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Drs. Muttarak and Wilde,

Editors

*Population and Development Review*

Dear Drs,

We are delighted to submit our manuscript titled “Heterogeneous associations between the Covid-19 pandemic and births across subnational areas in Brazil and Colombia. A registry-data-based analysis” for consideration to the *Population and Development Review* Supplement on the Covid-19 pandemic and its impact on fertility and family dynamics.

Thank you for considering our work.

Sincerely yours, also on behalf of Drs. Sacco, Pardo, Urdinola, and Acosta.

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**Heterogeneous associations between the Covid-19 pandemic and births across subnational areas Brazil and Colombia. A registry-data-based analysis**

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**Abstract**

This work contributes to understanding the potentially heterogeneous consequences of the Covid-19 pandemic for changes in the number of births by mothers’ age and educational attainment in contexts of high socioeconomic inequality and relatively poor institutional response to the health and economic crises spurred by the Covid-19 pandemic. Using register data on births and deaths for Brazil and Colombia, we document state-level correlations between the intensity of the pandemic -measured by current, nine-month lagged, and cumulative excess mortality, and the observed number of births relative to a Covid-19-free hypothetical scenario. We disaggregate these correlations according to the mother’s age and educational attainment to test the hypothesis that the prompt consequences of the Covid-19 on births interact with pre-existing forms of social inequality, potentially deepening socioeconomic gaps across subpopulations in these two countries. We argue that highlighting the socioeconomic-specific consequences of the pandemic is of utter importance and may go beyond differences by years of schooling as ethnic, migration status, and sexual minorities in several contexts, including high-income countries, may be suffering the consequences of Covid-19 pandemic differently compared to the majority of the population.

**Introduction**

Understanding the effects of the Covid-19 pandemic on population dynamics is urgent. These effects prove to be profound, extensive to every dimension of population dynamics, and likely to last for decades. Since the pandemic started, demographers have called attention to the necessity to consider the effects of Covid-19 not only in mortality but also on fertility (Tomas Sobotka et al. 2021; Aassve et al. 2020), fertility intentions (Emery and Koops 2022; Lindberg et al. 2020; Luppi, Arpino, and Rosina 2020), and migration (Ferris and Sorrell 2021; Guadagno 2020). Research has also described the impact of the pandemic on other dimensions of demographic change –including household composition, population aging, territorial distribution, and kinship networks (Verdery et al. 2020)–, and considered the impact of Covid-19 on fertility for population projections (Berrington et al. 2022).

Due to the magnitude and scope of the pandemic, most studies’ theorization hinges on the idea of an overarching pandemic impact on population dynamics. However, the influence of Covid-19 on reproductive behaviors and outcomes is likely to vary between and within countries (Aassve et al. 2021). Between-country variation arises from differential capacity to respond to the pandemic due to factors such as quality and coverage of national health systems, access to vaccines, timing and duration of the lockdowns, financial support for families and companies, and pre-existing patterns of reproductive behaviors and rights (e.g., fertility levels, access and prevalence of contraception, access to family planning, and abortion regulations). Analogously, sub-national disparities along these dimensions are potential sources of within-country variation in how the pandemic has and is influencing reproductive outcomes, particularly for countries with socioeconomically heterogeneous populations, large geographical extensions, and weak or absent welfare policies.

The differential influence of the Covid-19 pandemic on reproductive patterns by socioeconomic status has not been the focus of previous empirical studies, nor populations suffering from substantial socioeconomic cleavages. Despite institutional efforts, countries with the most significant socioeconomic disparities worldwide lag in timely assessing the consequences of the pandemic (Binstock et al. 2021). Unequal data availability and quality across countries and subpopulations implies that the influence of Covid-19 on population dynamics will be better understood in high-income countries, making it utterly necessary to measure these disparities in the rest of the world, particularly in Latin America and the Caribbean (LATAM), where the impact of the pandemic has been sizable. Assuming no underreport, Covid-related deaths in LATAM account for approximately one-quarter of the total, and, as of March 2022, three LATAM countries -Brazil, México, and Peru- are among the top ten in total deaths. Less is known about impacts on fertility and migration in the region, but the effect can be expected to be considerable (ECLAC 2021).

At the individual and household levels, large disparities in the access to crucial resources to cope with the pandemic (e.g., information, savings, social networks) are likely to deepen the potential divergent influence of Covid-19 on fertility patterns across socioeconomic groups. Disadvantaged populations have historically been more exposed to the negative consequences of social, economic, and health crises (Mamelund and Dimka 2021; Mamelund, Shelley-Egan, and Rogeberg 2021), and therefore their reproductive patterns are more likely to be affected (Lobkowicz et al. 2021; J. Schneider and Schneider 1996). This is likely the case for millions of families in LATAM, a region where more than one of every three persons lives in poverty (ECLAC 2022).

