.4)	33.9	34.0	-0.1	(-0.8; 0.7)
2	6694	5697	(5461; 5933)	997	(711; 1283)	17.5	(12.8; 22.6)	14.0	13.3	0.7	(0.2; 1.2)
3	2340	1967	(1829; 2104)	373	(206; 540)	19.0	(11.2; 27.9)	4.9	4.6	0.3	(-0.0; 0.6)
4 or more	2360	2269	(2116; 2423)	91	(-90; 271)	4.0	(-2.6; 11.6)	4.9	5.3	-0.4	(-0.7; -0.0)
total	47984	42994		4990		0.1		100.0	100.0	0.0	

Mexico

Data

For Mexico (2015-2021, n=13,788,132 live births), we used openly available individual-level data collected with birth certificates issued by the Civil Registry and provided through the Instituto Nactional de Estadística y Geografía (INEGI). (https://en.www.inegi.org.mx/programas/natalidad/#microdata)

Like for Ecuador, we used the most recent data (2015-2022), to include births that occurred in 2021 but were registered in 2022. Still, it is likely that these data do not capture all births that occurred in Mexico 2015-2021. However, the difference between registered and occurred births decreased slightly over the last years. While 1,616,988 out of 2,2412,558 babies born in 2015 were also registered in 2015 (the remaining births were registered 2016-2022), 1,432,072 out of 1,892,086 babies born in 2019 were also registered in 2019. With only one additional year of late registrations for the 2021 birth cohort, our number of live births for 2021 will be lower than the actual number of live births in 2021.

As mentioned for Ecuador, results will only be biased by incomplete coverage if the propensity to registration two or more years after birth is associated with parental characteristics. As late registrations will be more likely to happen in remote areas and for births outside hospitals, we believe that, if anything, our estimates for differences in socioeconomic composition will be underestimates. For example, in figure S31 and S32, we see that the number of live births remains unchanged in the exposed period for parents with elementary and primary education while there were fewer births among parents with upper secondary education. If late registration of live births was more common among lower educated parents, the difference between observed and expected number of live births would be higher and the socioeconomic composition of the December 2020 – December 2021 birth cohort therefore more disadvantaged compared with a counterfactual birth cohort than estimated.

The data collection did not allow us to form a subgroup with post-secondary or tertiary education. Parental education was collected through 8 levels: 1) no schooling, 2) 1-3 years of elementary, 3) 4-5 years of elementary, 4) completed elementary school, 5) lower secondary school, 6) upper secondary, 7) vocational upper secondary, and 8) other. According to OECD's profile of Mexico's educational system, these levels do not go beyond ISCED 3 levels (https://gpseducation.oecd.org/CountryProfile?primaryCountry=MEX&treshold=10&topic=EO). As this did not allow us to create groups similar to the other countries, our primary indicator for socioeconomic circumstances were 3 education levels: 1,2,3,4 to "elementary", level 5 as lower secondary education, levels 6,7,8 to "upper secondary".

Additionally, we estimated compositional change for highest parental education (using paternal education if maternal education was missing), maternal education in more detail, maternal age, and parity.

In Mexico, the ZIKV epidemic started and peaked in the second half of 2016.[7] If change in childbearing behaviour would respond to the number of cases, we would expect to see changes in the number of live births starting in the first half of 2017. However, like in Ecuador, using the indicator variable for an earlier period (August 2016 – December 2016) in accordance with the ZIKV epidemic in Brazil and official recommendations to postpone pregnancy in many Latin American countries, captured changes in the number of live births better. For an example, see the time series for missing information on maternal education in figure S31 (bottom right panel), where this model specification captures the increase in live births with missing information in the second half of 2016 well.

Results

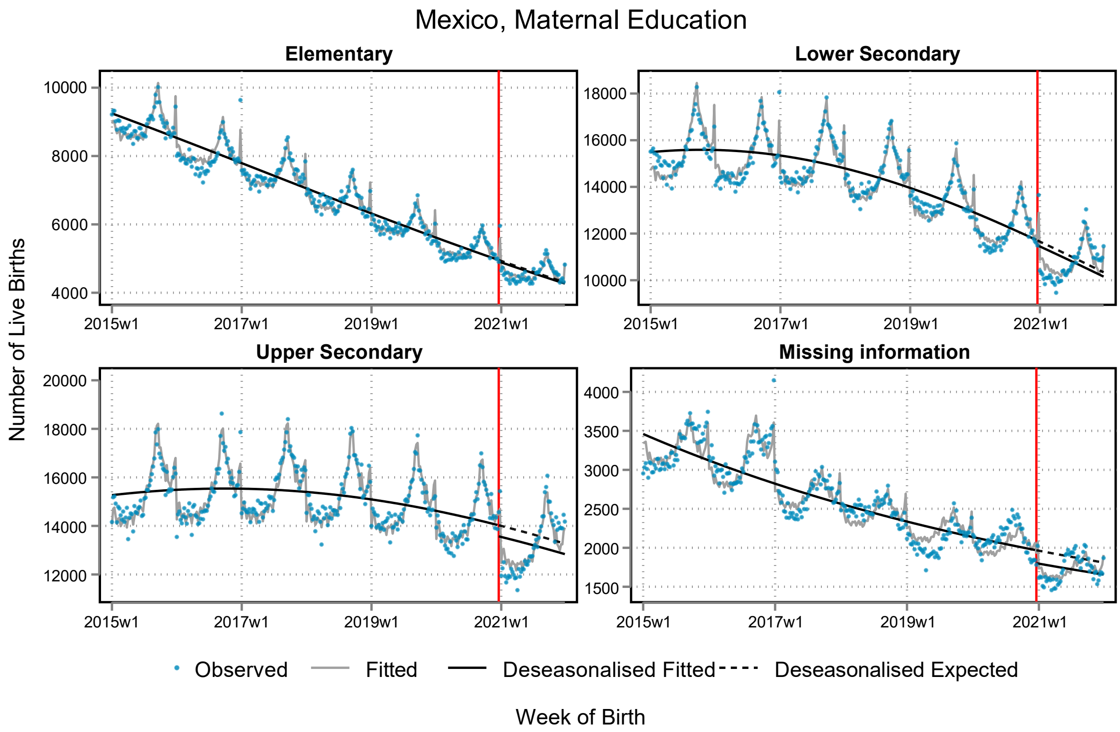


*Figure S31: Observed and expected weekly number of live births in **Mexico** by primary indicator of socioeconomic circumstances (maternal education). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December of 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

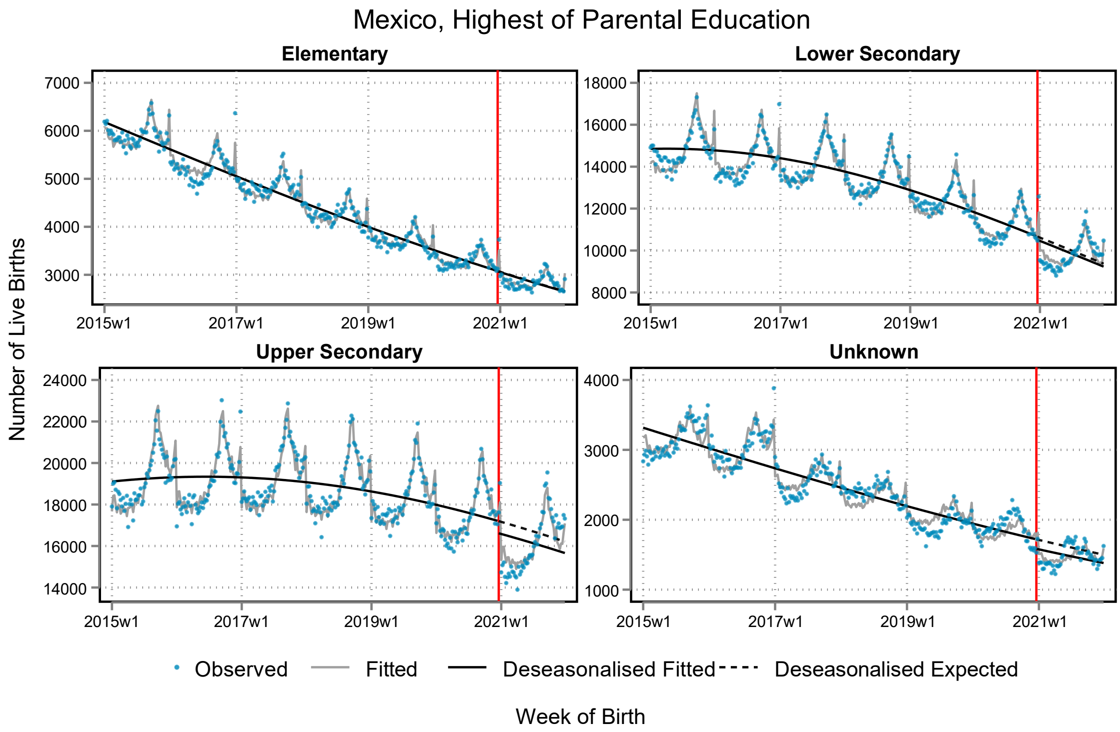


*Figure S32: Observed and expected weekly number of live births in **Mexico** paternal education. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

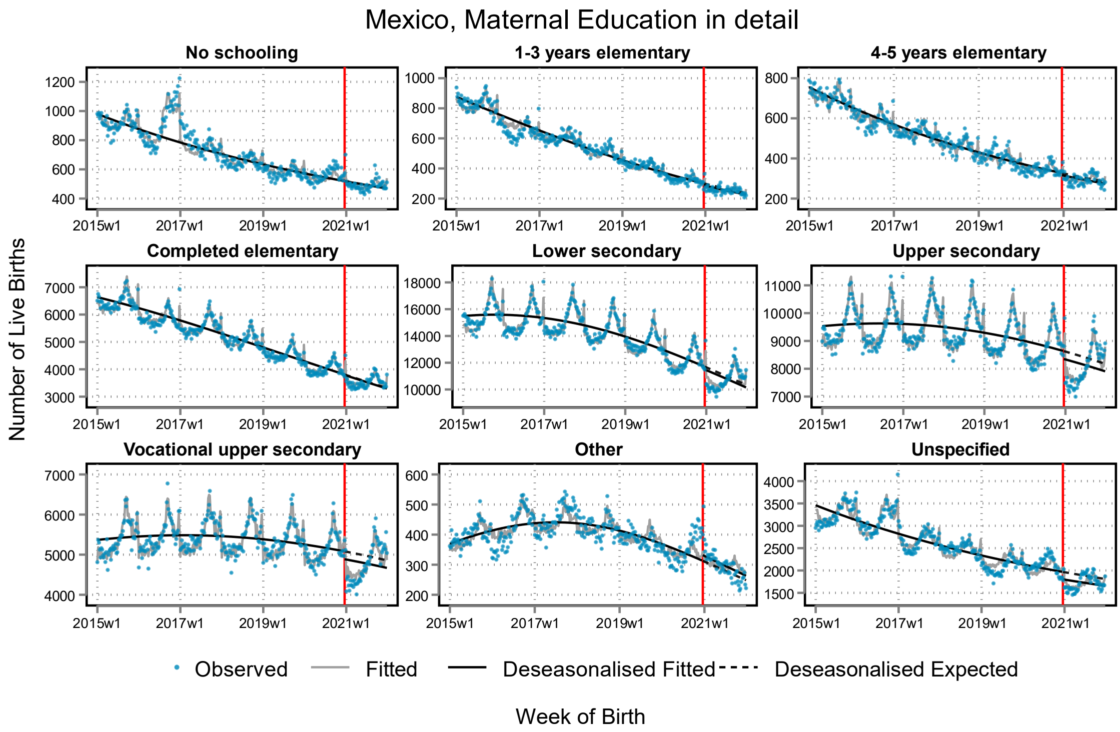


*Figure S33: Observed and expected weekly number of live births in **Mexico** by maternal education in detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

