The effects of temperature on congenital disorders: Evidence from Mexico*

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February 14, 2025

Very preliminary draft

Abstract

Congenital disorders are a principal cause of early mortality, long-term disabilities, impaired cognitive development and constitute a major challenge to families, communities, and health care systems alike. The origins of congenital disorders are not yet well understood with descriptive evidence from the fields of medicine and public health pointing towards the role of climate-related factors. Leveraging detailed micro-data from Mexico, this study aims to provide the first causal evidence on the role of climatic shocks in affecting the onset of congenital disorders. For this purpose, we compiled a large dataset comprising about 19 million births from about 63,000 Mexican localities for the period 2008 – 2021. Focusing on temperature shocks, our results indicate that an increase in temperatures by 1°C, is related to an increase in congenital disorders by 10 percent (0.1 percentage points).

Keywords: congenital disorders, climatic shocks, Mexico, fetal origin

JEL classifications: I14, I31, Q54

*We would like to thank the Inter-American Development Bank for financial support for the project. Additionally, we thank Isabelle Chort and Felipe Jordán for their valuable feedback.

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1 Introduction

Each year more than 40 million babies are born with a congenital disorder, representing 3% of all newborns in the world. Congenital disorders are functional anomalies that exist at or before birth and can be identified perinatally, at birth, or later in infancy. The most common congenital disorders are heart defects, neural tube defects, and Down syndrome (WHO, 2023).

Their consequences are massive: Over 400,000 of newborns with congenital disorders die within the first five years. Additionally, congenital disorders can cause long-term disabilities, retarded cognitive and physical development, bearing a significant burden on individuals, families, communities, and health care systems (WHO, 2023).

Despite its importance, the causes of most congenital disorders are still largely unknown. For a few congenital disorders genetic abnormalities and gene defects have been identified as one cause, e.g. with respect to Down syndrome. Moreover, lack of specific nutrients determines other types of congenital disorders such as neural tube defects.

Apart from genetic and socioeconomic factors, environmental conditions during the perinatal phase have been linked and discussed to influence congenital disorders. Correlative evidence suggests that weather events like storms, earthquakes, heat waves, among others might contribute to a higher risk of congenital disorders in newborns (e.g. Dalugoda et al., 2022; Haghighi et al., 2021; Harville et al., 2010; Li and Zhou, 2017; Van Zutphen et al., 2012). The present literature particularly indicates a relation between high ambient temperature and congenital disorders: First, animal studies provide causal evidence of such a link. Additionally, epidemiological and public health studies established correlative evidence between the relation of elevated ambient temperature and the prevalence of congenital disorders for humans (see Haghighi et al., 2021, for a review). Still today, quantitative, causal evidence on the relation of climatic conditions and the prevalence of congenital disorders in humans is missing.

Climate change is expected to increase global ambient temperature and the frequency and intensity of heat waves as well as other weather shocks such as storms and massive rainfall or droughts. Given this background, it is important to understand the link between exposure to climatic conditions in utero and the risk of congenital disorders to be able to derive adequate counter policies and preventive measures, reducing the burden of congenital disorders.

In this research project, we study the effects of high ambient temperature in utero on the likelihood of congenital disorders at birth. We aim to advance the literature by providing the first causal evidence on the effects of climatic conditions on congenital disorders for a representative sample of Mexicans. Our research questions are twofold: (1) Does high ambient temperature in utero increase congenital disorders? (2) If so, what are the mechanisms behind this impact?

Mexico provides an ideal case to study because it is considerably affected by climate change and has experienced several strong heat waves in recent years. At once, the region still falls short on global targets regarding neonatal health. Most importantly, the rich information in the Mexican birth registers allow us to precisely link diagnosis of congenital disorders of newborns to local weather circumstances during their time in utero.

Our study contributes to a rich economic literature that investigates conditions in utero on birth outcomes and health conditions in adulthood. Several empirical studies identified climatic conditions such as severe storms, high ambient temperature, or droughts in utero as one driver behind abnormal birth weight and height, child mortality, and worse socio-economic and health conditions in adulthood (e.g. Almond and Currie, 2011; Currie and Rossin-Slater, 2013). We contribute to this literature by being able to abstain from general health indicators, focusing on congenital disorders, a birth condition with particularly severe long-term consequences. Closely related to our analysis is the study by Currie and Rossin-Slater (2013) that establishes a causal link between exposure to hurricanes in utero and abnormal conditions at birth using birth records from Texas. Apart from exposure to tropical cyclones, our study considers temperature and precipitation conditions during pregnancy and focuses on congenital disorders. Additionally, our rich dataset allows us to elaborate on selection effects caused by stillbirth, miscarriages, and abortion, providing an estimate of the selective mortality bias.

Lastly, our study speaks to the medical and epidemiological literature investigating the determinants of congenital disorders. Heat exposure, particularly during the organogenesis (first trimester of pregnancy) has been associated with congenital disorders (Yu et al., 2022). Animal studies show that hyperthermia induces cell death that translates to malformations in numerous animal models (Bennett, 2010). Maternal fever, internal heat caused by hot tubs, saunas, electrical blankets and intensive exercising have been linked with birth defects in a number of human studies, though the evidence is mixed (Haghighi et al., 2021). Additionally, elevated ambient temperature goes along with behavioral and environmental changes such as a higher consumption of alcohol, more aggressive behavior, a higher risk of infections (vector-born or food-borne zoonosis), increased air pollutants that cause oxidative stress during gestation and might contribute to congenital disorders (Haghighi et al., 2021; Yu et al., 2022; Ravindra et al., 2021).

Our results show that high ambient temperature in utero increases the likelihood of congenital disorders of Mexican newborns. The effect is driven by elevated temperature in the first trimester. A one-degree Celsius higher maximum temperature during the first trimester is estimated to increase the likelihood of any congenital disorder by 0.1 percentage points, a 10% increase. Our analysis of mechanisms reveals that heat exposure causes congenital disorders through direct and indirect ways, among others it augments the risk of infections and malnutrition as well as the exposure to air pollutants.

2 Background

In the following we briefly provide additional background information on the Mexican context focusing on three areas, namely (i) the country's climate vulnerabilities, (ii) congenital birth disorders, and (iii) the legal framework around abortions. Under the United Nations Framework Convention on Climate Change (UNFCCC) Mexico is considered particularly vulnerable to the impacts of global climate change. Identified impacts relate to an increasing number of heat events, droughts, flooding, and storms. For instance, the continuous increase in sea surface temperature in the Gulf of Mexico, has been assessed to intensify hurricanes and changes in precipitation cycles. The vulnerability of Mexico to global warming has been established for a long period, resulting, among others, in the formulation of climate change strategies in the National Development from 2007-2012 and the Inter-Ministerial Commission on Climate Change in the year 2005.