In light of this context, this paper examines the association between the intensity of the Covid-19 pandemic –measured by excess mortality– and relative changes in the total number of births by mother's age and years of schooling at the subnational levels in Brazil and Colombia. We rely on more than 30 million vital records (23 million births and 7 million deaths) registered in these two countries from 2015 to 2019 to reconstruct time trends in overall mortality and the number of births by mother's age and education and predict 2020 and 2021. These predictions are our baseline for measuring changes in mortality (excess mortality) and relative births changes (*rbc*). Next, we examine trimester data on *rbc* and excess deaths during 2020 and 2021 and we find differential associations between excess mortality and the number of births by mothers’ years of schooling. Whereas the relative change in the number of births to women with eight or more years of schooling seems to be unaffected by excess mortality, the relative change in the number of births to less-educated women, particularly those with less than three years of schooling, displays a positive association with excess mortality. We found stronger and reversed-sign associations when we correlate nine-month-lagged excess mortality and the total number of births. This association is negative among women with few years of schooling in Brazil and positive in Colombia, and it is null or slightly negative for highly educated women in both countries.

We interpret these findings from a materialist perspective, i.e., assuming that the unequal distribution of material resources is a critical factor in the differential influence of the pandemic on demographic outcomes across subpopulations (Danna 2021). Our argument goes as follows. Periods of social, economic, and health crises are resource-demanding. Social groups with lower levels of or restricted access to resources are more likely to be affected by crises. This impact can be positive or negative for fertility, as has been observed for periods of conflict in Colombia (Castro Torres and Urdinola 2019), or forced sterilization in Brazil (Caetano and Potter 2004), respectively. Accordingly, groups in socioeconomic privileged positions are more likely to mobilize and use their resources to cope with the challenges imposed by the crisis (e.g., traveling abroad to gain access to medical services if national health systems are saturated). Although we are unable to specifically test the materialistic assumption, the consistency of the differential associations by years of schooling in both countries suggests that this interpretation is plausible. Moreover, following Sanchez-Ancochea (2021) in his argument about how the LATAM experience (enduring inequality, poor political leadership from economic elites, and lack of welfare states) can inform other countries, we contend that our results could serve for understanding the Covid-fertility link in other populations where fertility regimes (*quantum* and timing) are similar to those of Brazil and Colombia, inequalities are high or rising, and welfare states are absent or decaying in relevance for populations’ well-being.

**Background**

*Births during the pandemic*

Theoretically, the pandemic –i.e., its direct influence on morbidity, but also the impact of lockdowns and other restrictive measures imposed by governments, and the response of men and women of reproductive age to economic and social uncertainty– can affect fertility through various mechanisms. Shortly after the onset of the pandemic, researchers assumed that it could increase or decrease fertility rates in the short term, depending on which mechanisms would prevail.

On one side, many pathways lead to fertility reduction. The worsening of morbidity, affecting maternal mortality, miscarriages, fecundity, or sexual activity itself (Karimi et al. 2021; Seymen 2021) might not be extensive, but the indirect consequences of social isolation, lockdowns, stress, and uncertainty can affect the number of conceptions. This might happen if a) the formation of new couples decreases or non-cohabiting couples have less sexual activity due to physical distancing, or the dissolution of couples increases, and b) economic uncertainty and a harsher life-family balance make cohabiting couples decrease their fertility intentions (Aassve et al 2020). Besides, suspended assisted reproductive technology cycles may decrease in countries with high maternal age (Gromski et al. 2021; Somigliana et al. 2021).

On the other, the saturation of healthcare systems can undermine access to contraception and abortion, especially in low and middle-income countries or among low-income families in high-income countries, thus increasing fertility via unintended births (Lin et al. 2021). In the first months of Covid-induced isolation due to lockdowns and the fear of contagion, there was also vague speculation on a *pandemic baby boom,* given that couples’ daily cohabitation time was associated with more frequent sexual encounters. However, this hypothesis received more media coverage than actual academic support.

Human gestation takes on average 268 days; this lag between reproductive decisions and births prevented researchers from going beyond speculations regarding the incoming baby boom/bust until almost the end of 2020, although some alternative methods were helpful to estimate how many pregnancies were developing during the year –e.g, Google searches of birth-related items and themes (Wilde, Chen, and Lohmann 2020). Historical trends on previous pandemics and external shocks of similar magnitude were also helpful. The most obvious reference is the 1918-19 influenza pandemic, which caused fertility decline –e.g., 13% in the U.S. (Chandra et al. 2018)–, due to the disproportionately increased morbidity of people of reproductive age, but also because of the deceleration in conceptions, in a context of social isolation and fear of the virus.