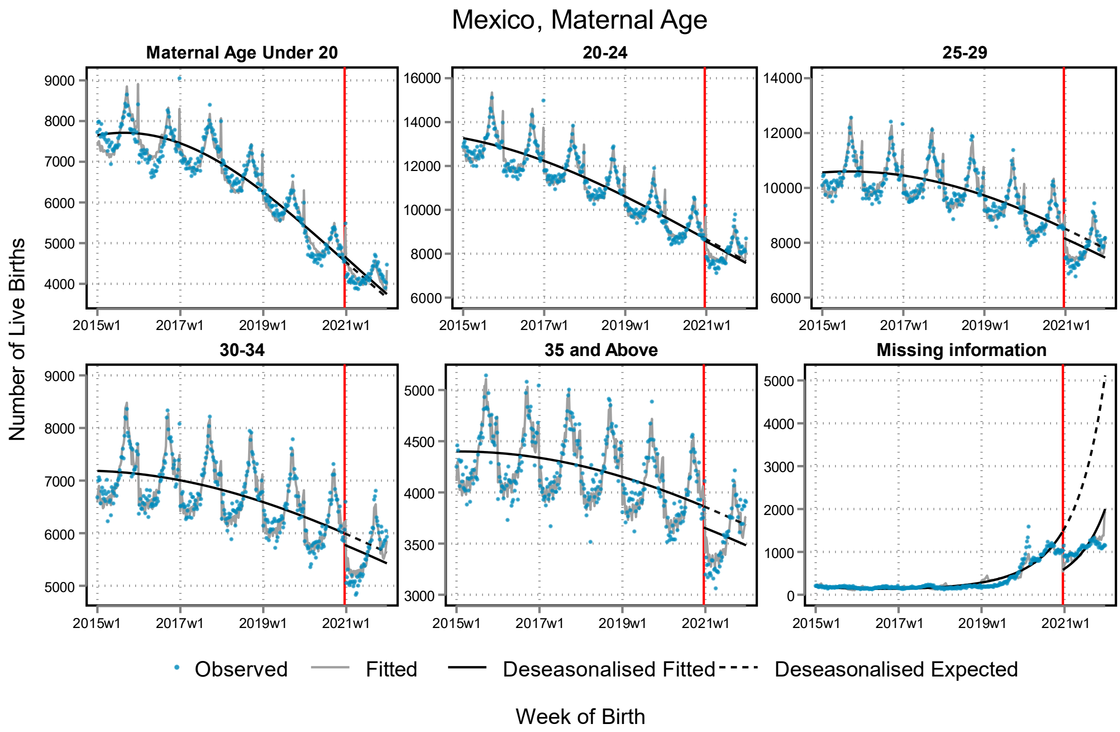


Figure S34: Observed and expected weekly number of live births in ***Mexico*** *maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

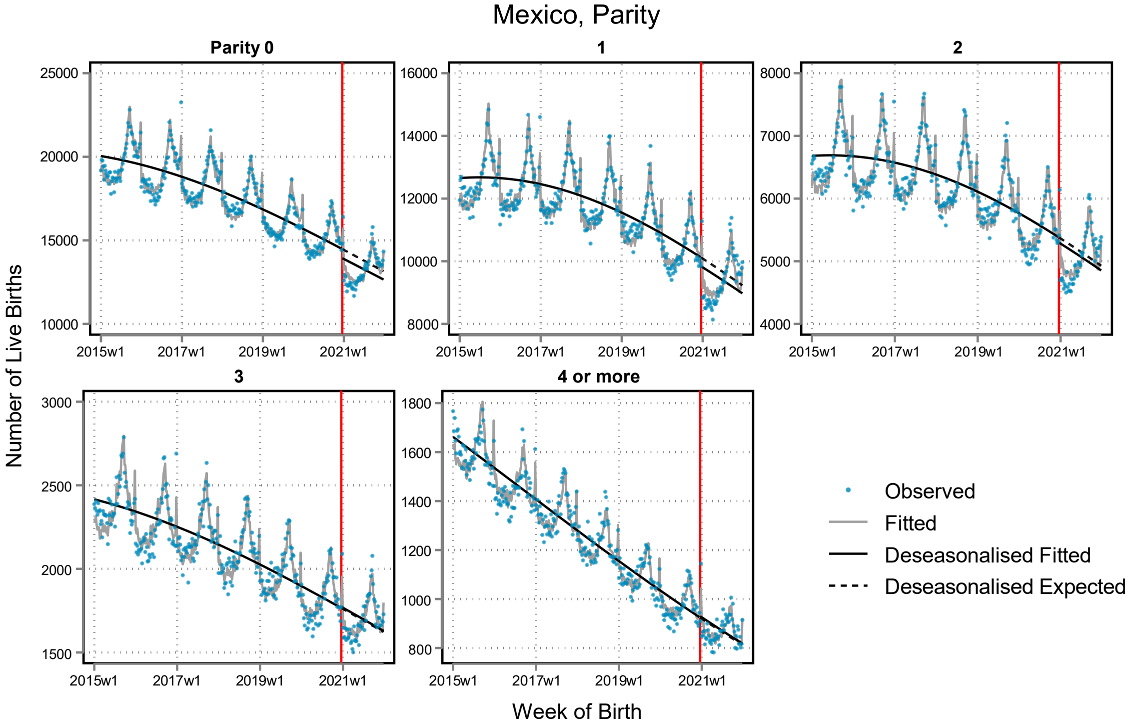


Figure S35: Observed and expected weekly number of live births in ***Mexico*** *by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting second week of December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for week of live birth to capture potential non-linearities in the secular time trends; week of the year fixed effects to account for seasonality; an indicator variable (August 2016-December 2016) to account for the 2015-2016 Zika virus epidemic.*

Table S7: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Mexico. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Highest Parental Education											
Elementary	154527	154932	(153738; 156126)	-405	(-1826; 1016)	-0.3	(-1.0; 0.5)	9.4	9.2	0.2	(0.2; 0.3)
Lower Secondary	533804	541742	(539427; 544057)	-7938	(-10660; -5216)	-1.5	(-1.9; -1.0)	32.5	32.1	0.4	(0.3; 0.5)
Upper Secondary	873804	904577	(901428; 907725)	-30773	(-34416; -27130)	-3.4	(-3.7; -3.1)	53.2	53.6	-0.4	(-0.5; -0.3)
Unknown	80189	87058	(86153; 87963)	-6869	(-7931; -5807)	-7.9	(-8.8; -6.9)	4.9	5.2	-0.3	(-0.3; -0.2)
total	1642324	1688308		-45984		0.0		100.0	100.0	0.0	
Maternal education detailed											
No Schooling	26740	26796	(26285; 27306)	-56	(-658; 547)	-0.2	(-2.1; 1.7)	1.6	1.6	0.0	(0.0; 0.1)
1-3 years elementary	13861	14458	(14118; 14797)	-597	(-1007; -186)	-4.1	(-6.3; -1.8)	0.8	0.9	0.0	(-0.0; 0.0)
4-5 years elementary	15942	16489	(16102; 16876)	-547	(-1006; -87)	-3.3	(-5.5; -1.0)	1.0	1.0	0.0	(-0.0; 0.0)
Completed Elementary	191538	192415	(191065; 193766)	-877	(-2477; 723)	-0.5	(-1.1; 0.2)	11.7	11.4	0.3	(0.2; 0.3)
Lower Secondary	585510	596123	(593680; 598567)	-10613	(-13480; -7746)	-1.8	(-2.2; -1.4)	35.7	35.3	0.3	(0.2; 0.5)
Upper Secondary	440252	455235	(452995; 457475)	-14983	(-17573; -12393)	-3.3	(-3.8; -2.8)	26.8	27.0	-0.2	(-0.3; -0.0)
Vocational Upper Secondary	258798	269171	(267435; 270907)	-10373	(-12375; -8371)	-3.9	(-4.5; -3.2)	15.8	15.9	-0.2	(-0.3; -0.1)
Other	16048	15143	(14772; 15515)	905	(458; 1351)	6.0	(3.4; 8.6)	1.0	0.9	0.1	(0.1; 0.1)
Unknown	93635	102284	(101270; 103298)	-8649	(-9828; -7471)	-8.5	(-9.4; -7.5)	5.7	6.1	-0.4	(-0.4; -0.3)
total	1642324	1688114		-45790		0.0		100.0	100.0	0.0	
Maternal age											
Below 20	227362	222072	(220675; 223469)	5290	(3609; 6971)	2.4	(1.7; 3.0)	13.8	12.5	1.3	(1.2; 1.4)
20-24	437267	442513	(440431; 444595)	-5246	(-7698; -2794)	-1.2	(-1.6; -0.7)	26.6	24.9	1.7	(1.6; 1.8)

25-29	422982	441556	(439407; 443705)	-18574	(-21073; -16076)	-4.2	(-4.7; -3.7)	25.8	24.9	0.9	(0.8; 1.0)
30-34	303145	314672	(312828; 316516)	-11527	(-13664; -9390)	-3.7	(-4.2; -3.1)	18.5	17.7	0.7	(0.6; 0.8)
Above 34	193310	204263	(202761; 205765)	-10953	(-12685; -9221)	-5.4	(-6.1; -4.7)	11.8	11.5	0.3	(0.2; 0.3)
Unknown	58258	148963	(146020; 151906)	-90705	(-93685; -87724)	-60.9	(-61.6; -60.1)	3.5	8.4	-4.8	(-5.0; -4.7)
total	1642324	1774040		-131716		-0.1		100.0	100.0	0.0	
Parity											
0	719624	747844	(745077; 750611)	-28220	(-31448; -24991)	-3.8	(-4.1; -3.4)	43.8	44.3	-0.5	(-0.6; -0.3)
1	508966	523526	(521189; 525863)	-14560	(-17283; -11836)	-2.8	(-3.2; -2.3)	31.0	31.0	0.0	(-0.1; 0.1)
2	274552	278815	(277106; 280524)	-4263	(-6257; -2270)	-1.5	(-2.1; -0.9)	16.7	16.5	0.2	(0.1; 0.3)
3	91955	91585	(90612; 92559)	370	(-771; 1510)	0.4	(-0.7; 1.5)	5.6	5.4	0.2	(0.1; 0.2)
4 or more	47227	46937	(46268; 47606)	290	(-503; 1083)	0.6	(-0.8; 2.1)	2.9	2.8	0.1	(0.1; 0.1)
total	1642324	1688707		-46383		0.0		100.0	100.0	0.0	

Netherlands

Data

For the Netherlands (2015-2021, n=1,198,205 live births), we used restricted access individual-level data from the live births registry dataset, which was linked to parental characteristics and household income records through Statistics Netherlands (CBS – Bureau voor de Statistiek) population records (project number 8552). We aggregated the data to monthly time series by household income quintile based on the population-wide equivalised household income distribution. Data on household income was drawn from the annual income of households dataset. This dataset contains information on household disposable income adjusted for household size and composition. To calculate household incomes for each reporting year, tax records and other income information up to January 1 of that year are used. For example, household incomes for the year 2020 are based on tax records and other income information up to January 1 of the year 2020. Thus, household income in 2020 cannot be affected by pandemic effects income. Household incomes of 2021, however, are affected by potential pandemic effects on household incomes. Household income was not lagged by 2 years (instead of 1) to obtain pre-pandemic household income (as done for Finland) due to a misunderstanding between collaborators. This means that the observed compositional change could be an artifact of pandemic-induced changes of the income distribution. This, however, would require a high number of households changing their pre-pandemic fifth in the household income distribution. As the results are consistent with those of other countries, we believe that the potential bias caused by this non-lagged measure of household income quintile is limited.

