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Evidence from Spanish Birth Registers

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Abstract

Demographic change almost never happens fast, except during wars, natural disasters, and pandemics. We ask what the joint consequences of the COVID-19 pandemic for fertility and birth outcomes are 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 (8–9 months after the first wave of the pandemic) compared with monthly trends in the ten previous years (2010-2019). The improvement in birth outcomes was shortly followed by a decline in the total fertility rate (TFR), especially among women at the beginning and the end of their reproductive age. These findings are consistent with the idea that the pandemic selectively affected conception, which showed up first as a birth-outcomes improvement due to the missing conception of frail-children-to-be (including pre-term children) and then as a lowered fertility rate due to the missing conception of at-term children.

Keywords: COVID-19, fertility, birth outcomes, selective conceptions

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Introduction

Demographic change almost never happens fast, except during wars, natural disasters, and pandemics. Human population have suffered an unprecedented distress since the WHO's declaration of the COVID-19 crisis as pandemic in February 2020. An accumulating body of research is highlighting how the COVID-19 pandemic had pervasive population effects by generating unprecedented life expectancy losses (Aburto et al., 2022), creating new barriers to international and internal migrations fluxes (Nathan et al., 2020), and by depressing the already low fertility rates of many developed countries (Aassve, Cavalli, Mencarini, Plach, & Livi Bacci, 2020; Aassve, Cavalli, Mencarini, Plach, & Sanders, 2021).

This article analyzes the joint consequences of the first wave of the COVID-19 pandemic for fertility and birth outcomes in Spain. The previous research left us with seemingly contrasting findings. On the one hand, the pandemic has coincided with a decline in fertility rates, which was largely attributed to increased economic losses and uncertainty in the future (Aassve et al., 2020; Aassve et al., 2021). On the other hand, the pandemic has coincided with an overall improvement of birth outcomes in terms of reduced preterm births (PTB) and low birth weight (LBW), which has been attributed to the reduction of socio-emotional stressor related to stay-at-home orders (Been et al., 2020; Chmielewska et al., 2021; Gemmill et al., 2022; Hedley et al., 2021; Philip et al., 2020).

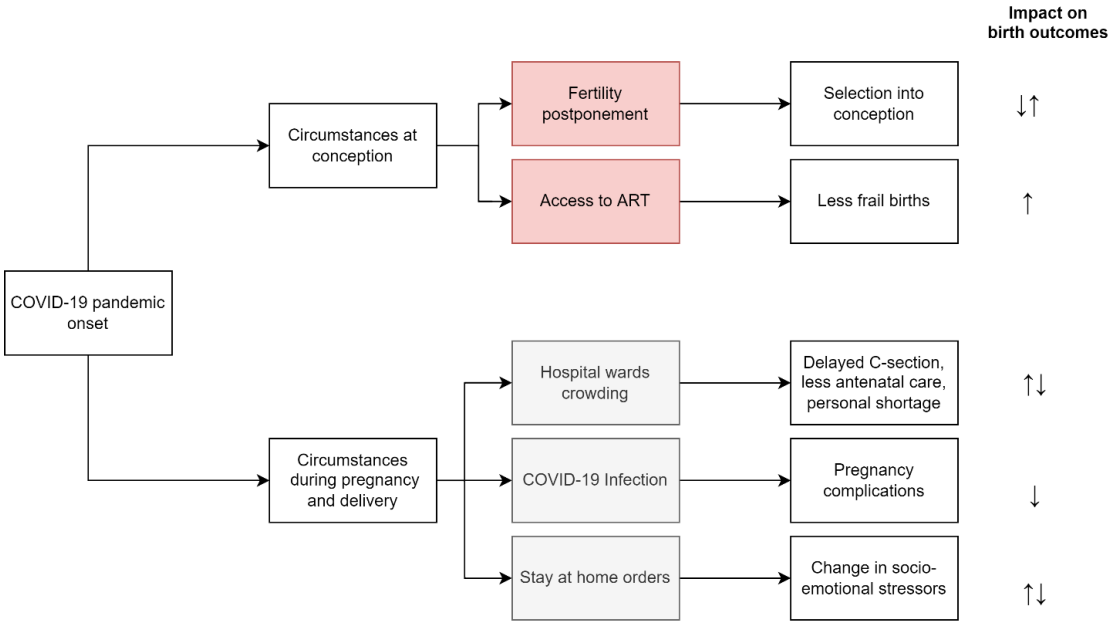
We reconcile these seemingly contradictory findings in a narrative that considers the determinants of fertility and birth outcomes at the time of conception, during pregnancy, and at the time of birth. We argue that the first COVID-19 wave has affected birth outcomes through three channels. First, by selectively affecting conception immediately after the pandemic outbreak. Second, by affecting the social, psychological, and health circumstances during pregnancy. Third, by affecting the timing and care circumstances around delivery. Our analysis draws on population administrative data on approximately four million births in Spain and explore how fertility and birth outcomes trends changed following the first wave of the COVID-19 pandemic. 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 15th, 2020 and issued tight nation-wide 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 across 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 simultaneously

pandemic-induced fertility behaviors and birth outcomes in a single and coherent 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. We analytically distinguish determinants at time of conception, during pregnancy, and around delivery. Figure 1 summarizes the potential mechanisms at play in each of these three stages (determinants during pregnancy and around delivery are grouped together for simplicity). Red boxes highlight the influence of the COVID-19 pandemic on birth outcomes through fertility behaviors. Some pandemic-induced mechanism may have contributed toward worsening birth outcomes. Others, like selectivity in conception, may instead have contributed to better outcomes. Below we discuss the most important mechanisms and their prevalence to understand the likely overall outcome of the COVID-19 for birth outcomes at the population level.

Figure 1. Pathways linking the onset of the COVID-19 pandemic with fertility and birth outcomes



Note: ↑ = improvment; ↓ = worsening

Circumstances around the time of conception

The COVID-19 pandemic has been linked to large drops in fertility nine months after. Recent assessments show a decline in crude birth rates between 6–9% when compared to the same months in 2019. Spain displays one of the largest declines across developed countries (Aassve et al., 2021; Arpino, Luppi, & Rosina, 2021). Such fertility declines are likely not randomly distributed among the population. The literature on natural and man-made disasters highlighted that women with different socio-economic status (SES) have different fertility responses due to heightened risk of exposures and different adaptive responses (Brown, 2018; Currie & Rossin-Slater, 2013; Torche & Villarreal, 2014). The large economic uncertainty generated by the COVID-19 pandemic may have delayed fertility plans (Luppi, Arpino, & Rosina, 2020; Vignoli, Tocchioni, & Mattei, 2020), and likely at a higher rate among young, precarious, and low SES workers. If low SES workers were more likely to postpone fertility behaviors due to uncertainty, than birth outcomes observed nine months after should improve compared to the previous years because low SES mothers are also more likely to deliver children with poor birth outcomes (Aizer & Currie, 2014; Kramer, Séguin, Lydon, & Goulet, 2000).

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. The drop in social contacts also resulted in limited chances to engage in sexual activity with non-domestic partners. Young people were affected the most by the lack of contacts and mobility (Caselli, Grigoli, Sandri, & Spilimbergo, 2022). Mobility constraints and lack of social contacts likely limited unintended pregnancies among the (younger) population that is more prone to risky behaviors and lifestyles and also have worse birth outcomes on average (Chen et al., 2007; Navarro, Mehegan, Murrin, Kelleher, & Phillips, 2020; Nykjaer et al., 2014)

The halt in access to medical assisted reproduction (MAR) treatments during the pandemic may also work towards the improvement of birth outcomes nine months later. MAR children have on average worse birth outcomes when compared to naturally conceived children (Goisis, Remes, Martikainen, Klemetti, & Myrskylä, 2019). In Spain, all MAR activities were interrupted from mid-March to mid-April 2020 (Requena et al., 2020). Spain traditionally stands out as one of the countries with the highest prevalence of MAR treatments in Europe (De Geyter et al., 2018). Therefore, such a sudden interruption in MAR treatment in Spain may have had the unintended consequence 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. Pregnant women were subject to both general stressors caused by life during the pandemic and the direct strain caused by the infection. Hospitals burdens skyrocketed due to increased patient inflows, high staff-infection rates and burnout, and obligations to follow COVID-19 protocols. Stressors, direct infection, and disservice in hospital wards may all relate to birth outcomes.