More recent historical episodes reinforced the hypothesis of the connection between perceived uncertainty and temporary fertility decline. Mainly, the 2008-2009 Great Recession (Tomáš Sobotka, Skirbekk, and Philipov 2011; Comolli 2021; D. Schneider 2017), a context that fostered different theories on the emotional pathways that may underlie the relationshipbetween disasters and fertility preferences, highlighted the relevance of subjective well-being as a channel, and the central role that uncertainty and anxiety play (Comolli and Vignoli 2021; Nitsche and Lee 2021; Vignoli, Mencarini, and Alderotti 2020; Vignoli et al. 2022).

In a separate study, the baby boom hypothesis proved to be mainly wrong in the 21 high-income countries analyzed by Sobotka et al. (2021). A widespread fertility decline between November 2020 and February 2021, approximately nine months after the onset of the pandemic in the Northern hemisphere, was registered. Compared to the same month of the previous year, the number of births dropped by an average of 5.1% in November, 6.5% in December, and 8.9% in January. These decreases were not observed in Denmark, Finland, the Netherlands, and Norway, and were particularly important in southern European countries, arguably the places with relatively less robust welfare regimes compared to northern European countries (Rendall et al. 2010).

Aassve et. al. (2021) later assessed fertility declines –measured by the Crude Birth Rate– in the same sample of countries but controlled by the ongoing trends at the time of the pandemic. A net negative effect of the pandemic was then found in seven countries: Austria, Belgium, Hungary, Italy, Portugal, Singapore, and Spain. More recent research emphasized this baby bust as a short-term effect, followed by the reversion of fertility rates to pre-pandemic levels in most countries (UNFPA 2021). A scenario of partial recovery seems probable, although trends can also be unstable, moving in cycles of busts and recoveries, similar to the cycles of the pandemic.

Finally, subnational data is becoming available, allowing researchers to examine these trends in a more disaggregated manner. The first work on subnational patterns shows regional within-country heterogeneity in terms of “excess births” –see Nitsche et. al. (2021) for European countries– and also the largest fertility reduction in places most affected by the pandemic in terms of infection rates and reductions in mobility –Cohen (2021) for counties within Florida and Ohio, in the U.S.

*The case of Brazil and Colombia*

The similarities between these two countries in terms of overarching fertility trends (Guzmán et al. 2006) and social stratification systems (Portes and Hoffman 2003) warrant the comparability of our results. Meanwhile, some differences in terms of population size, geographical extension, the functioning of national health systems, the legacy of armed internal conflict in Colombia, and economic development may account for potential divergent results.

In terms of similarities, although the population of these countries is still growing, the natural growth rate has slowed considerably in recent years to below 1% per year. These relatively low growth rates result from rapid and sustained fertility declines throughout the second half of the 20th century, with persisting gaps by geography and socioeconomic status (Adserà and Menendez 2011; Castro Torres 2021). Colombian fertility has been declining from high levels since the 1960s and has reached below-replacement levels since 2015. Brazil’s fertility has shown a similar trajectory, with the most rapid decline beginning in the late 1970s and reaching below-replacement levels even earlier, in the first years of the current century (Rios-Neto, Miranda-Ribeiro, and Miranda-Ribeiro 2018). Although fertility patterns are peculiar in LATAM -e.g., adolescent fertility rates are typically high-, social norms relating to stopping mechanisms and later transition to motherhood are emerging in both countries, as expected in low-fertility contexts (Castanheira and Kohler 2017; B. P. Urdinola and Ospino 2015).

The limited governmental response to the health and economic crises spurring from the spread of the virus is also a common aspect between these two countries (Hale et al. 2021), both countries ranked poorly according to international measures such as the Covid-performance index of the Lowy Institute[[1]](#footnote-1). Also, geography is a major axis of socioeconomic inequalities in both nations, highly correlated with the spatial distribution of ethnic minorities, and heavily reflected in access to quality health services. In fact, mortality during the pandemic first wave killed mostly inhabitants of the Amazons region in each country, and overall mortality at the subnational level in pre-pandemic years is higher in the least developed and populated zones, while large urban areas hold the best mortality conditions (Queiroz et al. 2020; P. Urdinola 2021). This territorial heterogeneity is reflected in the diversity of resources available to each region in terms of economic conditions, public infrastructure, and health care facilities, all of which were key to responding to the pandemic (Tan-Torres et al. 2020).

