The Consequences of the COVID-19 Pandemic for Fertility and Birth Outcomes: Evidence from Spanish Birth Registers

MARCO COZZANI, PETER FALLESEN, GIAMPIERO PASSARETTA, JUHO HÄRKÖNEN AND FABRIZIO BERNARDI

We examine the joint consequences of the COVID-19 pandemic for fertility and birth outcomes by drawing on full population administrative data from Spain. We find a surprising improvement in birth outcomes in November and to a less extent in December 2020 (eight to nine months after the first wave of the pandemic) compared with monthly trends in the 10 previous years (2010–2019). The improvement in birth outcomes was shortly followed by a decline in fertility, which concentrated on first births, births to women without a tertiary degree, and births to young and old mothers, respectively. These findings are consistent with the idea that the pandemic selectively affected conception, which showed up first as an improvement in birth outcomes due to the missing conceptions of frail-children-to-be (preterm and low birth weight) and then as a lowered fertility rate due to the missing conception of at-term children.

Introduction

Demographic change never happens fast, except during wars, natural disasters, and pandemics. Human populations have suffered unprecedented distress since the WHO's declaration of the COVID-19 crisis as pandemic in February 2020. Surging literature highlights that the COVID-19 pandemic had pervasive population effects via life expectancy losses (Aburto et al. 2022), barriers to international and internal migration (Nathan et al. 2020), and lower fertility rates in many developed countries (Aassve et al. 2020, 2021).

Marco Cozzani, European University Institute, Florence, Italy and University of Bologna, Bologna, Italy. Email: marco.cozzani@eui.eu. Peter Fallesen, Stockholm University, Stockholm, Sweden and Rockwool Foundation, Copenhagen. Giampiero Passaretta, Universitat Pompeu Fabra, Barcelona, Spain. Juho, Härkönen, European University Institute, Florence, Italy. Fabrizio Bernardi, UNED, Madrid, Spain.

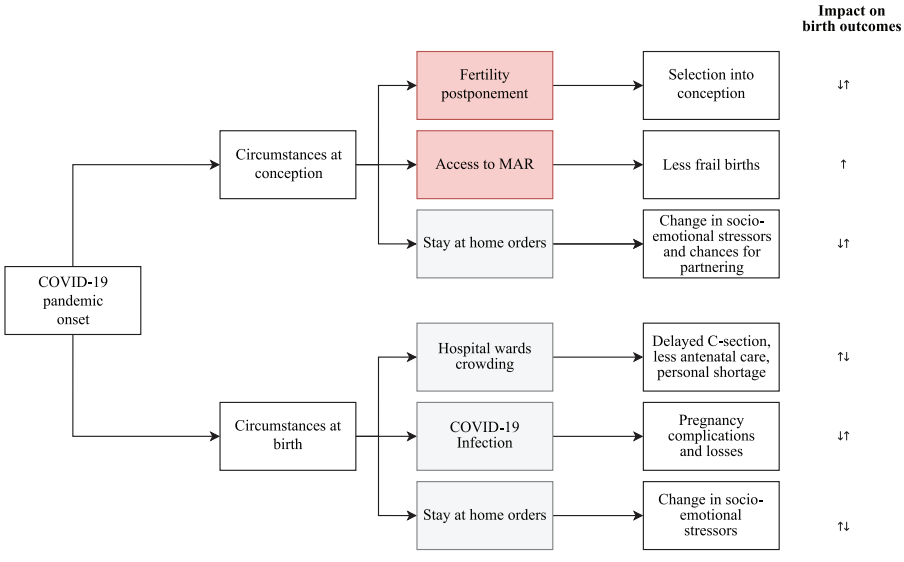
This article analyzes the joint consequences of the first wave of the COVID-19 pandemic for fertility and birth outcomes in Spain. Previous research on the effects of the pandemic on fertility and birth outcomes presents a puzzle. On the one hand, the pandemic led to a decline in fertility rates in many countries, which was largely attributed to increased economic losses and uncertainty of the future (Aassve et al. 2020, 2021). On the other hand, the pandemic has also coincided with an overall improvement in birth outcomes in terms of decreased rates of preterm births (PTB) and low birth weight (LBW), which has been attributed to the reduction of socioemotional stressors related to stay-at-home orders (Philip et al. 2020; Gemmill, Casey, Catalano et al. 2022; Been et al. 2020; Hedley et al. 2021; Chmielewska et al. 2021). We reconcile these seemingly contradictory findings in a narrative that considers the determinants of fertility and birth outcomes at the time of *conception*, during *pregnancy*, and at *delivery*. We propose that the first wave of the pandemic affected birth outcomes via selective conception right after the pandemic outbreak (Oberndorfer et al. 2022), worse social, psychological, and health conditions during pregnancy, and changed timing and care circumstances around delivery.

Our analysis draws on population administrative data on approximately four million births and explores how fertility and birth outcomes trends changed following the first wave of the COVID-19 pandemic in Spain (which took place between March and May 2020). Spain was one of the countries that suffered the most from the first wave of the COVID-19 pandemic. The central government declared the state of emergency on March 15, 2020, and issued tight nationwide stay at-home orders. These orders were only relaxed a month and a half later, in late April, and were completely retracted together with the state of emergency only in late June 2020. Moreover, Spain also experienced one of the largest fertility declines among developed countries in the aftermath of the pandemic (Aassve et al. 2021). To the best of our knowledge, this article is the first to explore pandemic-induced fertility behaviors and birth outcomes within a unified theoretical and empirical framework.

The link between COVID-19, fertility, and birth outcomes: A framework

This section discusses the main mechanisms linking the COVID-19 pandemic with fertility trends and birth outcomes. Figure 1 summarizes the potential mechanisms at play at three stages: conception, pregnancy, and delivery (mechanisms during pregnancy and around delivery are grouped together for simplicity). Red boxes highlight mechanisms related to individual choice and fertility behavior. Some pandemic-induced mechanisms may have contributed toward poorer birth outcomes. Others, like selectivity in conception, may instead have contributed to better outcomes. Below

FIGURE 1 Pathways linking the first wave of the COVID-19 pandemic with fertility and birth outcomes



we discuss the most important mechanisms to characterize the compound effect of COVID-19 on birth outcomes at the population level.

Circumstances around the time of conception

The COVID-19 pandemic resulted in reductions in fertility after nine months. Recent assessments report a 6–9 percent decline in crude birth rates compared to the same months in 2019. Spain experienced one of the largest declines among developed countries (Arpino, Luppi, and Rosina 2021; Aassve et al. 2021). These fertility declines may reflect decisions to delay childbearing due to increased uncertainty of the immediate future and temporarily barred access to reproductive health care (tempo effects) but also foregone births because of increased uncertainty or reductions in (unintended) conceptions due to limited socializing opportunities (quantum effects).

The literature on natural and man-made disasters has highlighted that fertility responses vary by socioeconomic status (SES) due to different risks of exposures and adaptive responses (Currie and Rossin-Slater 2013; Torche and Villarreal 2014; Brown 2018). The large economic uncertainty generated by the COVID-19 pandemic may have delayed fertility plans (Luppi, Arpino, and Rosina 2020; Vignoli, Tocchioni, and Mattei 2020), especially among young, precarious, and low SES workers. If low SES workers were more likely to postpone fertility behaviors due to uncertainty, birth outcomes observed nine months after would be expected to improve because low SES mothers are also more likely to deliver children

with poor birth outcomes (Aizer and Currie 2014; Kramer et al. 2000). However, another scenario is also possible. High-SES mothers may have better access to contraception and reproductive healthcare, which improves their opportunities for avoiding pregnancies under uncertain times; thus, producing a wave of missing children that would have been more likely to have better health at birth if born.

The lockdown and stay-at-home orders issued during the first wave of the pandemic radically cut the possibility to socialize in work environments and public spaces. Young people were affected the most by the lack of contact and mobility (Caselli et al. 2022). Mobility constraints and lack of social contacts likely have limited unintended pregnancies among the (younger) population that is more prone to risky behaviors and lifestyles and also have worse birth outcomes on average (Nykjaer et al. 2014; Navarro et al. 2020; Chen et al. 2007).

The halt in access to medical-assisted reproduction (MAR) treatments during the pandemic (including both artificial reproduction technologies and intrauterine insemination) may also work toward the improvement in birth outcomes. MAR children have on average worse birth outcomes than naturally conceived children (Goisis et al. 2019). Spain stands out as one of the countries with the highest prevalence of MAR treatments in Europe (De Geyter et al. 2018). However, all MAR activities were interrupted from mid-March to mid-April 2020 (Requena et al. 2020). The sudden interruption of MAR treatments may have had the unintended consequence of improving birth outcomes by preventing conception of frail-children-to-be.

Circumstances during pregnancy and around delivery

The COVID-19 pandemic strained pregnant women and hospital wards alike. Pregnant women were subject to both general pandemic-related stressors and the direct strain caused by the infection. Hospitals problems skyrocketed due to increased patient inflows, high staff infection rates and burnout, and obligations to follow COVID-19 protocols. General stressors, direct infection, and lower service in hospital wards may all relate to birth outcomes in ways whose effect is not immediately clear.