Congenital disorders are the second leading cause of infant mortality in Mexico and a major contributor to the onset and exacerbating of disability-related reductions in physical functioning. Despite its severe health and economic impact, it has been noted that in many Latin American countries including Mexico there is scope for more concerted policy efforts to improve surveillance, prevention measures, and care with key policy areas (Zarante et al., 2019).

The principal legislation on abortion is at the state and federal level. Until the year 2021, state-laws exclusively prohibited abortion (on-demand), the exception being the federal district of Mexico City which de-criminalized abortion practices in the year 2007 and which abortions became allowed for the first twelve weeks of pregnancy. In 2021 the Mexican Supreme Court ruled that penalizing abortion is unconstitutional across the country. Consequently, states were asked to revise their legislation. Until early 2025, about 60 percent of all states had adjusted their legislation to allow for abortions in the first 12 weeks of pregnancy, while public-sector abortion services operated in all Mexican states.

3 Data and measures

Our analytical sample is an individual-by-month pseudo panel that covers any registered newborn in Mexico between the years 2008 to 2021. Combining detailed birth-related information from publicly-available, administrative sources (birth registry from the Mexican Ministry of Health) with GIS-linked climate-related information, our sample covers 18,619,593 individual-level observations from 63,139 localities in Mexico. Climate-related data are linked to the birth registry at the level of localities (administrative level 3) using geographical administrative maps from the Mexican statistical office (INEGI).

Our main dependent variable is an indicator variable that identifies whether a newborn had a congenital disorder at the time of birth. Information on newborns' health, especially on congenital disorders is taken from Mexico's birth registers provided by the Ministry of Health. The registers document the timing, location, and several characteristics of newborns and mothers for any registered birth in Mexico. Crucial for our analysis are: First, the availability of information on the precise location and timing of the birth, gestation period, as well as the place of residence of the mother (admin-3 level) allowing us to construct an exact measure of exposure to climatic conditions in utero. Second, the registers systematically report on congenital disorders and birth conditions caused by conditions in the perinatal period using the ICD-10 classification system. We consider any diagnosis that falls into the category Q "Malformations, deformations and chromosomal abnormalities" of the ICD-10 as an indication of a congenital disorder. This category includes microcephaly, spina bifidia, congenital heart defects, cleft palate, down syndrome, among others. Additionally, we take category P "Conditions of the newborn originating in the perinatal phase" of the ICD-10 into account to investigate mechanisms such as infections in utero or malnutrition and illness of the mother during pregnancy. In the data cleaning process, we dropped observations with a gestational age below 22 weeks as there is hardly no chance of surviving for the foetus. In our sample, 1% of newborns are diagnosed with a congenital disorder. Figure 1 plots the rate of congenital disorders per municipality in our sample.

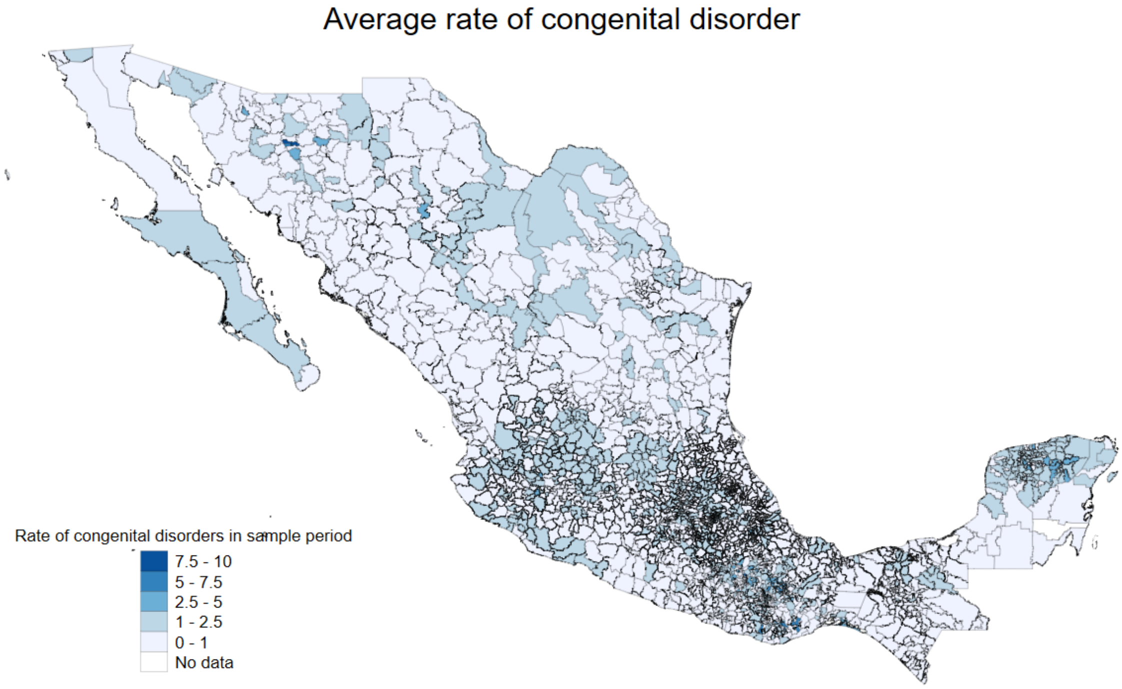


Figure 1: Rate of congenital disorders per municipality

Notes: The map shows the average rate of congenital disorders per municipality over the sample period of 2008 - 2021.

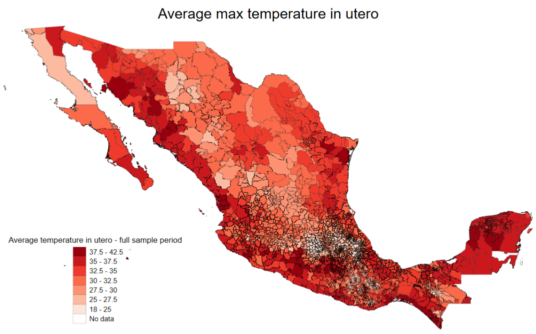
Our main explanatory variable gives the average maximum temperature the newborn is exposed in utero. To construct this variable, we take information on monthly maximum temperature at the 2.5 arc minute resolution from the WorldCLim database (Fick and Hijmans, 2017) and link it to the locality of mothers' residence. Several grids might fall into one locality (admin 3 level). If this is the case, we take the average of those grids. Grids that fall partly into one locality enter the average weighted by the area. To get an individual exposure measure, we afterwards take the average over the period, the newborn is in utero. The time period of in utero is calculated by subtracting the reported pregnancy months from the date of birth.

Apart from temperature, we also consider the average monthly precipitation in utero and the exposure to tropical cyclones in utero. Information on precipitation is taken from the WorldClim database as well. For information on the location, timing, and influence area of cyclones, we rely on data from Pérez-Alarcón et al. (2022). The data allows us to identify newborns that have been exposed to a tropical cyclone in utero. We define a locality to experience a tropical cyclone if it falls within the outer radius of a tropical cyclone.