Apart from compositional changes in the household income composition, we analysed compositional changes regarding maternal age and between first born and higher order births.

Results

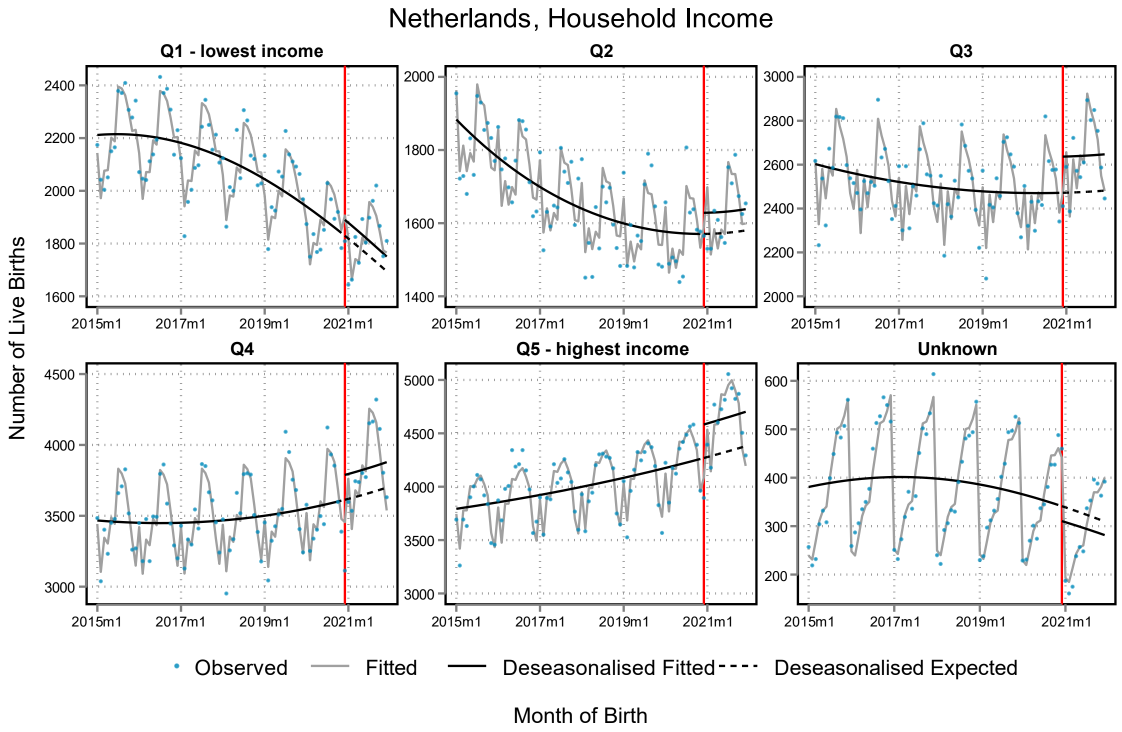


Figure S36: Observed and expected monthly number of live births in ***the Netherlands*** *by quintile of equivalised disposable household (primary socioeconomic indicator). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

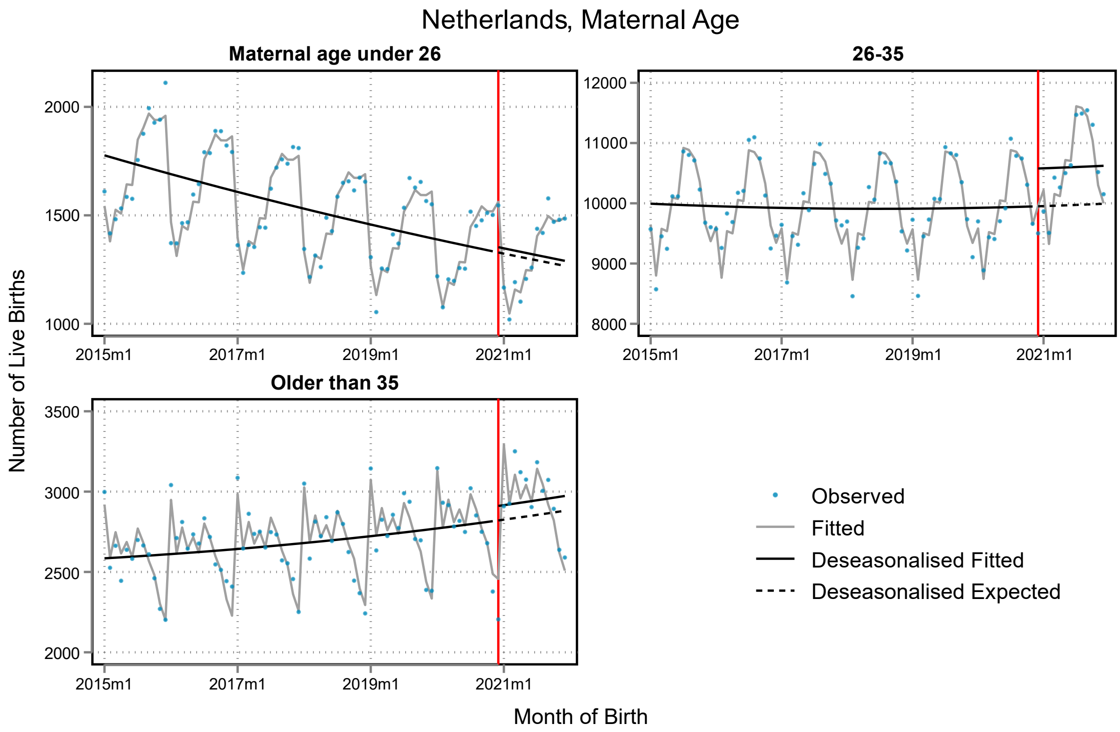


*Figure S37: Observed and expected monthly number of live births in **the Netherlands** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

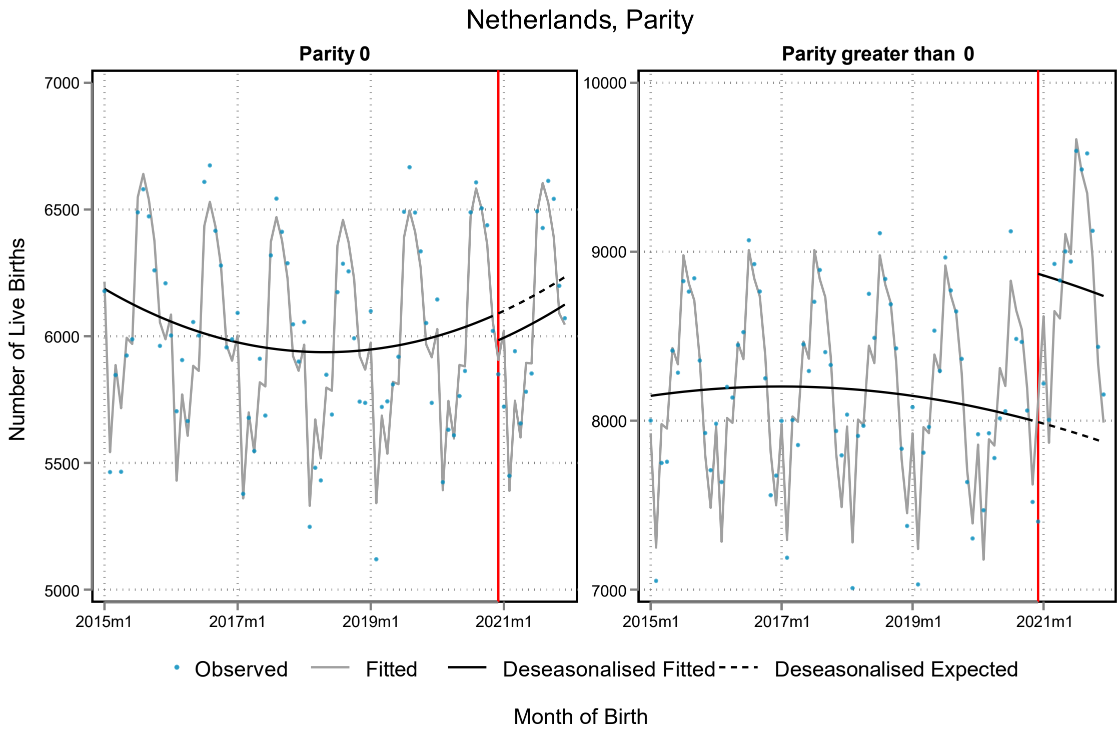


*Figure S38: Observed and expected monthly number of live births in **the Netherlands** by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S8: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in the Netherlands. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal age											
Below 26	17363	17049	(16613; 17486)	314	(-193; 821)	1.8	(-0.7; 4.5)	9.0	9.3	-0.3	(-0.5; -0.1)
26-35	137174	129036	(127792; 130279)	8138	(6699; 9578)	6.3	(5.3; 7.3)	71.3	70.6	0.7	(0.3; 1.1)
Older than 35	37772	36603	(35933; 37272)	1170	(399; 1940)	3.2	(1.3; 5.1)	19.6	20.0	-0.4	(-0.7; -0.1)
total	192309	182687		9622		0.1		100.0	100.0	0.0	
Parity											
Firstborn	78597	79988	(78996; 80980)	-1391	(-2525; -257)	-1.7	(-2.9; -0.5)	40.9	43.8	-3.0	(-3.4; -2.6)
Second or higher birth order	113712	102462	(101369; 103555)	11250	(9972; 12528)	11.0	(9.8; 12.2)	59.1	56.2	3.0	(2.6; 3.4)
total	192309	182450		9859		0.1		100.0	100.0	0.0	

Scotland

Data

For Scotland (2015-2021, n=344,134 live births), we used openly available aggregated monthly time series from the Scottish Morbidity Record 02 (SMR02) by quintiles of the Scottish Index of Multiple Deprivation 2020 (SIMD) and maternal age categories. (https://scotland.shinyapps.io/phs-covid-wider-impact/) The SMR02 covers around 99% of births registered with the National Records of Scotland.

The SIMD combines 33 indicators from 7 domains (income, employment, health, education, geographic access to services, crime, and Housing) and is measured on the data zone level. (See here for technical notes:

https://www.gov.scot/binaries/content/documents/govscot/publications/statistics/2020/09/simd-2020-technical-notes/documents/simd-2020-technical-notes/simd-2020-technical-notes/govscot%3Adocument/SIMD%2B2020%2Btechnical%2Bnotes.pdf)

There are 6,976 data zones in Scotland with an average population of 784 people. Births are allocated to a quintile of the SIMD based on their mother's residential data zone. The SIMD is created such that each quintile contains a fifth of the overall population of Scotland.

