Assessing the Impact of Temperature Anomalies on Fertility: A Municipality-Level Analysis of Birth Rates in Mexico (1985- 2020)

Olguín, Itza; Cheritel, Côme; Muttarak, Raya

1. Background

The constant temperature increase, as a principal manifestation of climate change, will have diverse consequences on population dynamics. Numerous studies have already documented the effects of extreme temperatures on mortality (Analitis et al., 2008; Carleton et al., 2022; Vicedo-Cabrera et al., 2021) as well as on migration (Berlemann & Steinhardt, 2017; Clement et al., 2021; Hoffmann et al., 2020). However, far fewer studies have been conducted on how climate changes could impact fertility and reproductive health (Grace, 2017; Segal & Giudice, 2022). Considering that fertility is one fundamental component influencing population growth and given that any population can currently be affected by unprecedented temperature changes, it deems necessary to delve deeper into the study of the impact of climate change on fertility.

Studies that have previously investigated climate-induced alterations in reproductive patterns typically consider two different types of climate events: sudden-onset events and slow-onset events or long-run climate anomalies. Fertility has been observed to respond both positively and negatively to both types of events. Regarding sudden-onset events, which usually are characterized by their unexpected and concentrated nature; Davis (2017) found higher fertility rates just after the occurrence of Hurricane Mitch in Nicaragua, especially in areas with higher mean precipitation. Similar trends were observed after the Indian Ocean tsunami in some Indonesian communities in 2004. In places where tsunami-related mortality was high, Nobles et al. (2015) documented an increase in fertility. In contrast, other studies have indicated that extreme events are more likely to have a negative effect on fertility. Tong et al. (2011), for instance, observed a significant decrease in both birth rates and fertility rates following the Red River flood in North Dakota.

The impact of slow-onset events or long-run climate anomalies on fertility is also mixed. On the one hand, it has been observed exposure to drought in the growing season accelerated transition to into first unions and into first births within unions of young women who live in rural areas of Malawi (Andriano & Behrman, 2020). Similarly, Simon (2017) has studied links between fertility decision making and the variations of precipitation. Combining household event history data and precipitation measurements, the author observed that in historically dry communities in Mexico, households are more likely to have a child following periods of above-average precipitation. However, the effect of long seasons of climate anomalies may vary from one country to another confirming mixed evidence in the scientific literature. For example, Barreca et al. (2018) discovered that in the United States, extended periods of above-average temperatures lead to a decline in birth rates 8 to 10 months later. Similar findings were exposed by Cho (2020) in South Korea, where an additional day of maximum temperatures between 30 to 32°C, decreased the birth rates 9 months later. Furthermore, other related studies also hint about the negative effects of elevated temperature on reproductive health e.g., in the sperm quality in mammals (Hansen, 2009), fetal development, birth complications (Rylander et al., 2013), as well as gestational length (Barreca & Schaller, 2020).

The outcomes of previous studies indicate that the impact of extreme weather events and prolonged periods of extreme weather on fertility varies based on different mechanisms. In some cases, the changes in fertility patterns are linked to affections in reproductive health resulting from climatic conditions (Barreca et al., 2018; Rylander et al., 2013). In other cases, these changes occur through indirect mechanisms, such as a form of adaptation to the changes in the time use of physical labor, as a response of food insecurity, or due to a reduction in resources and income (Grace, 2017; Thiede et al., 2022).

There is no consensus on the direction and on the reasons why fertility patterns change as a response to climate events. This is the reason that motivates our study of the impact of climate change on fertility in Mexico given the availability of a long series of birth data at a refined geographic scale. Moreover, aside from Simon (2017) Davis (2017), and Marteleto et al. (2023) there appears to be a limited amount of research examining the correlation between climate-related phenomenon and variations in fertility trends within Latin America, especially with recent data. To contribute more to this field, the aim of this investigation is to analyze how fertility patterns in Mexico change as a response to rising temperatures. To perform the empirical analysis, we construct a harmonized municipality fertility database using administrative records and Census information from 1985 to 2020 combined with meteorological data which allows us to estimate the impact of climate variability on Mexican fertility trends.

2. Data

The primary objective of this section is to present the methodology used for compiling the detailed birth rates data that spans from 1985 to 2020 and the subsequent steps to integrating this data with weather data.

2.1. Mexico administrative structure and spatial harmonization of municipalities

The United Mexican States is a federal republic with various levels of administrative division. First, Mexico is composed of 32 federal entities: 31 states and Mexico City. Each state is composed of various numbers of municipalities of different sizes, shapes, and population. Municipalities are the second-level administrative divisions of Mexico (whereas federal entities are the first) with the greatest granularity for which we can have access to birth data in the administrative records.