Recent reviews and meta-analyses find that COVID-19 infection during pregnancy was associated with increased risk for PTB, preeclampsia, cesarean delivery, and LBW (Allotey et al. 2020; Elsaddig and Khalil 2021; Khalil et al. 2020 Wei et al. 2021; Yee et al. 2020). Only some studies reported an increased risk of pregnancy losses (Kazemi et al. 2021), although the difficulty in measuring pregnancy losses, especially in the first months of pregnancy (Woods 2009) probably mean that they are underreported. There is also mixed evidence on whether pregnancy increased the risk of COVID-19-related mortality (Elsaddig and Khalil 2021; Rajewska et al. 2020; Jamieson and Rasmussen 2022). Thus, it is difficult to adjudicate whether COVID-19 infections led to better birth outcomes due to positive

selection of fetuses (increased pregnancy losses) or worse birth outcomes due to worsening perinatal health of survivors.

Ironically, the introduction of nonsanitary measures to contain the infection may have improved birth outcomes. Lockdowns reduced pregnant women's exposure to socioemotional and environmental stressors that affect life in ordinary circumstances. The lowered exposure to stressors may have contributed to better birth outcomes because stress during pregnancy is linked with premature deliveries (McLean et al. 1995; Torche 2011; Cozzani, Triventi et al. 2021). Moreover, pregnant women may have experienced less travel-related stress and viral or bacterial infection due to fewer social interactions, as well as they may have benefitted from reduced exposure to pollution. However, stay-at-home orders may have also triggered mechanisms that worsen birth outcomes. For example, lockdowns increased exposure to domestic violence (Piquero et al. 2021), deteriorated health behaviors (Mata et al. 2021), increased load in housework (Brini et al. 2021), reduced access to medical care, and increased economic uncertainty.

Lockdowns have been linked to declining PTB in many countries including Denmark (Hedermann et al. 2021), Ireland (Philip et al. 2020), the Netherlands (Hedermann et al. 2021), Italy (De Curtis, Villani, and Polo 2021), Australia (Matheson et al. 2021), Austria (Kirchengast and Hartmann 2021), and Botswana (Caniglia et al. 2021). Other studies found no change or even increasing rates of prematurity in Argentina (Cuestas et al. 2021), Jordan (Badran et al. 2021), and Spain (Arnaez et al. 2021). A recent systematic review and meta-analysis found indications of a decrease in PTB but no indication of an increase in stillbirths (Yang et al. 2021).

The congestion and strain of hospital wards may have also played a role. Hospitals suffered due to supply shortage (Ranney, Griffeth, and Jha 2020), personnel shortage (Garcia-Basteiro et al. 2020; Houlihan et al. 2020; Nguyen et al. 2020), and burnout (Torrente et al. 2021; Shechter et al. 2020; Quintana-Domeque et al. 2021). A direct consequence of hospital strains was delay in deliveries (Breman et al. 2021), which may have increased the risk of complications during deliveries. However, a potential decline or delay in the use of c-sections and medically induced labor increase gestational age and, consequently, birthweight (Saccone et al. 2019). Lower use of c-sections and induced labor have been causally linked to better birth outcomes during nonpandemic periods (Maibom et al. 2021), and a similar logic may play out during the pandemic.

Data and methods

Data

We use Spanish birth certificate data to assess early trends in fertility and birth outcomes after the onset of the COVID-19 pandemic. Birth certificates

are cross-sectional population-level birth registers including the whole universe of births in Spain, and they are collected by the Spanish Statistical Institute (*Instituto Nacional de Estadistica*—INE) since 1975. They are constructed from a questionnaire filled by parents at the time of the inscription of the newborn into the civil register and collection of information on the circumstances of delivery, parental sociodemographic characteristics, and children's anthropometric measures. It is worth noting that anthropometric measures in the birth certificates are generally consistent with hospital records, especially for frail deliveries (Juárez et al. 2012). Our target population consists of about 4.2 million births occurred in Spain between 2010 and 2020.

Variables

We combine information from birth certificates and population statistics from INE to construct age-specific fertility rates (ASFR) and total fertility rates (TFR) at the monthly level. ASFR measures the number of children born per thousand women at each age. We calculate the ASFRs across age 15–49. Since we use monthly data on births, we multiply the thus calculated ASFRs by 12 months to transform them into more commonly used annualized measures. TFR captures the expected number of children born to a woman if she was to follow the current ASFR across her reproductive lifetime.

We use four widely adopted indicators of perinatal health that proxy for children's developmental potential (Torche and Conley 2016; Boardman et al. 2002)—two continuous indicators measuring birth weight (grams) and gestational age (weeks), and two binary indicators reporting whether the child is born preterm (<37 weeks of gestation, PTB) or LBW (<2,500 g, LBW). The latter binary indicators are particularly relevant as they capture frail newborns more at risk of future morbidity and mortality (Aarnoudse-Moens et al. 2009).

Some of the analyses are performed separately by parity and maternal education. Parity distinguishes firstborns from other siblings. Maternal education is used as a proxy for maternal SES and measures whether mothers have a tertiary degree.

Analytical strategy

First, we estimate monthly development in (seasonally adjusted[1]) TFR and decompose TFR changes in October–December 2020 across age, parity, and maternal education. Second, we perform OLS regressions to examine if birth outcomes (birth weight, gestational age, PTB, and LBW) changed immediately after the outbreak of the COVID-19 pandemic. More specifically, we estimate a separate OLS model for each birth outcome predicting their

value for each month between January 2010 and December 2020 (based on a model including a combination of month and year of birth among the predictors). In this way, we highlight any deviation in the trends over 2020 compared to the 10 years prior. All analyses are adjusted for the sex of the newborn, maternal age, parity, maternal marital status, municipality size, and the province of birth. Also, these analyses are performed separately by parity and maternal education. The unadjusted results are largely similar to the ones reported in the main text (see Supplementary Figures A1–A3 and Supplementary Tables A1–A4 for the unadjusted birth outcomes monthly levels). We further cross-validate main findings on birth outcomes using an alternative empirical strategy.

The impact of the pandemic on birth outcomes may not have been constant along the distribution of birthweight and gestational age. If, for example, the pandemic led to early pregnancy loss of very frail fetuses, the effect on birthweight should be driven by fewer very low birthweight births and concentrated at the bottom of the distribution. On the other hand, if the pandemic caused mothers to be more cautious, thereby general increasing gestational length and birthweight, we should expect a more uniform impact across the birthweight distribution. To consider heterogeneity across the continuous outcome variables, we estimate counterfactual distributions (Chernozhukov, Fernández-Val, and Melly 2013). This allows us to examine what parts of the distribution of birthweight and gestational age changed the most during the pandemic, including considering the possibility effect may be heterogeneous and even of opposite sign at different parts of the distribution under the assumption of rank stability (i.e., that no children's birth outcomes switched places in the distribution conditional on covariates).

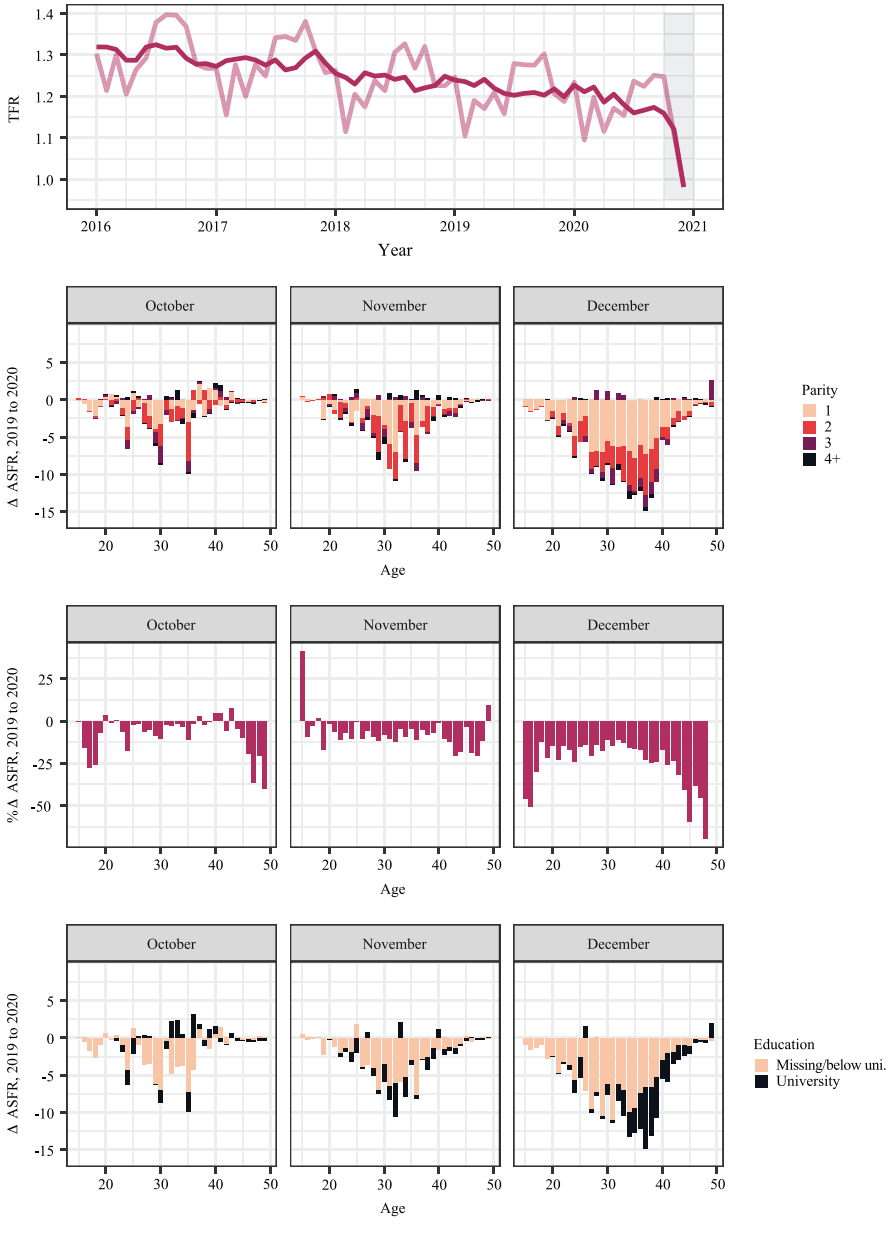
As a robustness check, we account for seasonal patterns and autocorrelation (Gemmill, Casey, Margerison et al. 2022) by estimating changes in birthweight and gestational age using an interrupted time series design (Box and Tiao 1975), examining whether including the last three months of 2020 as distinct events corroborated the findings from the OLS models. This allows us to examine how these months departed from expected trends. For the sake of brevity, we briefly comment on these findings in the main text and include the results in the Supporting Information.

