Fertility Trends during Successive Novel Infectious Disease Outbreaks: Zika and Covid-19

Letícia J. Marteleto[1]
Luiz Gustavo Sereno Fernandes[1]
Raquel Z. Coutinho[2]
Sandra Valongueiro Alves[3]
Molly Dondero[4]
Andrew Koepp[1]
Ryan Lloyd[1]
Ana Paula Portella[1]

Abstract: The goal of this paper is to estimate fertility trends in Brazil during the 2010s, during the ZIKV and COVID-19 crises. We use SARIMA forecast, normality test and Box Cox transformation. We find that fertility trends were stable in the 2011-2015 period, with expected seasonality. Fertility dropped during the Zika epidemic and rebounded in 2017, after the epidemic, but increases do not configure a baby-boom. Rather, peak levels never returned to those from the pre-Zika period. Correcting for Civil Registry data for the most recent period shows that fertility levels never truly rebounded after the Zika epidemic, and were already declining when the COVID-19 pandemic hit. We argue that the uncertainties generated by novel infectious disease epidemics have tangible consequences for fertility that can be even more dramatic in Brazil because of successive timing of the Zika and COVID-19 emergencies, as well as economic and political crises during these periods. In the absence of publicly available data from Brazil's Ministry of Health since 2019, and in light of the cancelation of the 2020 Census, it is imperative to devise methodologically sound ways to use available data with the goal of uncovering the consequences of all of the crises overlapping in the country. Further, policies providing women with the means to meet their fertility intentions become even more important during periods of public health crises, as resources are shifted from reproductive health care towards confronting novel disease outbreaks.

Acknowledgments: This research was funded by grant R01HD091257, Reproductive Responses to the Zika Virus Epidemic in Brazil, awarded to PI L. J. Marteleto by the Eunice Kennedy Shriver National Institute of Child Health and Human Development. This research was also supported by grant P2CHD042849, Population Research Center, awarded to the PRC at The University of Texas at Austin by the Eunice Kennedy Shriver National Institute of Child Health and Human Development. This study was conducted under Institutional Review Board approval #2018-01-0055 from the University of Texas at Austin and the Brazilian National Commission for Research Ethics (also known as CONEP, or Comissão Nacional de Ética em Pesquisa) study approval CAAE: 34032920.1.0000.5149.

---

[1] University of Texas at Austin
[2] Federal University of Minas Gerais
[3] Federal University of Pernambuco
[4] American University

Introduction

In March 2020, less than three years after the end of the Zika epidemic, Brazil was hit by Covid-19. Brazil is currently an epicenter of the pandemic, with more than 400,000 deaths due to Covid-19, and no end in sight at the time of writing in May 2021[1].

Brazil was also the epicenter of the ZIKV (Zika Virus) epidemic and the devastating consequences of its accompanying surge in congenital Zika syndrome (CZS) in 2015-2017. Fertility rates declined during the ZIKV epidemic, with the steepest declines occurring roughly nine months after the link between Zika and fetal malformation was publicized[2].

Covid-19 and ZIKV are distinct viruses with different modes of transmission, symptoms, and effects. However, the novelty of such diseases generates extreme uncertainty over infection risks and a chaotic prevention response, especially for typically high-risk groups like pregnant people and their babies.

Early on in the Zika epidemic, there was a great deal of uncertainty about whether the ZIKV could be transmitted from a pregnant woman to her fetus, and whether the ZIKV was harmful to newborns in other ways. Later, fetal transmission was confirmed—along with the risk of severe fetal abnormalities.[3]

The specific risk of COVID-19 to pregnant people and their infants is not yet entirely clear. Early in the pandemic, evidence suggested that pregnancy posed no greater risk to COVID-19. In June 2020, however, the U.S. Centers for Disease Control added pregnancy to the list of health conditions that make COVID-19 patients more likely to be admitted to the intensive care unit. There is now evidence of increases in stillbirth and preterm delivery during the pandemic, although it is not entirely clear whether these increases result from SARS-CoV-2 infection or indirect effects such as stress or reluctance to seek medical care.[4] Recent evidence coming from Brazil also shows higher mortality rates for pregnant and post-partum women[5] and a large number of newborn deaths directly and indirectly related to Covid-19.[6]

The goal of this paper is to examine fertility trends in Brazil during the 2010s and early 2020s, periods covering pre- and post- Zika epidemic, and the first wave of the COVID-19 pandemic, as well as economic and political crises. Combined, these crises have generated a great deal of uncertainty in the lives of women of childbearing ages.