Results

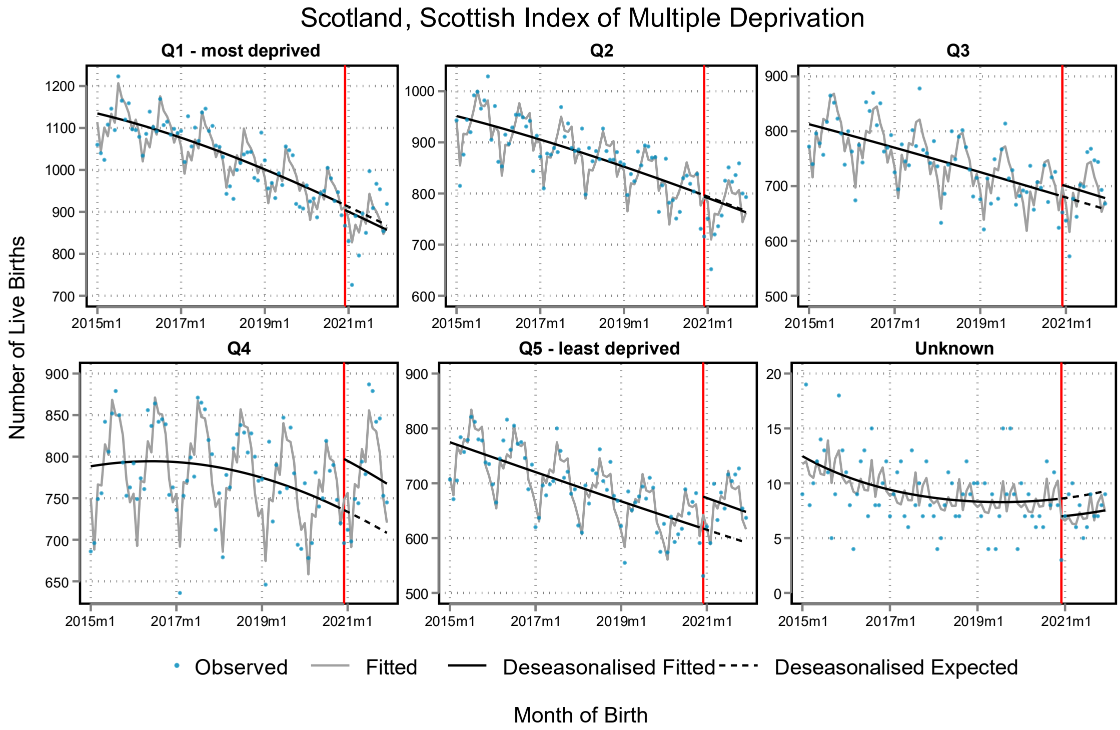


*Figure S39: Observed and expected monthly number of live births in **Scotland** by quintile of Scottish Index of Multiple Deprivation of maternal residential location (primary socioeconomic indicator). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

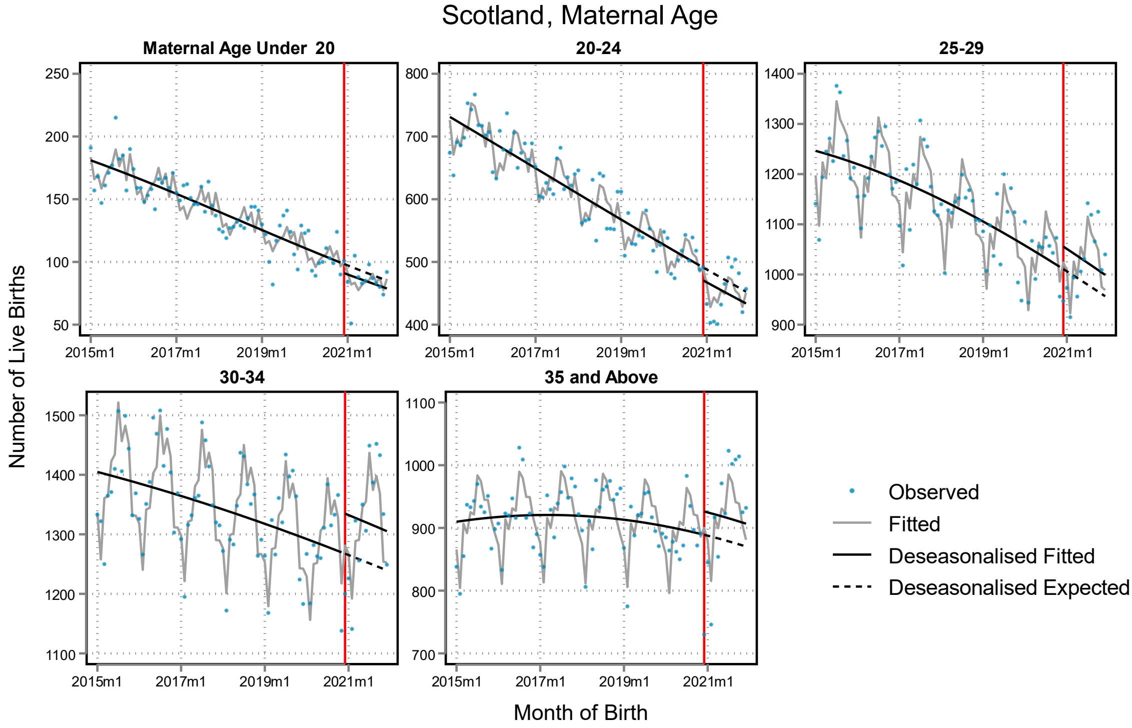


*Figure S40: Observed and expected monthly number of live births in **Scotland** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S9: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Scotland. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal age											
Below 20	1111	1200	(1092; 1308)	-89	(-215; 37)	-7.4	(-15.1; 1.7)	2.3	2.5	-0.3	(-0.5; -0.0)
20-24	5893	6150	(5895; 6405)	-257	(-553; 39)	-4.2	(-8.0; 0.0)	11.9	12.9	-0.9	(-1.4; -0.4)
25-29	13323	12756	(12381; 13131)	567	(129; 1005)	4.4	(1.5; 7.6)	27.0	26.7	0.3	(-0.4; 1.0)
30-34	17106	16244	(15811; 16676)	862	(359; 1366)	5.3	(2.6; 8.2)	34.7	34.0	0.7	(-0.1; 1.4)
Above 34	11891	11414	(11048; 11779)	477	(54; 901)	4.2	(0.9; 7.6)	24.1	23.9	0.2	(-0.5; 0.9)
total	49324	47764		1560		0.0		100.0	100.0	0.0	

Spain

Data

For Spain (2015-2021; n=2,636,143 live births), we used the openly available individual-level birth register data (collected from birth certificates) provided by the Instituto Nacional de Estadística (INE): (https://www.ine.es/dyngs/INEbase/en/operacion.htm?c=Estadistica_C&cid=1254736177007&menu=resultados&secc=1254736195443&idp=1254735573002#!tabs-1254736195443). We aggregated the data to monthly time series by maternal education, highest parental education, age, and parity. This data source covers the whole "universe" of births in Spain.

For the analysis of the socioeconomic composition of birth cohorts, we use data from 2016-2021 as data collection on parental educational changed for vital statistics from 2016 onwards. Since 2016, data on parental education is drawn from 11 different register-based data sources to improve data quality. They collect 12 different educational levels: 1) Illiterates, 2) Incomplete primary education, 3) Primary Education, 4) First stage of secondary education, 5) Second stage of secondary education with general orientation, 6) Second stage of secondary education with professional orientation, 7) Non-higher post-secondary education, 8) Vocational training, visual arts and design, and higher-level sports education and the equivalent; university degrees requiring a baccalaureate diploma, lasting two years or more, 9) University degrees of 240 ECTS credits, university graduates, own university expert or specialist qualifications and equivalent, 10) University degrees of over 240 ECTS credits, bachelor's degrees, 11) Specialities in Health Sciences for the residence system and similar, and 12) University PhD. (See page 22-24 in the documentation: https://www.ine.es/en/metodologia/t20/t2030301_en.pdf)

We assigned the CNED-A (National Classification of Education) levels 1,2,3,4 to lower secondary education or lower ("No Highschool Diploma" in Figure S41, S42); level 5,6 to upper secondary education; level 7 to 12 to post-secondary and tertiary education.

Additionally, we estimated compositional change regarding highest parental education (if maternal education was missing, we used paternal education), maternal age, and parity.

In the Spanish Vital Statistics, the educational level is only assigned to people over 25 years of age. Thus, our analysis of changes in socioeconomic composition only refers to mother aged 26 or older. Further, assignment of educational levels changed in 2018 causing an abrupt change in the level (not seasonality or trend) of the number of births between 2016-2017, and 2018-2021. To account for this jump in the time series, we included a binary variable indicating the years 2016 and 2017 in our models estimating level changes in the number of births by parental education.

For analyses regarding maternal age and parity, we used data covering 2015-2021 in line with analyses for other countries.

Results

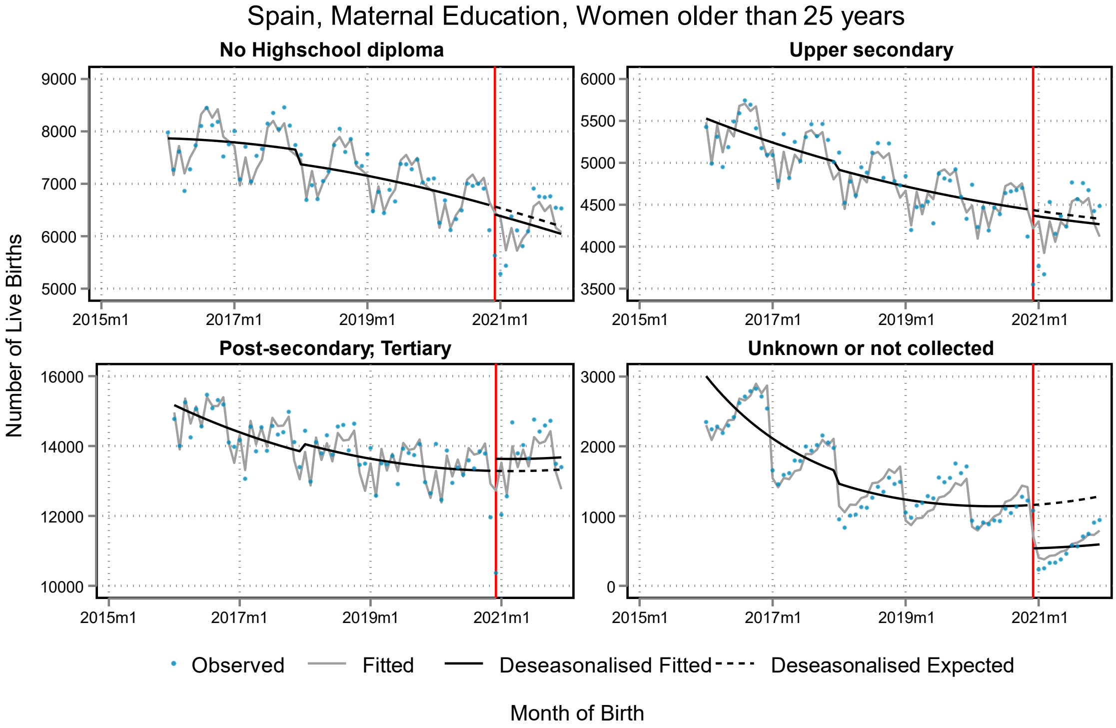


*Figure S41: Observed and expected monthly number of live births in **Spain** by maternal education (primary socioeconomic indicator). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable for 2016 and 2017 to capture changes in data collection on maternal education. Data is restricted to women older than 25 due to restricted data quality on maternal education below 26 years of age. The time series starts in 2016 because data collection on maternal education changed in 2016.*