Results

Trends in fertility

The upper panel of Figure 2 shows the monthly TFR trends from January 2016 to December 2020. The lighter line shows the actual TFR trend, and the darker line refers to the seasonally adjusted TFR using the software provided by Sax and Eddelbuettel (2018). The middle-upper panel shows changes in ASFR decomposed by parity in comparison to the same month in 2019. The middle-lower panel displays relative changes in the ASFR

FIGURE 2 Spanish TFR (2016–2020) and differences in ASFR (2019–2020)



NOTE: The upper panel shows monthly TRF (lighter line) and seasonally adjusted monthly TFR (darker line). We adjust for seasonality using the X-13ARIMA-SEATS seasonal adjustment program (Sax and Eddelbuettel 2018). The upper-middle panel shows ASFR decline (2020 vs. 2019) decomposition by parity. The lower-middle panel displays relative changes in the ASFR between the same month in 2019 and 2020. The bottom panel shows ASFR decline decomposition by maternal education. For the lower middle figure for December 2020, we have left out women at age 49.
SOURCE: Spanish birth certificates (2010–2020) and population figures from INE (women aged 14–49)

between the same months in 2019 and 2020. Finally, the bottom-lower panel shows ASFR changes between 2019 and 2020 decomposed by maternal education.

Although there is an ongoing trend of TFR decline for the entire period considered, we observe a sharp drop in TFR in November and especially, December 2020. TFR drops to about 1.13 in November and below 1 in December, thus reaching unprecedentedly low levels. Most of the fertility decrease is driven by first births in November and especially December (see the middle-upper panel). In December, the decline is heavily driven by both young mothers without a tertiary degree and highly educated mothers above 34 years of age (lower panel). The largest relative ASFR decrease occurred in women at the beginning and the end of the reproductive age span (below 20 and above 40), around 20–25 percent in October and November and 40–50 percent in December (middle-lower panel), respectively.

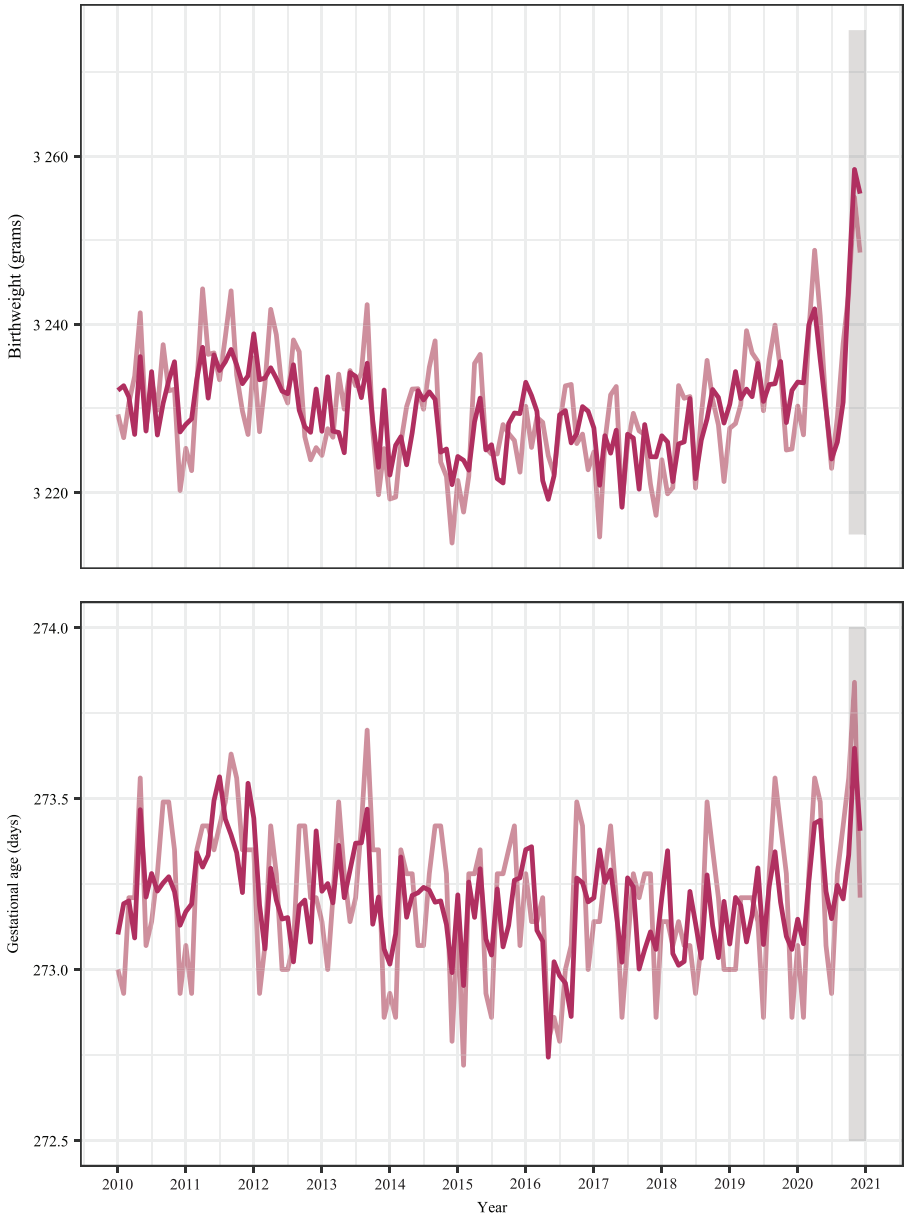
Trends in birth outcomes following the COVID-19 pandemic

Figure 3 shows the monthly averages of birthweight and gestational age for the period 2010–2020, without (lighter line) and with (darker line) seasonal adjustment. Births likely to be affected by the pandemic (October–December 2020) are marked by a gray box. Even after adjusting for seasonality, the average birthweight in October–December 2020 was well above any monthly average recorded in 10 ten years prior. November 2020 represents the highest average gestational age in the entire time series, and the average gestational age in December 2020 was also higher than the average since 2010.

Figure 4 displays trends and 95 percent confidence intervals of birth weight (grams), gestational age (weeks), PTB, and LBW for each month between January 2010 and December 2020, obtained using OLS models and adjusting for covariates. Supplementary Figure S1 reports the unadjusted results. Gray lines show monthly trends in birth outcomes for each year between 2010 and 2019; the red line displays the monthly trend in birth outcomes for 2020. We generally observe deviations from decennial trends in birth outcomes eight-to-ten months after the declaration of the state of emergency in March 2020. A remarkable improvement in the month of November occurred for all the birth outcomes considered, accompanied by smaller improvement in December and partly in October (for gestational age, the difference is only statistically significant in November). These results are in line with evidence from the United States, where it is found that the largest improvement in birth outcomes occurred in November 2020 (Gemmill, Casey, Catalano et al. 2022).

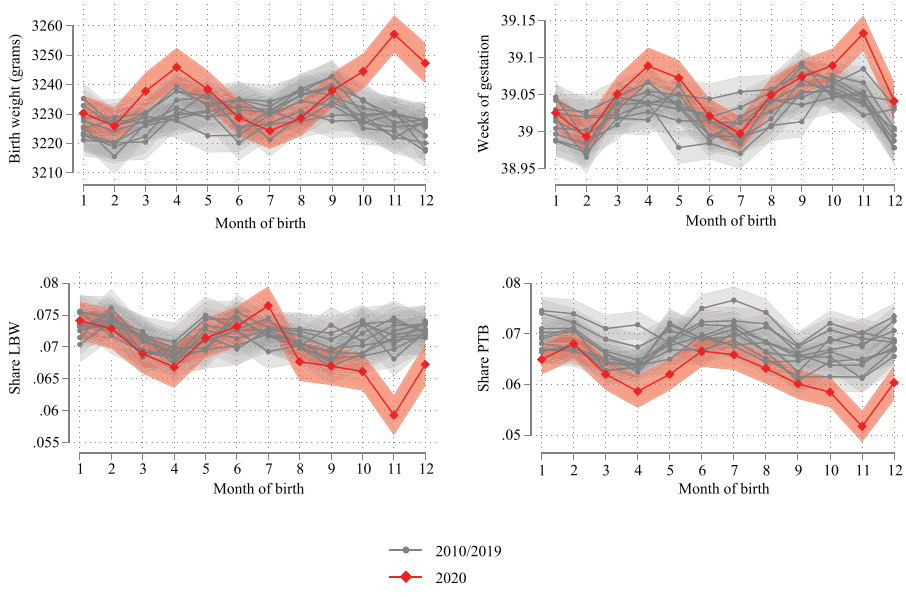
In November 2020, children weighted on average about 3,257 g, 27 g more than the highest average of the same month within the previous decade (2011: 3,230 g). In December, the same increase was of about 19 g (3,247 g in 2020 vs. 3,228 in December 2019). Similarly, the share of LBW

FIGURE 3 Monthly trends in birth weight and gestational age with (dark line) and without (lighter line) seasonal adjustment for Spain, 2010–2020



NOTE: The upper panel shows the monthly mean for birthweight. The lower panel shows the monthly mean for gestational age. We adjust for seasonality using the X-13ARIMA-SEATS seasonal adjustment program (Sax and Eddelbuettel 2018).
SOURCE: Spanish birth certificates 2010–2020.

