What to Expect When It Gets Hotter: The Impacts of Prenatal Exposure to Extreme Heat on Maternal Health*

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December 29, 2019

Abstract

We use temperature variation within narrowly-defined geographic and demographic cells to show that exposure to extreme heat during the first trimester increases the risk of maternal hospitalization during pregnancy. We find that this effect is driven by women residing in historically cooler rather than hotter counties, suggesting that adaptation plays a role in mitigating the health impacts of weather shocks. We also find that the heat-induced deterioration in maternal pregnancy health is larger for black than for white mothers, suggesting that projected increases in extreme heat over the next century may further exacerbate the black-white maternal health gap.

*We thank Alan Barreca, Ciaran Phibbs, as well as participants at the American Society of Health Economists 2019 Annual Meeting. We use the State Inpatient Databases from the Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality, provided by the Arizona Department of Health Services, the New York State Department of Health, and the Washington State Department of Health. We thank Jean Roth at the National Bureau of Economic Research for assistance with the data.

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1 Introduction

The United States has experienced a deterioration in maternal pregnancy- and childbirth-related health over the last several decades (Kassebaum et al., 2016), and the burden of health complications is not borne equally by all mothers. For instance, black women are 3.3 times more likely to die from a pregnancy-related cause than their white counterparts (Petersen et al., 2019). Most discussions about maternal health have focused on the role of the health care system, but we know much less about other—*environmental*—determinants of maternal health and the racial disparities in it.[1] This paper studies the impact of an environmental factor that is becoming increasingly relevant due to the growing consensus that climate change is contributing to a gradual warming of the earth (NASA, 2013): exposure to extreme heat.

Specifically, we estimate the effect of exposure to extreme temperature during pregnancy on maternal health, using the universe of administrative inpatient discharge records from three U.S. states: Arizona, New York, and Washington. In addition to providing us with rich data on maternal health during pregnancy, at childbirth, and in the postpartum period, these states vary in their historical weather patterns, allowing us to examine the role of adaptation in mitigating the potential health impacts of temperature shocks. As individuals in historically hotter places may adapt to high temperatures through the adoption of mitigating technologies such as air conditioning and behavioral responses such as spending more time indoors (Graff Zivin and Neidell, 2014), the health costs of extreme heat may be disproportionately borne by individuals residing in historically cooler areas. Consistent with this notion, several studies have documented such geographic heterogeneity in the relationship between temperature and elderly mortality (Deschênes and Greenstone, 2011; Barreca et al., 2015; 2016; Carleton et al., 2018).

To identify the causal effects of extreme temperature, we leverage arguably exogenous temporal variation within narrowly-defined geographic and demographic cells. Our preferred models control for a full set of birth-county×birth-month×race fixed effects, birth-state×birth-year fixed effects, and a quadratic time trend interacted with birth-county×birth-month indicators. As a concrete example, consider a black woman giving birth in Queens county, New York, in August 2010 and a black woman giving birth in the same county in August 2011. Our empirical strategy leverages the difference between these women in the temperature deviation during their pregnancies from the Queens-specific quadratic trend among all August births, while controlling for the average difference in pregnancy temperature exposure between all New York state births in 2010 and 2011.

We find that exposure to extreme heat has adverse impacts on women's health during pregnancy, and that this health cost is not distributed equally across mothers. We estimate that an additional

[1]For examples of these discussions in the press, see: `https://www.vox.com/science-and-health/2017/6/26/15872734/what-no-one-tells-new-moms-about-what-happens-after-childbirth`
`https://www.npr.org/2017/05/12/528098789/u-s-has-the-worst-rate-of-maternal-deaths-in-the-developed-world`
`https://www.npr.org/2017/05/12/527806002/focus-on-infants-during-childbirth-leaves-u-s-moms-in-danger`.

day during the first trimester with an average temperature above 90°F increases the likelihood that a woman is hospitalized during pregnancy by 0.03 percentage points, which represents a 0.8 percent effect at the sample mean. This effect is driven by hospitalizations for emergency or urgent reasons, suggesting that it represents a deterioration in underlying maternal health rather than a change in women's ability to access health care.