The primary difference between these two countries is their population size and geographical extension. Brazil’s population (213 million) and area (8.5 million Km2) are more than four and eight times Colombia’s, respectively. Secondly, despite being both ethnically diverse nations, the Afro Descendant population is much more prominent in Brazil compared to Colombia (Woo-Mora 2021). In addition, Brazil’s economy is much more robust and developed than Colombia’s (Williamson 2010), and economic inequality is slightly higher in the former country with Gini Indexes for 2019 of 53.4 and 51.3, respectively (World Bank Group 2020). This difference in the Gini index is similar across other measures of inequality such as the income share of the top 1%: 27% in Brazil and 19% in Colombia in 2019, which indicates that income distribution in Brazil is even more concentrated in the top than in Colombia (World Inequality Lab 2020).

Despite larger inequalities in Brazil than in Colombia, public health expenditures and health systems rank better in the former than the latter. These differences occur in the context of a long-lasting deficit in health systems in LATAM, despite positive trends in recent decades (Ruano et al. 2021). Importantly, across several measures of health systems (e.g., health expenditures as a percentage of the GDP, health expenditures per capita, number of hospital beds, etc.) Colombia not only ranks lower than Brazil in the levels but also in the pace of improving these indicators over time (Kanavos et al. 2019).

Finally, and given its relation to demographic dynamics including fertility and contraception (Svallfors and Billingsley 2019), the decades-long internal armed conflict in Colombia implies that a large share of the Colombian population (e.g., more than 7 million internally displaced people) have been suffering the negative consequence of internal violence conflict (Ibáñez and Moya 2010). Arguably, the negative consequences of the Covid-19 pandemic are likely to be more consequential for the internally displaced population or other victims of the internal conflict.

Considering all these aspects, a differential association between the Covid-19 pandemic and fertility is to be expected across geographies and mothers’ socioeconomic status. Previous studies assessed the probable effects of the pandemic on fertility rates and demographic dynamics, mostly in Brazil (Coutinho et al. 2020; Diniz Alvez 2021), where the decline was described for its six major cities (Lima, Soares, and Monteiro da Silva 2021), but also in Colombia, where some fertility decline was detected towards the end of 2020 (Montaño Mendoza et al. 2021). This is not without debate, as in UNFPA (2021), instead, no evident impact of the pandemic on births in Brazil and Colombia is noticed. More importantly, the effect of the pandemic on fertility in a comparative perspective by mothers’ age and years of schooling is lacking.

**Data and methods**

*Baseline and relative measures of births and deaths*

For our dependent variable -the difference in births during the pandemic trimesters in 2020 and 2021 relative to the expected number- we rely on official records of the number of registered live births (2015-2021) published by the Colombian National Bureau of Statistics (DANE) and the Brazilian Departamento de Informática do Sistema Único de Saúde form the Ministry of Health (DATAUS). The Brazilian data includes births until December 2021, whereas the Colombia data stops in September 2021. Data is preliminary for the last two years in Colombia, but reflects about 95% of the final figures[[2]](#footnote-2). In total, we use information from 23.5 million births (19.2 from Brazil, and 4.3 from Colombia).

We use the 2015-2019 information to calculate an expected number of births (i.e., baseline births) accounting for time trends and seasonality. Using these expected numbers of births we calculate our dependent variable as the ratio between observed and baseline births. These ratios, denoted as *rbc* (i.e., relative birth changes), are analogous to those of excess mortality as they express the relative change in the number of births with respect to a pandemic-free scenario. These calculations are disaggregated by mothers’ age (10-19, 20-24, 25-29, 30-34, 35-39, 40-54) and years of schooling groups (0 to 3 y.s., 4 to 7 y.s., 8 to 11 y.s., and 12 or more y.s.)[[3]](#footnote-3). Disaggregation by mothers’ age groups allows us to account for the age pattern of fertility, and the years of schooling groups serve as a proxy for women’s socioeconomic position. Given the nature of educational systems in these two countries, and the characteristic of the labor markets, particularly for women, our years of schooling groups are a good proxy, not only for human capital accumulation but also for women's socioeconomic status (Sánchez-Ancochea 2021; De Ferranti et al. 2004).

We supplement our data on relative birth changes (*rbc*) with subnational estimates of excess mortality during 2020 and 2021. We define excess mortality as the difference between all-cause observed mortality and all-cause expected mortality in the absence of the pandemic, also denoted as the baseline mortality. We estimated weekly baseline mortality by fitting a Generalized Additive Model (Wood 2017) to weekly deaths between January 2015 and March 2020, which accounts for secular and seasonal variations in mortality, and changes in population over time. Following recent developments/good practices on excess mortality measurement, our measure of excess mortality uses the p-score index, which indicates the percentage difference between the observed deaths relative to the mortality baseline (Helleringer and Queiroz 2022). The use of p-scores allows us to compare mortality excess across different populations, regardless of differences in pre-pandemic mortality level and population size. We are not able to account for differences in population age structure, as the weekly mortality series in Colombia have no information on age.