Recent reviews and meta-analyses find that COVID-19 infection during pregnancy was associated with increased risk for pre-term birth, preeclampsia, cesarean delivery, and low birth weight (Allotey et al., 2020; Elsaddig & Khalil, 2021; Khalil et al., 2020; Wei, Bilodeau-Bertrand, Liu, & Auger, 2021; Yee et al., 2020). Only some studies reported increased infant mortality. However, pregnancy did not increase the risk of COVID-19 related mortality. Thus, rather than increasing positive selection of newborns, infection among pregnant women likely increased risk of adverse birth outcomes (Elsaddig & Khalil, 2021; Rajewska et al., 2020).

Ironically, the introduction of non-sanitary measures to contain the infection such as stay-at-home orders may have worked toward the improvement of birth outcomes. Lockdowns reduced the exposure of pregnant women to socio-emotional and environmental stressors that commonly affect our everyday life in ordinary circumstances. For example, pregnant women may have experienced less travel-related stress, benefitted from reduced exposure to pollution, and had less chances to suffer common viral and bacterial infection due to everyday social interactions. The lowered exposure to stressors in the aftermath of worldwide lockdowns may have contributed to better birth outcomes because stress during pregnancy is linked with premature deliveries (Cozzani, Triventi, & Bernardi, 2021; McLean et al., 1995; Torche, 2011). However, stay-at-home orders may have also led to mechanisms that worsen birth outcomes. Amon the others, lockdowns resulted in increased exposure to domestic violence (Piquero, Jennings, Jemison, Kaukinen, & Knaul, 2021), deteriorating health behaviors (Mata et al., 2021), excessive burdens in housework (Brini, Lenko, Scherer, & Vitali, 2021), reduced access to medical care, and increased economic uncertainty.

Lockdowns has been linked to a decline in pre-term births during lockdowns in many countries in and outside Europe including Denmark (Hedermann et al., 2021), Ireland (Philip et al., 2020), the Netherlands (Hedermann et al., 2021), Italy (De Curtis, Villani, & Polo, 2021), Australia (Matheson et al., 2021), Austria (Kirchengast & Hartmann, 2021), and

Botswana (Caniglia et al., 2021). However, studies found no change or even or 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 pre-term birth 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 supply shortage (Ranney, Griffeth, & Jha, 2020), personal shortage (Garcia-Basteiro et al., 2020; Houlihan et al., 2020; Nguyen et al., 2020) and burnout (Quintana-Domeque et al., 2021; Shechter et al., 2020; Torrente et al., 2021). A direct consequence of hospital strains were changes in birthing location and delays (Breman et al., 2021). Such delays may increase the risk of complications during deliveries. However, a potential decline or delay in the use of c-sections and medically induced labor may increase gestational age, thereby increasing birthweight (Saccone et al., 2019). Lower usage of c-sections and induced labor have been causally linked to better birth outcomes during non-pandemic periods (Maibom, Sievertsen, Simonsen, & Wüst, 2021), and a similar logic may play out during the pandemic.

Data and Methods

Data

We use Spanish population-level birth certificates to assess early trends in fertility and birth outcomes after the onset of the COVID-19 pandemic. Birth certificates 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. These data cover the whole population of Spanish newborns born to legal residents, collecting information on the circumstance of the delivery, the parental socio-demographic characteristics, and the children's anthropometric measures. Anthropometric measurements are consistent with hospital records, especially for frail deliveries (Juárez, Alonso Ortíz, Ramiro-Fariñas, & Bolúmar, 2012). We define our population as each child born in Spain between 2010 and 2020, consisting of about 4.2 million births.

Variables

We draw on population statistics from INE, which combined with birth counts from the birth certificates, we use to reconstruct age-specific population figures to combine with age-specific births rates to generate monthly total fertility rates (TFRs) and age-specific fertility

rates (ASFR).To capture perinatal health, we use four widely adopted indicators of birth outcomes that proxy children's future developmental potential (Boardman, Powers, Padilla, & Hummer, 2002; Torche & Conley, 2016)—two continuous measures of birth outcomes (birth weight measured in grams and gestational age reported in weeks of gestation) and two binary indicators [whether the child is born pre-term (<37 weeks of gestation - PTB); and whether the child is born low birth weight (<2,500 grams - LBW)]. These latter binary measurements are particularly relevant as they capture frail newborns more at risk of future morbidity and mortality (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009), whereas the continuous measures also allow us to examine differences in impact across the full range of the outcomes.

Analytical Strategy

First, we estimate TFR and seasonally adjusted TFR trends that we then we decompose by age, parity, and maternal education. Second, we perform OLS regressions to examine how birth outcomes changed in the following of the onset of the COVID-19 pandemic. We estimate average birth weight in grams and gestational weeks as well as incidence of PTB and LBW and related 95% confidence intervals for each month between January 2010 and December 2020. Doing so allow us to assess whether we observe any deviation in birth outcomes in 2020 compared to the ten years prior. We include years since 2010 to test whether 2020 displays a deviation in respect to the previous decade. We perform these analyses also by parity (firstborns, and those of higher birth order) and maternal education (university vs. less than university). Throughout the manuscript we display results for baseline models assessing the unadjusted trends in birth outcomes. Supplementary Figures S1-S2 also reports the same trends adjusting for a set of controls: sex of the newborn, maternal age, parity, maternal marital status, municipality size, and provincial fixed effects. Estimates are largely unchanged by the inclusion of those additional controls, and we prefer unadjusted models, as they reflect the unconditional population changes.

We consider both the average changes in the binary and continuous outcomes during the pandemic, as well as the changes in the distribution of the continuous variables using the inference on counterfactual distribution approach provided by 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 heterogenous and even of opposite sign at different parts of the

distribution under the assumption of rank-stability (i.e., that birth outcomes were affected monotonically).