When we examine the timing of prenatal hospitalization, we find that extreme heat in the first trimester has both immediate and latent impacts, as measured by heightened risks of hospitalization both in the first and third trimesters. Analysis of diagnosis codes further indicates that this effect is driven by hospitalizations due to a variety of pregnancy complications, including hemorrhage in early pregnancy, antepartum hemorrhage, excessive vomiting, early or threatened labor, and infectious and parasitic conditions.

We next document that the aggregate effect on pregnancy hospitalizations is entirely driven by women residing in historically cooler counties with below-median daily mean temperatures. For these women, we observe a 0.1 percentage point increase in the likelihood of an emergency or urgent hospitalization during pregnancy (4.4 percent at the sample mean). This pattern suggests that because historically cooler places are likely less adapted to extreme heat than historically hotter areas, mothers residing in cooler places bear a disproportionate cost to their pregnancy health.[2]

We also show that the effects on prenatal hospitalizations are much more pronounced for black than for white mothers. For black women, an additional day during the first trimester with average temperature above 90°F increases the likelihood of first and third trimester hospitalization by 0.04 and 0.08 percentage points, respectively, representing 3.2 and 2.3 percent effect sizes at the sample means. By contrast, for white women, the corresponding coefficients are much smaller and statistically insignificant.

Lastly, we estimate that an additional day with above-90-degree heat in the first trimester raises maternal length of hospital stay at the time of childbirth by 0.006 days (0.2 percent). Similar to the findings on prenatal hospitalizations, the increase in length of stay at childbirth is greater in cooler than in hotter counties. However, we find that the effect on length of hospital stay at childbirth is driven entirely by white rather than black mothers. We further show that, for white mothers, prenatal heat exposure reduces the likelihood of postpartum hospital readmission. These results may reflect racial disparities in women's ability to access health care resources when compensating for adverse health shocks—white mothers may be more able to compensate for prenatal health shocks by staying longer at the hospital when giving birth, thus averting future hospital readmissions in the postpartum period.

[2]We have also considered modeling differences in effects based on air conditioning (AC) adoption rates. However, AC data, available from the Residential Energy Consumption Survey (RECS), only exist in three years over our sample period (2001, 2005, and 2009) and are aggregated to the Census region level. Given that we only use inpatient data from three states in our analysis, we do not have sufficient variation to estimate heterogeneous effects based on AC adoption rates.

Our study contributes to a burgeoning literature, which has identified adverse short-term impacts of extreme temperature on several outcomes, including elderly mortality (Deschênes and Moretti, 2009; Deschênes and Greenstone, 2011), population-level emergency department visits and hospitalizations (Green et al., 2010; White, 2017), and cognitive performance (Cho, 2017; Garg et al., 2018; Goodman et al., 2018; Graff Zivin, Hsiang, and Neidell, 2018). Multiple studies have further documented negative effects of *in utero* heat exposure on birth outcomes—including birth weight, gestation length, and the probability of stillbirth (e.g., Deschênes et al., 2009; Dadvand et al., 2011; Schifano et al., 2016; Auger et al., 2017; Ha et al., 2017a,b; Kuehn and McCormick, 2017; Barreca and Schaller, 2019)—highlighting the sensitivity of the prenatal period to extreme heat.[3] To the best of our knowledge, only one prior study has analyzed the relationship between prenatal heat exposure and *maternal* health, using information on mothers' pregnancy risk factors and labor/delivery complications reported on birth certificates (Cil and Cameron, 2017). However, as multiple validation studies indicate that maternal pregnancy risk factors, obstetric procedures, and complications of labor and delivery are heavily under-reported on birth certificates (Parrish et al., 1993; Buescher et al., 1993; Piper et al, 1993; Dobie et al., 1998; Reichman and Hade, 2001; DiGiuseppe et al., 2002; Roohan et al., 2003; Lydon-Rochelle et al., 2005), and the degree of under-reporting varies with maternal demographic characteristics and birth outcomes (Reichman and Schwartz-Soicher, 2007), analyses of maternal health based on birth records data are likely subject to bias from non-random measurement error. We address this issue by instead using inpatient discharge records that provide more accurate information on maternal health at each hospital visit, and allow us to examine diagnoses and the timing of prenatal health insults.