However, as boundaries change during the time span that we considered, and the available data of the geographical division of the place where the births occurred changes as well, we produced a harmonization of Mexican municipalities. The principal objective of harmonizing was to have a common denominator comparable across the time and space to aggregate the birth and the climate data to build a panel dataset at municipality level. We have harmonized information from the census exercises generated every ten years from 1970 to 2020 and intercensal harmonized information between each census exercise since 1995. For example, by merging two or three current municipalities that at one point could not be distinguished because they were only a single municipality. From 2469 different municipalities in 2020, our dataset considers 2195 harmonized units at the municipality level.

2.2. Birth data

Birth data are available at the municipality level, these come from the *Registos Administrativos de Natalidad* [Births Administrative Records of Mexico] and were processed by the National Institute of Statistics and Geography (INEGI). This data can be freely downloaded from the year 1985 onwards, which is why the years considered for this analysis span from 1985 to 2020. The administrative records capture the date and municipality of occurrence of birth as well as the date and municipality of registration since, in some cases, the processing of the birth certificate - i.e., the registration in the administrative records - may occur months or even years after the actual birth occurred (Mier et al., 2019). In this case, we consider the monthly municipality count of births defined by the date of birth. The total births considered for each month is the sum of the births that occurred and were registered in the corresponding month plus the births that occurred in that month but were registered after.

To calculate birth rates, we aggregate the total number of births in each (harmonized) municipality monthly. This aggregated count is then divided by the total population of that municipality, expressed per 100,000 residents. The population data utilized for computing these birth rates is derived from census exercises conducted in 1990, 2000, 2005, 2010, and 2015, from IPUMS. For the year 2020, we directly obtained the population information from the INEGI census outcomes for that year, which were subsequently grouped and processed through the spatial harmonization, specifically conducted for this research. In order to estimate the population for each year within the harmonized municipality dataset, we employ linear interpolation between the available census years.

2.3. Weather data

We consider data of average monthly temperature and precipitation from the CRU-TS database (Beguería et al., 2010, 2014; Harris et al., 2020) and Standardized Precipitation-Evapotranspiration Index (SPEI) database (Beguería et al., 2010, 2014; Vicente-Serrano et al., 2010). Data are aggregated at the harmonized municipality level in two different ways: by weighting them by the surface area of the cell or by the population per cell; and by the population data coming from the Global Human Settlement database (Schiavina et al., 2023). For average monthly temperature and precipitation, we estimate long-term average and standardized anomaly with a reference period spanning from 1983 to 2016.

3. Summary statistics

Table 1 shows the birth rates and important climate variables for all the Mexican territory over the entire period of analysis. The table also includes the number of municipalities obtained after the harmonization, and the number of harmonized municipalities-months that represent the total sample.

Sample	Mean
Daily birth rate per 1,000 inhabitants	0.07
Mean births by month	198,412
Number of municipalities in 2020	2469
Total of harmonized municipalities	2195
Total of month-years	432
Number of harmonized municipalities-months	863,952

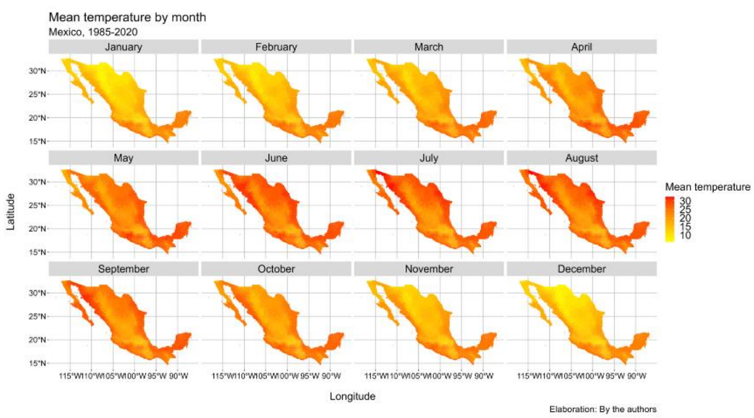

Figure 1. Mean monthly temperature by harmonized municipalities

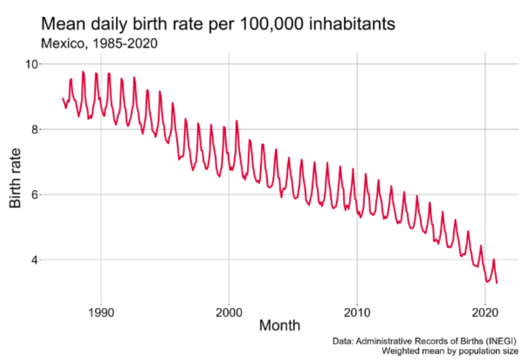

Figure 2. Mean daily birth rates for the period 1985-2020

4. Methodology

In the next step, we plan to study the dynamic temperature-fertility relationship in Mexico from 1985 to 2020. We would like to analyze the impact of high temperatures anomalies on fertility following a panel regressions method:

$$Y_{i,t} = \sum_{l=0}^{L} \beta_l T_{anom,i,t-l} + X_{i,t} + \pi_{i,month} + \pi_{i,month1} t + \varepsilon_{i,t}$$

Where Yi,t denotes the log birth rate at place i at time t. $Tanom, i, t-l$ is the vector that contains the temperature anomalies at time t in place i of the current month and the past temperatures up 24 months.