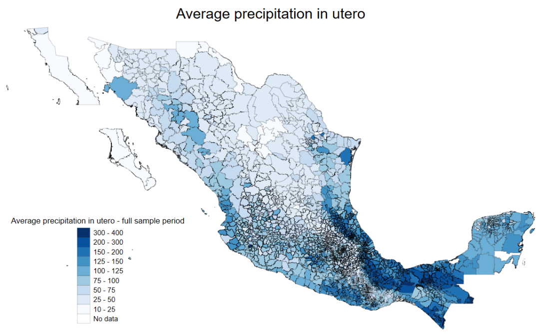
We use the average monthly maximum temperature in utero as our main temperature measure as we believe it captures well heat exposure, yet we also consider anomalies of the maximum temperature and the average temperature during utero in a robustness check. Information on the average temperature is taken from the GHCN CAMS Gridded 2m Temperature dataset that reports monthly average temperatures in degree Kelvin at the surface on a 0.5 degree grid cell level and is provided by NOAA (Fan and Van den Dool, 2008).

The maximum monthly temperature averaged over the perinatal phase ranges from 11.53 to 48 degrees Celsius with a mean of 31.43 degrees in our sample. The mean of the average temperature is 22.08 degree Celsius and average monthly precipitation is 8.38 cm. Figure **??** depicts the graphical distribution of the climate variables in our sample period and Table 1 in the appendix reports the descriptive statistics of the main variables.

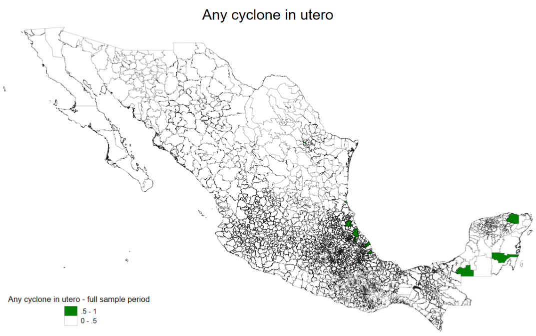
In all our regression models, we control for population density. Information on population density is taken from the Gridded Population of the World (GPW) dataset (version 4) provided by SEDAC. We interpolate values for unobserved years. Moreover, we utilize several further datasets for the analysis of mechanisms and the robustness checks. We leverage data on environmental and socioeconomic characteristics of localities including information air pollution (estimated PM2.5 concentrations based on satellite data provided by the Washington University



(a) Average maximum monthly temperature



(b) Average monthly rainfall



(c) Municipalities with exposure to cyclones

Notes: The maps show a) the maximum monthly temperature in utero averaged per municipality and over the sample period of 2008 - 2021, b) the average monthly rainfall amount in mm in utero of newborns per municipality over the sample period, and c) municipalities in which newborns have been exposed to a cyclone in our sample period.

in St. Louis, Van Donkelaar et al. (2021), droughts measured by the Standard Precipitation and Evapotranspiration Index (SPEI) (SPEIbase v2.9, Vicente-Serrano et al. (2010)), risk of vector-born infections proxied by a zika suitability index provided by Messina et al. (2016).

Lastly, to account for potential mortality selection effects, we analyse the link between climatic conditions and foetal deaths using the administrative death registers provided by the Mexican health ministry that are publicly available for the years 2012 - 2021.

4 Empirical strategy

In order to infer the average effect of climatic conditions in utero on the likelihood of any congenital disorder of a newborn, we exploit the variation in climatic conditions in space and time. Our econometric model regresses an indicator variable that is 100[1] if child i from mother

[1]We abstain from the standard version of 1 and multiply by 100 to improve readability of the coefficients in the table.

m residing in locality l that is part of municipality r and is born on date d (month-year) has been diagnosed with a congenital disorder Y_{imlrd} on the exposure to climatic characteristics in the perinatal phase $Climate_{mlrd}$ and further controls:

$$Y_{imlrd} = \beta Climate_{lmrd} + X'_{imrld}\eta + \theta_{lm} + \mu_{rd} + \varepsilon_{imlrd}, \tag{1}$$

whereby X_{lmd} refers to a vector of control variables including child, mother, as well as characteristics of the locality. Our baseline controls include population density, the age and educational attainment of the mother, and the gender of the newborn. Locality-month fixed effects θ_{ld} account for the average propensity of a location to experience climatic conditions in a certain month and municipality specific time fixed effects μ_{rd} capture any changes over time that can relate to changes in the climate and newborn health such as policy reforms or phenomena like el Niño/a at the second administrative level. ε_{imlrd} represents standard errors that we cluster at the locality level.

Our coefficient of interest is β which captures the effect of climatic conditions in utero on our outcome of interest, having a congenital disorder. We consider the average monthly maximum temperature in utero, the average monthly precipitation in utero, and the exposure to a tropical cyclone in utero as climatic variables.

Our identification strategy rests on the assumption that climatic conditions are exogenous once controlled for location and time fixed effects. This approach follows previous literature (e.g. Rocha and Soares, 2015). Yet, our identification strategy faces a potential measurement bias caused by the determination of exposure to climatic conditions based on the place of residence of mothers at the monthly level. While pregnant women are generally less mobile, extreme climatic conditions might force them to migrate, biasing our estimates.

We address this endogeneity threat by focusing on the years 2020/21, where COVID-19 contingency measures considerably reduced mobility. Additionally, we validate that our results are not driven by the period of the COVID-19 pandemic, the measurement of climatic conditions, the correction of standard errors, and the robustness to other potential confounders such as the birth facility or other climatic conditions.

Mechanisms are identified with heterogeneous treatment effects analysis along mother's and location characteristics and with treatment effects using alternative outcomes, notably the health status of the mother and conditions of the newborn originating in the perinatal phase.

5 Empirical results

5.1 Baseline results

Table 2 presents our main results. Column 1 controls for year, location, and month fixed effects, in column 2 we add basic characteristics of the child, mother, and the locality to the regression. Columns 3 to 5 step-wise adjust the fixed effects specification to be more restrictive: in column 3 we utilize year, location and locality-month fixed effects that allow for local seasonal patterns in temperature and health outcomes of newborns. Column 4 replaces the year and month fixed effects with year-month fixed effects and column 5 utilizes municipality-date fixed effects in combination with locality-month fixed effects. The latter specification is our preferred specification, which accounts for local seasonality as well as any kind of regional shocks. Starting in column 1, we find a positive effect of the average monthly maximum temperature in utero on the likelihood of a congenital disorder. On average, a one-degree Celsius higher average maximum temperature in utero increases the rate of congenital disorders by 0.082 percentage points, which corresponds to an around 10%-change. The inclusion of basic socioeconomic characteristics (column 2) does not change the main coefficient of interest. The coefficients of the socioeconomic characteristics are in line with previous literature: female newborns have on average a lower likelihood of a congenital disorder and the rate of congenital disorders increases with the age of the mother. In our preferred specification (column 5), our coefficient of interest augments to 0.2, a change of 0.2 percentage points.