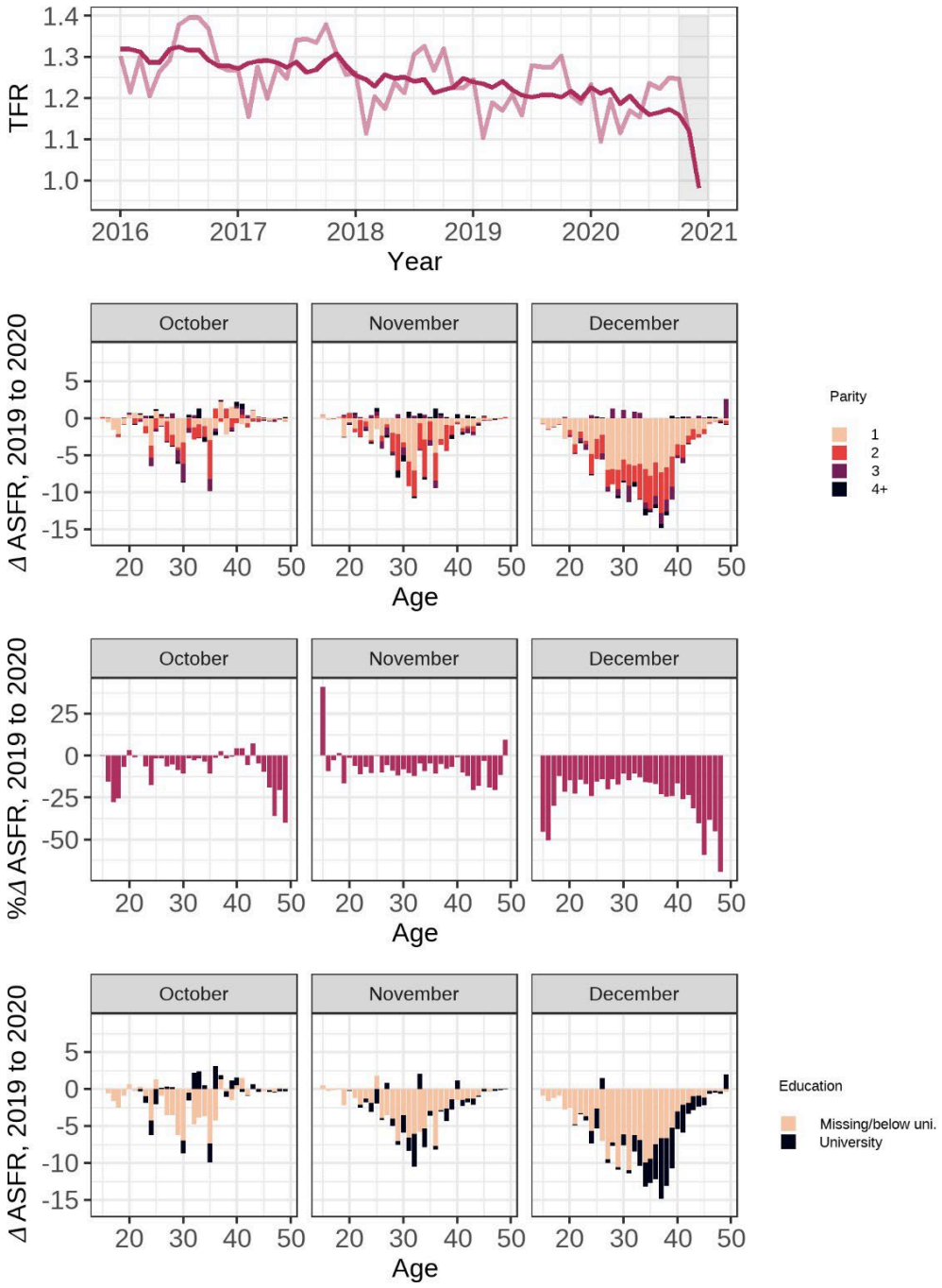
Results

Trends in fertility

First, we investigate how fertility changed after the onset of the COVID-19 pandemic in Spain. In Figure 2 below, the top panel (Panel 1) shows the monthly TFR trend from Jan. 2016 to Dec. 2020, showing the expected number of children born to a woman if she was to follow the fertility schedule for the given month across her entire fertility career. The lighter line shows the actual TFR trends, the darker line seasonally adjusted TFR using the software provided by Sax and Eddelbuettel (2018). Middle-upper panel (Panel 2) shows the changes in age-specific fertility rates decomposed by parity in comparison to the same month in 2019. Middle-lower panel (Panel 3) displays relative changes in the ASFR between same month in 2019 and 2020. Bottom-lower panel (Panel 4) 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 in December 2020. TFR drops to about 1.13 in November and below 1 in December, reaching unprecedented low levels. This reduction happened selectively. Most of the decreases is driven by first births (Panel 2), especially in December, but also in November. In December the decline is also heavily driven by university educated mother above 34 years of age (Panel 3). The largest relative ASFR decrease occur to women at the beginning and the end of their reproductive age (below 20 and above 40), with ASFR declines for these two groups between 20% and 25% in October and November, and between about 40% and 50% in December (Panel 3). The decreases among women above 40 driven by declines in first births is compatible with the interruption of MAR treatments in Spain. In the next section, we investigate birth outcomes in 2020.

Figure 2. Spanish TFR (2016-2020) and differences in ASFR (2019-2020)



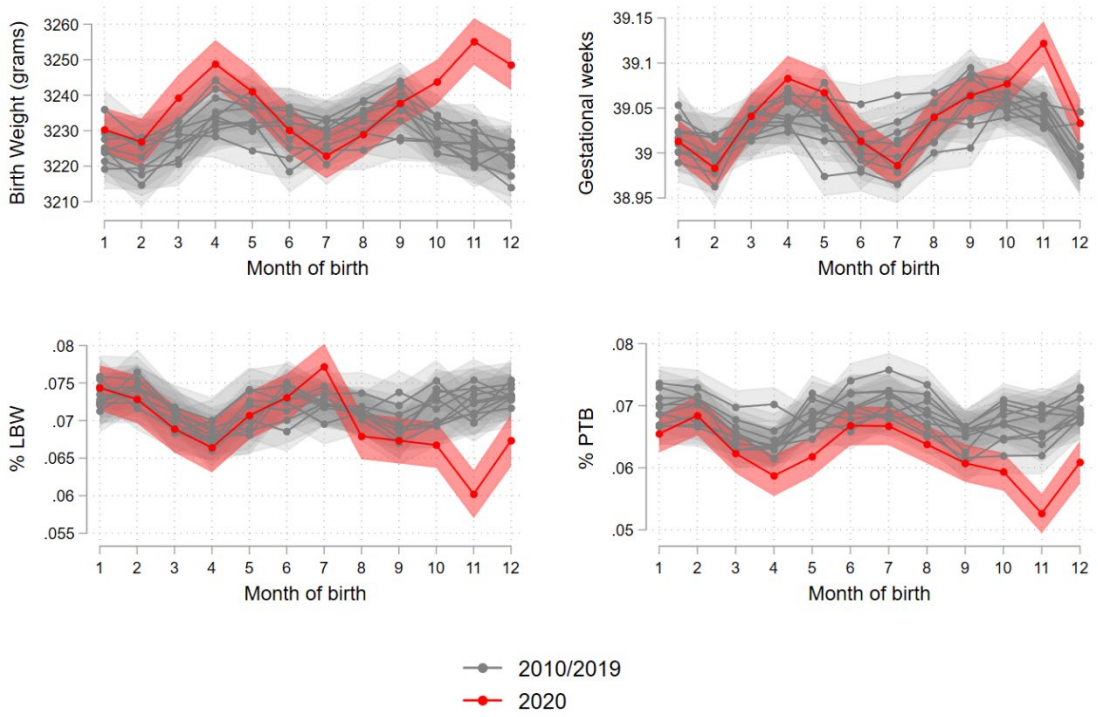
Note: Upper panel shows monthly TRF (lighter line) and seasonally adjusted monthly TFR (darker line). Upper-middle panel shows ASFR decline (2020 vs. 2019) decomposition by parity. Lower-middle panel displays relative changes in the ASFR between same month in 2019 and 2020. Bottom panel shows ASFR decline decomposition by maternal education. For lower middle figure for December 2020, we have left out women at age 49.

Trends in birth outcomes following the COVID-19 pandemic

Figure 3 displays trends and 95% confidence intervals of birth weight (grams), gestational age (weeks), PTB, and LBW for each month-year between January 2010 and December 2020. Supplementary Figure S1 reports the same results adjusted with covariates defined as in the methods section, and results are unchanged. Gray lines and confidence intervals display yearly trends in birth outcomes for each year between 2010 and 2019; the red line and related confidence intervals displays trends in birth outcomes for 2020. All the estimates reported in Figure 3 are reported in Supplementary Tables S1-S4.