Using multivariate linear models, we correlate subnational p-score excess mortality with the *rbc* in each trimester from the beginning of the pandemic (i.e., the second trimester of 2020) to the third trimester of 2021. We weight each observation (combination of subnational area, trimester, mother's age and years of schooling groups) by the number of births in each cell relative to the total number of births in the country. This weighting strategy improves the representativeness of our results by giving more importance to age groups where fertility concentrates, bigger subnational areas population-wise, and years of schooling groups that account for a large share of births.

In a multivariate model, we use two versions of the p-scores as a predictor, one for the current trimester (current excess mortality herein) and a two-trimester lagged p-score (lagged excess mortality herein). The current excess mortality p-score serves us as a test for the potential prompt influence of the pandemic on fertility (e.g., due to the worsening of reproductive-health related services, increasing or decreasing the number of pregnancy interruptions or fetal deaths). Instead, with the lagged excess mortality p-score, we account for the nine months of pregnancy, and therefore test the potential influence of the pandemic on fertility decisions (e.g., as couples postpone or abandon fertility plans) and opportunities for conception (as non-cohabitant couples may have reduced encounters due to lockdown measures). Because deaths (including excess deaths) are the result of individual processes of varying duration (e.g., long-lasting chronic diseases, medical procedure or treatment failures, accidents), excess mortality measures for a given period carry a lag. In the context of a health crisis, excess mortality in a given month or trimester may reflect the worsening of health services over the preceding months. Therefore, our two measures of excess mortality (current and nine-month lagged) offer a parsimonious overview of how the crisis unfolding may relate differently with ongoing pregnancies, and conceptions that may occur (planned or unplanned) right after the consequences of the Covid-19 pandemic began to spread. These are not perfect measures, however, their differences in timing allow us to capture relevant aspects of ongoing mortality and fertility in a sensible manner.

We estimate four multivariate specifications and compare their goodness of fit using the Akaike Information Criterion (AIC); lower AIC implies a better fit. The first specification (M.S.1) predicts the *rbc* based on the p-score of excess mortality and dummy variables for mothers’ age and years of schooling groups. This specification is our benchmark for: (i) the association between excess mortality and fertility and (ii) models’ goodness of fit. Our second specification (M.S.2) accounts for pre-existing subnational differences in populations’ socioeconomic capacity to respond to the pandemic. We use the 2019 subnational Human Development Index (HDI) for this purpose (Smits and Permanyer 2019). Our third specification (M.S.3) includes dummy variables for each subnational level. Finally, our last specification (M.S.4) tests the potential existence of an interaction between excess mortality and mothers’ years of schooling, i.e., a potential differential association between the pandemic and the fertility of women with divergent levels of educational attainment. This specification includes dummies for subnational areas.

**Results**

Time trends suggest a negative association between the pandemic and the number of births. In Figure 1, all series of observed births in 2020 and 2021 (black lines) are below the series for the expected number of births (red dotted lines).

\*\*\* Figure 1 \*\*\*

According to Figure 1, there is relative stability in the total number of births to women with eight to 11, and 12 or more y.s. The other two y.s. groups display, instead, slight negative trends. These diverging trends by years of schooling conflate differences in fertility and fertility timing by educational attainment and changes in the educational composition of the population. Moreover, these trends imply that the predicted number of births (red dotted line) is a conservative baseline to measure pandemic-related changes. If we were to use the average number of births from 2015 to 2019 (blue lines in Fig. A1) as a baseline, we would overestimate the potential effect of Covid-19 on fertility, particularly among groups with declining trends in the number of births (e.g., women with four to seven years of schooling).

Despite the educational expansion and the associated negative trends in the number of births to mothers with less than eight years of schooling (which corresponds to middle years of education), there is a substantial number of babies to mothers with less than four years of schooling, arguably a group of women that are at the very bottom of LATAM stratification systems. This is a particular feature of fertility in the context of Brazil and Colombia, and perhaps in other countries and populations in the global South. Combined, mothers with 0 to 3 and 4 to 7 years of schooling gave birth to more than 485,000 and 108,000 babies in 2019 in Brazil and Colombia, respectively. It is worth noting that seven years of schooling provide basic numeracy and literacy skills, whereas three years of schooling provide just literacy.