To get a better understanding of the effects, we divide congenital disorders by its type based on the sub-categories of the ICD-10 classification system. The results shown in table 3 indicate that exposure to high temperature in utero causes all kinds of congenital disorders.

5.2 Robustness checks

We provide further analysis testing the robustness and sensitivity of our main regression results to a) alternative birth outcomes, b) the measurement of climatic conditions, c) the correction of standard errors, d) the regression model specification and further cofounders, and e) by climate zone. Moreover, we address the potential measurement bias arising from migration, and potential estimation biases caused by selective mortality. The estimation results are shown in tables in the appendix.

Apart from congenital disorders, the birth registers report on several general measures of newborn health such as birth weight, APGAR score, and Silverman index. We can also identify birth conditions that originate in the perinatal phase based on the reported ICD-10 codes. Using our main regression specification, table A.1 documents that apart from congenital disorders, higher temperatures in utero also cause more birth conditions related to the perinatal phase and worse general health of newborn: lower birth weight, lower APGAR scores, and higher values on the Silverman index. Additionally, our results estimate that, on average, a one-degree higher average maximum temperature relates to an earlier birth by more than a week.

In table A.4, we vary the measurement of temperature. We consider temperature anomalies in column 1 by subtracting the maximum monthly temperature data from its long-term mean (1960-2007) and dividing it by its standard deviation. In column 2, we use the average temperature throughout the perinatal phase, and column 3 counts the number of months in which the average temperature is above 40 °C. The estimation results show positive and statistically significant effects for temperature anomalies and average temperature in utero. The coefficient on the number of months above 40 °C in utero is statistically insignificant, potentially being less precise in measuring temperature variations.

We measure temperature exposure based on the residence of the mother at the locality level. As our treatment is determined on the locality, we have clustered our standard errors so far at that level. Nevertheless, standard error corrections at higher administrative levels might be adequate, for instance if reporting in birth registers differs between municipalities or states. To investigate the robustness of our main results to the level of standard error clustering, we run further regressions that cluster standard errors at the level of locality in combination with year (column 1), at the municipality level (column2), and at the state level (column 3). The results shown in table A.2 confirm the robustness of our main results to the diverse specifications of clustered standard errors.

In table A.3, we show the robustness of our main effect to the inclusion of additional potential confounders, namely mother characteristics, birth facility-specific effects, weather conditions, and time-trends. Specifically, in column 1, we include the gestational age as control and in column 2, we account for a set of mother characteristics: the marital status of the mother, her health insurance status, the number of children born dead and alive as well as whether the mother is indigenous and received prenatal care. In column 3, we include a locality-specific time trend and in column 4 we add birth-facility fixed effects that absorb differences at the hospital level. Lastly, column 5 accounts for wind speed and direction as well as humidity, weather conditions that might be correlated with our temperature measure. The inclusion of these controls does not change our main coefficient of interest much.

Our empirical strategy faces a potential endogeneity bias if mothers migrate because of climatic conditions. This could lead to an over- or underestimation of the true effect depending on who is migrating. To estimate the direction and magnitude of the bias, we would ideally observe migration histories of mothers and can directly link ambient temperature of the location of mothers to newborn health. As the data available do not allow us to observe migration trajectories, we aim to approach this issue by estimating the main regression specification for the years 2020/21, the period in which mobility was highly restricted due to the COVID-19 pandemic. Please note that our municipality-date fixed effects account for the number of COVID-19 infections at the municipality level. The results shown in table A.5 find a positive and statistically significant effect for both sub-samples (COVID-19 and non-COVID-19 years), reassuring us that migration cannot fully explain the estimated effect.

A final concern relates to selective mortality. On the one hand, foetuses with a congenital birth defect might be more fragile and susceptible to climatic conditions and as a result might have a higher likelihood to be miscarried. If this is the case, we would not observe the full effect of temperature in utero on congenital disorders at birth given that a part of the foetuses with a congenital disorder have died before the observation. On the other hand, prenatal diagnosis allows parents to know about congenital disorders of their unborn perinatally, potentially leading to abortions of foetuses with congenital disorders. Using the foetal death registers provided by the Health Ministry of Mexico that are available for the years 2012- 2021 and appending them to the birth registers, we analyse in how far temperature conditions in utero are related to foetal deaths as well as miscarriages, stillbirth, and abortion separately. Additionally, we can estimate heterogeneous effects by the diagnosis of a congenital disorder of dead and alive foetuses. The results presented in table A.6 document that higher average maximum temperature in utero increases the likelihood of stillbirth and abortion. The effect of temperature in utero on foetal death is stronger for foetuses diagnosed with a congenital disorder compared to others.

Not only temperature, but also floods and storms might influence the health of newborns. In order to see, in how far other climatic conditions impact congenital disorders, we regress our main outcome of interest on average monthly precipitation in utero and on the exposure to cyclones in utero using our main specification (column 5 of Table 2). The results presented in table A.7 show that congenital disorders increase with the amount of precipitation in utero. We find no statistically significant relation between exposure to cyclones in utero and congenital disorders. With respect to the magnitude, a one cm^2 increase in the average monthly amount of rainfall in utero raises the likelihood to be diagnosed with a congenital disorder by 0.03 percentage points or a one standard deviation increase in average monthly precipitation (5.63) augments the likelihood of congenital disorder by 0.17 percentage points.

Lastly, we analyse differential effects by climate zone. Based on the climate zone map provided by the Natioanl Statistics office of Mexico, Mexico can be divided into 25 climatic areas. In Table A.8 we show differential effects by each climate zone relative to. The results reveal that the effect of higher ambient temperature on congenital disorders occurs in localities that fall into climate zones with hotter climate such as tropical and semi-arid zones.

5.3 Mechanisms

Heat exposure might impact the health of newborns through several ways. On the one hand, animal models and medical studies show that high body temperature of the mother can interrupt the typical sequence of gene activity and cause cell death during organogenesis (first trimester), leading to congenital disorders directly (Bennett, 2010; Haghighi et al., 2021). On the other hand, congenital disorders might occur a) at later stages of the pregnancy or b) indirectly through changes in the environmental condition that go along with heat exposure.

First, heat waves harm agricultural production and reduce local water reserves that can result in mal- or undernutrition of the foetus, a further determinant of congenital disorders. Second, high ambient temperature is associated with a higher risk of vector-borne and food-born infections such as zika and rubella infections or toxoplasmosis that are harmful for the health of the unborn and have been linked to malformations and birth disorders (Rostami et al., 2021; Tesla et al., 2018). Third, there is some evidence that the effects of air pollution on health are enforced with higher temperature. On the one hand high ambient temperature increases ozone concentrations and on the other hand temperature traps pollutants closer to the ground, increasing ground-level PM2.5 density (Zhou et al., 2023; Stingone et al., 2019; Liu et al., 2017). Lastly, high temperature might influence newborn health via maternal stress (Currie and Rossin-Slater, 2013; Persson and Rossin-Slater, 2018; Gu and Guan, 2021). Heat exposure is associated with a higher risk of intimate partner violence and child maltreatment (Sanz-Barbero et al., 2018; Evans et al., 2025) that can result in disorders of the unborn.