Methods

To examine fertility trends in Brazil during the 2011-2021 period we calculate General Fertility Rates (GFRs) using the formula:

$$GFR_{ti} = \frac{live\ births_{ti}}{pop\ w\ 15-49_{ti}}$$

where $pop\ w\ 15-49_{ti}$ is the number of women ages 15-49 in each month and year *t* in state *i*. We use population projections (UFRN).

The $live\ births_{ti}$ term is the number of live births in each month and year *t* in state *i*. We use two publicly available datasets on live births—[2]Ministry of Health Sinasc data for 2011-2019 and civil registration data for 2015-2021. The Sinasc data has a documented 96% coverage of births, but the most recent publicly available is for 2019 only, excluding recent trends. Civil registry data is the most recent publicly available data on births in Brazil, but presents underreporting issues.[7] We employ three techniques to determine and correct for underreporting typical of civil registry data and estimate fertility during and beyond 2021.

First, we examine differences in live birth between civil registry and Sinasc datasets in years these datasets overlap, 2015-2019. We confirm that civil registry data shows significant differences from Sinasc data until 2017, and datasets become remarkably similar since then (Appendix A).

We next run ADF tests for each dataset in Brazil's 27 states in 2017-2019 (Appendix B). We determine that live births in both time series datasets are non-stationary processes. Both the first difference and the t-1 variation are stationary. We proceed to model t-1 variation.

Our third step is to estimate the proportion of Sinasc live births variation (t-1) that can be explained by civil registry live births variation (t-1). To identify the states where civil registry live births is a reliable predictor of Sinasc live births, we regress Sinasc data on civil registry data. Each state regression in each month and year is represented as:

$$\Delta Bsin_t = \alpha + \gamma \Delta Breg_t + \varepsilon_t$$

We define two criteria for classifying states according to these regressions modelling the difference between datasets. The first criteria is explanatory power. That is, α_i can't be statistically different from zero (cut in 5%), the relationship between γ variables needs to be statistically different from zero (cut in 5%) and the variation in civil registry data needs to explain at least 50% of the variation in the Sinasc data (R2>0.5). The second criteria is based on regression residuals; that is, there must be no serial autocorrelation. This is particularly important for our analysis because measurement error can result in autocorrelation.

Finally, we run Durbin Watson (DW) tests of the regression models and ADFs for the residuals. To meet our criteria, the residuals must be stationary (ADF test $p < 0.05$) with zero mean and the null hypothesis of no first-order auto-correlation from the DW test must not be rejected (p-value > 0.05) (Appendix B).

We therefore proceed with calculating the GFR using both datasets. Analyses in Appendix C show the GFR for all states, noting the eleven states that meet both of our criteria. These states hold 66.62% of the Brazilian population in December 2019 and account for 66.79% and 61.92% of all live births between 2017 and 2019. Our analysis shows GFRs for these states.

Results

The straight black line in Figure 1A shows the GFRs calculated using 2011-2019 Sinasc data, and the straight gray line shows the GFRs calculated using 2017-2021 civil registry data for the entire country. The dotted black line shows GFRs using Sinasc data and the dotted gray line shows GFRs estimated through SARIMA using civil registry data for 13 states. Seven results are noteworthy:

- There is a remarkably steady trend in fertility in the 2011-2015 pre-Zika epidemic period, with peaks in March-May;
- This stable trend is disrupted in 2016, during the Zika epidemic;
- Fertility returns to pre-Zika levels in 2017, with no signs of a catch up or baby boom effect. That is, the births that did not happen in 2016 were not *replaced* in 2017 or 2018. Rather, fertility peaks in March-May 2018 and March-May 2019 are lower than peaks in previous years, showing an overall decline trend post-Zika.

- The GFRs calculated using civil registry data show a trend similar to the Sinasc data trend for the 2017-2019 period—this is particularly true for the 13 states.
- The 2020 GFRs follow the 2019 GFRs in a decline trend.
- In the first trimester of 2021, the GFRs declined slightly when compared to the first trimester of 2020, although it is worth noting that there was already a decline trend.

Discussion

As we continue the urgent task of documenting the effects of the Covid-19 pandemic, it remains critical to monitor its demographic consequences beyond mortality. The ZIKV epidemic had already left recent imprints on fertility in Brazil before the Covid-19 pandemic started. We show that fertility recovered to levels pre-Zika epidemic in 2017, but that fertility started to decline again shortly after. This decline has accelerated in 2019, a year before Covid-19 was reported. We estimate that this trend persists in 2021.