Overall, we observe deviations from decennial trends in birth outcomes eight-to-ten months after the declaration of the state of emergency in March 2020. We observe a remarkable improvement in the month of November for all the birth outcomes considered, accompanied by smaller improvements in both December and October for all outcomes (for gestational age measured in weeks only significant in November). These results are in line with evidence from the US, that found that the largest improvement in birth outcomes after the onset of the COVID-19 pandemic occurred in November 2020 (Gemmill et al., 2022). In November, children weighted on average about 3255 grams, 25 grams heavier than the highest average of the same month within the previous decade (2011; 3230 grams). In December, the same increase was of about 24 grams (3249 grams in 2020 vs. 3225 in Dec. 2019). Birth weight trends were also at a decade-high during the first COVID-19 wave, but the variation is more in line with the previous decade, with 95% confidence intervals overlapping with previous years' trends. Similarly, the share of LBW children reached the decade lowest with only 6% of total births being born LBW in November 2020 compared to the previous lowest of 7% in 2010 (15% decrease). In December, 6.7% of children were born LBW, 0.4 percentage point less than the previous decade lowest in the same month in 2011 (6% decrease). In the rest of the 2020, LBW trends do not show any other remarkable pattern. Measures of gestational age and PTB follow a similar pattern compared to infant weight indicators. November is the month showing the largest improvements in both gestational age and PTB. Gestational age increased with about 0.42 days in November 2020 with respect to the previous highest in November 2015. Incidence of PTB dropped to 5.2%, one percentage point less than the lowest incidence observed in the previous decade in 2019, a 15% decrease. Across 2020, trends in gestational age remained within the range of the previous decade, with the only exception of November. Trends in PTB remained quite low when compared with the previous decade.

Figure 3. Birth outcomes trends 2010-2020

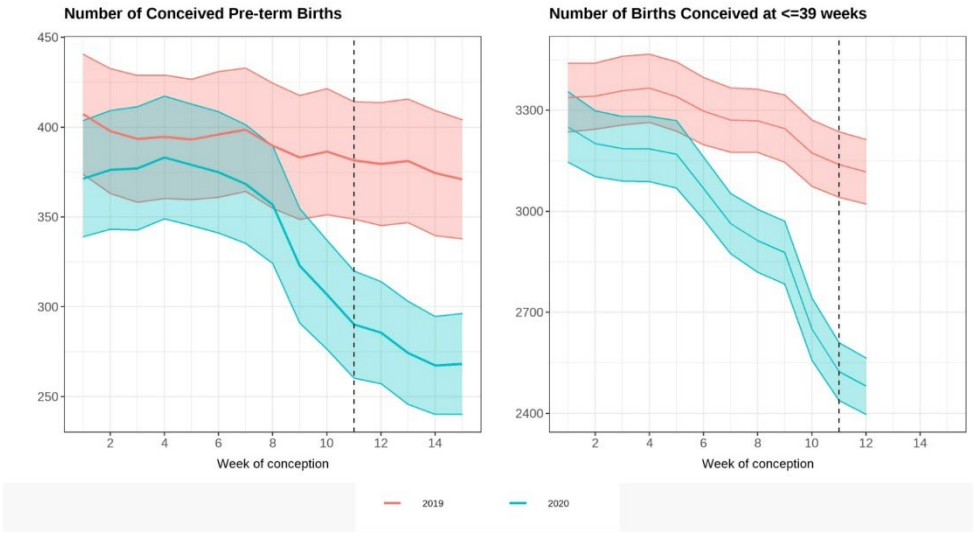


Note: Unadjusted trends.

To contextualize our estimated improvements in birth outcomes, we compare them with estimates from research on the Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) developed in the US, which specifically targeted low-income mothers. Birth weight improvement in November (25 grams) is about half of the estimated beneficial effects of WIC participation (53-63 grams) (Bitler & Currie, 2005; Blakeney, Herting, Zierler, & Bekemeier, 2020). LBW improvements in November are directly comparable with WIC's improvement, being in the order of one-percentage point and about 10% reduction (Bitler & Currie, 2005; Blakeney et al., 2020). The gestational length increase (0.06 weeks) is about one-quarter of the estimated increase as a consequence of the WIC program (Hamad, Collin, Baer, & Jelliffe-Pawlowski, 2019). PTB improvements are comparable in size with WIC, being in the order of a percentage point (Soneji & Beltrán-Sánchez, 2019). All in all, improvements in LBW and PTB resemble those of WIC program, and average changes are smaller in size.

To investigate if the observed reduction in fertility in December and the improvements in birth outcomes in November originated at the same time, we investigate whether they coincide at time of conception. Since precise information on the date of birth is not available, we use information on gestational weeks, randomly assign a day of birth within a given month, and by conducting 1000 simulation draws we reconstruct the (likely) week of conception. Figure 4 below displays the number of normal and pre-term and at term conceptions in the first 15 weeks of 2020 compared to 2019. Red line reports the number of premature conceptions in 2019, light blue line 2020. We observe that a sharp decline starts around the 9th week of 2020 (February 24th-March 2nd), 2 weeks before the declaration of the state of emergency and the nationwide stay-at-home order in Spain (March 14th, 2020) for pre-term births, 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 is reasonable to believe that the decline in pre-term occurred simultaneously with the begin of the first COVID-19 wave in Spain.

Figure 4. Trends in conceptions by pre-term status 2019-2020, week 1 to week 15



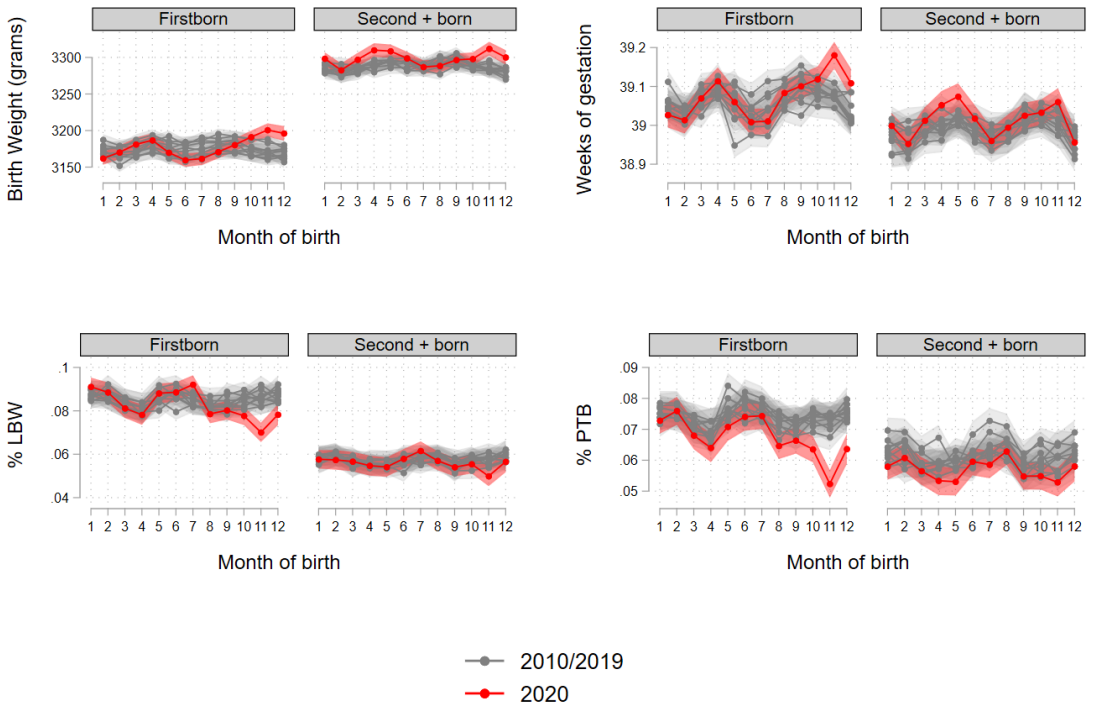
Note: Left panel displays number of conceptions of children born before the 37th week of gestation. Right panel displays the number of conceptions of children born between the 37th and 39th week of gestation. Figure obtained by estimating the week of conception by randomly assigning date of birth and by subtracting the weeks of gestation. Estimates obtained by bootstrapping 1000 simulations.