To investigate the direct effect of heat proposed by medical studies, we consider climatic conditions in each pregnancy trimester separately and regress our main outcome of interest on these variables. Table 4 illustrates the results, whereby column 1 reports the results for average maximum temperature in the first trimester, column 2 of the second trimester, column 3 of the third trimester, and column 4 includes the temperature measures jointly. In column 5, we additionally include two placebo tests with the inclusion of the average maximum temperature before and after the period of in utero. Throughout the regression specifications, we find that higher temperature in the first trimester raises the likelihood of congenital disorders. We find no statistically significant relation between temperature in later stages of the pregnancy or before conception or after birth in line with the medical and biological literature that indicates a direct effect of heat exposure in the critical phase of organogenesis.

To examine the proposed indirect mechanisms (nutritional deficit, infections, air pollution), we successively shut down one of these channels and consider them individually in our regression with a mediation analysis based on characteristics of the location. For instance, if we assume that the relation between high temperature and congenital disorders is driven by nutritional deficits of the unborn child that might originate from a worse harvest resulting from droughts, we would expect that the effect is a) partly captured when we account for indicators of local droughts in the regression. Alternatively, we would expect that the effect is more pronounced in locations that experience higher temperature in combination with droughts. Similarly, we analyse the mechanism via virus infections and air pollution. We proxy the risk of virus infections with an index that captures the geographical suitability for mosquito's that transmit zika and other harmful viruses and use PM2.5 density as a proxy for air quality.[2]

The results presented in table 5 show that the inclusion of the number of drought months based on the SPEI index does not change the relation between average maximum temperature in utero and the likelihood of congenital disorders. The results in column 3 show no evidence for a differential effect between locations that are suitable for the mosquito's transmitting zika and others. With respect to column 4, we find that the inclusion of PM2.5 as an indicator of air pollution changes the coefficient on avg. max temperature in utero. The mediation analysis (column 5) reveals that higher temperature in utero that goes along with higher air pollution has a stronger effect on the likelihood of congenital disorders, explaining part of the effect. Lastly, the results in column 6 do not suggest that domestic violence is a crucial mechanism.

To complement the analysis on the indirect mechanisms, we provide additional analyses at the individual level. The birth registers allow us to determine specific birth conditions that originate in the perinatal phase and provide information on sickness of the mother. We apply a two step analysis: First, we relate average maximum temperature with these conditions and afterwards

[2]Please note that zika suitability is a time invariant measure.

we link those conditions to congenital disorders of the newborn. With respect to the nutrition channel, we link high ambient temperature in utero with reported malnutrition of the mother and foetus and correlate malnutrition with congenital disorders of foetuses. For the channel "infection" we consider whether the mother or child had an infection during pregnancy and with respect to air pollution we focus on respiratory and cardiovascular conditions of the mother and unborn diagnosed during pregnancy or at birth. Those birth conditions are determined with sub-categories of the category “P” of the ICD-10 classification system that are reported in the birth registers. The regression results are reported in table 6 and show that higher temperature in utero increases the share of newborns that are diagnosed with malnutrition, infections and respiratory and ciruculatory diseases. These factors are correlated with the diagnosis of a congeital disorder.

6 Conclusion

This study examines the effects of high ambient temperature during the perinatal phase on the likelihood of congenital disorder. Using Mexican birth registers that report over 18 million birth during the years 2008 to 2021 and linking them to temperature conditions based on the residence of mothers, we estimate the causal effect of exposure to ambient temperature in utero on the likelihood of congenital disorders with a restrictive fixed effects regression model that accounts for location and time-specific effects. Our results show that high temperatures considerably impact the health of newborns. A rise of one-degree Celsius of the average monthly maximum temperature during utero causes a 10% change in the rate of congenital disorders diagnosed at birth.

Our channel analysis reveals that particularly temperature increases in the first pregnancy trimester are harmful for the foetus. Moreover, we find that temperature impacts the likelihood of congenital disorders both directly and indirectly. We provide empirical evidence that among others increased perinatal ambient temperature exposure results in a higher likelihood of congenital disorders through a) a more severe exposure to air pollutants that cause respiratory and cardiovascular diseases, b) higher likelihood of infections and c) lack of necessary nutrients.

We test the robustness of our main result to the sensitivity of regression model specification as well as other confounders. The analysis reveals that our estimate is rather a lower bound given that a) some congenital disorders are diagnosed later in life and b) given the evidence for a selective mortality bias.

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Tables

Table 1: Descriptive statistics

	Mean	SD	Min.	Max.	Obs.
Congenital birth defect	0.90	9.47	0.00	100	18856257
Any birth condition	3.62	18.68	0.00	100	18856257
Birth condition originating in perinatal phase	2.72	16.27	0.00	100	18856257
Apgar index	8.88	0.83	0.00	10	18708239
Silverman score	0.23	0.99	0.00	10	18634040
Height at birth (cm)	49.88	2.70	7.00	84	18467878
Birth weight (g)	3146.46	468.00	22.00	8700	17882658
Female	0.49	0.50	0.00	1	18856257
Week of pregnancy	38.73	1.72	22.00	49	18856257
Age of mother	25.50	6.31	13.00	62	18856257
No educational degree	0.07	0.25	0.00	1	18856257
Primary degree	0.05	0.23	0.00	1	18856257
Secondary degree	0.39	0.49	0.00	1	18856257
Tertiary degree and higher	0.37	0.48	0.00	1	18856257
Indigenous	0.07	0.25	0.00	1	10126568
Indigenous based on language	0.05	0.22	0.00	1	10112386
No. of dead children born	0.17	0.48	0.00	25	18733814
No. of children born alive	2.05	1.21	0.00	25	18838965
Mother has health insurance	0.89	0.32	0.00	1	18856257
Received prenatal care	0.98	0.15	0.00	1	18752604
Urban	0.82	0.39	0.00	1	18856257
IHS(population)	7.78	1.82	0.00	12	18856257
IHS(nightlight)	4.21	0.95	0.00	5	18856257
Suitability of zika infection (index)	0.12	0.24	0.00	1	16800143
Avg. max temperature in utero (°C)	31.43	4.09	11.53	48	18856257
Avg. monthly temperature in utero	22.15	6.01	7.56	47	18856257
Avg. max temp anomaly in utero	0.14	0.20	-5.04	6	18856257
Avg. precipitation in utero (cm)	8.39	5.64	0.00	131	18854054
No. of months with cyclone in utero	0.00	0.02	0.00	1	18856257
Avg. water mass change in utero	-2.93	7.92	-89.82	113	14264027
Avg. PM2.5 density in utero	19.68	6.15	1.70	89	18853593
No. of drought months in utero	0.58	1.07	0.00	9	18856257
Avg. max temperature$_{tri1}$	28.13	4.45	9.46	43	18856257
Avg. max temperature$_{tri2}$	28.35	4.37	10.01	43	18856257
Avg. max temperature$_{tri3}$	28.32	4.61	9.00	44	18609928
Avg. max temp 11-13 months before birth (°C)	28.22	4.47	9.98	43	18856252
Avg. max temp 1-3 months after birth (°C)	28.15	4.41	9.98	43	18723801