Fertility was already in an all-time low in Brazil, following a declining trend before the Covid-19 pandemic hit. Considering that the spread of Covid-19 through the country has accelerated in 2021, we argue that the compounding effects of the uncertainties of the Zika and Covid-19 crises on fertility have the potential to be even more significant in Brazil because of the back-to-back timing of these outbreaks and its. consequent lack of appropriate time for recovering from the uncertainties they bring. The pandemic also coincides with significant economic and political crises, indicating additional effects.

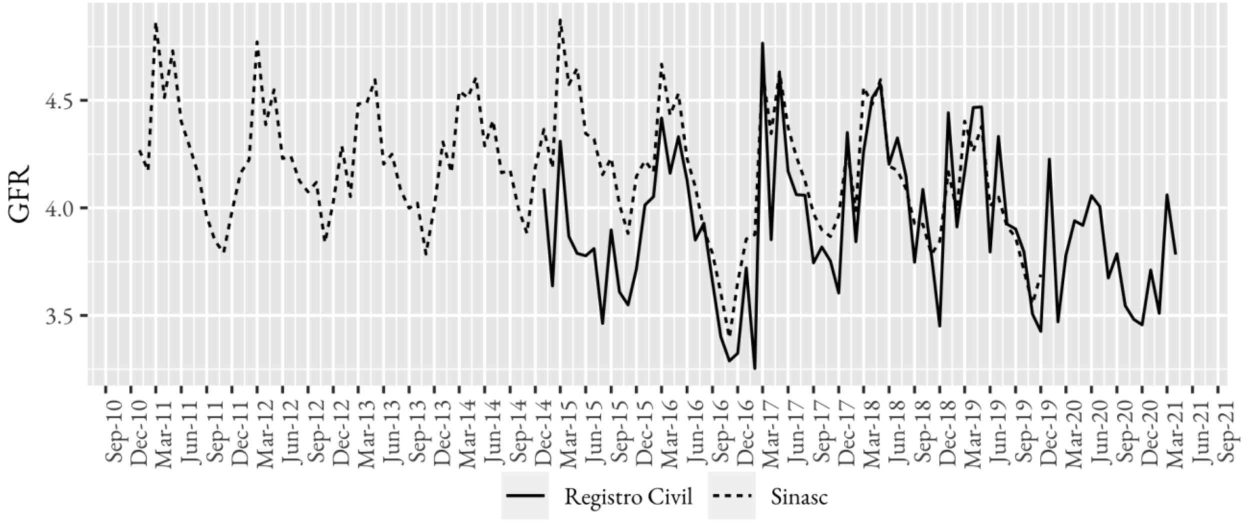
While it is difficult to identify the precise mechanisms driving fertility responses during epidemics, it is clear that the effects go beyond the direct effect of virus mortality. Epidemics can also affect fertility by inducing behavioral changes because of generalized uncertainties due to interruptions in health care access and loss of child care provision, for example. As such, promoting policies aimed at providing women with the conditions to match their fertility behaviors to their intentions becomes even more important in periods of public health crises, when resources are shifted from reproductive care towards confronting novel outbreaks. Because such crises disrproportionatelly affect minority populations, it is also important to focus on policies aimed at targeting minority groups.

As Brazilian women experience successive novel infectious disease outbreaks, the ages at which they experience these crises will also determine their effects. This is just another facet of the long reach that these successive outbreaks will have on when and how women have children in Brazil.