Our findings suggest that, in the absence of mitigating interventions, the projected increase in exposure to extreme heat over the next century may contribute to further worsening of maternal health. This deterioration in maternal health is likely to be greater in historically cooler areas, which have had less scope for adaptive responses. Moreover, since black women are both more likely to be exposed to extreme heat (due to differences in residence locations and in access to mitigating technologies such as air conditioning, see O'Neill et al., 2005; Gronlund, 2014) and experience larger adverse impacts of heat exposure on pregnancy-related health, our estimates imply that climate change could further exacerbate racial disparities in maternal health.

2 Data

Our data comes from the State Inpatient Databases (SID) from the Healthcare Cost and Utilization Project (HCUP). The SID are state-specific files that contain the universe of inpatient records from participating states. Since the availability of variables varies across states and years,

[3]Fetuses and infants are sensitive to extreme heat due to their developing thermoregulatory and sympathetic nervous systems; see Young (2002); Knobel and Holditch-Davis (2007); Xu et al. (2012). Two recent studies have also shown that early life heat exposure has lasting negative effects on long-term cognitive ability (Hu and Li, 2019) and adult earnings (Isen, Rossin-Slater, and Walker, 2017).

we focus on three states that contain all three of the key variables necessary for our analysis: (1) patient county of residence, (2) admission month, and (3) encrypted person identifiers to track patients over time in the same state. Our resulting sample consists of 2.72 million inpatient records of 2.24 million mothers from Arizona (2003 to 2007), New York (2003 to 2013), and Washington (2003 to 2013).

We use diagnosis codes to identify inpatient visits associated with childbirth.[4] Since less than two percent of all births occur outside of hospitals during our analysis time period, we observe the near-universe of all mothers giving birth in our analysis states.[5] We also identify maternal hospitalizations during pregnancy (i.e., those occurring in the 9 months before delivery) and postpartum hospital re-admissions using patient identifiers.

To measure temperature exposure, we obtain data from the National Oceanic and Atmospheric Administration (NOAA). We have information on the mean, maximum, and minimum daily ground temperature and precipitation levels for every county and year-month during our analysis time frame. We then merge these data to the maternal inpatient records, using information on the mother's county of residence at the time of delivery. We use the mother's year and month of delivery to assign exposure to temperature during pregnancy by assuming a 40-week pregnancy duration for all observations.[6]

Distribution of Temperature Exposure. Figure 1 shows the distribution of daily average temperature in Arizona, New York, and Washington during our sample period. We compute the average number of days per year falling into each of the 10 temperature bins expressed in Fahrenheit degrees. When we measure temperature exposure during pregnancy for each woman, we find that five percent of observations in our data have non-zero exposure to above-90-degree heat.

Summary Statistics. Panel A of Table 1 shows the average number of days per year with mean temperature falling in different bins in each of our three analysis states. Arizona on average experiences 17 days per year with mean temperatures above 90°F. By contrast, New York and Washington have substantially fewer days with above 90°F mean temperatures. These differences underscore the importance of examining heterogeneity across local areas with different historical climates.

Panel B of Table 1 provides means of maternal health outcomes that we analyze (expressed as

[4] We use DRG 370-375 or 765-768 & 774-775, depending on the version of DRG.

[5] See `https://www.cdc.gov/nchs/products/databriefs/db144.htm` for statistics on out-of-hospital births in the U.S.