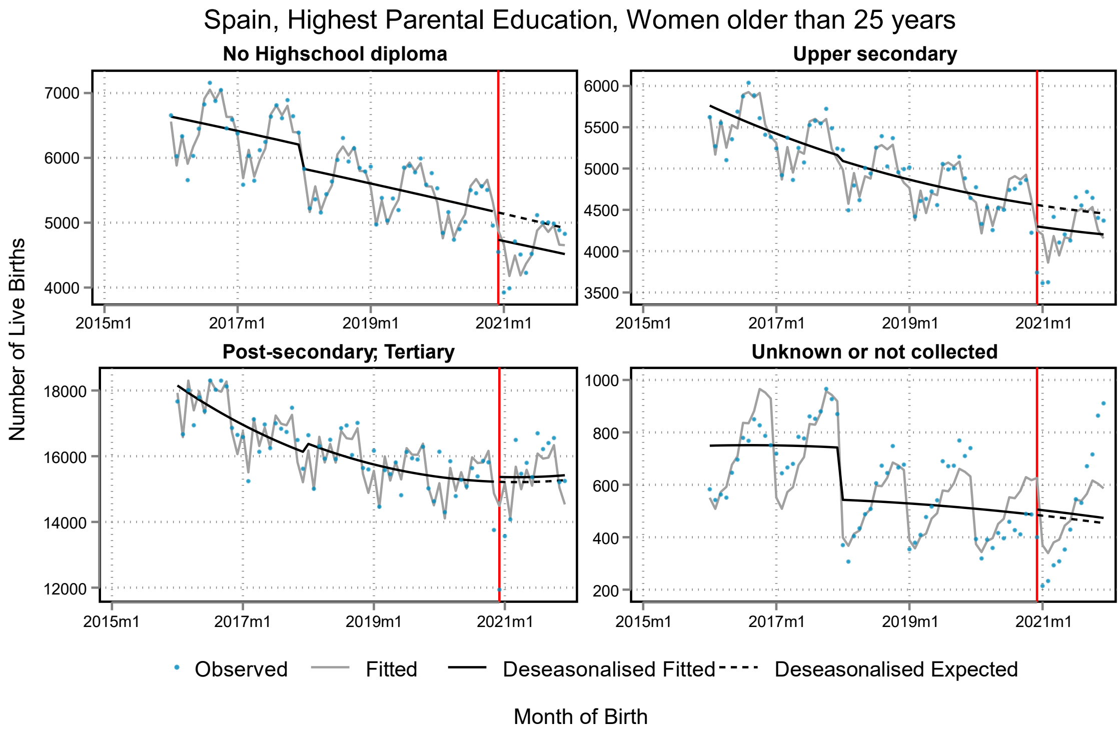


*Figure S42: Observed and expected monthly number of live births in **Spain** by highest parental education. We used father's education if maternal education was not available. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable for 2016 and 2017 to capture changes in data collection on maternal education. Data is restricted to women older than 25 due to restricted data quality on maternal education below 26 years of age. The time series starts in 2016 because data collection on maternal education changed in 2016.*

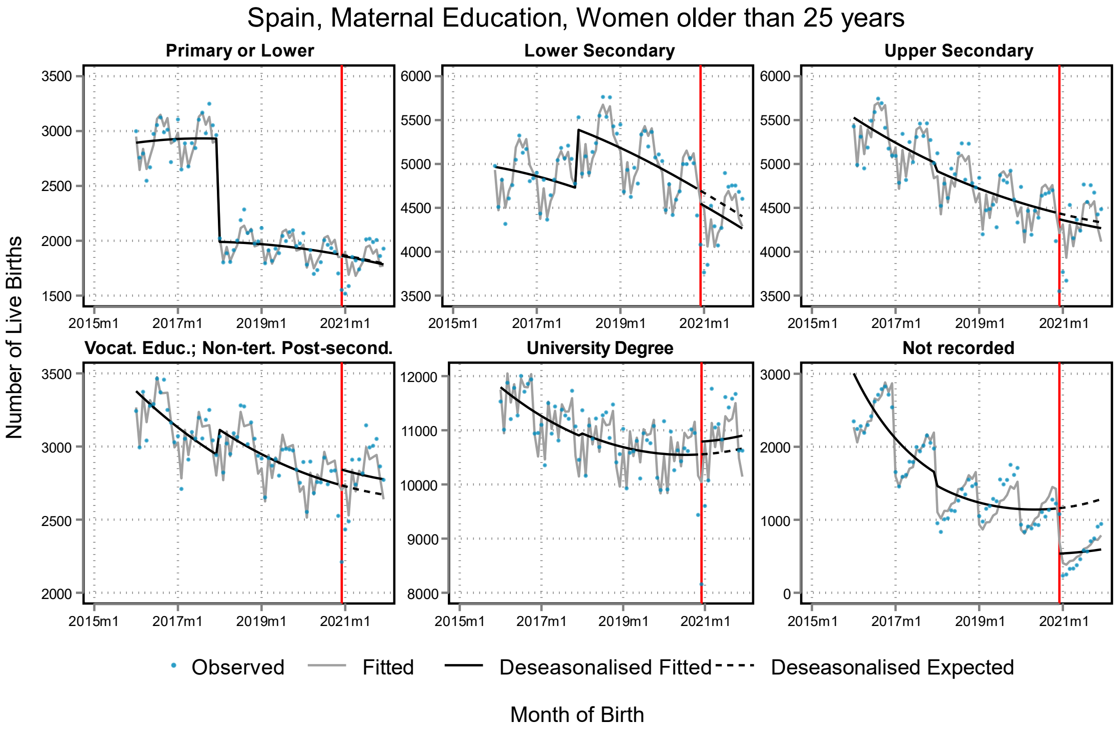


*Figure S43: Observed and expected monthly number of live births in **Spain** by maternal in detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality; an indicator variable for 2016 and 2017 to capture changes in data collection on maternal education. Data is restricted to women older than 25 due to restricted data quality on maternal education below 26 years of age. The time series starts in 2016 because data collection on maternal education changed in 2016.*

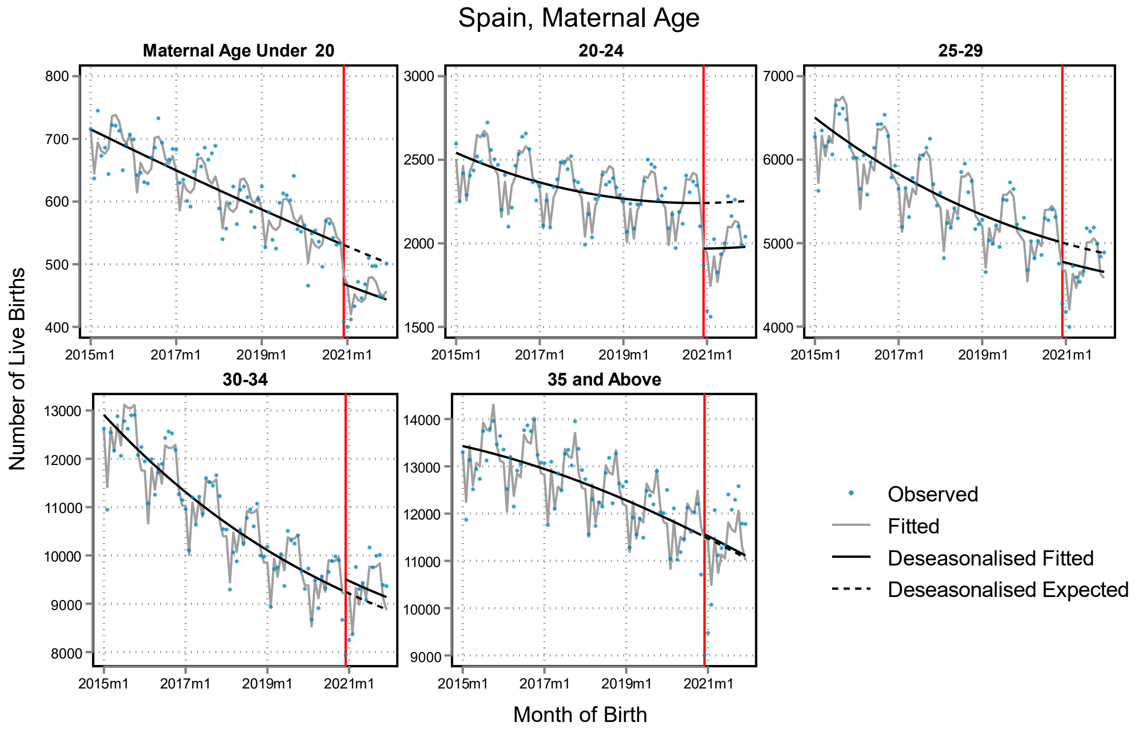


Figure S44: Observed and expected monthly number of live births in ***Spain*** *by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