Notes:

Table 2: Temperature and congenital disorders

	Congenital disorder				
	(1)	(2)	(3)	(4)	(5)
Avg. max temp$_{utero}$	0.082***	0.081***	0.126***	0.136***	0.200***
	(0.008)	(0.008)	(0.009)	(0.011)	(0.010)
Population density		-0.049	-0.054	-0.054	-0.607*
		(0.098)	(0.099)	(0.098)	(0.342)
Female		-0.242***	-0.243***	-0.243***	-0.244***
		(0.010)	(0.010)	(0.010)	(0.010)
Age of mother		0.011***	0.011***	0.011***	0.011***
		(0.001)	(0.001)	(0.001)	(0.001)
No education		0.035**	0.035*	0.035*	0.035**
		(0.018)	(0.018)	(0.018)	(0.018)
Primary education		-0.012	-0.015	-0.015	-0.020
		(0.014)	(0.015)	(0.015)	(0.015)
Tertiary education		-0.030**	-0.030**	-0.030**	-0.035***
		(0.012)	(0.012)	(0.012)	(0.013)
Year FE	Yes	Yes	Yes		
Location FE	Yes	Yes			
Month FE	Yes	Yes			
Locality-month FE			Yes	Yes	Yes
Date FE				Yes	
Municipality-date FE					Yes
Observations	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257

Notes: The table reports OLS coefficient estimates and standard errors of the regression of any congenital disorder on the average maximum temperature in utero and further controls. Fixed effects are included in the regression as indicated in the table. Standard errors are clustered at the locality level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 3: Types of congenital disorders

	nerve	sense	circ	resp	mouth	digestion	genital	urinary	muscle	chromoson	other	alcohol
Avg. max tem_{utero}	0.032***	0.007***	0.011***	0.005***	0.017***	0.017***	0.022***	0.006***	0.064***	0.009***	0.008***	0.005***
	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)	(0.002)	(0.001)	(0.004)	(0.001)	(0.001)	(0.001)
Municipality-date FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257

The table reports OLS coefficient estimates and standard errors of temperature in utero on several types of congenital disorders. Types are classified using the sub-categories of the ICD-10 category "Q" and refer to congenital disorders. "Nerve" reports congenital disorders of the nervous system (Q00-Q09); " Sense" refers to congenital disorders of eye, ear, face, and neck (Q10-Q19); "Circ" refers to congenital malformations of the circulatory system (Q20-Q29); "resp" captures congenital disorders of the respiratory system (Q30-34); mouth refers to congenital disorders associated with the mouth (Q35-37); "digestion" refers to congenital disorder of the digestive system (Q38-Q45); "genital" captures congenital malformations of the genital organs (Q50-Q56), "urinary" of the urinary system (Q60-Q63); "muscle" of the muskulosceleta system (Q65-Q79), "chromoson" refers to chromosomal abnormalities not elsewhere classified (Q90-Q99), "other" refers to other congenital disorders (Q80-88), and "alcohol" refers to the diagnosis of fetal alcohol syndrome (Q86). Standard errors clustered at the locality level. * p <0.1, ** p <0.05, *** p <0.01.

Mechanisms

Table 4: Temperature per trimesters and congenital disorders

	Congenital disorder				
	(1)	(2)	(3)	(4)	(5)
Avg. max temp 11-13 months before birth					-0.001
					(0.007)
Avg. max temp in 1st trimester	0.013***			0.010***	0.012***
	(0.003)			(0.003)	(0.003)
Avg. max temp in 2nd trimester		0.002		0.003	0.005
		(0.003)		(0.003)	(0.003)
Avg. max temp in 3d trimester			-0.000	0.000	0.002
			(0.004)	(0.004)	(0.005)
Avg. max temp 1-3 months after birth					-0.004
					(0.007)
Municipality-date FE	Yes	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,607,578	18,607,578	18,475,144

Notes: The table reports OLS coefficient estimates and standard errors of regressing the indicator variable identifying congenital disorders on the average maximum monthly temperature in the pregnancy trimesters. Fixed effects as indicated in the table. Standard errors are clustered at the locality level. Mean of the dependent variable is 0.001. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 5: Heterogeneous effects by macro conditions

	Congenital disorder				
	(1)	(2)	(3)	(4)	(5)
Avg. max temp$_{utero}$	0.194***	0.196***	0.219***	0.182***	0.107***
	(0.009)	(0.009)	(0.012)	(0.009)	(0.014)
Drought$_{utero}$	-0.199***	-0.040			
	(0.017)	(0.050)			
Avg. max. temp$_{utero}$ $\times$ Drought$_{utero}$		-0.005***			
		(0.002)			
Avg. max. temp$_{utero}$ $\times$ Zika suitability			-0.031		
			(0.033)		
PM25$_{utero}$				0.087***	-0.066**
				(0.006)	(0.030)
Precipitation$_{utero}$				0.027***	0.025***
				(0.004)	(0.004)
Avg. max. temp$_{utero}$ $\times$ PM25$_{utero}$					0.005***
					(0.001)
Municipality-date FE	Yes	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Municipality FE					
Date FE					
Observations	18,856,257	18,856,257	16,798,997	18,851,150	18,851,150

Notes: The table reports OLS coefficient estimates and corresponding standard errors of congenital disorders on temperature in utero and interactions with locality characteristics. $Droughts_{utero}$ gives the number of drought months in utero. A drought months is defined by a SPEI index value below -1. Water loss is an indicator variable that identifies a negative water mass change during the period of in utero. $PM2.5_{utero}$ gives the average particular matter density of size 2.5 μm during utero, and zika suit is an indicator ranging from 0 to 1 that captures the climatic suitability of Aedes mosquitos that transmit the zika virus. Domestic violence are administrative data of reported cases. The sample is reduced to the years 2015-2022. Fixed effects as indicated in the table. Standard errors are clustered at the locality level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Congenital disorders and mothers' and child illness and birth conditions

	Mother malnutrition	Mother infect	Mother resp. circ.	Child malnutrition	Child infection	Child resp. circ.
	(1)	(2)	(3)	(4)	(5)	(6)
Avg. max temp$_{utero}$	0.001*	0.000	0.001***	0.007***	0.024***	0.479***
	(0.000)	(0.000)	(0.000)	(0.002)	(0.003)	(0.036)
	Congenital disorder					
Explanatory factor	0.000	-0.004	-0.003	0.005*	0.003**	0.002**
	(0.006)	(0.003)	(0.007)	(0.003)	(0.001)	(0.001)
Municipality-date FE	Yes	Yes	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257	18,856,257