FIGURE 4 Birth outcome trends 2010–2020



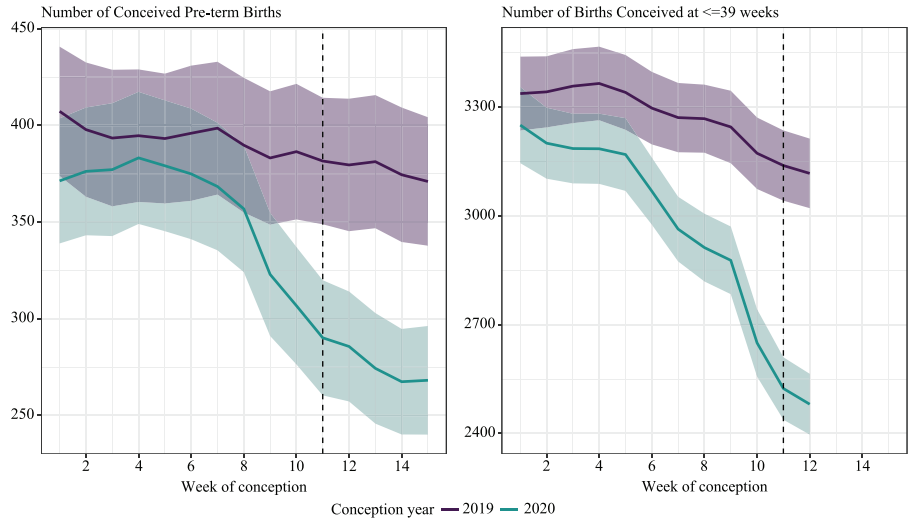
NOTE: Estimates obtained by adjusting for maternal age, migrant status, child's sex, province, and municipal size. Standard error clustered at the province level.
SOURCE: Spanish birth certificates 2010–2020.

children reached the decade trough (5.9 percent) in November 2020 compared to the previous one of 7 percent in November 2010. In December, 6.7 percent of children were born LBW, that is 0.4 percentage point less than the lowest figure for the same month in the previous decade (in 2011). Estimated trends for the rest of the 2020 are in line with trends from the previous years. Results for gestational age and PTB follow a similar pattern. November 2020 is the month with the largest improvements. Gestational age increased by about one-third of a day (0.048 weeks) in November 2020 with respect to the previous peak in November 2015. The incidence of PTB dropped to 5.2 percent, one percentage point lower than at the previous trough in the same month (2019).

Modeling birthweight and gestational age as time series yield similar results. The time-series models reported in table S5 in the Supporting Information show a 11-g increase in birthweight in October 2020, a 34-g increase in November, and a 21-g increase in December relative to expected levels (after adjusting for general and seasonal autoregressive terms). For gestational age, we find no significant increase in October and 1.4 and 0.8 days increases in November and December 2020, respectively.

To investigate if the observed reduction in fertility in December and the improvements in birth outcomes in November originated at the same time, we explore whether they coincide at the time of conception. Precise information on the date of birth was not available as the data only included

FIGURE 5 Trends in conceptions by preterm status 2019–2020, week 1 to week 15



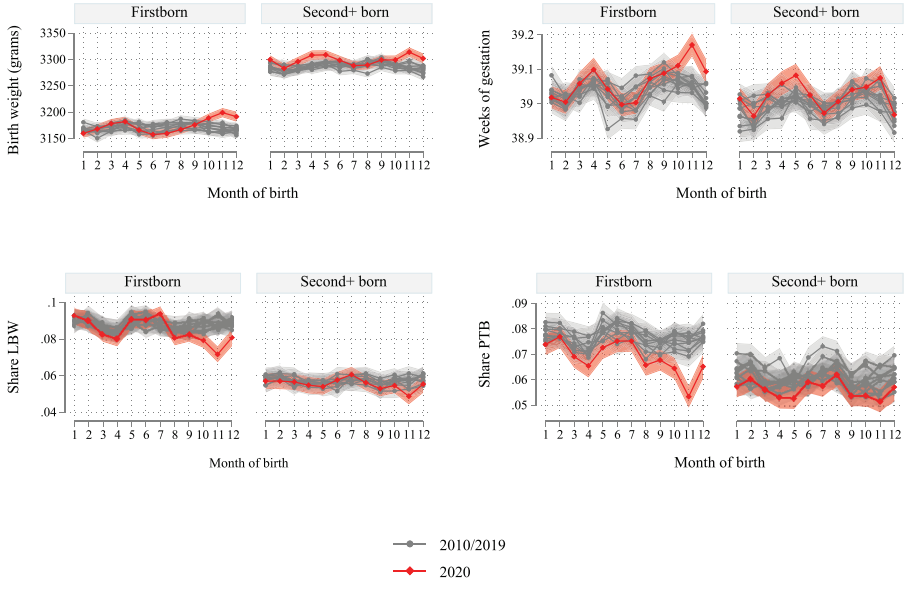
NOTE: The left panel displays a number of conceptions of children born before the 37th week of gestation. The right panel displays the number of conceptions of children born between the 37th and 39th week of gestation. Figure obtained by estimating the week of conception by randomly assigning the date of birth and by subtracting the weeks of gestation. Estimates obtained by bootstrapping 1000 simulations.
SOURCE: Spanish birth certificates 2010–2020.

information on birth month. We reconstructed the week of conception using information on gestational weeks and randomly assigned the exact day of birth in a month in 1,000 simulation draws. Because we do not know neither day nor week of birth, and because gestational age has an error margin of ±14 days, we cannot expect to see a clear drop in conceptions at the start of the pandemic even if our hypothesis holds. What we instead should see is a gradual decline in the weeks leading up to the pandemic. Figure 5 displays the number of preterm and at-term conceptions in the first 15 weeks of 2020 compared to 2019. We observe that a sharp decline starts around the ninth week of 2020 (February 24–March 2), two weeks before the declaration of the state of emergency and the nationwide stay-at-home order in Spain (March 14, 2020) for PTB, and slightly before for conceptions resulting in at-term birth. Assuming a two-week difference between the last menarche and when the conception occurred, it seems that the decline in conceptions ending up in a preterm delivery occurred in coincidence with the beginning of the first COVID-19 wave in Spain.

Heterogeneities by parity, maternal education, and along the distribution of birth weight and gestational age

Figure 6 replicates Figure 4 by parity. Supplementary Figure S2 reports results without conditioning on covariates. Overall, second or higher parity

FIGURE 6 Birth outcome trends 2010–2020 by parity



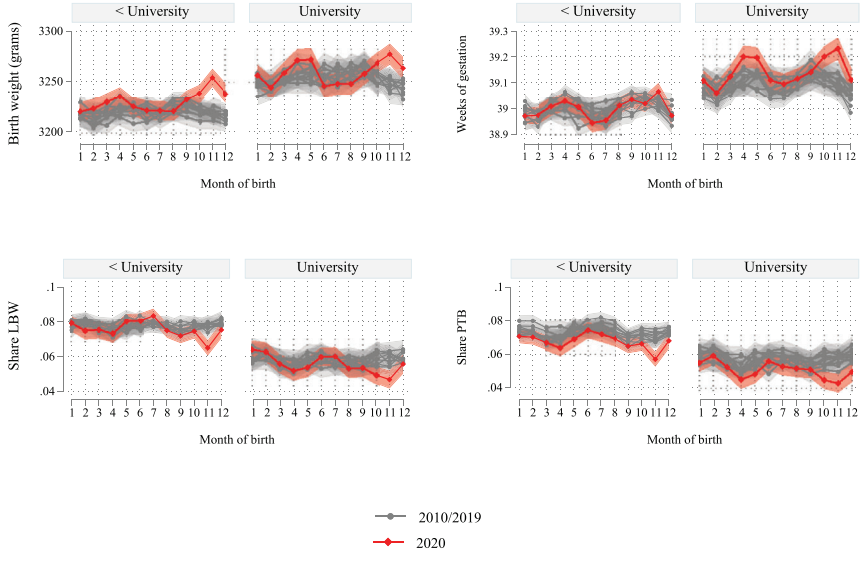
NOTE: Estimates obtained by adjusting for maternal age, migrant status, child's sex, province, and municipal size. Standard error clustered at the province level.
SOURCE: Spanish birth certificates 2010–2020.

born have better average birth outcomes than firstborns. And yet improvements in birth outcomes in November concentrate on firstborns (especially when looking at LBW and PTB). For example, LBW decreased to 7 percent in November 2020 from a previous low of 8.2 percent in 2010 for firstborns. Declines are even stronger in PTB. In November 2020, PTB decreased to 5.3 percent from a low of 6.9 percent in November 2019.

Figure 7 replicates Figure 4 by the mother's education. Results from models that do not adjust for covariates are in Supplementary Figure S3. Overall, birth outcomes improved in November and December regardless of the mother's education, with mothers with tertiary degrees seeing bigger improvement in birthweight and gestational age, but mothers without university education seeing larger improvements with regard to LBW and PTB.