X represents some control variables. π represents fixed effects of unobserved heterogeneities between municipalities and over time. Adding municipality specific would be considered and spatial HAC standard errors (Conley, 1999) would be used to estimate the significance of our estimates.

5. Results

Figure 4 represents some of the preliminary results of the impact of the temperature anomalies on the log birth rate. Increases in temperature on month t have an effect of reduction of births nine months later. The positive effects of the temperature on the log birth rates in subsequent months likely reflect birth postponement. To control the possible autocorrelation the model considers Conley-HAC standards errors and the precipitation anomalies as control variables.

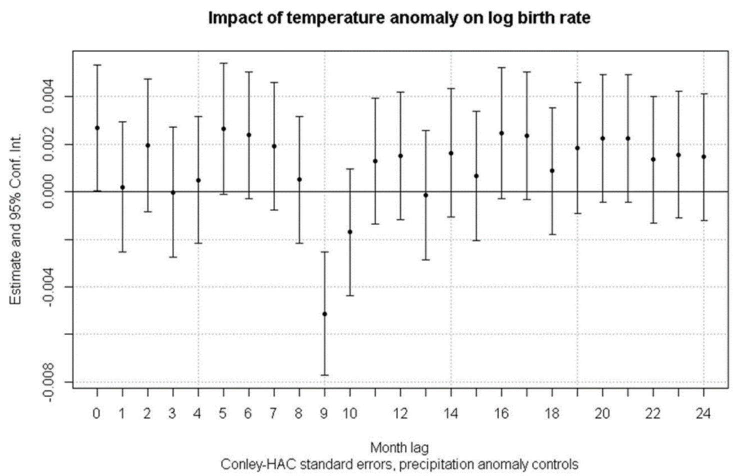

Figure 3. Impacts of temperature anomaly on log birth rates, Mexico 1985-2020

Considering the previous results, we estimate a model that explores the relation between the temperature anomalies taking as control variables the changes in the precipitation seasons and the Standardized Precipitation-Evapotranspiration Index (SPEI). To check the robustness of the result we consider proofs with different standard errors to avoid the potential spatial autocorrelation between the municipalities.

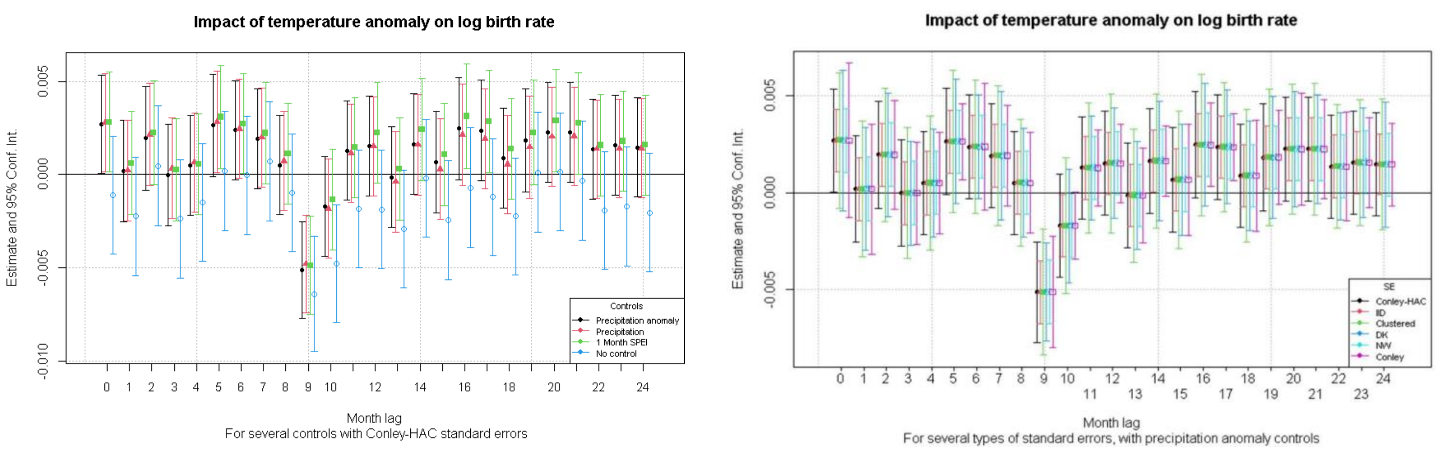

Figure 4. Impacts of temperature anomaly on log birth rate with different control variables and different for robustness check, Mexico 1985-2020

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