Most of the births occur to women with 8 to 11 years of schooling (1,740,000 in Brazil, and 357,000 in Colombia in 2019). These years of schooling are not fully comparable with High School graduates in the US, in fact, they are closer to middle years program. Although complete secondary education is supposed to give access to tertiary education (technical, technological, or professional), quality differences across schools and public educational systems, and the myriad of private alternatives for formal training, make this group very heterogeneous in terms of the socioeconomic background and the economic prospects of women with these years of schooling (Balan, 2003; Sanchez-Ancochea, 2021). In other words, these groups are likely a mix of low and middle-low class women in terms of social stratification, rather than a middle-class. Finally, women with more than 12 years of schooling are at the top of the social stratification with a growing number of births: 603,000 in Brazil, and 174,000 in Colombia in 2020.

The subnational heterogeneity in the severity of the pandemic –measured by the excess mortality p-scores– suggests that the association between Covid-19 and fertility could vary in magnitude across space and over time. As seen in Figure 2 the timing and intensity of the pandemic were not the same in Brazil and Colombia. In the former country, excess mortality was already positive by the second trimester of 2020 in at least 18 of the 26 subnational areas. Indeed, in the state of Amazonas, the observed mortality in Apr-Jun 2020 was close to twice the expected mortality (p-score near 100%). In contrast, by the same trimester, excess mortality in Colombia was only large and positive in four out of the 32 departments, with a maximum of 75% in Atlantico. Notably, high p-scores were first observed in relatively small subnational areas, population-wise.

\*\*\* Figure 2 \*\*\*

According to Figure 2, as the pandemic evolved, excess mortality in Colombia increased and stayed higher than in Brazil during the last two trimesters of 2020. This relationship reversed in the first trimester of 2021 when p-scores were positive in all Brazilian subnational areas with a median p-score of 40%. Excess mortality from April 2021 onwards remained high in Colombia and decreased in Brazil, further highlighting the changing nature of the pandemic. Figure 2 also reveals substantial within-country heterogeneity (y-axis range) and that relatively small population-wise subnational units, typically located within countries’ borders, suffer the most mortality excess. The changing of the top-two subnational units according to excess mortality speaks to the within-countries spatial dynamics.

Figure 3 displays the scatter plot of subnational current excess mortality (x-axis) and the total number of registered births relative to baseline births by trimester (y-axis). The top panels correspond to Brazil and the bottom panels to Colombia. Both measures are on a logarithmic scale and the axes are labeled according to the percentage difference to favor readability. Each data point represents a combination of mothers’ age (colors) and years of schooling groups (panels), subnational area, and trimester (from April-June 2020 to July-September 2021). The size of the points is proportional to the population of the subnational area in 2020, and robust local regression lines (lowess) are included for each age group and the pooled data (overall).

Differences in the association between excess mortality and fertility by years of schooling groups are consistent with our expectations: The association between the severity of the pandemic and the *rbc* is contingent on women’s socioeconomic conditions, proxied by years of schooling groups. Hence, the main result in Figure 3 is that the higher the years of schooling, the less heterogeneous, weaker, and more uniformly patterned (flat) the relationship between excess mortality and the *rbc* is. The panels for women with 0 to 3 y.s. display the largest heterogeneity of all along the y-axis. Moreover, in Brazil, the log-scaled *rbc* among women 10 to 29 years old is above zero, meaning that fertility was higher than expected among younger women. Notably, the slope of the lowess lines is more positive for the first age group (10-19) compared to the others, meaning that higher excess mortality is associated with higher fertility, particularly among young women with fewer years of schooling: two sociodemographic characteristics that are typically associated with disadvantaged living conditions.

In both countries, there is a positive association between excess mortality and the number of births among women with 0 to 3 y.s. The slopes of the lowess lines indicate that places where excess mortality was higher, were associated with a higher relative number of births among women with 0 to 3 y.s. This is true for values of excess mortality between 0 and 100. The higher severity of the pandemic in Colombia than in Brazil (max excess mortality = 300) suggests there may be turning points where the relationship between excess mortality and the number of births among women with lower educational attainment reverses. In sharp contrast, the number of births to women with more than 8 y.s., both in Brazil and Colombia is below or very close to zero, meaning that between 2020 and 2021 the number of births was slightly lower than expected for almost all educated women across subnational areas in Brazil and Colombia, at all ages. Additionally, the flat pattern in the lowest lines indicates that there is no association between excess mortality and the number of births among educated mothers. If anything there is a slight negative slope among women with the highest educational attainment (12 or more y.s.), as summarized by the overall line.

When excess mortality is lagged by two trimesters, i.e., when we measure the potential influence of the pandemic on fertility decisions and opportunities by accounting for the average duration of pregnancies, the general pattern among educated women is the same as in Figure 2: the association between nine-month lagged excess mortality and the number of births seems to be null (see Figure A2). Instead, among women with less than 3 years of schooling, this association is negative, meaning that higher mortality in a given trimester is associated with fewer births nine months after. The same is true, although the slope is less negative, for women with 4 to 7 years of schooling. Again, the greater range of excess mortality in Colombia than in Brazil yields more erratic associations between the number of births and excess mortality in areas with more than 100% excess deaths.