Were improvements in birth outcomes heterogeneous along the distribution of birthweight and gestational age? To analyze this question, we compare the cumulative distribution of birth weight and gestational age in 2020 and 2019. Figure 8 shows the probability of children born between September and December 2020 to remain below a certain threshold of birth weight and gestational weeks compared to the same months in 2019. We also include September to benchmark a month where we expect no major differences. Vertical lines show the WHO thresholds for LBW (2,500 g) and very LBW (1,500 g) and PTB (37 weeks), very PTB (32 weeks), and

FIGURE 7 Birth outcome trends by maternal education (2010–2020)



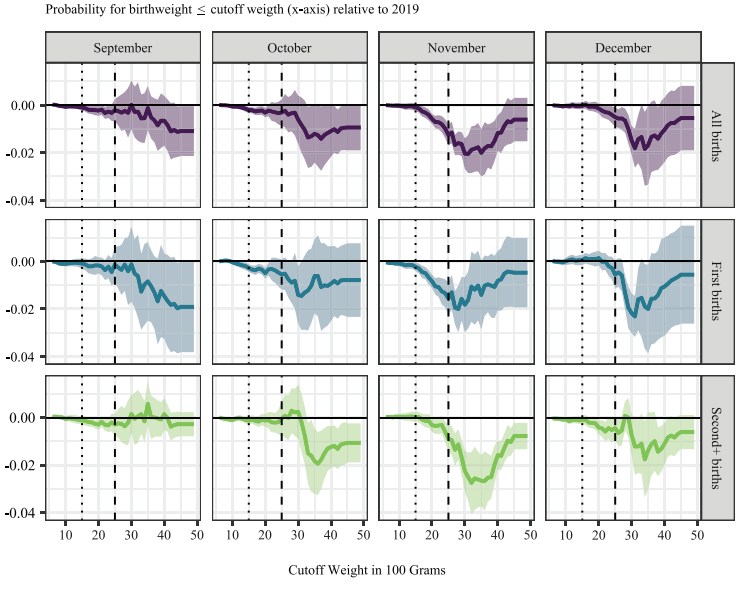
NOTE: Estimates obtained by adjusting for maternal age, migrant status, child's sex, province, and municipal size. Sample limited to those with educational information. Standard error clustered at the province level.
SOURCE: Spanish birth certificates 2010–2020.

extremely PTB (27 weeks). Overall, we find that in November children's birth weight and gestational age shifted toward the center of the distribution, with firstborns being particularly less likely to be born around the LBW and PTB thresholds. Higher order births experienced a similar shift toward higher weight and longer gestational ages, but predominantly among the part of the distributions located at the right of the thresholds for LBW and PTB. In December, only firstborns in the middle of the distribution improved their birth weight and gestational age.

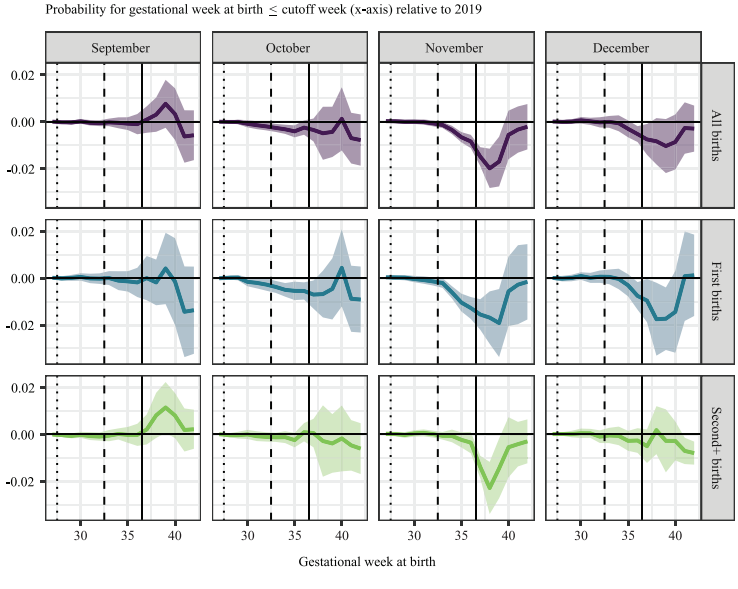
Trends in maternal age and multiple births

We now compare the composition of births in 2020 and 2019 in terms of maternal age and multiple births. We choose the 2019 as comparison year because the general increase in maternal age across the 2010s and the secular trends in twin births may introduce unwanted biases in gauging the magnitude of the 2020 change (Pison, Monden, and Smits 2015). Results are presented in Supplementary Figure S4. In line with ASFR estimates, there is a substantial decrease in maternal age in December 2020 (smaller in November). Regarding multiple births, there is a similar decrease in both November and December. The simultaneous decrease in multiple births and maternal age, together with ASFR reduction among women at the end of their fertile age, suggests that access to MAR may have played a role in shaping the fertility dip in November and December 2020. Older women

FIGURE 8 Difference across birth weight and gestational age distributions between 2019 and 2020 (September–December)



Dashed line: threshold for low birthweight. Dotted line: threshold for very low birthweight.
Results adjusted for maternal age, maternal migrant status, child's sex, province, municipal size. Standard errors clustered on province level.
95% confidence bands.



Solid line: Threshold for premature birth. Dashed line: threshold for very premature birth. Dotted line: threshold for extremely premature birth.
Results adjusted for maternal age, maternal migrant status, child's sex, province, municipal size. Standard errors clustered on province level.
95% confidence bands.

NOTE: Estimates obtained by adjusting for maternal age, migrant status, child's sex, province, and municipal size. Standard error clustered at the province level.
SOURCE: Spanish birth certificates 2010–2020.

are more likely to use MAR and deliver multiple births (Goisis et al. 2019; ESHRE 2003). MAR is also linked with worse birth outcomes (Goisis et al. 2019), and thus fewer MAR children due to unavailability of treatments during lockdowns may have contributed to the general improvement in birth outcomes.

Conclusions and discussion

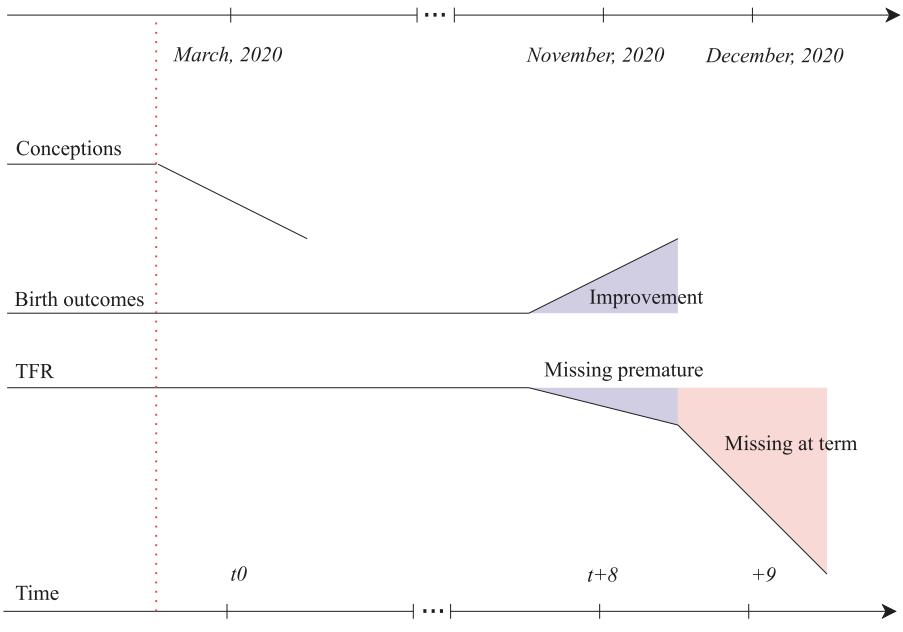
Birth outcomes improved while fertility declined in the wake of the first wave of the COVID-19 pandemic in Spain. These two observations were reported by many studies analyzing either fertility or birth outcomes in a variety of countries. To the best of our knowledge, this article is the first to jointly observe the two dynamics by adopting a coherent theoretical and empirical framework. We reconcile these seemingly contradictory findings by linking determinants of fertility and birth outcomes at the time of conception, pregnancy, and delivery. We showed that birth outcomes improved in November 2020, eight months after the first wave of the COVID-19 pandemic hit Spain. This was then followed by a reduction in the fertility rate beginning in November 2020 but with the largest reduction occurring in December. The reduction occurred predominantly for first births, for women without tertiary education, and at the tails of the reproductive age span.

Why did the first wave of the COVID-19 pandemic result in reduced fertility and improved birth outcomes eight–nine months later? And why did we observe an improvement in birth outcomes first and a reduction in fertility only after? We argued that the COVID-19 pandemic had a selective impact on fertility and changed the composition of live births in November and December. The selective fertility response to the first wave of the pandemic thus generated a wave of ''missing children'' that would have been at higher risk of frailty.

Regarding the selective nature of the fertility response, we presented evidence from three groups of women that substantiate this narrative. First, the large decline in first births and births to relatively young and low educated mothers is compatible with the narrative of decreases in fertility due to increased uncertainty of the future (Aassve et al., 2021; Arpino, Luppi, and Rosina, 2021). Whether this reflects a postponement or a more permanent forgoing of childbearing depends on the willingness and ability of these women to have children in the future. Because mothers with low education are more likely to deliver children with poorer birth outcomes (Kramer et al. 2000; Aizer and Currie 2014), this (temporary) decline has likely contributed to the aggregate-level improvements in birth outcomes that we observe.