Notes: The table reports OLS coefficient estimates and standard errors of temperature in utero on several types of congenital disorders and the regression of those types on congenital disorder. Types are classified using the sub-categories of the ICD-10 category "Q". "Mother infection" refers to infectious diseases of the mother during pregnancy (P00.2), "Mother resp. circ." captures respiratory and cardiovascular diseases of the mother (P00.3); "Mother malnutrition" refers to malnutrition of the mother that harms the foetus (P00.4). Additionally, we consider diagnosis of the foetus related to the perinatal phase: "Child infection" captures diagnosis of foetus infections (P35-P39); "Child resp. circ." refers to respiratory and cardiovascular conditions originating in the perinatal phase (P20-P29); "Child malnutrition" refers to diagnosis that fall into category "P052". Standard errors clustered at the locality level. Fixed effects and controls as stated in the table. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Appendix A Additional figures and tables

Robustness checks

Table A.1: Temperature and other birth outcomes

	Any birth condition	Birth cond. perinatal	APGAR	Silverman	Birth weight	Gestational age
	(1)	(2)	(3)	(4)	(5)	(6)
Avg. max temperature$_{utero}$	1.955***	1.780***	-0.071***	0.091***	-180.843***	-1.131***
	(0.132)	(0.127)	(0.003)	(0.005)	(7.833)	(0.048)
Municipalitly-date FE	Yes	Yes	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,705,340	18,628,726	17,868,830	18,856,257

Notes: Table reports coefficient estimates and standard errors of the main regression model using alternative indicators of newborn health. Any birth condition refers to any diagnosis that falls into ICD-10 category "Q" or "P"; "Birth condition perinatal" indicates that the newborn has been diagnosed with a birth condition that originates in the perinatal phase. Standard errors clustered at the locality level. * p <0.1, ** p <0.05, *** p <0.01.

Table A.2: Robustness check: Variation of the level of cluster for the standard errors

Dependent: Congenital disorder	Locality and year SE	Municipality SE	State SE
	(1)	(2)	(3)
Avg. max temp$_{utero}$	0.200***	0.200***	0.200***
	(0.027)	(0.012)	(0.026)
Municipality-date FE	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,856,257

Notes: The table reports OLS coefficient estimates and standard errors of the main regression specification with alternative specifications of clustered standard errors. Column 1 uses standard errors that are clustered at the locality and year level, column 2 at the municipality level and column 3 at the state level. * p <0.1, ** p <0.05, *** p <0.01.

Table A.3: Robustness check: Controlling for additional socioeconomic characteristics

	Congenital disorder				
	(1)	(2)	(3)	(4)	(5)
Avg. max temperature$_{utero}$	0.013***	0.227***	0.203***	0.154***	0.154***
	(0.005)	(0.012)	(0.010)	(0.007)	(0.009)
Gestational age at birth	-0.165***				
	(0.004)				
Municipality-date FE					
Locality-month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Locality-specific time trend			Yes		
Birth facility FE				Yes	
Weather controls					Yes
Observations	18,856,257	9,760,205	18,856,257	17,482,270	18,856,257

Notes: The tables reports OLS coefficient estimates and standard errors of the main regression specification including additonal controls and fixed effects as indicated in the table. In column 4, we implement an instrumental variable approach using average maximum temperature of the 9 months before birth as an instrument for average maximum temperature during in utero. Mother controls include marital status, no. of children alive and dead, no. of pregnancies, type of residence and residence area. * p <0.1, ** p <0.05, *** p <0.01.

Table A.4: Robustness check: Alternative measurements of temperature

	Congenital disorder			
	(1)	(2)	(3)	(4)
Avg. max temp. anomaly$_{utero}$	0.073***			
	(0.025)			
Average temp$_{utero}$		0.423***		
		(0.026)		
Max monthly temp$_{utero}$			-0.096***	
			(0.007)	
Min monthly temp$_{utero}$				-0.052
				(0.082)
Municipality-date FE	Yes	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	18,856,257	18,856,257	18,856,257	18,856,257

Notes: The table reports OLS coefficient estimates and standard errors of alternative temperature measures on congenital disorders. The main regression specification is used. Standard errors are clustered at the locality level. Avg. max. temp. anomaly are standardized anomalies of the average maximum monthly temperature in utero; average temperature refers to the average temperature over the period in utero and max. monthly temperature in utero gives the maximum value of temperature during utero. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.5: Robustness check: COVID-19 period

	Congenital disorder	
	(1)	(2)
Avg. max temp.$_{utero}$	0.415***	0.280***
	(0.026)	(0.014)
Municipality-date FE	Yes	Yes
Locality-month FE	Yes	Yes
Controls	Yes	Yes
Observations	3,042,644	13,871,854

Notes: The table reports OLS coefficient estimates and standard errors of the main regression. Sample is restricted to the years 2020 and 2021 in column 1 and to the years 2008 - 2019 in column 9. Standard errors are clustered at the locality level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6: Robustness check: Foetal death and temperature in utero

	Foetal death	Stillbirth	Miscarriage	Abortion	Foetal death
	(1)	(2)	(3)	(4)	(5)
Avg. max temp$_{utero}$	0.129***	0.008	0.069***	0.001***	0.061***
	(0.050)	(0.006)	(0.024)	(0.000)	(0.020)
Congenital disorder					-6.403*
					(3.825)
Avg. max temp$_{utero}$ $\times$ congenital disorder					0.421***
					(0.153)
Municipality-Date FE	Yes	Yes	Yes	Yes	Yes
Location-months FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	14,731,657	14,731,657	14,726,046	14,726,046	14,658,546

Notes: The table reports OLS coefficient estimates and standard errors of average maximum temperature on foetal death and sub-categories. Foetal death refers is an indicator variable identifying any registered death before or at birth. Stillbirth refers to deaths after gestational age of 28th week, whereas miscarriage captures foetal death beforehand. Abortion refers to a provocated foetal death. The sample includes all registered birth and foetal deaths. Sample is restricted to the years 2012 - 2021 for which information on foetal death is available. Standard errors are clustered at the locality level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7: Other climate shocks and congenital disorders

	Congenital disorder		
	(1)	(2)	(3)
Avg. monthly precipitation$_{utero}$	0.026***		0.017***
	(0.003)		(0.004)
Cyclone$_{utero}$		-0.024	-0.107
		(0.472)	(0.481)
Avg. max temperature$_{utero}$			0.199***
			(0.010)
Municipality-date FE	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	18,853,870	18,856,257	18,853,870

Notes: Fixed effects as indicated in the table. Standard errors are clustered at the locality level. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table A.8: Heterogeneous effects by climate zones