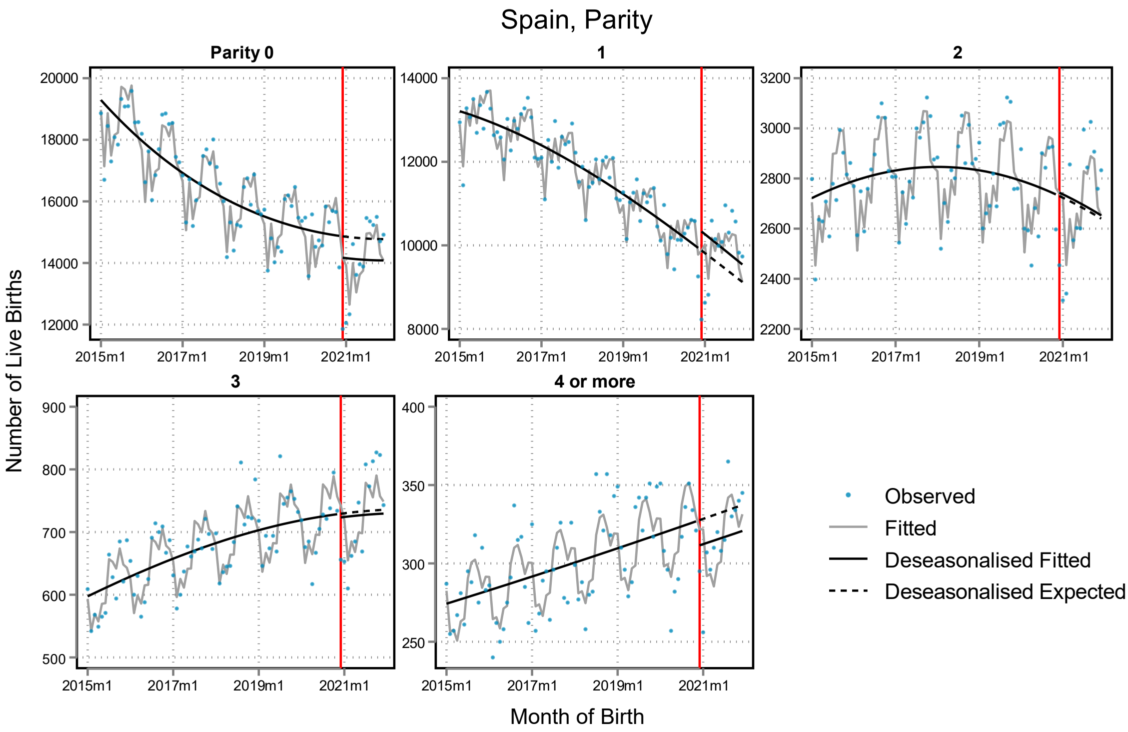


*Figure S45: Observed and expected monthly number of live births in **Spain** by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S10: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Spain. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/ less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Maternal education detailed											
Primary or Lower	23708	23813	(23223; 24403)	-105	(-768; 558)	-0.4	(-2.8; 2.1)	7.4	7.3	0.1	(-0.1; 0.3)
Lower Secondary	57285	59152	(58213; 60090)	-1867	(-2915; -818)	-3.2	(-4.7; -1.6)	17.8	18.0	-0.2	(-0.4; 0.1)
Upper Secondary	55956	56812	(55886; 57738)	-856	(-1892; 179)	-1.5	(-3.1; 0.1)	17.4	17.3	0.1	(-0.1; 0.4)
Vocational Education; Non-Tertiary Postsecondary	36343	34968	(34244; 35691)	1375	(561; 2190)	3.9	(1.8; 6.1)	11.3	10.7	0.7	(0.5; 0.9)
University Degree	140132	137070	(135605; 138536)	3062	(1423; 4700)	2.2	(1.2; 3.3)	43.7	41.8	1.9	(1.5; 2.2)
Unknown	7507	16213	(15684; 16743)	-8706	(-9262; -8150)	-53.7	(-55.2; -52.1)	2.3	4.9	-2.6	(-2.8; -2.4)
total	320931	328028		-7097		0.0		100.0	100.0	0.0	
Highest Parental Education											
No Highschool Diploma	60253	65610	(64621; 66600)	-5357	(-6457; -4257)	-8.2	(-9.5; -6.8)	18.8	20.0	-1.3	(-1.5; -1.0)
Upper Secondary	55173	58507	(57565; 59450)	-3334	(-4383; -2286)	-5.7	(-7.2; -4.2)	17.2	17.9	-0.7	(-0.9; -0.4)
Post-secondary; Tertiary	199037	197096	(195350; 198842)	1941	(-12; 3894)	1.0	(0.1; 1.9)	62.0	60.2	1.8	(1.5; 2.2)
Unknown	6468	6201	(5901; 6502)	267	(-73; 606)	4.3	(-0.5; 9.6)	2.0	1.9	0.1	(0.0; 0.2)
total	320931	327415		-6484		0.0		100.0	100.0	0.0	
Maternal age											
Below 20	5940	6730	(6457; 7003)	-790	(-1102; -478)	-11.7	(-15.2; -8.0)	1.6	1.8	-0.2	(-0.3; -0.1)
20-24	25650	29199	(28608; 29791)	-3549	(-4219; -2879)	-12.2	(-13.9; -10.3)	7.1	8.0	-0.9	(-1.1; -0.8)
25-29	61191	64132	(63280; 64984)	-2941	(-3922; -1961)	-4.6	(-5.8; -3.3)	17.0	17.6	-0.7	(-0.9; -0.4)
30-34	120804	117473	(116337; 118608)	3331	(2008; 4655)	2.8	(1.9; 3.8)	33.5	32.3	1.2	(1.0; 1.5)
Above 34	147285	146615	(145327; 147902)	670	(-821; 2161)	0.5	(-0.4; 1.3)	40.8	40.3	0.6	(0.3; 0.8)

total	360870	364149		-3279		0.0		100.0	100.0	0.0	
Parity											
0	183488	192491	(191000; 193982)	-9003	(-10714; -7292)	-4.7	(-5.4; -3.9)	50.8	52.8	-2.0	(-2.3; -1.7)
1	128705	123052	(121910; 124193)	5653	(4312; 6994)	4.6	(3.6; 5.6)	35.7	33.8	1.9	(1.6; 2.1)
2	35087	34916	(34278; 35554)	171	(-565; 907)	0.5	(-1.3; 2.4)	9.7	9.6	0.1	(-0.0; 0.3)
3	9469	9546	(9200; 9892)	-77	(-472; 318)	-0.8	(-4.3; 2.9)	2.6	2.6	0.0	(-0.1; 0.1)
4 or more	4121	4334	(4098; 4569)	-213	(-480; 54)	-4.9	(-9.8; 0.6)	1.1	1.2	0.0	(-0.1; 0.0)
total	360870	364339		-3469		0.0		100.0	100.0	0.0	

United States

Data

For the US (2015-2021; n=26,597,063 live births), we used openly available aggregated time series data on the number of monthly births by maternal and paternal education, age, and parity requested through the Centers for Disease Control and Prevention WONDER portal (https://wonder.cdc.gov/natality.html) that provides access to the Natality online databases. The data is generated by birth certificates and capture births occurring in the United States from US residents.

Since 2016, all reporting areas are using the 2003 US Standard Certification of Live Birth (see data description: https://wonder.cdc.gov/wonder/help/natality-expanded.html). Thus, our time series data for maternal and paternal education are covering 2016-2021. Parental education is assigned to 8 levels: 1) 8th grade or less, 2) 9th through 12th grade with no diploma, 3) high school graduate or GED completed, 4) some college credit, but no degree, 5) associate degree (AA, AS), 6) Bachelor's degree (BA, AB, BS), 7) Master's degree (MA, MS), 8) Doctorate (PhD, EdD) or professional degree (MD, DDS, DVM, LLB, JD). We grouped levels 1,2, to "No Highschool Diploma", levels 3,4 to "Upper Secondary", and levels 5-8 to "post-secondary and tertiary education".

We analysed change in socioeconomic composition regarding maternal and paternal education. In addition, we provide results for more detailed measures of maternal education, maternal age, and parity. Analyses regarding maternal age and parity are using data covering 2015-2021.

Results

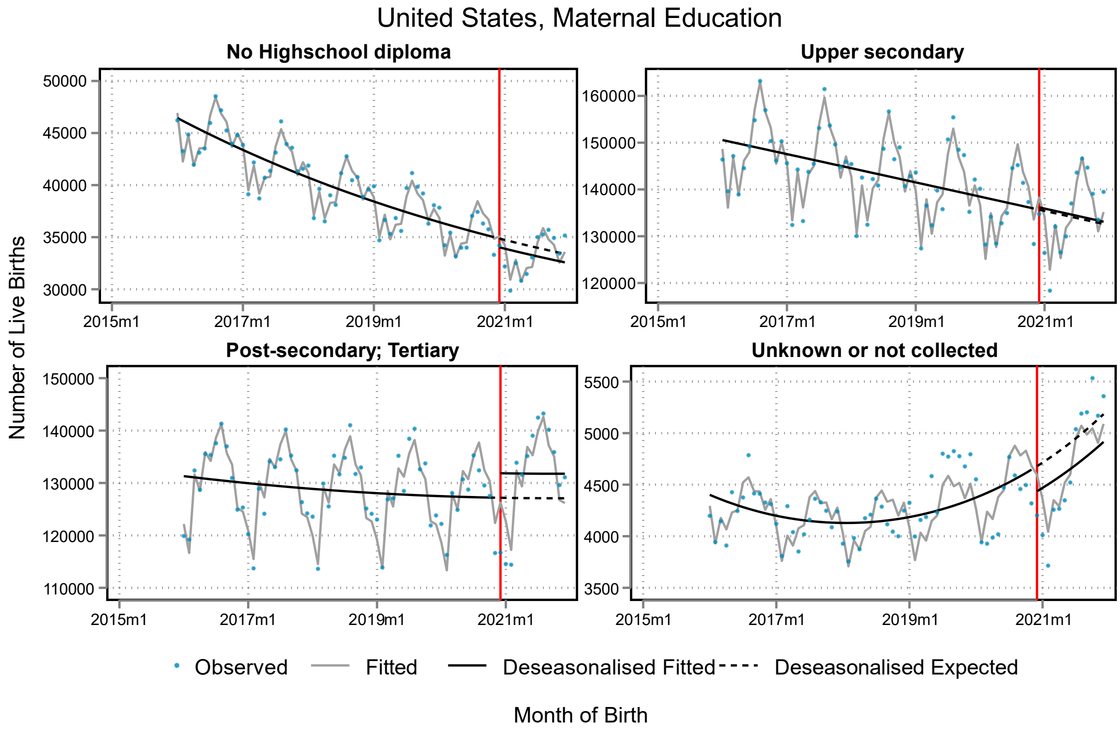


Figure S46: Observed and expected monthly number of live births in ***the United States*** *by maternal education (primary socioeconomic indicator). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality. Time series is restricted to 2016-2021 as birth certificates were not standardised regarding education across all states before 2016.*