Second, we observed a simultaneous decline in births to older highly educated mothers as well as in multiple births eight-to-nine months after the sudden closure of MAR centers in March 2020 (Vermeulen et al. 2020).

FIGURE 9 Conceptual model on the timing of conceptions, birth outcomes, and TFR changes



MAR conceptions are more likely among childless highly educated older women and more often result in multiple births (Cozzani, Aradhya et al. 2021; Goisis et al. 2020). MAR conceptions are also more likely to result in an early delivery and poor birth outcomes more in general (Goisis et al. 2019).

Third, we observe a simultaneous decline in births among (very) young women and first births in November and December 2020. This suggests a decline in unplanned pregnancies, which are at higher risk of poor birth outcomes (Chen et al. 2007), immediately after the introduction of stay-at-home orders in March 2020.

Altogether, these fertility-related factors suggest that the first wave of the COVID-19 pandemic (March 2020) may have contributed to a wave of "missing children" at higher risk of frailty through a reduction in fertility of three groups of women among whom poor birth outcomes are overrepresented: the very young, the low educated, and women conceiving with the aid of MAR treatments.

How did this selective reduction in conceptions translate to an improvement in population-level birth outcomes in November that weakened in December, but a decline in births in November that gained strength in December? We summarize our argument in Figure 9.

The reduction in March conceptions that would have led to PTB (and LBW) meant that fewer children were born prematurely (seven to eight

months after conception) in November than in the preceding months. In other words, there was a reduction in the numerator (premature births) of the PTB rate ($\frac{\text{Pretermbirths}}{\text{Allbirths}}$). However, since at-term births—which constitute the bulk of all births—in November were conceived already before the start of the first COVID-19, the denominator of the PTB rate (all births) was less affected. This changed in December when the effect of the decrease in March conceptions became fully visible with a drop in at-term births. This can have contributed to the weakening of population-level birth outcomes compared to November through a decrease in the denominator of the PTB rate. As the number of births declined, the PTB rate would increase even without a change in PTB. Yet the latter may also have changed, as MAR clinics opened again in April (Requena et al., 2020) and socialization became possible again after the relaxation of stay-at-home measures after late May 2020, which may have led to an increase in conceptions in April and May and increase in PTB births in December. Although the above narrative relates primarily to PTB, it will account for a majority of LBW births as well as most LBW can be attributed to PTB in modern societies such as Spain.

In addition to selective conception rates, pregnancy losses (Woods, 2009) due to the socioemotional circumstance around the onset of the COVID-19 pandemic as well as the direct consequences of infections can have contributed to the selective decline in births, where the frailest fetuses are most likely to be lost. Unfortunately, data on early pregnancy losses, when most of them occur (Holman and Wood 2001), are usually not available in large-scale administrative data, including ours, and we leave for future research to assess the role of pregnancy loss in accounting for the joint decline in fertility and improvement in population-level birth outcomes.

In conclusion, we caution overinterpreting improvements in birth outcomes in the aftermath of the first wave of the COVID-19 pandemic as positive side effects from a social justice or a public-health perspective. Indeed, they appear at least in part to be explained by selectivity into conception, thus representing a change in the composition of children being born. A follow-up on the cohort of children exposed to the COVID-19 pandemic in utero with the compositional changes in mind may be necessary for a better understanding of the long-term consequences.

Data availability statement

Data and codes are available upon request to the corresponding author

Conflict of interest

Authors declare no conflict of interest.

Ethics approval statement

Ethical approval was not required as the study used anonymized, publicly available data.

Patient consent statement

No patient was involved in the study.

Permission to reproduce material from other sources

None. Only original material is included.

Acknowledgments

This work was supported by the Academy of Finland under Grant 324613; the Rockwool Foundation under Grant 1227 and Grant 1254; and the Swedish Research Council for Health, Working Life and Welfare under Grant 2016-07099. We are grateful to the editors, guest editors, and anonymous reviewers for the constructive feedback they provided. We also thank participants at ECSR 2022 annual conference in Amsterdam, UNED Inequality and Social Demography Seminar Series, and Risto Conte Keivabu for helpful suggestions on the manuscript. All mistakes remain ours.

Note

1 We adjust for seasonality using the X-13ARIMA-SEATS seasonal adjustment program (Sax and Eddelbuettel 2018)

References

Aarnoudse-Moens, Cornelieke Sandrine Hanan, Nynke Weisglas-Kuperus, Johannes Bernard Goudoevervan, and Jaap Oosterlaan. 2009. "Meta-Analysis of Neurobehavioral Outcomes in Very Preterm and/or Very Low Birth Weight Children." *Pediatrics* 124(2): 717–728.

Aassve, Arnstein, Nicolo Cavalli, Letizia Mencarini, Samuel Plach, and Massimo Livi Bacci. 2020. "The COVID-19 Pandemic and Human Fertility." *Science* 369(6502): 370–371.

Aassve, Arnstein, Nicolò Cavalli, Letizia Mencarini, Samuel Plach, and Seth Sanders. 2021. "Early Assessment of the Relationship between the COVID-19 Pandemic and Births in High-Income Countries." *Proceedings of the National Academy of Sciences* 118(36): e2105709118https://doi.org/10.1073/pnas.2105709118.

Aburto, José Manuel, Jonas Schöley, Ilya Kashnitsky, Luyin Zhang, Charles Rahal, Trifon I Missov, Melinda C Mills, Jennifer B Dowd, and Ridhi Kashyap. 2022. "Quantifying Impacts of the COVID-19 Pandemic through Life-Expectancy Losses: A Population-Level Study of 29 Countries." *International Journal of Epidemiology* 51(1): 63–74.

Aizer, A., and Janet Currie. 2014. "The Intergenerational Transmission of Inequality: Maternal Disadvantage and Health at Birth." *Science* 344(6186): 856–861.

Allotey, John, Elena Stallings, Mercedes Bonet, Magnus Yap, Shaunak Chatterjee, Tania Kew, Luke Debenham, Anna Clavé Llavall, Anushka Dixit, and Dengyi Zhou. 2020. "Clinical Manifes-

tations, Risk Factors, and Maternal and Perinatal Outcomes of Coronavirus Disease 2019 in Pregnancy: Living Systematic Review and Meta-Analysis." *BMJ* 370: m3320.

Arnaez, Juan, Carlos Ochoa-Sangrador, Sonia Caserío, Elena Pilar Gutiérrez, Maria del Pilar Jiménez, Leticia Castañón, Marta Benito, Ana Peña, Natalio Hernández, and Miryam Hortelano. 2021. "Lack of Changes in Preterm Delivery and Stillbirths during COVID-19 Lockdown in a European Region." *European Journal of Pediatrics* 180(6): 1997–2002.

Arpino, Bruno, Francesca Luppi, and Alessandro Rosina. 2021. "Regional Trends in births during the COVID-19 crisis in France, Germany, Italy, and Spain." Preprint mnwh8. SocArXiv. https://doi.org/10.31235/osf.io/mnwh8 .

Badran, Eman F, Rula M Darwish, Yousef Khader, Rama AlMasri, Mira Al Jaberi, Mohammad AlMasri, Farah AlSa'di, and Noor al-Badaineh. 2021. "Adverse pregnancy outcomes during the COVID-19 lockdown. A descriptive study." *BMC pregnancy and childbirth* 21(1): 1–8.

Been, Jasper V., Lizbeth Burgos Ochoa, Loes C. M. Bertens, Sam Schoenmakers, Eric A. P. Steegers, and Irwin K. M. Reiss. 2020. "Impact of COVID-19 Mitigation Measures on the Incidence of Preterm Birth: A National Quasi-Experimental Study." *The Lancet Public Health* 5(11): e604-e611. https://doi.org/10.1016/S2468-2667(20)30223-1.

Boardman, Jason D, Daniel A Powers, Yolanda C Padilla, and Robert A Hummer. 2002. "Low Birth Weight, Social Factors, and Developmental Outcomes among Children in the United States." *Demography* 39(2): 353–368.

Box, George EP, and George C Tiao. 1975. "Intervention Analysis with Applications to Economic and Environmental Problems." *Journal of the American Statistical Association* 70(349): 70–79.

Breman, Rachel Blankstein, Carrie Neerland, Dani Bradley, Adriane Burgess, Erik Barr, and Paul Burcher. 2021. "Giving Birth during the COVID-19 Pandemic, Perspectives from a Sample of the United States Birthing Persons during the First Wave: March-June 2020." *Birth* 48(4): 524–533.

Brini, Elisa, Mariya Lenko, Stefani Scherer, and Agnese Vitali. 2021. "Retraditionalisation? Work Patterns of Families with Children during the Pandemic in Italy." *Demographic Research* 45: 957–972.

Brown, Ryan. 2018. "The Mexican Drug War and Early-Life Health: The impact of Violent Crime on Birth Outcomes." *Demography* 55(1): 319–340.

Caniglia, Ellen C, Lerato E Magosi, Rebecca Zash, Modiegi Diseko, Gloria Mayondi, Judith Mabuta, Kathleen Powis, Scott Dryden-Peterson, Mosepele Mosepele, and Rebecca Luckett. 2021. "Modest Reduction in Adverse Birth Outcomes following the COVID-19 Lockdown." *American Journal of Obstetrics and Gynecology* 224(6): 615.e1–615.e12.