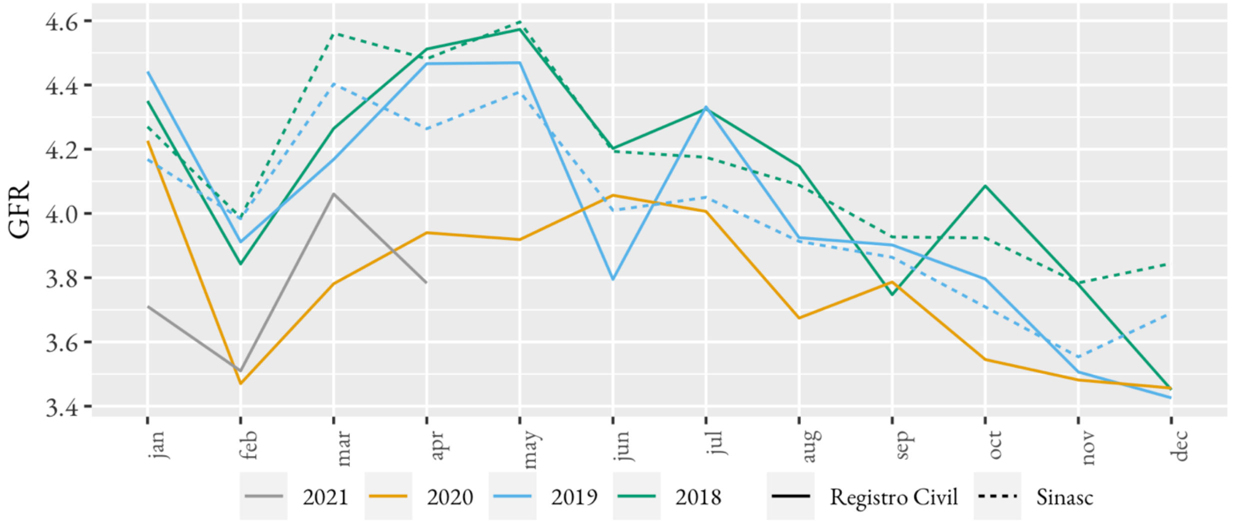
Citations

1. COVID-19 Map. Johns Hopkins Coronavirus Resource Center. Accessed April 28, 2021. https://coronavirus.jhu.edu/map.html
2. Marteleto LJ, Guedes G, Coutinho RZ, Weitzman A. Live Births and Fertility Amid the Zika Epidemic in Brazil. *Demography*. 2020;57(3):843-872. doi:10.1007/s13524-020-00871-x
3. Rasmussen SA, Jamieson DJ, Honein MA, Petersen LR. Zika Virus and Birth Defects — Reviewing the Evidence for Causality. *N Engl J Med*. 2016;374(20):1981-1987. doi:10.1056/NEJMsr1604338
4. Khalil A, von Dadelszen P, Draycott T, Ugwumadu A, O'Brien P, Magee L. Change in the Incidence of Stillbirth and Preterm Delivery During the COVID-19 Pandemic. *JAMA*. 2020;324(7):705. doi:10.1001/jama.2020.12746
5. Alex Sandro Rolland Souza, Melania Maria Ramos Amorim. Mortalidade materna pela COVID-19 no Brasil. *Rev Bras Saúde Materno Infant*. 21(supl 1). doi:https://doi.org/10.1590/1806-9304202100s100014
6. Kc A, Gurung R, Kinney MV, et al. Effect of the COVID-19 pandemic response on intrapartum care, stillbirth, and neonatal mortality outcomes in Nepal: a prospective observational study. *Lancet Glob Health*. 2020;8(10):e1273-e1281. doi:10.1016/S2214-109X(20)30345-4
7. COVID-19 - PAHO/WHO Response, Report 42 (25 January 2021) - PAHO/WHO | Pan American Health Organization. Accessed April 28, 2021. https://www.paho.org/en/documents/covid-19-pahowho-response-report-42-25-january-2021
8. Portal da Transparência - Registro Civil. Accessed April 28, 2021. https://transparencia.registrocivil.org.br/registros

192 **Figure 1** General Fertility Rate by Month, 2010-2021. Sinasc & Civil Registry Data. Brazil.