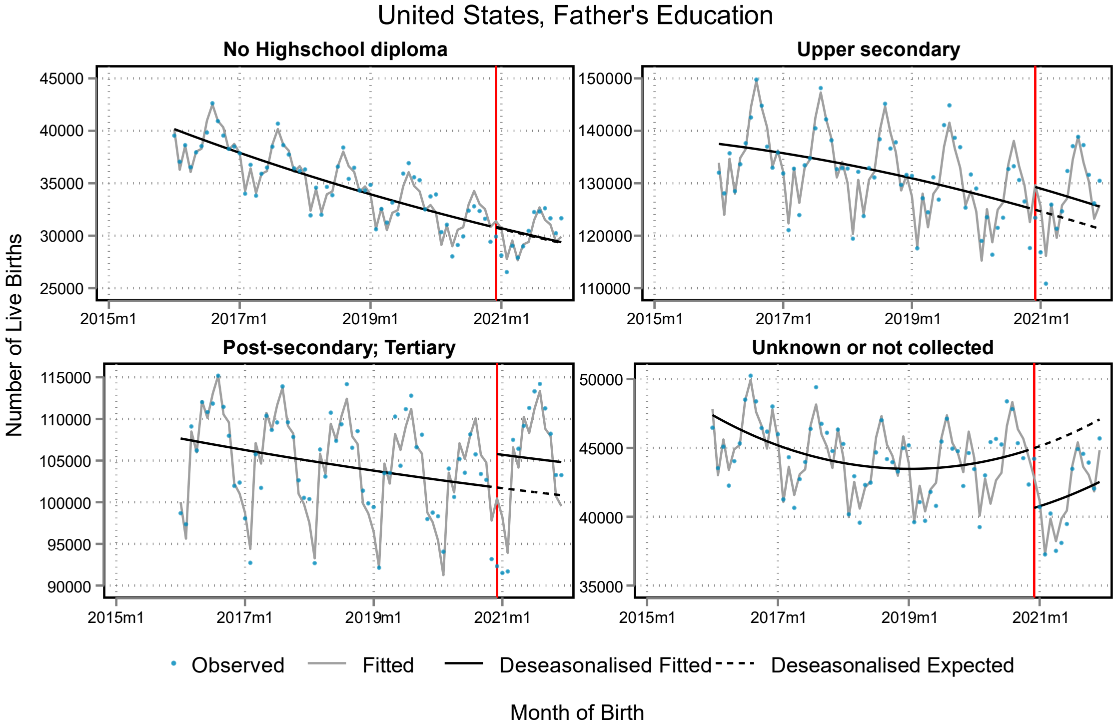
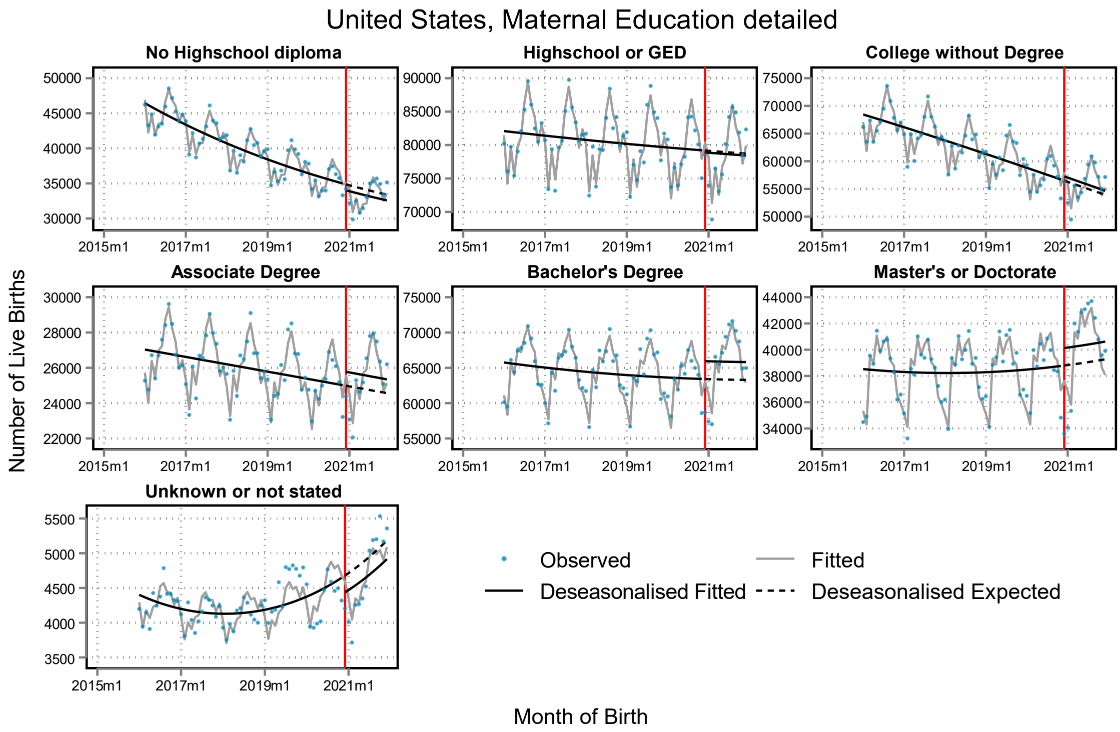


*Figure S47: Observed and expected monthly number of live births in **the United States** by paternal education in detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality. Time series is restricted to 2016-2021 as birth certificates were not standardised regarding education across all states before 2016.*



*FigureS48: Observed and expected monthly number of live births in **the United States** by maternal education in detail. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality. Time series is restricted to 2016-2021 as birth certificates were not standardised across all states before 2016 regarding education.*

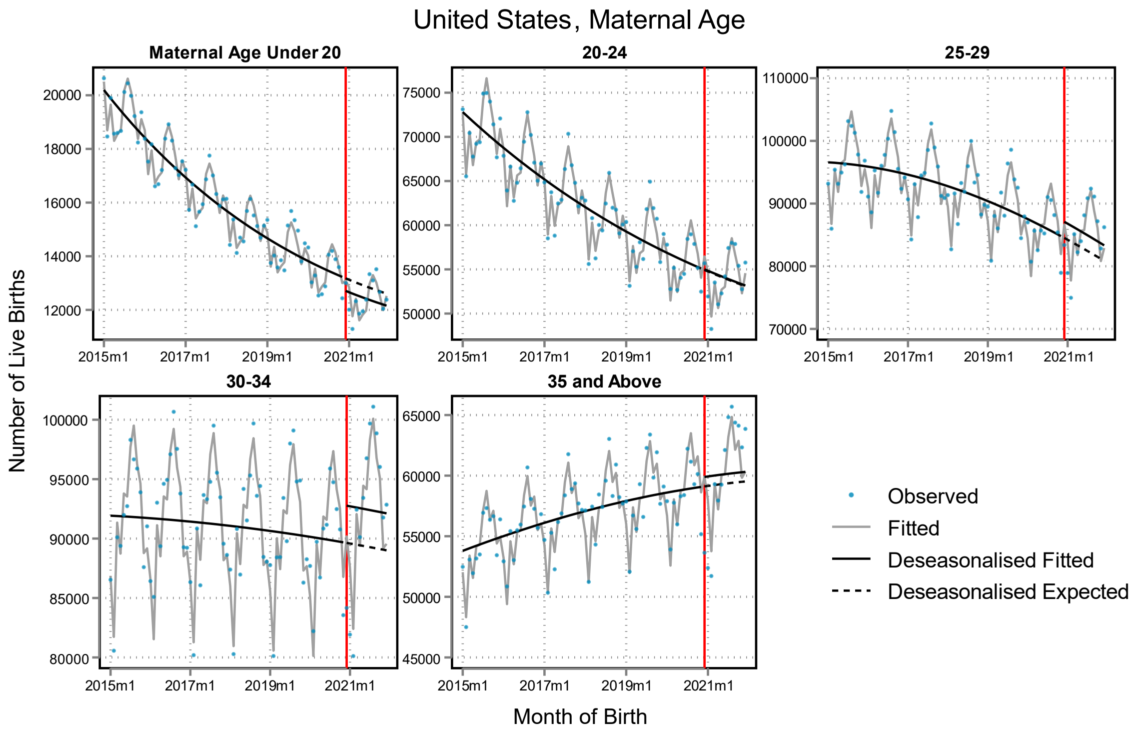


*Figure S49: Observed and expected monthly number of live births in **the United States** by maternal age. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

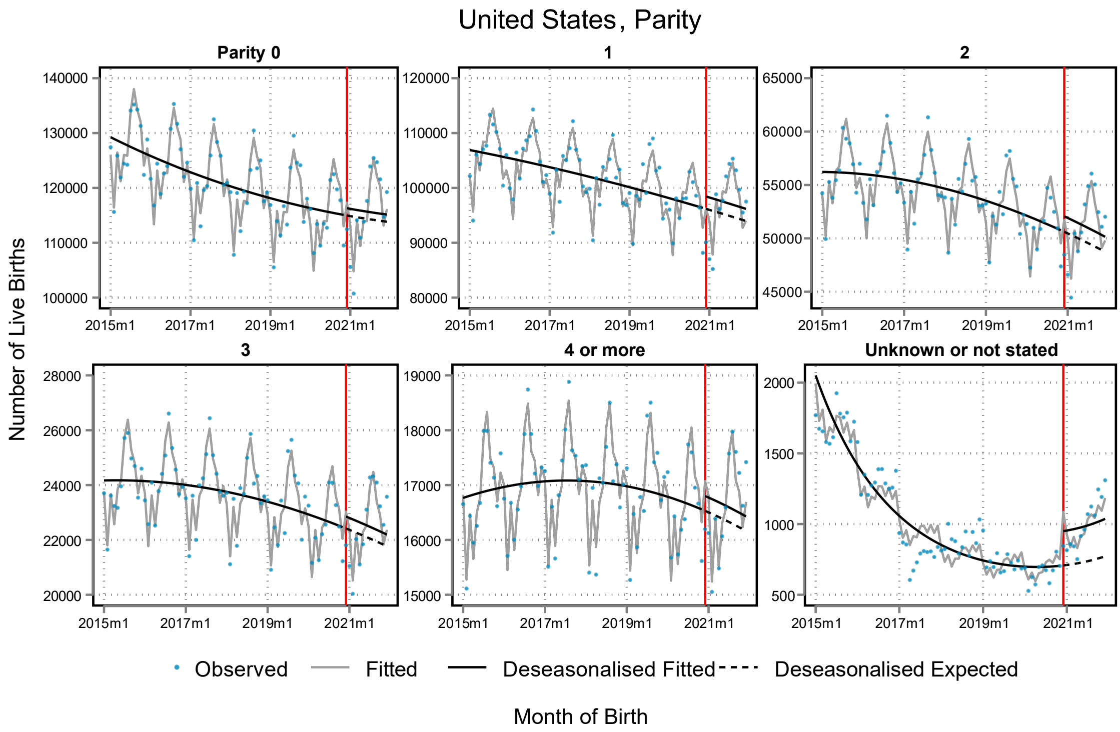


*Figure S50: Observed and expected monthly number of live births in **the United States** by parity. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S11: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in the United States. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Paternal Education											
Primary or Lower Secondary	391727	390712	(388345; 393080)	1015	(-1652; 3681)	0.3	(-0.3; 0.9)	9.9	10.0	-0.1	(-0.2; -0.0)
Upper Secondary	1656827	1601082	(1596193; 1605971)	55745	(50244; 61246)	3.5	(3.2; 3.8)	41.9	41.0	0.9	(0.8; 1.0)
Post-secondary; Tertiary	1363477	1311741	(1307268; 1316213)	51737	(46712; 56761)	3.9	(3.6; 4.3)	34.5	33.6	0.9	(0.8; 1.0)
Unknown	542139	600088	(596954; 603222)	-57949	(-61399; -54498)	-9.7	(-10.1; -9.2)	13.7	15.4	-1.7	(-1.7; -1.6)
total	3954170	3903623		50548		0.0		100.0	100.0	0.0	
Maternal Education in Detail											
No Highschool Diploma	433594	444395	(441864; 446927)	-10801	(-13643; -7960)	-2.4	(-3.0; -1.9)	11.0	11.4	-0.4	(-0.5; -0.4)
Highschool or GED	1024110	1027800	(1023814; 1031787)	-3690	(-8143; 762)	-0.4	(-0.7; 0.0)	25.9	26.3	-0.4	(-0.5; -0.4)
College without Degree	727975	718146	(714915; 721376)	9829	(6192; 13467)	1.4	(0.9; 1.8)	18.4	18.4	0.0	(-0.1; 0.1)
Associate Degree	332040	321848	(319640; 324056)	10192	(7712; 12672)	3.2	(2.5; 3.9)	8.4	8.2	0.1	(0.1; 0.2)
Bachelor's Degree	853424	820678	(817123; 824233)	32746	(28756; 36735)	4.0	(3.5; 4.4)	21.6	21.0	0.5	(0.5; 0.6)
Master's or Doctorate	522217	504846	(502031; 507662)	17371	(14219; 20522)	3.4	(2.9; 4.0)	13.2	12.9	0.3	(0.2; 0.3)
Unknown	60810	64144	(63088; 65199)	-3334	(-4495; -2172)	-5.2	(-6.7; -3.6)	1.5	1.6	-0.1	(-0.1; -0.1)
total	3954170	3901857		52313		0.0		100.0	100.0	0.0	
Maternal age											
Below 20	161848	167798	(166447; 169149)	-5950	(-7514; -4385)	-3.5	(-4.3; -2.8)	4.1	4.3	-0.2	(-0.3; -0.2)
20-24	704171	703197	(700390; 706004)	974	(-2280; 4227)	0.1	(-0.3; 0.5)	17.8	18.1	-0.3	(-0.4; -0.3)
25-29	1107375	1074653	(1071169; 1078138)	32722	(28672; 36771)	3.0	(2.7; 3.4)	28.0	27.7	0.3	(0.2; 0.4)
30-34	1199221	1158734	(1155023; 1162444)	40487	(36201; 44774)	3.5	(3.2; 3.8)	30.3	29.9	0.4	(0.3; 0.5)
Above 34	781555	771327	(768247; 774408)	10228	(6693; 13762)	1.3	(0.9; 1.7)	19.8	19.9	-0.1	(-0.2; -0.1)