Caselli, Francesca, Francesco Grigoli, Damiano Sandri, and Antonio Spilimbergo. 2022. "Mobility under the COVID-19 Pandemic: Asymmetric Effects across Gender and Age." *IMF Economic Review* 70(1): 105–138.

Chen, Xi-Kuan, Shi Wu Wen, Nathalie Fleming, Kitaw Demissie, George G Rhoads, and Mark Walker. 2007. "Teenage Pregnancy and Adverse Birth Outcomes: A Large Population Based Retrospective Cohort Study." *International Journal of Epidemiology* 36(2): 368–373.

Chernozhukov, Victor, Iván Fernández-Val, and Blaise Melly. 2013. "Inference on Counterfactual Distributions." *Econometrica* 81(6): 2205–2268.

Chmielewska, Barbara, Imogen Barratt, Rosemary Townsend, Erkan Kalafat, Jan van der Meulen, Ipek Gurol-Urganci, Pat O'Brien, Edward Morris, Tim Draycott, Shakila Thangaratinam, Kirsty Le Doare, Shamez Ladhani, Peter von Dadelszen, Laura Magee, and Asma Khalil. 2021. "Effects of the COVID-19 Pandemic on Maternal and Perinatal Outcomes: A Systematic Review and Meta-Analysis." *The Lancet Global Health* 9(6): e759–e772. https://doi.org/10.1016/S2214-109X(21)00079-6.

Cozzani, Marco, Siddartha Aradhya, and Alice Goisis. 2021. "The Cognitive Development from Childhood to Adolescence of Low Birthweight Children Born after Medically Assisted Reproduction—A UK Longitudinal Cohort Study." *International Journal of Epidemiology* 50(5): 1514–1523.

Cozzani, Marco, Moris Triventi, and Fabrizio Bernardi. 2021. "Maternal Stress and Pregnancy Outcomes Evidence from a Natural Experiment: The 2004 Madrid Train Bombings." *European Sociological Review* 38: 390–407. https://doi.org/10.1093/esr/jcab045.

Cuestas, Eduardo, Martha E Gómez-Flores, María D Charras, Alberto J Peyrano, Clara Montenegro, Ignacio Sosa-Boye, Verónica Burgos, Graciela Giusti, Mario Espósito, and Silvyana S Blanco-Pool. 2021. "Association between COVID-19 Mandatory Lockdown and Decreased Incidence of Preterm Births and Neonatal Mortality." *Journal of Perinatology* 41(10): 2566–2569.

Currie, Janet, and Maya Rossin-Slater. 2013. "Weathering the Storm: Hurricanes and Birth Outcomes." *Journal of Health Economics* 32(3): 487–503.

De Curtis, Mario, Leonardo Villani, and Arianna Polo. 2021. "Increase of Stillbirth and Decrease of Late Preterm Infants during the COVID-19 Pandemic Lockdown." *Archives of Disease in Childhood-Fetal and Neonatal Edition* 106(4): 456-456.

De Geyter, Ch, C Calhaz-Jorge, M S Kupka, C Wyns, E Mocanu, T Motrenko, G Scaravelli, J Smeenk, S Vidakovic, V Goossens., The European IVF-monitoring Consortium for the European Society of Human Reproduction, and Embryology. 2018. "ART in Europe, 2014: Results Generated from European Registries by ESHRE: The European IVF-Monitoring Consortium (EIM) for the European Society of Human Reproduction and Embryology (ESHRE)." *Human Reproduction* 33(9): 1586–1601. https://doi.org/10.1093/humrep/dey242.

Elsaddig, Maab, and Asma Khalil. 2021. "Effects of the COVID Pandemic on Pregnancy Outcomes." *Best Practice & Research Clinical Obstetrics & Gynaecology* 73: 125–136.

ESHRE. 2003. "6. Ethical Issues Related to Multiple Pregnancies in Medically Assisted Procreation." *Human Reproduction* 18(9): 1976–1979. https://doi.org/10.1093/humrep/deg357.

Garcia-Basteiro, Alberto L, Gemma Moncunill, Marta Tortajada, Marta Vidal, Caterina Guinovart, Alfons Jimenez, Rebeca Santano, Sergi Sanz, Susana Méndez, and Anna Llupià. 2020. "Seroprevalence of Antibodies against SARS-CoV-2 among Health Care Workers in a Large Spanish Reference Hospital." *Nature Communications* 11(1): 1–9.

Gemmill, Alison, Joan A Casey, Claire E Margerison, Jennifer Zeitlin, Ralph Catalano, and Tim A Bruckner. 2022. "Patterned outcomes, Unpatterned Counterfactuals, and Spurious Results: Perinatal Health Outcomes following COVID-19." *American Journal of Epidemiology* 191(11): 1837–1841.

Gemmill, Alison, Joan A. Casey, Ralph Catalano, Deborah Karasek, Claire E. Margerison, and Tim Bruckner. 2022. "Changes in Preterm Birth and Caesarean Deliveries in the United States during the SARS-CoV-2 Pandemic." *Paediatric and Perinatal Epidemiology* 36: 485–489. https://doi.org/10.1111/ppe.12811.

Goisis, Alice, Siri Eldevik Håberg, Hans Ivar Hanevik, Maria Christine Magnus, and Øystein Kravdal. 2020. "The Demographics of Assisted Reproductive Technology Births in a Nordic Country." *Human Reproduction* 35(6): 1441–1450. https://doi.org/10.1093/humrep/deaa055.

Goisis, Alice, Hanna Remes, Pekka Martikainen, Reija Klemetti, and Mikko Myrskylä. 2019. "Medically Assisted Reproduction and Birth Outcomes: A Within-Family Analysis Using Finnish Population Registers." *The Lancet* 393(10177): 1225–1232.

Hedermann, Gitte, Paula Louise Hedley, Marie Bækvad-Hansen, Henrik Hjalgrim, Klaus Rostgaard, Porntiva Poorisrisak, Morten Breindahl, Mads Melbye, David M Hougaard, and Michael Christiansen. 2021. "Danish Premature Birth RATES DURING THE COVID-19 Lockdown." *Archives of Disease in Childhood-Fetal and Neonatal Edition* 106(1): 93–95.

Hedley, Paula L., Gitte Hedermann, Christian M. Hagen, Marie Bækvad-Hansen, Henrik Hjalgrim, Klaus Rostgaard, Anna D. Laksafoss, Steen Hoffmann, Jørgen Skov Jensen, Morten Breindahl, Mads Melbye, Anders Hviid, David M. Hougaard, Lone Krebs, Ulrik Lausten-Thomsen, and Michael Christiansen. 2021. "Preterm Birth, Stillbirth and Early Neonatal Mortality during the Danish COVID-19 Lockdown." *European Journal of Pediatrics* 181(3): 1175–1184. https://doi.org/10.1007/s00431-021-04297-4.

Holman, Darryl J, and James W Wood. 2001. "Pregnancy Loss and Fecundability in Women," in P. T. Ellison (ed.), *Reproductive Ecology and Human Evolution*, pp. 15–38.

Houlihan, Catherine F, Nina Vora, Thomas Byrne, Dan Lewer, Gavin Kelly, Judith Heaney, Sonia Gandhi, Moira J Spyer, Rupert Beale, and Peter Cherepanov. 2020. "Pandemic Peak SARS-

CoV-2 Infection and Seroconversion Rates in London Frontline Health-Care Workers." *The Lancet* 396(10246): e6–e7.

Jamieson, Denise J., and Sonja A. Rasmussen. 2022. "An Update on COVID-19 and Pregnancy." *American Journal of Obstetrics and Gynecology* 226(2): 177–186. https://doi.org/10.1016/j.ajog.2021.08.054.

Juárez, Sol, Tomás Alonso Ortíz, Diego Ramiro-Fariñas, and Francisco Bolúmar. 2012. "The Quality of Vital Statistics for Studying Perinatal Health: The Spanish Case." *Paediatric and Perinatal Epidemiology* 26(4): 310–315.

Kazemi, Seyyedeh Neda, Bahareh Hajikhani, Hamidreza Didar, Sareh Sadat Hosseini, Sara Haddadi, Farima Khalili, Mehdi Mirsaeidi, and Mohammad Javad Nasiri. 2021. "COVID-19 and Cause of Pregnancy Loss during the Pandemic: A Systematic Review." *PloS ONE* 16(8): e0255994.

Khalil, Asma, Erkan Kalafat, Can Benlioglu, Pat O'Brien, Edward Morris, Tim Draycott, Shakila Thangaratinam, Kirsty Le Doare, Paul Heath, and Shamez Ladhani. 2020. "SARS-CoV-2 Infection in Pregnancy: A Systematic Review and Meta-Analysis of Clinical Features and Pregnancy Outcomes." *EClinicalMedicine* 25: 100446.

Kirchengast, Sylvia, and Beda Hartmann. 2021. "Pregnancy Outcome during the First COVID 19 Lockdown in Vienna, Austria." *International Journal of Environmental Research and Public Health* 18(7): 3782.

Kramer, Michael S, Louise Séguin, John Lydon, and Lise Goulet. 2000. "Socio-Economic Disparities in Pregnancy Outcome: Why Do the Poor Fare So Poorly?" *Paediatric and perinatal epidemiology* 14(3): 194–210.

Luppi, Francesca, Bruno Arpino, and Alessandro Rosina. 2020. "The Impact of COVID-19 on Fertility Plans in Italy, Germany, France, Spain, and the United Kingdom." *Demographic Research* 43: 1399–1412.