193



194
195

Appendix A

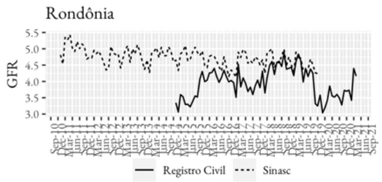
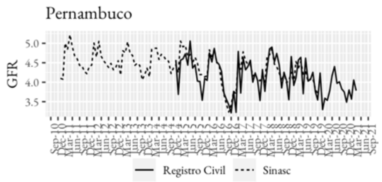
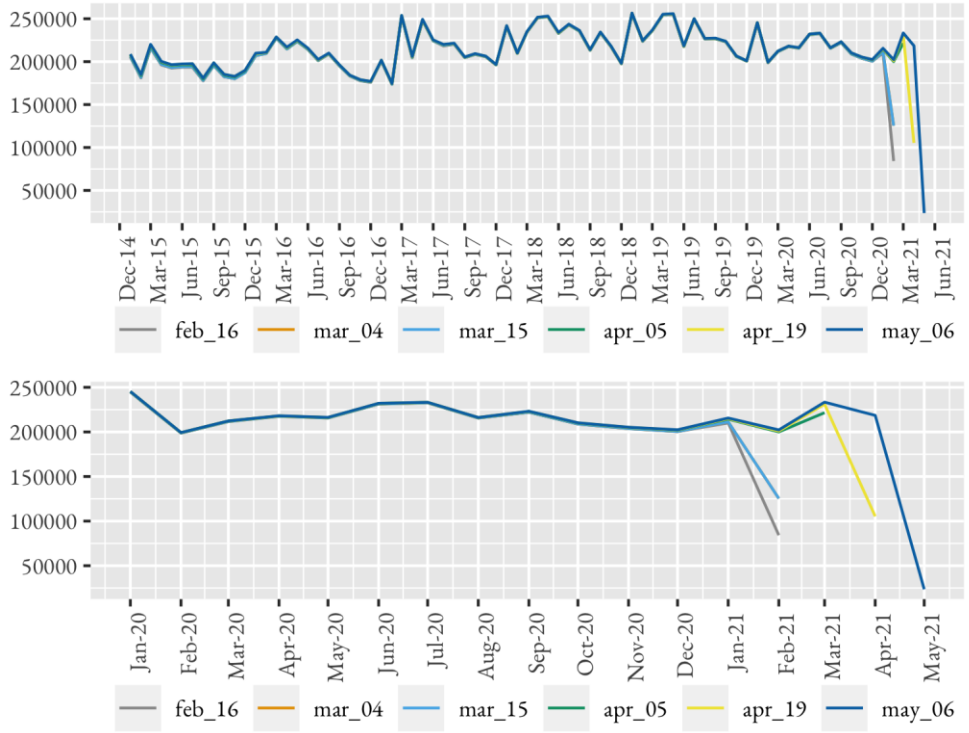
		…

Figure 1 for state?

Appendix B

Number of Live Birth from Civil Registry on different data collection dates, Brazil



Estimações para os 27 estados

UF	**Sinasc ADF**	**Civil Registry ADF**	α **(p value)**	γ **(p value)**	**R2**	**Residuals mean**	**Residuals ADF**	**Res(t-1) p-values**	**Escolha**
11	0.010	0.010	0.706	0.000	0.616	0.000	0.010	0.120	1
12	0.010	0.010	0.965	0.000	0.421	0.000	0.010	0.001	0
13	0.010	0.010	0.657	0.014	0.170	0.000	0.010	0.130	0
14	0.010	0.010	0.634	0.446	0.018	0.000	0.010	0.018	0
15	0.010	0.010	0.708	0.000	0.479	0.000	0.010	0.102	0
16	0.035	0.010	0.890	0.011	0.182	0.000	0.010	0.007	0
17	0.010	0.010	0.959	0.000	0.496	0.000	0.010	0.642	0
21	0.010	0.010	0.888	0.001	0.296	0.000	0.010	0.281	0
22	0.010	0.010	0.858	0.031	0.133	0.000	0.010	0.247	0
23	0.013	0.010	0.818	0.000	0.482	0.000	0.010	0.346	0
24	0.010	0.010	0.740	0.000	0.465	0.000	0.010	0.146	0
25	0.011	0.010	0.870	0.000	0.642	0.000	0.010	0.053	1
26	0.022	0.010	0.876	0.000	0.595	0.000	0.010	0.087	1
27	0.016	0.010	0.865	0.000	0.569	0.000	0.010	0.404	1
28	0.041	0.010	0.954	0.000	0.352	0.000	0.010	0.405	0
29	0.046	0.010	0.560	0.000	0.560	0.000	0.010	0.094	1
31	0.025	0.010	0.900	0.000	0.582	0.000	0.010	0.210	1
32	0.020	0.010	0.940	0.000	0.576	0.000	0.010	0.004	0
33	0.042	0.010	0.815	0.000	0.723	0.000	0.010	0.307	1
35	0.037	0.010	0.893	0.000	0.661	0.000	0.025	0.116	1
41	0.027	0.010	0.870	0.000	0.712	0.000	0.010	0.023	0
42	0.010	0.010	0.837	0.000	0.430	0.000	0.010	0.064	0
43	0.010	0.010	0.667	0.000	0.602	0.000	0.010	0.052	1
50	0.050	0.010	0.923	0.000	0.667	0.000	0.019	0.468	1
51	0.010	0.010	0.596	0.000	0.523	0.000	0.010	0.150	1
52	0.010	0.010	0.918	0.000	0.587	0.000	0.010	0.047	0
53	0.010	0.010	0.312	0.000	0.702	0.000	0.010	0.000	0