	Congenital disorder		
	(1)	(2)	(3)
Avg. max temp$_{utero}$	0.200***	0.096	0.045
	(0.010)	(0.069)	(0.072)
× Cold Desert Climate		0.000	
		(.)	
× Cold Semi-Arid Climate		0.121	
		(0.075)	
× Cold Subtropical Highland / Subpolar Oceanic		-0.522	
		(0.536)	
× Hot Desert Climate		0.126*	
		(0.075)	
× Hot Semi-Arid Climate		0.132*	
		(0.073)	
× Hot-Summer Mediterranean Climate o		0.058	
		(0.193)	
× Humid Subtropical Climate		-0.012	
		(0.074)	
× Subpolar Oceanic Climate		0.039	
		(0.102)	
× Subtropical Highland Climate or Temperate Oceanic Climate		0.108	
		(0.073)	
× Temperate Oceanic Climate		0.029	
		(0.077)	
× Tropical Monsoon		-0.010	
		(0.071)	
× Tropical Rainforest		0.002	
		(0.076)	
× Tropical Savanna (Wet and Dry Climate)		0.200***	
		(0.075)	
× Tundra Climate		-0.054	
		(0.084)	
× Warm Oceanic Climate/Humid Subtropical Climate		0.140*	
		(0.074)	
× Warm-Summer Mediterranean Climate		0.028	
		(0.122)	
× Mediterranean climate			0.085
			(0.114)
× Subtropical climate			0.157**
			(0.074)
× Tropical climate			0.140*
			(0.073)
× Cold desert			0.051
			(0.100)
× Cold semi-arid climate			0.172**
			(0.078)
× Hot desert			0.177**
			(0.078)
× Hot semi-arid climate			0.182**
			(0.076)
× Oceanic climate			0.083
			(0.079)
× Tundra climate			-0.003
			(0.087)
Municipality-date FE	Yes	Yes	Yes
Locality-month FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Observations	18,856,257	18,849,756	18,856,257

Notes: The table reports OLS coefficient estimates and standard errors of the main regression specification and heterogeneous effects with dummies indicating diverse climatic zones. Fixed effects as indicated in the table. * p <0.1, ** p <0.05, *** p <0.01.

Table A.9: Variable definition and data source

Dependent and main variables	
Avg. max. temp$_{utero}$	The variable gives the average value of the monthly maximum temperature at the locality of mothers residence during the phase the newborn is in utero. Source: WorldClim database
Congenital disorder	Indicator variable that takes 100 if the newborn has been diagnosed with a congenital disorder and 0 otherwise. Congenital disorder are defined as any diagnosis of the categories "Q" of the ICD-10 classification. Source: Birth register
Types of congenital disorders	The variables are indicator variables for specific types of congenital disorders based on the ICD-10 sub-categories of category Q. Source: Birth register
Control variables	
Female	Dummy that is one if the newborn is female. Source: Birth register
Age of mother	Age of the mother in years Source: Birth register
No education	Indicator variable that is one if the mother has no educational degree Source: Birth register
Primary education	Indicator variable that is one if the mother has primary education completed. Source: Birth register
Tertiary education	Indicator variable that is one if the mother has tertiary education completed. Source: Birth register
Population density	Inverse hyperbolic sine of population density. Source: Gridded Population of the World dataset (version 4) from SEDAC
Mechanisms and others	
Avg. max temp 1st,2nd, 3d trimester	Gives the average monthly maximum temperature at the locality of mothers' residence during the respective time period, when the mother is in her 1st, 2nd or 3d pregnancy trimester Source: WorldClim database, birth register
Mother malnutrition	Indicator variable that is one if the mother is diagnosed to be malnourished during pregnancy or at birth that potentially harms the fetus. Definition based on the ICD-10 classification code P00.4 Source: Birth register
Mother infection	Indicator variable that is one if the mother was diagnosed with an infection. Birth register reports the ICD-10 code P00.2 Source: Birth register
Mother resp. circ.	Indicator variable that is one if the mother was diagnosed with a respiratory or circulatory disease that harms the fetus as defined in ICD-10 code P00.3 Source: Birth register
Child malnutrition	Indicator variable that is one if the newborn was diagnosed with malnutrition as defined in ICD-10 code P052. Source: Birth register
Child infection	Indicator variable that is one if the newborn was diagnosed with an infection as defined in ICD-10 codes P35 - P39. Source: Birth register
Child resp. circ.	Indicator variable that is one if the newborn was diagnosed with a respiratory and circulatory disease as defined in ICD-10 codes P20-P29. Source: Birth register
Drought$_{utero}$	The variable gives the number of drought months during period the unborn is in utero. Drought is defined with a SPEI index below -1. Source: SPEIbase, Vicente-Serrano et al. (2010)
Zika suitability	Index that captures the geographical suitability of a location for mosquitos that transmit zika and other vector-born diseases Source: Messina et al. (2016)

$PM25_{utero}$	The variable gives the average particular matter density 2.5 of the locality of mothers' residence over the phase in utero. Source: Van Donkelaar et al. (2021)
$Precipitation_{utero}$	The variable gives the average monthly precipitation of the locality of mothers' residence during the period the newborn is in utero. Source: WorldClim database
	Robustness checks
Any birth condition	Indicator variable that is 100 if any diagnosis that falls into the categories "Q" and "P" of the ICD-10 is reported in the birth register. Source: Birth register
Birth cond. perinatal	Indicator variable that is 100 if any birth condition is diagnosed (category "P". Source: Birth register
APGAR	Index ranging from 1 to 10 that describes the general health condition directly after birth. It is a standardized assessment. Source: Birth register
Silverman	Index to assess respiratory distress of newborns ranging from 0 no distress to 10 severe distress. Source: Birth register
Birth weight (g)	The variable gives the weight of the newborn at birth in gramm. Source: Birth register
Gestational age	The variable gives the number of pregnancy weeks at birth. Source: Birth register
Average $temp_{utero}$	The variable gives the average monthly temperature in degree Kelvin. Values are averages over the geographical area of the locality of the mothers residence and over the period in utero. Source: GHCN CAMS Gridded 2m temperature dataset
Max monthly $temp_{utero}$	The variable gives the maximum value of the monthly temperature of the mothers residence locality during the period the newborn is in utero. Source: WorldClim database
Min monthly $temp_{utero}$	The variable gives the minimum value of the monthly temperature of the mothers residence locality during the period the newborn is in utero. Source: WorldClim database
Foetal death	Indicator variable that is 100 if the reported fetus is born dead. Source: Foetal death register
Stillbirth	Indicator variable that is 100 if the reported fetus has died in the womb after the gestational age of 20. Source: Foetal death register
Abortion	Indicator variable that is 100 if the foetal death register reports that the fetus was aborted.
Avg. monthly $precipitation_{utero}$	Gives the average monthly amount of precipitaiton at the locality of the mothers residence during the newborn is in utero. Source: WorldClim Database
$Cyclone_{utero}$	Indicator variable that is one if the locality of the mothers residence was exposed to a cyclone during the newborn was in utero. Source: Pérez-Alarcón et al. (2022)