Heterogeneities by parity, maternal education, and across birth outcomes distribution

In this section we explore trends in birth outcomes by parity, maternal education, and whether the changes in birth outcomes were heterogeneous across the birth weight and gestational age distributions. First, we explored trends in birth outcomes by parity, distinguishing between

firstborn children and second or higher order newborns. Figure 5 below replicates Figure 3 by parity. Supplementary Figure S2 reports the same results adjusted by covariates as defined in the Methods section. Results are unchanged by adjusting. Overall, we observe second order or more children tend to have better birth outcomes on average than first born children. Yet, we observe again remarkable improvements in birth outcomes in November for all the outcomes considered, but with those improvements being mostly concentrated among firstborns, especially for LBW and PTB. For example, LBW decreased to 7% in November 2020 from 8.2% in 2010 for firstborns (1.2 percentage points / 16% decrease). For second born or greater order children it declined by only 0.4 percentage points, from 5.4% in 2016 to 5% in 2020 (7.5% decrease). We observe a more remarkable decline in PTB for firstborns. In November 2020 PTB decreased to 5.2% from 6.7% in Nov. 2019, 1.2 percentage points less and a 22.5% decrease. For second or higher second order children this decrease is of only 0.3 percentage points in 2020 compared to the lowest of the previous decade in 2019 (from 5.6 in 2019 to 5.3 in 2020, a 5.8% decrease).

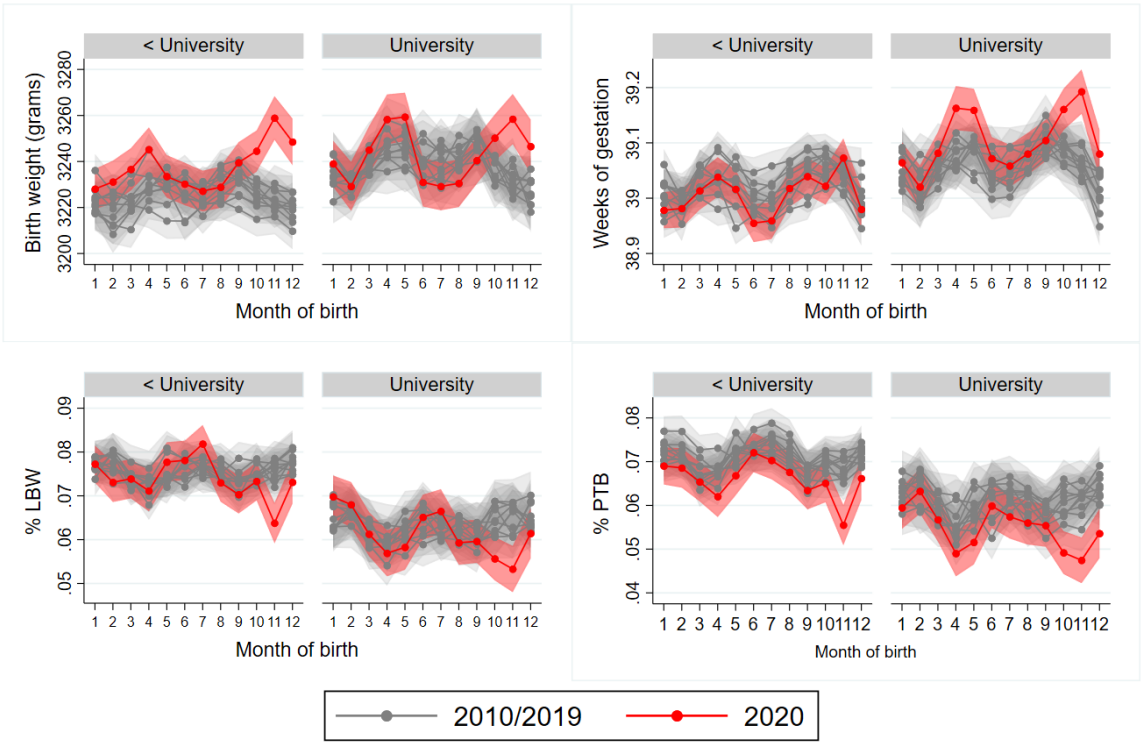
Figure 5. Birth outcomes trends 2010-2020 by parity



Note: Unadjusted trends

Second, Figure 6 below also replicates Figure 3 by maternal educational status, distinguishing between mothers with less than a university degree (left panel) and mother with more than a university degree (right panel). Results are unchanged by adjusting. Overall, all mothers see an improvement in their newborn's birth outcomes in November and December. Birth outcomes seems to improve more sharply in November for newborns of mothers with less than a university education, and children of university educated mothers seems to have a less sharp but more even improvement in both November and December, especially in terms of pre-term birth. Children of university educated mothers seems to have also experienced a smaller improvement in April and May, maybe suggesting a heterogeneous beneficial effect of lockdowns as mentioned by a number of medical studies mentioned above (Philip et al., 2020).

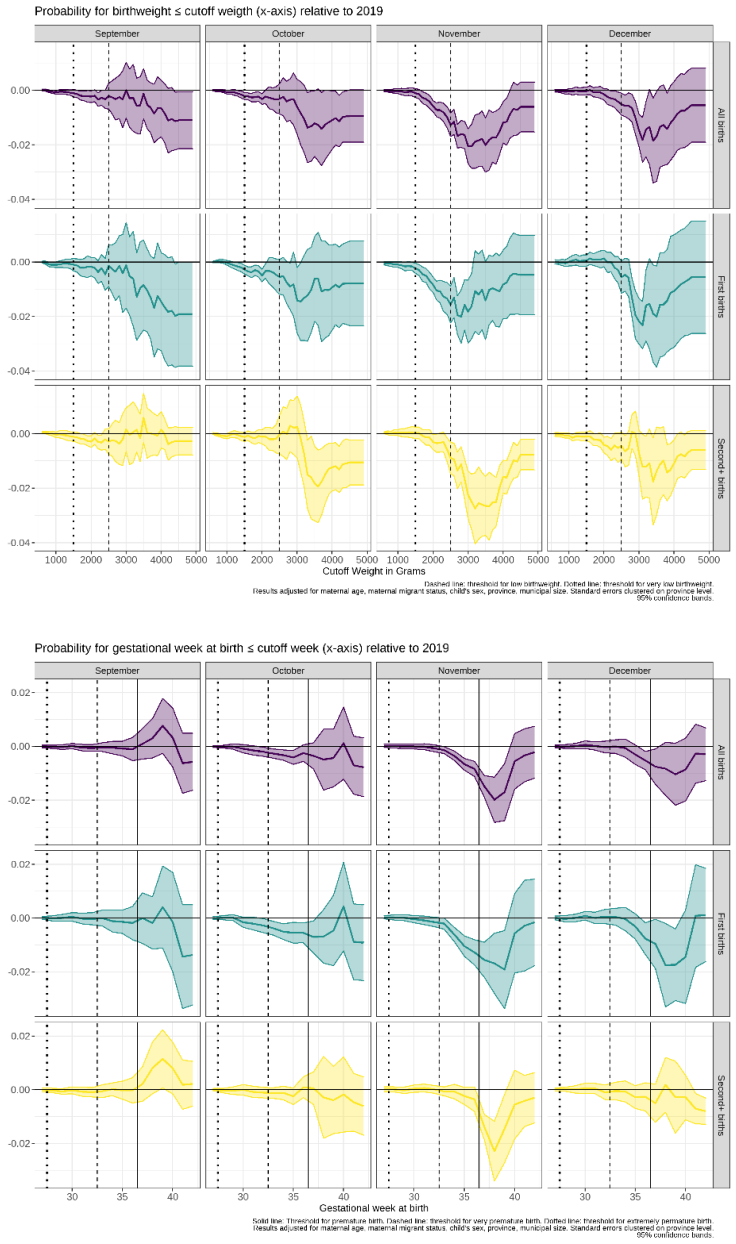
Table 6. Birth outcomes trends by maternal educational status (2010-2020)