total	3954170	3875709		78461		0.0		100.0	100.0	0.0	
Parity											
0	1504918	1487844	(1483665; 1492022)	17075	(12254; 21895)	1.1	(0.9; 1.4)	38.1	38.4	-0.3	(-0.4; -0.2)
1	1262823	1233806	(1230027; 1237584)	29017	(24644; 33391)	2.4	(2.0; 2.7)	31.9	31.8	0.1	(0.0; 0.2)
2	664089	645530	(642815; 648245)	18559	(15409; 21709)	2.9	(2.4; 3.3)	16.8	16.6	0.1	(0.1; 0.2)
3	293024	287445	(285620; 289269)	5579	(3469; 7690)	1.9	(1.3; 2.6)	7.4	7.4	0.0	(-0.0; 0.0)
4 or more	216324	212833	(211250; 214416)	3491	(1664; 5318)	1.6	(0.9; 2.4)	5.5	5.5	0.0	(-0.1; 0.0)
Unknown	12992	9675	(9347; 10002)	3317	(2921; 3714)	34.3	(29.9; 39.0)	0.3	0.2	0.1	(0.1; 0.1)
total	3954170	3877132		77038		0.0		100.0	100.0	0.0	

Wales

Data

For Wales (2015-2021; n=216,797 live births), we purchased monthly time series (2015-2022) of the number of live births by deciles of the Index for Multiple Deprivation (IMD) from the Office for National Statistics. These data are now openly available due to our purchase.

(https://www.ons.gov.uk/peoplepopulationandcommunity/birthsdeathsandmarriages/livebirths/adhocs/1703livebirthsbymonthofoccurrenceandimddecileenglandandwales2015to2022)

These data are considered to cover 100% of live births and there are only a low number of late registrations which, for 2021, are already captured in our data.

The IMD is created for Lower Super Output Areas (LSOAs) of mothers' residence. IMD deciles for 2015 are based on 2015 census data and IMD deciles for 2016-2022 are based on 2019 census data.

We use quintiles of the IMD as primary indicator of socioeconomic circumstances but show results also for deciles.

Results

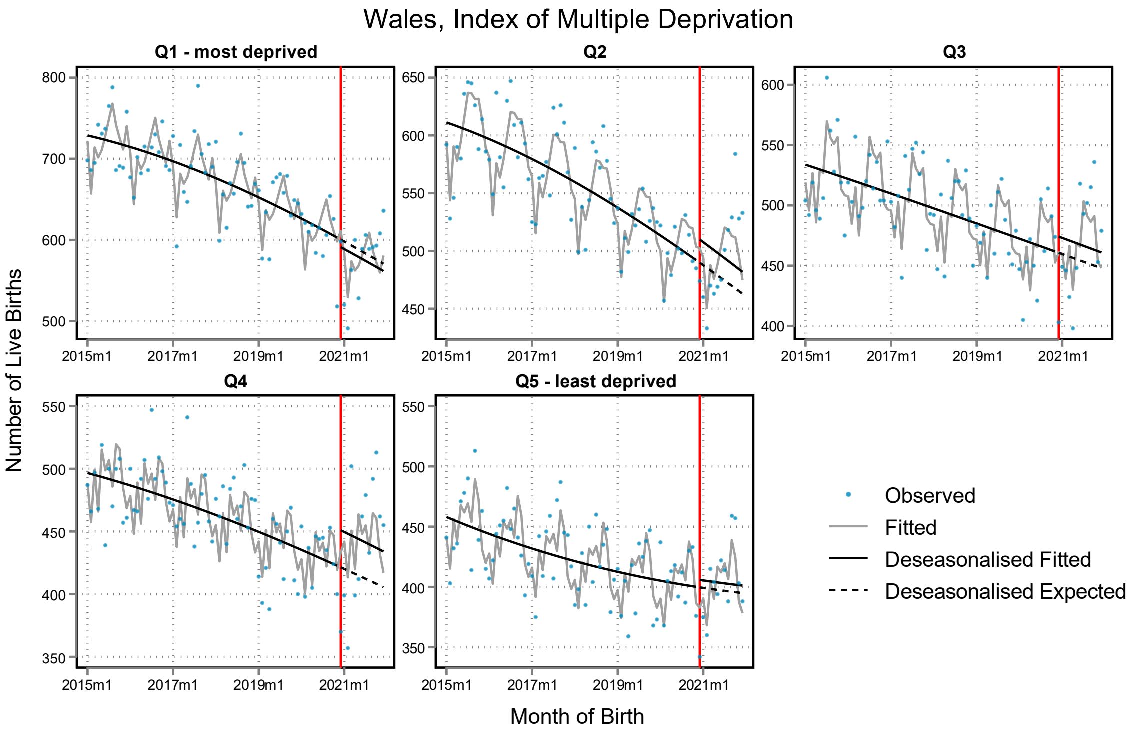


*Figure S51: Observed and expected monthly number of live births in **Wales** by primary indicator of socioeconomic circumstances (area deprivation in Lower Super Output Areas of maternal residence). Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

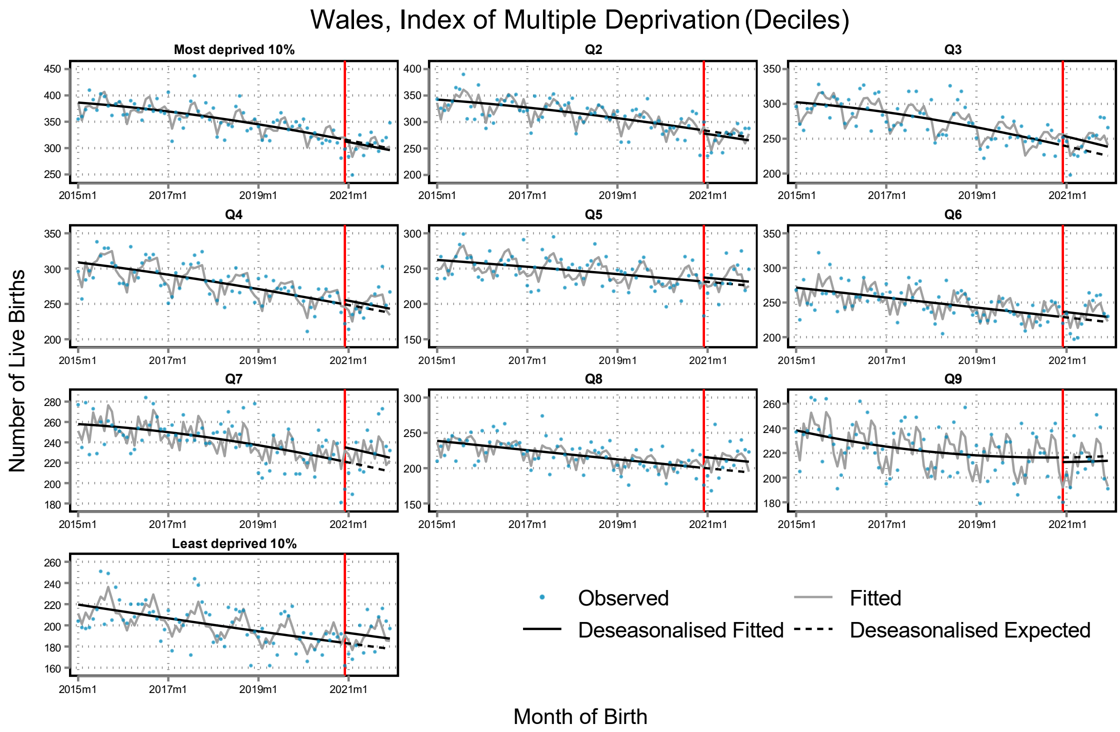


Figure S52: Observed and expected monthly number of live births in ***Wales*** *by decile of the Index of Multiple Deprivation of Lower Super Output Area of maternal residential location. Expected numbers are estimated by subgroup-specific Poisson regression modes on the full time series including an indicator variable for the exposed period (starting December 2020 to December 2021) to estimate the average effect of the COVID-19 pandemic over the entire period; a linear and a quadratic term for month of live birth to capture potential non-linearities in the secular time trends; month of the year fixed effects to account for seasonality.*

Table S12: Relative and Percentage Point Differences in the Composition of the December 2020 – December 2021 Birth Cohort in Wales. "Observed" is abbreviated by "OBS" and "Counterfactual" is abbreviated by "CF". Statistical methods for the estimations are described in the main manuscript.

Characteristic	Observed (OBS) Births	Counterfactual (CF) Births	95%CI: CF Births	OBS - CF Births	95%CI: OBS - CF Births	% more/less than CF	95%CI: % more/less than CF	OBS proportion	CF proportion	OBS - CF proportion	95%CI: OBS - CF proportion
Index of Multiple Deprivation											
D1 - Most Deprived	3965	4008	(3797; 4220)	-43	(-288; 201)	-1.1	(-6.0; 4.4)	12.8	13.3	-0.5	(-1.1; 0.2)
D2	3547	3623	(3421; 3825)	-76	(-309; 157)	-2.1	(-7.3; 3.7)	11.5	12.0	-0.5	(-1.2; 0.1)
D3	3205	3030	(2848; 3212)	175	(-38; 388)	5.8	(-0.2; 12.5)	10.3	10.0	0.3	(-0.3; 0.9)
D4	3232	3155	(2968; 3341)	77	(-140; 295)	2.5	(-3.3; 8.9)	10.4	10.4	0.0	(-0.6; 0.6)
D5	3042	2968	(2783; 3153)	74	(-140; 288)	2.5	(-3.5; 9.3)	9.8	9.8	0.0	(-0.6; 0.6)
D6	3022	2924	(2742; 3106)	98	(-114; 309)	3.3	(-2.7; 10.2)	9.8	9.7	0.1	(-0.5; 0.6)
D7	2988	2809	(2631; 2986)	179	(-28; 387)	6.4	(0.1; 13.6)	9.6	9.3	0.4	(-0.2; 0.9)
D8	2747	2550	(2381; 2720)	197	(-1; 395)	7.7	(1.0; 15.4)	8.9	8.4	0.4	(-0.1; 1.0)
D9	2749	2798	(2616; 2980)	-49	(-258; 160)	-1.7	(-7.7; 5.1)	8.9	9.3	-0.4	(-1.0; 0.2)
D10 - Least Deprived	2472	2345	(2182; 2508)	127	(-63; 317)	5.4	(-1.4; 13.3)	8.0	7.8	0.2	(-0.3; 0.7)
total	30969	30210		759		0.0		100.0	100.0	0.0	

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