[6] We have information on gestational age for only about 10 percent of our HCUP sample, which comes from diagnosis codes. It appears that gestational age is only recorded in cases where there are health complications, and we find that children with gestational age information have lower birth weight, longer length of stay, and higher likelihoods of readmission and death than those without gestational age information. Moreover, using actual pregnancy duration to assign exposure can be problematic due to the possible endogeneity of gestational age with respect to the *in utero* shock (Currie and Rossin-Slater, 2013).

rates per 100 mothers). Approximately four percent of women get hospitalized during pregnancy, with the most common diagnosis being a pregnancy-related complication. Overall, 0.5, 1.2, and 2.6 percent of women are hospitalized in the first, second, and third trimesters, respectively. There are some meaningful differences in the maternal health outcomes across the three states, highlighting an additional reason for including state×year fixed effects in all our regression models, which we describe in more detail next.

3 Empirical Strategy

A robust medical literature discusses the biological mechanisms through which extreme heat could be damaging to human health, and highlights that exposure to extreme temperature can be particularly risky for pregnant women. The underlying issue is that pregnant women are not able to regulate temperature as efficiently as non-pregnant individuals due to the physiologic changes they undergo during gestation (Schifano et al., 2016), which means that elevated body temperature during pregnancy can lead to various complications. Heat exposure can alter placental blood flow patterns, which can reduce the integrity of the placenta and increase the chance of abruption (He et al., 2018). Heat could further raise the likelihood of other serious pregnancy complications, including hypertension, preeclampsia, and prolonged premature rupture of membranes (Beltran et al., 2014, Yackerson et al., 2007). In addition, elevated temperature can increase the fetal heart rate and lead to uterine contractions (Vaha-Eskeli and Erkkola, 1991). All of these issues can translate into women needing to be hospitalized during pregnancy and experiencing complications at and even after childbirth.

The goal of this paper is to quantify the causal relationship between extreme heat and maternal health. A central challenge is that exposure to hot days is not randomly assigned. For instance, several studies have documented differences in the health and human capital outcomes of children born in different months of the year due to selection into conception based on parental characteristics and differential exposure to seasonal factors such as the influenza virus (Buckles and Hungerman, 2013; Currie and Schwandt, 2013). In addition, there is non-random sorting of families into hotter and colder regions of the country based on incomes, preferences, and other characteristics, suggesting that cross-sectional comparisons between mothers residing in different regions are unlikely to isolate the causal effects of temperature exposure from the influences of other factors.

To address this challenge, we follow the prior literature by leveraging temperature variation *within* narrowly defined geographic and demographic cells, and flexibly accounting for local outcome trends. We first collapse our data into cells defined by all possible combinations between the mother's county of residence at delivery, the year-month of childbirth, and race/ethnicity categories (White, Black, Hispanic, Asian American, and other). We then use the following regression model to estimate the effects of exposure to extreme temperature during pregnancy:

$$Y_{c,y,m,r} = \alpha + \sum_{t=1}^{3} \sum_{j=1,j\neq 7}^{10} \beta_{t,j} Temp_{c,y,m}^{t,j} + \sum_{t=1}^{3} f(Precip_{c,y,m}^{t}) + \theta_{c,m,r} + \eta_{y,s(c)} + \delta_{c,m} \times f(y) + \epsilon_{c,y,m,r} \quad (1)$$

$Y_{c,y,m,r}$ is an outcome for a mother residing in county c, giving birth in year y and month m, of race/ethnicity r, and we rescale the outcomes by multiplying by 100 (e.g., the number of mothers admitted to the hospital during pregnancy per 100 mothers). The variables $Temp_{c,y,m}^{t,j}$ represent the number of days in trimester t falling into each (j) of the 10 bins of temperature, ranging from less than 10°F to 90°F or more, as illustrated in Figure 1.[7] The bin representing temperatures in the $[60^oF,\ 70^oF)$ range is omitted as the reference group. Thus, the $\beta_{t,j}$ coefficients can be interpreted as estimates of the impact of an additional day in a given temperature range (j) relative to a day in the $[60^oF,\ 70^oF)$ range in trimester t. We are particularly interested in the coefficient $\beta_{t,10}$, which measures the effect of an additional above-90-degree day in each trimester t.