To test the robustness of the descriptive patterns depicted in Figures 3 and A2, and to assess the degree of uncertainty regarding the slopes of the lowess lines, Table 1 summarizes the regression coefficients for the excess mortality measures (current and lagged) and the number of births according to the four above-mentioned model specifications. To favor the models’ performance and interpretability, the excess mortality measures and the *rbc* enter the model on the logarithmic scale.

\*\*\* Table 1 \*\*\*

Table 1 confirms that the influence of current excess mortality on *rbc* is contingent on women’s socioeconomic status. For Brazil, model specifications 1 to 3 suggest that current excess mortality negatively influences the number of births. Even after including the subnational HDI (M.S. 2) , the coefficient for current excess mortality is -0.07. This coefficient implies that a 10% increase in excess mortality is associated with a 0.7% decrease in the number of births. M.S. 4 reveals that the association between current excess mortality and the number of births is positive for women with 0 to 3 y.s. (slope = 0.35), virtually null for women with 4 to 7 y.s. (slope = 0.35 - 0.31 = 0.04), and negative for the remaining groups (0.35 - 0.4 = -0.05, and 0.35 - 0.45 = -0.1, respectively).

For Colombia, subnational differences in the HDI account for the overall negative relationship between current excess mortality and relative fertility; the excess mortality coefficients in M.S. 2 and M.S. 3 are small and statistically non-significant. However, the interaction terms included in M.S. 4 reveal significant association across years of schooling groups. These associations are similar in direction and slightly larger in magnitude than those observed for Brazil. For example, the association between excess mortality and *rbc* among women with 0 to 3 y.s. is 0.39, implying that a 10% increase in excess mortality is associated with a 3.9% increase in the number of births. At the other end of the educational attainment groups (slope = 0.39 - 0.44 = -0.05), a 10% increase in mortality is associated with a 0.5% decrease in the number of births. The divergence between the signs of the association for low educated (i.e., low social position) and highly educated women (i.e., high social class), speaks to the heterogeneous influence of the pandemic.

Results for lagged excess mortality are less consistent between countries. Although M.S. 1 indicates a negative correlation between lagged excess mortality and relative fertility for both countries (-0.03 in Brazil, and -0.07 in Colombia), these associations are not robust to the inclusion of the subnational HDI and the dummy variables for subnational areas. Moreover, the sign of the interaction coefficients also differs by country. For example, the association between lagged excess mortality and the number of births to women with less than 3 y.s. is negative in Brazil (-0.21) and positive in Colombia (0.23). These two associations imply approximately a 2% decrease and increase, respectively, in the number of births given a 10% increase in lagged excess mortality. These divergent associations could be related to the higher degree of socioeconomic vulnerability of low educated women in Colombia due to the legacy of the armed conflict, and the relatively worse public health system in the Andean country compared to Brazil. As the years of schooling increase, the association between lagged excess mortality and the *rbc* becomes negative in both countries, suggesting that educated and higher educated women display more similar associations between countries than women at the lower end of the educational ladder.

All in all, our results underline the importance of accounting for women's socioeconomic conditions when assessing the potential consequences of the Covid-19 pandemic on the number of births. Diverging associations of current and lagged excess mortality by mothers’ years of schooling (positive for women with low educational attainment and null or negative for highly educated women) imply that the influence of the Covid-19 pandemic interacts with existing forms of social differentiation regarding access to resources and opportunities to enact reproductive preferences. Despite our data limitations[[4]](#footnote-4) and the simplicity of our models, we feel confident with this interpretation for three reasons. First, model specifications with interaction terms yield a better fit than model specifications without them (refer to AIC rows in Table 1). Second, our results are robust when we exclude the lower and upper 1% of the distribution of the *rbc* (i.e., outliers where relative change is extremely low or high due to the small number of registered or predicted births), and also when we use cumulative measures of excess mortality (i.e, cumulative p-scores and lagged cumulative p-scores). This is particularly true for the coefficients associated with cumulative p-scores. Third, this interpretation is consistent with the extant and cited literature on the connection between fertility patterns and social stratification in LATAM.