Note: Unadjusted trends

Next, we investigate whether the improvement in birth outcomes after the COVID-19 pandemic are constant or heterogenous across birthweight and gestational weeks distributions. To this aim, we compared the cumulative distribution of birth weight and gestational weeks in 2020 with the year before (2019). In Figure 7 below, we display the probability and 95% confidence intervals of children born between Sep. and Dec. 2020 to be below a certain level of birth weight and gestational weeks distribution compared to the same period in 2019. We also include September to benchmark a month where we expect no major differences. Each column displays a month, purple lines are estimates for the whole population, green lines are the estimates for firstborns, and yellow lines are estimates for second or higher order newborns. The probability of being below a certain birth weight or gestational age threshold is estimated adjusting for sex of the newborn, maternal age, parity (in the whole population), whether the mother is Spanish, maternal marital status, municipality size, and provincial fixed effects. Top panel shows the results for birth weight, bottom panel the results for gestational weeks. Vertical lines show thresholds for clinical cut off for degrees of LBW and PTB. Overall, we find that in November, children shifted their birth weight and gestational age towards more central parts of the distribution, with firstborn being particularly less likely to be born around LBW and PTB threshold. Higher order births experienced a similar shift towards higher weight and longer gestational age, but predominantly among the part of the distributions located to the right of the thresholds for LBW and PTB. In December only firstborn in the middle of the distribution improved their birth weight and gestational age.

Figure 7. Difference across birth weight and gestational age distribution between 2019 and 2020 (September-December)



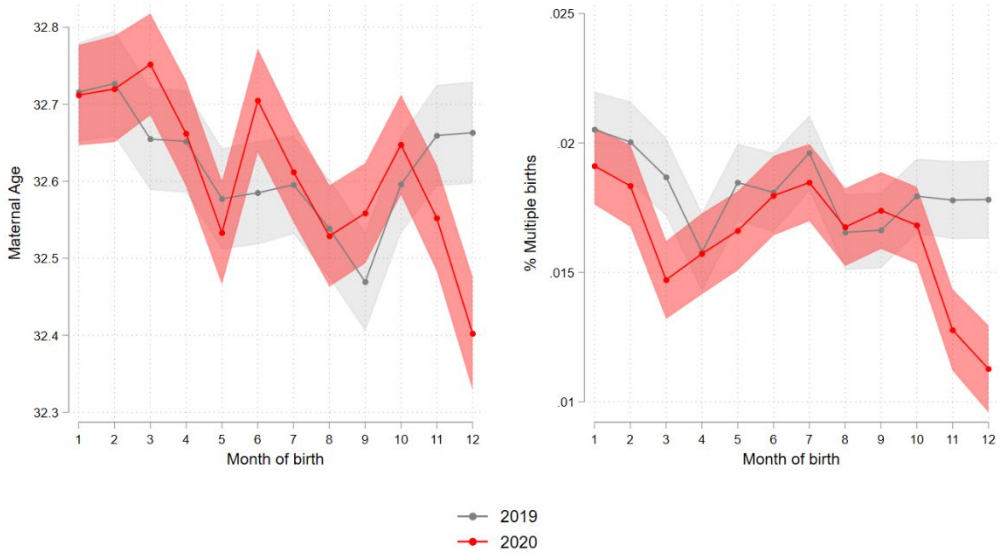
Note: Estimates obtained adjusting for maternal age, migrant status, child's sex, province, municipal size. Standard error clustered at provincial level.

Trends in maternal age and multiple births

We further explore the composition of births in 2020 respect to 2019 in regard of average maternal age and the share of multiple births. We choose 2019 as the sole comparison, because if we include earlier years, the general increase in maternal age across the 2010s (from 31.2 in 2010 to 32.3 years in 2019 according to INE) and secular trends in twin births

may introduce unwanted biases in gauging the magnitude of the 2020 change (Pison, Monden, & Smits, 2015). Figure 8 below displays the results. In line with ASFR estimates, we observe a substantial decrease in maternal age in December, with also a smaller decrease in November. Regarding multiple births, we observe a large decrease in both November and December. Multiple births decreased from about 1.8% in 2019 to 1.3% of all births in November 2019, a 28% decrease. December shows a decrease of similar magnitude (about 37%), from 1.78% of all births in Dec. 2019 to about 1.12% in Dec. 2020. The simultaneous decrease in multiple births and maternal age, together with ASFR reduction among women at the end of their fertile age, suggests that the access to MAR may have played a role in shaping the fertility dip in November and December, especially as MAR children tend to be deliver by older women and to be more likely to be multiple births (ESHRE, 2003; Goisis et al., 2019). MAR is also linked with worse birth outcomes (Goisis et al., 2019), and thus less MAR children due to a decline in availability of treatment during lockdown may have contributed to the general improvement in birth outcomes; we discuss the implications of a smaller number of MAR deliveries for our results in the next section.

Figure 8. Trends in average maternal age and multiple births 2019-2020



Note: Unadjusted trends

Conclusions & Discussion

Birth outcomes improved while fertility declined in the wake of the first wave of the COVID-19 pandemic. 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 observe jointly the two dynamics in a single case-study by adopting a coherent theoretical and empirical framework. We reconcile these seemingly findings in a narrative 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 among first births, and the youngest and oldest women in the reproductive age decreased their relative fertility the most.

Why did the first wave of the COVID-19 pandemic result in reduced fertility and improved birth outcomes nine month after? And why did we observe an improvement of birth outcomes first and a reduction if fertility only after? We argued that the COVID-19 pandemic impacted fertility behaviors and changed the composition of live births in November and December 2020 through the selectivity of conceptions nine months earlier. Our results suggest that the reduction in conceptions during the first wage did not happen at random. Rather, the reduction in conception was likely selective, thus generating a wave of 'missing children' that would have been at higher risk of frailty.

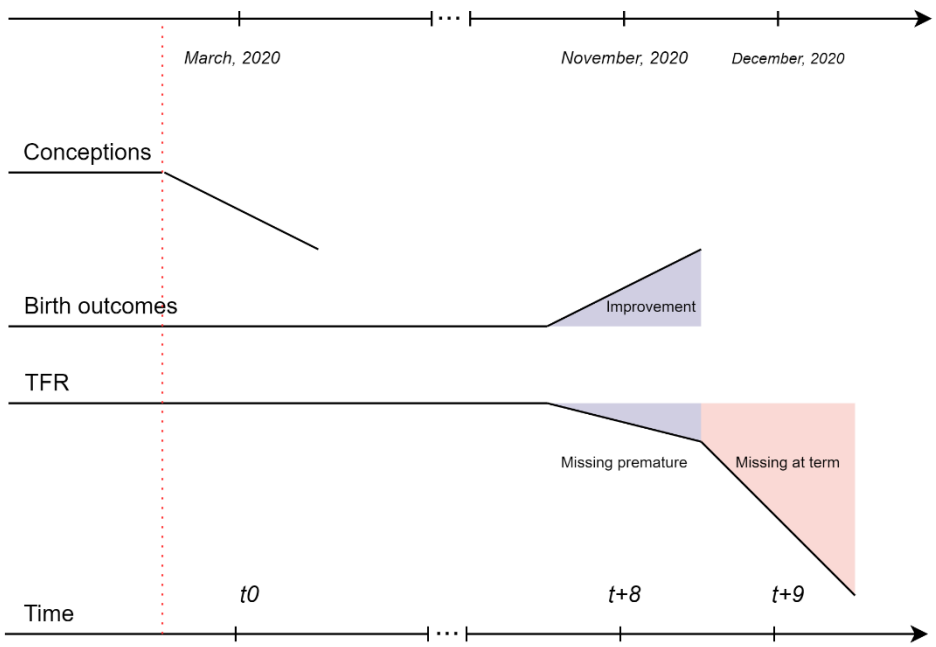
Two sets of evidence substantiate this narrative. First, we simultaneously observed three patterns eight-to-nine months after the declaration of the emergency state in Spain: a decline in a decline in ASFR among older ages, highly educated mothers, first births, and a decline in multiple births. These patterns coincided eight-to-nine months after the sudden cease in activity of MAR centers in March 2020 (Vermeulen et al., 2020). MAR conceptions are more likely among highly educated older women, being the first child of a woman, and they more often result in multiple births (Cozzani, Aradhya, & Goisis, 2021; Goisis, Håberg, Hanevik, Magnus, & Kravdal, 2020), and are also more likely to result in children with poor health (Goisis et al., 2019).