Maibom, Jonas, Hans H Sievertsen, Marianne Simonsen, and Miriam Wüst. 2021. "Maternity Ward Crowding, Procedure Use, and Child Health." *Journal of Health Economics* 75: 102399.

Mata, Jutta, Alexander Wenz, Tobias Rettig, Maximiliane Reifenscheid, Katja Möhring, Ulrich Krieger, Sabine Friedel, Marina Fikel, Carina Cornesse, Annelies G. Blom, and Elias Naumann. 2021. "Health Behaviors and Mental Health During the COVID-19 Pandemic: A Longitudinal Population-Based Survey in Germany." *Social Science & Medicine* 287: 114333. https://doi.org/10.1016/j.socscimed.2021.114333.

Matheson, Alexia, Claire J McGannon, Atul Malhotra, Kirsten R Palmer, Alice E Stewart, Euan M Wallace, Ben W Mol, Ryan J Hodges, and Daniel L Rolnik. 2021. "Prematurity Rates during the Coronavirus Disease 2019 (COVID-19) Pandemic Lockdown in Melbourne, Australia." *Obstetrics and Gynecology* 137(3): 405.

McLean, Mark, Andrew Bisits, Joanne Davies, Russell Woods, Philip Lowry, and Roger Smith. 1995. "A Placental Clock Controlling the Length of HUMAN PRegnancy." *Nature Medicine* 1(5): 460–463.

Nathan, Barker, C. Austin Davis, López-Peña Paula, Mitchell Harrison, A. Mushfiq Mobarak, Naguib Karim, Reimão Maira Emy, Shenoy Ashish, and Vernot Corey. 2020. *Migration and the Labour Market Impacts of COVID-19*. Helsinki, Finland: UNU-WIDER.

Navarro, Pilar, John Mehegan, Celine M Murrin, Cecily C Kelleher, and Catherine M Phillips. 2020. "Associations between a Maternal Healthy Lifestyle Score and Adverse Offspring Birth Outcomes and Childhood Obesity in the Lifeways Cross-Generation Cohort Study." *International Journal of Obesity* 44(11): 2213–2224.

Nguyen, Long H, David A Drew, Mark S Graham, Amit D Joshi, Chuan-Guo Guo, Wenjie Ma, Raaj S Mehta, Erica T Warner, Daniel R Sikavi, and Chun-Han Lo. 2020. "Risk of COVID-19 among Front-line Healthcare Workers and the General Community: A Prospective Cohort Study." *The Lancet Public Health* 5(9): e475-e483.

Nykjaer, Camilla, Nisreen A Alwan, Darren C Greenwood, Nigel AB Simpson, Alastair WM Hay, Kay LM White, and Janet E Cade. 2014. "Maternal Alcohol Intake prior to and during Pregnancy and Risk of Adverse Birth Outcomes: Evidence from a British Cohort." *Journal of Epidemiology and Community Health* 68(6): 542–549.

Oberndorfer, Moritz, Ruth Dundas, Alastair H Leyland, and Anna Pearce. 2022. "The LoCo (Lockdown Cohort)-effect: why the LoCo may have better life prospects than previous and subsequent birth cohorts." *European Journal of Public Health* 32(3): 339–340. https://doi.org/10.1093/eurpub/ckac049.

Philip, Roy K, Helen Purtill, Elizabeth Reidy, Mandy Daly, Mendinaro Imcha, Deirdre McGrath, Nuala H O'Connell, and Colum P Dunne. 2020. "Unprecedented Reduction in Births of Very Low Birthweight (VLBW) and Extremely Low Birthweight (ELBW) Infants during the COVID-19 Lockdown in Ireland: A 'Natural Experiment' Allowing Analysis of Data from the Prior Two Decades." *BMJ Global Health* 5(9): e003075. https://doi.org/10.1136/bmjgh-2020-003075

Piquero, Alex R., Wesley G. Jennings, Erin Jemison, Catherine Kaukinen, and Felicia Marie Knaul. 2021. "Domestic Violence during the COVID-19 Pandemic - Evidence from a Systematic Review and Meta-Analysis." *Journal of Criminal Justice* 74: 101806. https://doi.org/10.1016/j.jcrimjus.2021.101806.

Pison, Gilles, Christiaan Monden, and Jeroen Smits. 2015. "Twinning Rates in Developed Countries: Trends and Explanations." *Population and Development Review* 41(4): 629–649.

Quintana-Domeque, Climent, Ines Lee, Anwen Zhang, Eugenio Proto, Michele Battisti, and Antonia Ho. 2021. "Anxiety and Depression among Medical Doctors in Catalonia, Italy, and the UK during the COVID-19 Pandemic." *PloS ONE* 16(11): e0259213.

Rajewska, Aleksandra, Wioletta Mikołajek-Bedner, Joanna Lebdowicz-Knul, Małgorzata Sokołowska, Sebastian Kwiatkowski, and Andrzej Torbé. 2020. "COVID-19 and Pregnancy—Where Are We Now? A Review." *Journal of Perinatal Medicine* 48(5): 428–434.

Ranney, Megan L, Valerie Griffeth, and Ashish K Jha. 2020. "Critical Supply Shortages—The Need for Ventilators and Personal protective equipment during the Covid-19 pandemic." *New England Journal of Medicine* 382(18): e41.

Requena, Antonio, María Cruz, Vanessa Vergara, Nicolás Prados, Daniela Galliano, and Antonio Pellicer. 2020. "A Picture of the Covid-19 Impact on IVIRMA Fertility Treatment Clinics in Spain and Italy." *Reproductive BioMedicine Online* 41(1): 1–5.

Saccone, Gabriele, Luigi Della Corte, Giuseppe M Maruotti, Johanna Quist-Nelson, Antonio Raffone, Valentino De Vivo, Gennaro Esposito, Fulvio Zullo, and Vincenzo Berghella. 2019. "Induction of Labor at Full-Term in Pregnant Women with Uncomplicated Singleton Pregnancy: A Systematic Review and Meta-Analysis of Randomized Trials." *Acta Obstetricia et Gynecologica Scandinavica* 98(8): 958–966.

Sax, Christoph, and Dirk Eddelbuettel. 2018. "Seasonal adjustment by x-13arima-seats in r." *Journal of Statistical Software* 87: 1–17.

Shechter, Ari, Franchesca Diaz, Nathalie Moise, D Edmund Anstey, Siqin Ye, Sachin Agarwal, Jeffrey L Birk, Daniel Brodie, Diane E Cannone, and Bernard Chang. 2020. "Psychological Distress, Coping Behaviors, and Preferences for Support among New York Healthcare Workers during the COVID-19 Pandemic." *General Hospital Psychiatry* 66: 1–8.

Torche, Florencia. 2011. "The Effect of Maternal Stress on Birth Outcomes: Exploiting a Natural Experiment." *Demography* 48(4): 1473–1491.

Torche, Florencia, and Dalton Conley. 2016. "A Pound of Flesh: The Use of Birthweight as a Measure of Human Capital Endowment in Economics Research." In *The Oxford Handbook of Economics and Human Biology*, edited by John Komlos and Inas Kelly. New York, NY: Oxford University Press. pp. 632–639.

Torche, Florencia, and Andrés Villarreal. 2014. "Prenatal Exposure to Violence and Birth Weight in Mexico Selectivity, Exposure, and Behavioral Responses." *American Sociological Review* 79(5): 966–992.

Torrente, Maria, Pedro A. C Sousa, Ana Sánchez-Ramos, Joao Pimentao, Ana Royuela, Fabio Franco, Ana Collazo-Lorduy, Ernestina Menasalvas, and Mariano Provencio. 2021. "To Burn-Out or Not to Burn-Out: A Cross-Sectional Study in Healthcare Professionals in Spain during COVID-19 Pandemic." *BMJ Open* 11(2): e044945.

Vermeulen, Nathalie, Baris Ata, Luca Gianaroli, Kersti Lundin, Edgar Mocanu, Satu Rautakallio-Hokkanen, Juha S Tapanainen, and Anna Veiga. 2020. "A Picture of Medically Assisted Re-

production Activities during the COVID-19 Pandemic in Europe." *Human Reproduction Open* 2020(3): hoaa035.

Vignoli, Daniele, Valentina Tocchioni, and Alessandra Mattei. 2020. "The Impact of Job UNCERTAINTY ON First-BIRTH POSTponement." *Advances in Life Course Research* 45: 100308. https://doi.org/10.1016/j.alcr.2019.100308.

Wei, Shu Qin, Marianne Bilodeau-Bertrand, Shiliang Liu, and Nathalie Auger. 2021. "The Impact of COVID-19 on Pregnancy Outcomes: A Systematic Review and Meta-Analysis." *CMAJ* 193(16): E540-E548.

Woods, Robert. 2009. *Death Before Birth: Fetal Health and Mortality in Historical Perspective*. Oxford, UK: Oxford University Press.

Yang, Jie, Rohan D'souza, Ashraf Kharrat, Deshayne B Fell, John W Snelgrove, Kellie E Murphy, and Prakesh S Shah. 2021. "COVID-19 Pandemic and Population-Level Pregnancy and Neonatal Outcomes: A Living Systematic Review and Meta-Analysis." *Acta Obstetricia et Gynecologica Scandinavica* 100(10): 1756–1770.

Yee, Jeong, Woorim Kim, Ji Min Han, Ha Young Yoon, Nari Lee, Kyung Eun Lee, and Hye Sun Gwak. 2020. "Clinical Manifestations and Perinatal Outcomes of Pregnant Women with COVID-19: A Systematic Review and Meta-Analysis." *Scientific Reports* 10(1): 1–7.