**Conclusions**

Based on vital records for the 2015-2021 period, this work offers a thorough examination of the association between the Covid-19 pandemic and the total number of registered births in Brazil and Colombia. We examine the immediate and lagged influence of excess mortality on the number of births at the subnational level by mother’s age and years of schooling (as a measure of socioeconomic status). Heterogeneous associations between these two demographic processes –excess mortality and births– by mothers’ years of schooling underline how the negative consequences of the pandemic interacted with pre-existing forms of inequality in women’s living conditions and access to resources. This interaction is fundamental to understanding the long-term consequences of Covid-19 on demographic patterns, particularly for countries with high or rising levels of socioeconomic inequality, and weak or absent welfare states. The same is true for population subgroups that, despite residing in rich welfare states, do not benefit from welfare policies fully due to their minority, sexual identity, or migration/citizenship status.

The contribution of this study to the literature on the so-called pandemic babies stems from our materialist perspective (Danna 2021; Lebaron 2003). Previous studies have listed the logical mechanisms that could lead to higher or lower fertility in contexts of health crises (e.g., higher maternal mortality, miscarriages, restricted access to sexual-health-related services including contraception, family planning, and abortion, and fertility postponement due to financial uncertainty). However, this list of mechanisms does not specify the material conditions for them to become prevalent or effective. From a purely behavioral perspective, any individual may be affected by or susceptible to enacting these mechanisms. However, our results are not consistent with this behaviorist assumption. From a materialistic perspective, assuming that everyone is capable of or susceptible to any logic mechanism confuses the “things of logic” -deductively derived logical mechanisms- and the “logic of things'' -the material conditions for mechanisms to operate (Burawoy 2018). Our study suggests that the operation of these mechanisms is contingent on women’s access to the material resources for controlling reproduction (e.g., access to contraception, abortion, family planning), and that may be particularly scarce or diminished in the context of a health crisis for certain populations.

In other words, thanks to a materialist perspective, our study identifies the subpopulation groups with the living material conditions that make them susceptible to the theoretical mechanisms that predict increases, such as an undermined access to contraception or preganacy interruption in weakened health systems (potentially operating among vulnerable women) and decreases, such as economic uncertainty (potentially operating among non-vulnerable women) in the number of births. Although our measurement of socioeconomic status (i.e., years of schooling) captures only indirectly women’s access to sexual- and reproductive-health-related services, the consistency of the results in the two countries, and the stronger associations documented in Colombia among socioeconomically vulnerable women (i.e., where women’s vulnerability are exacerbated due to the legacy of the armed conflict and relatively weaker health systems), suggest this is a sensible, plausible and informative interpretation.

Because women from extremely vulnerable socio-economic backgrounds do not contribute the largest share of births, studies that do not disaggregate effectively by socioeconomic status will gloss over the divergent consequences of the pandemic among subpopulation groups. Indeed, a country-level aggregated analysis will completely neglect the experience of minorities. Given that one-third of the population in LATAM lives in poverty (ECLAC 2022), highlighting the socioeconomic-specific consequences of the pandemic is of utter importance and may go beyond the group of women with 0 to 3 years of schooling if other dimensions of socioeconomic status are considered (e.g., income, household assets, race/ethnicity).

More generally, these results suggest that ethnic, migration status, and sexual minorities in other contexts, including potentially high-income countries, may be suffering the consequences of Covid-19 differently than the majority of the population, especially individuals in socioeconomically privileged positions. Consequently, future research that tests the validity of the mechanisms by which a health crisis can affect fertility, requires the identification of social groups with varying capacities/opportunities to enact (e.g., postpone motherhood) or suffer from (e.g., restricted access to family planning services) them.

Finally, our results also inform potential future scenarios of fertility in contexts of ongoing or ending the pandemic. To the extent that socioeconomic inequalities are likely to be increased by the negative consequences of Covid-19, we would expect ongoing differential associations between the pandemic and the number of births by socioeconomic groups for the short- and medium-terms. For example, if fertility is to recover after the pandemic, our results suggest this recovery would be enacted first by women with sufficient resources to resume their reproductive schedules while coping with the potential negative legacy of the pandemic period.

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1. https://interactives.lowyinstitute.org/features/covid-performance/ [↑](#footnote-ref-1)
2. Relationship presented in mortality as preliminary data from 2019 was compared to final data for the same year once reached the final status. [↑](#footnote-ref-2)
3. The 1.0% and 3.9% of births with missing information on mothers' years of schooling were assigned to the 0 to 3 years of schooling groups. [↑](#footnote-ref-3)
4. These data limitations include the potential under-registration of births, particularly in subnational poor areas and among women with few years of schooling (y.s.). Because these under-registration patterns were present before the pandemic, we partially account for them when including dummy variables for subnational areas in model specifications 3 and 4. Moreover, the positive association between excess mortality and relative birth changes among women with 0 to 3 y.s. suggests that births under-registration is unlikely to have increased with Covid-19 especially among the most vulnerable. [↑](#footnote-ref-4)