Second, we observe a simultaneous decline in births among (very) young women and first births in November and December 2020. This suggests a decline of unplanned pregnancies of very young women, which are more at risk of poor pregnancy 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 that would have otherwise been born starting from November 2020.

We have also shown that the improvement in birth outcomes immediately preceded (November 2020) the decline in fertility (December 2020). This pattern was puzzling at first but is mechanically related to the drop in conceptions in March 2020. As figure 9 shows, the drop in conceptions in March 2020 mechanically shows up first in terms of improved birth outcomes due to the wave of 'missing, pre-term children' (7-8 months after) and then as in terms of a sharper decline in fertility due to the wave of 'missing, at-term children'. When the pandemic started in March, it generated a share of missing frail conceptions who would have naturally been born seven-to-eight months after its first onset, and this shows up immediately before the largest share of missing at term children in December. This is also suggested by the simultaneous decline in premature and at term conceptions we observe in the early weeks of 2020. Improvement in birth outcomes was larger in November than in December. We believe this may be explained by the transitory nature of selectivity into conception. For example, MAR facilities shut off their operations for only about a month (Requena et al., 2020) and prevented pregnancies due to lockdowns stopped after the relaxation of stay at home measures between late April and early May 2020.

Figure 9. Conceptual model on the timing of conception drops, birth outcomes and TFR changes



We also observe some indications that highly educated mothers had slightly better birth outcomes for children born during the first wave of the COVID-19 pandemic. This may be driven by two factors. On the one hand, they might have been more likely to benefit of the reduction of socio-emotional stressor induced by stay-at-home orders, such as reduced exposures to pollutants and common pathogens in their everyday life. On the other hand, it may be associated with postponement in c-section and labor inducement due to crowded hospital wards and high infection rates among staff.

Last, we caution over-interpreting improvements in birth outcomes in the aftermath of the first wave of the COVID-19 pandemic as positive side-effects from 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. 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.

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Supplementary material

Supplementary table S1. Average birthweight by month and year of birth

	Year										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Month of birth											
1	3229.28	3225.24	3236.00	3224.42	3219.22	3221.42	3230.24	3224.81	3223.88	3227.63	3230.27
2	3226.52	3222.60	3227.23	3227.58	3219.45	3217.67	3225.36	3214.71	3219.84	3228.20	3226.86
3	3230.65	3232.76	3232.89	3226.57	3225.90	3221.94	3228.94	3226.03	3220.58	3230.44	3239.24
4	3233.84	3244.22	3241.78	3234.07	3230.22	3235.35	3228.34	3231.61	3232.71	3239.24	3248.81
5	3241.37	3236.43	3238.78	3229.92	3232.30	3236.42	3224.37	3232.60	3231.21	3236.60	3241.00
6	3227.55	3236.60	3232.30	3234.50	3232.34	3225.30	3222.21	3218.48	3231.41	3235.58	3230.14
7	3233.27	3233.41	3230.65	3232.71	3229.91	3224.57	3228.14	3225.82	3220.54	3229.73	3222.88
8	3229.78	3238.49	3238.14	3234.23	3234.91	3224.58	3232.68	3229.41	3229.16	3235.78	3228.94
9	3237.58	3243.98	3236.74	3242.34	3238.03	3228.07	3232.85	3227.33	3235.71	3239.90	3237.71
10	3232.09	3233.99	3226.64	3227.38	3223.62	3227.01	3225.82	3226.89	3231.06	3234.39	3243.76
11	3232.27	3229.67	3223.89	3219.73	3221.90	3226.18	3226.94	3220.99	3228.03	3225.05	3255.13
12	3220.24	3226.90	3225.33	3225.21	3213.99	3222.42	3222.70	3217.28	3221.30	3225.17	3248.53

Supplementary Table S2. Average gestational age (weeks) by month and year of birth

	Year										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Month of birth											
1	39.00	39.01	39.05	39.02	38.99	39.02	39.04	39.02	39.02	39.00	39.01
2	38.99	38.99	38.99	39.00	38.98	38.96	39.02	39.02	39.02	39.00	38.98
3	39.03	39.05	39.01	39.03	39.05	39.04	39.02	39.04	39.01	39.03	39.04
4	39.03	39.06	39.06	39.07	39.04	39.04	39.03	39.06	39.02	39.03	39.08
5	39.08	39.06	39.04	39.04	39.04	39.05	38.97	39.03	39.01	39.03	39.07
6	39.01	39.05	39.00	39.02	39.01	38.99	38.98	38.98	39.01	39.02	39.01
7	39.02	39.06	39.00	39.03	39.01	38.98	38.97	39.01	38.99	38.98	38.99
8	39.04	39.07	39.01	39.06	39.04	39.04	39.00	39.04	39.01	39.04	39.04
9	39.07	39.09	39.06	39.10	39.06	39.04	39.01	39.03	39.07	39.08	39.06
10	39.07	39.08	39.06	39.05	39.06	39.05	39.07	39.04	39.05	39.06	39.08
11	39.05	39.05	39.03	39.05	39.04	39.06	39.06	39.04	39.03	39.04	39.12
12	38.99	39.05	39.03	38.98	38.97	39.01	39.00	38.98	39.00	38.98	39.03

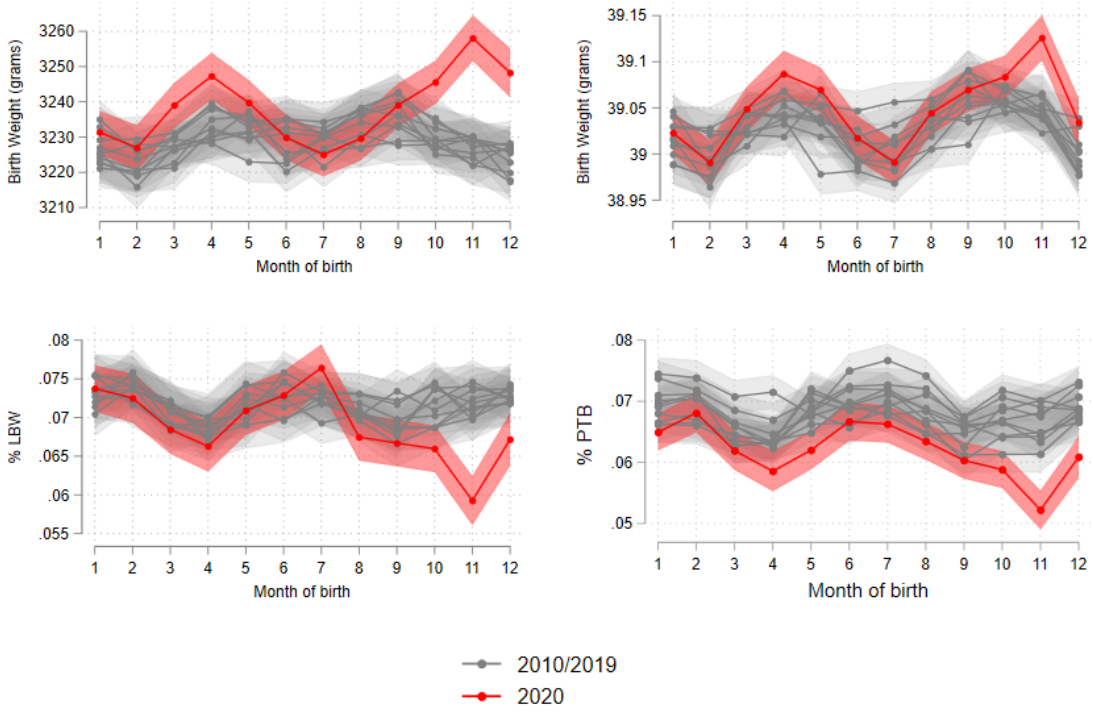
Supplementary Table S3. LBW incidence by year and month of birth

	Year										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Month of birth											
1	0.0723	0.0746	0.0728	0.0755	0.0742	0.0759	0.0713	0.0721	0.0724	0.0735	0.0744
2	0.0724	0.0731	0.0746	0.0716	0.0745	0.0755	0.0744	0.0765	0.0742	0.0730	0.0728
3	0.0702	0.0711	0.0683	0.0690	0.0718	0.0711	0.0685	0.0713	0.0718	0.0695	0.0689
4	0.0681	0.0660	0.0675	0.0674	0.0666	0.0690	0.0699	0.0686	0.0701	0.0676	0.0664
5	0.0681	0.0701	0.0700	0.0727	0.0720	0.0706	0.0740	0.0690	0.0741	0.0686	0.0707
6	0.0743	0.0686	0.0739	0.0725	0.0714	0.0729	0.0748	0.0751	0.0725	0.0701	0.0731
7	0.0720	0.0720	0.0717	0.0696	0.0730	0.0735	0.0724	0.0722	0.0746	0.0723	0.0772
8	0.0719	0.0715	0.0709	0.0710	0.0709	0.0737	0.0707	0.0708	0.0701	0.0710	0.0679
9	0.0708	0.0691	0.0676	0.0677	0.0696	0.0720	0.0687	0.0738	0.0670	0.0692	0.0673
10	0.0729	0.0700	0.0738	0.0742	0.0727	0.0753	0.0693	0.0716	0.0694	0.0694	0.0668
11	0.0697	0.0709	0.0743	0.0725	0.0754	0.0707	0.0710	0.0742	0.0734	0.0723	0.0602
12	0.0730	0.0717	0.0728	0.0734	0.0732	0.0754	0.0733	0.0748	0.0743	0.0731	0.0674

Supplementary Table S4. PTB incidence by year and month of birth

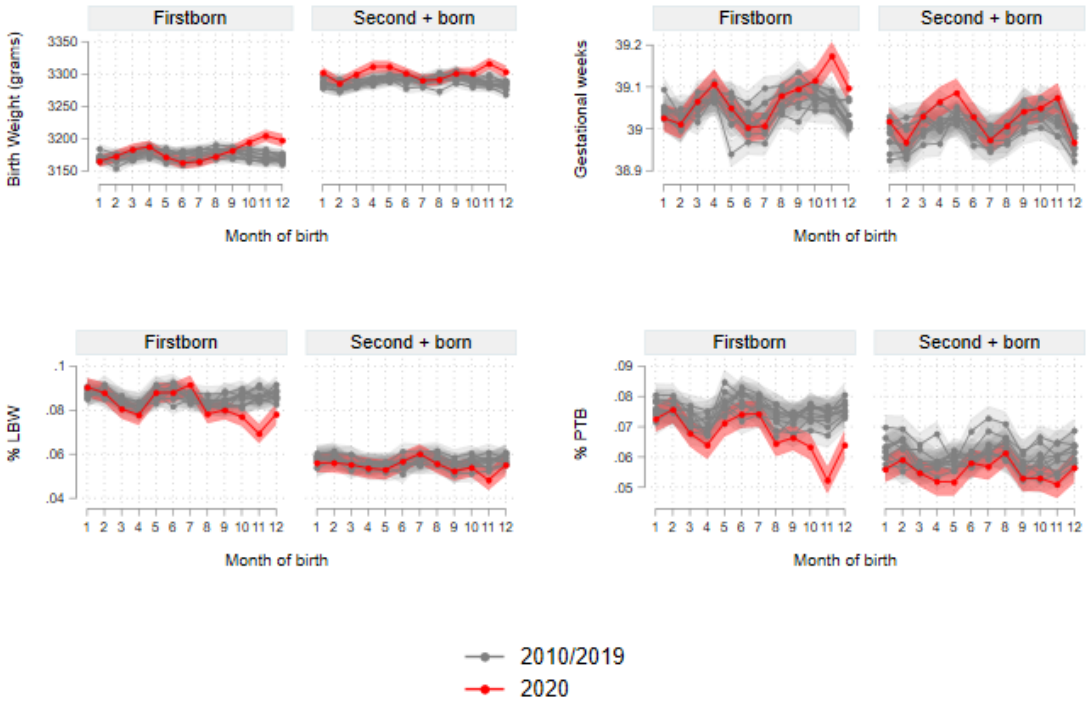
	Year										
	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Month of birth											
1	0.0736	0.0730	0.0686	0.0702	0.0712	0.0699	0.0669	0.0686	0.0667	0.0668	0.0655
2	0.0729	0.0712	0.0702	0.0702	0.0712	0.0716	0.0684	0.0675	0.0670	0.0666	0.0684
3	0.0698	0.0678	0.0655	0.0657	0.0665	0.0629	0.0629	0.0648	0.0650	0.0639	0.0623
4	0.0702	0.0659	0.0615	0.0629	0.0645	0.0631	0.0635	0.0636	0.0635	0.0632	0.0587
5	0.0666	0.0691	0.0683	0.0711	0.0672	0.0680	0.0720	0.0646	0.0682	0.0663	0.0618
6	0.0740	0.0678	0.0720	0.0691	0.0695	0.0721	0.0694	0.0701	0.0658	0.0668	0.0668
7	0.0758	0.0687	0.0725	0.0678	0.0723	0.0722	0.0715	0.0680	0.0702	0.0688	0.0667
8	0.0734	0.0708	0.0719	0.0686	0.0685	0.0672	0.0693	0.0650	0.0667	0.0654	0.0638
9	0.0665	0.0667	0.0661	0.0625	0.0656	0.0663	0.0666	0.0650	0.0607	0.0616	0.0607
10	0.0710	0.0703	0.0685	0.0694	0.0673	0.0670	0.0645	0.0671	0.0648	0.0619	0.0594
11	0.0695	0.0688	0.0701	0.0678	0.0686	0.0638	0.0650	0.0653	0.0656	0.0620	0.0526
12	0.0725	0.0683	0.0689	0.0730	0.0712	0.0687	0.0695	0.0684	0.0673	0.0679	0.0609

Supplementary figure S1. Adjusted birth outcomes trends 2010-2020



Note: Estimates obtained adjusting for parity, maternal age, migrant status, child's sex, province, municipal size. Standard error clustered at provincial level.

Supplementary figure S2. Adjusted birth outcomes trends by parity 2010-2020



Note: Estimates obtained adjusting for maternal age, migrant status, child's sex, province, municipal size. Standard error clustered at provincial level.

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