We control for indicators for the bottom and the top terciles of mean precipitation in each trimester, $f(Precip_{c,y,m}^{t})$. $\theta_{c,m,r}$ are fixed effects for every birth-county×birth-month×race cell. $\eta_{y,s(c)}$ are birth-state×birth-year fixed effects, which account for differential outcome trends across states, any state time-varying policies, and the fact that we observe states in different sets of years in the HCUP data. $\delta_{c,m} \times f(y)$ are county-by-calendar-month-specific trends (e.g., Queens-County-by-August-specific trends), which we model with a quadratic polynomial. To further account for differential population sorting based on temperature, we control for the average number of mothers per 100 residing in zip codes in different quartiles of the median income distribution. We weight all regressions by cell size.[8] Because weather is highly spatially correlated, we cluster our standard errors on the commuting zone level.[9]

Identifying Assumption. Our model identifies the effects of extreme heat exposure using year-to-year deviations in temperature from the county-month trend within each cell. Thus, our estimates of $\beta_{t,j}$ represent causal effects of pregnancy exposure to temperature under the assumption that the within-cell variation in temperature (conditional on birth-state×birth-year fixed effects and county×calendar-month trends) is uncorrelated with other determinants of maternal health. While this assumption is inherently untestable, we present some indirect tests to assess its plausibility.

First, we check whether there is any systematic relationship between temperature variation and population demographic characteristics. We collapse our data to the birth-county×birth-year×birth-month level, and estimate a version of equation (1), excluding controls for demographic

[7] In some specifications, we examine the effect of the number of days during the *entire period of pregnancy* falling into each temperature bin. That is, we replace $\sum_{t=1}^{3} \sum_{j=1,j\neq 7}^{10} \beta_{t,j} Temp_{c,y,m}^{t,j}$ in equation (1) with $\sum_{j=1,j\neq 7}^{10} \beta_j Temp_{c,y,m}^{j}$.

[8] Results based on collapsed data with cell size weights are identical to those using the underlying individual-level data, since we do not have any other individual-level controls.

[9] Our results are also robust to using an alternative adjustment of standard errors to reflect spatial dependence, as modeled by Conley (1999) and implemented by Hsiang (2010). Results available upon request.

characteristics and zip code income quartiles. For outcomes, we consider the number of mothers who are of different races/ethnicities and the numbers of mothers residing in zip codes in different quartiles of the median income distribution per 100.

Panel A of Appendix Table B.1 shows that our measure of extreme heat exposure is not correlated with the share of mothers who are white, black, or Asian. However, we do find a positive correlation between the number of mothers who are Hispanic and the number of days above 90 degrees during pregnancy, suggesting the importance of examining the effects of heat exposure within cells defined by different race/ethnicity subgroups.

In panel B of Appendix Table B.1, we find a marginally significant positive correlation between heat exposure during pregnancy and the share of mothers residing in zip codes in the third quartile of the median income distribution (but not with the shares of mothers in other quartiles). To address the concern that differential trends in exposure to heat are correlated with income, we include controls for zip code level income quartiles in all of our regression models.

Second, we test the robustness of our results to including hypothetical exposure to temperature assuming a mother gave birth two years prior to her actual delivery year-month. As we show below, we find that our main effects of exposure during pregnancy remain strong and significant even when we add two-year leads in temperature exposure.

4 Results

Table 2 and Figure 2(a)-(c) show that extreme heat exposure during the first trimester raises the likelihood that a mother is hospitalized during pregnancy. Specifically, we find that an additional day with above-90-degree heat during the first trimester raises the likelihood that a mother is hospitalized during pregnancy by 0.03 percentage points, which translates into a 0.8 percent effect size when evaluated at the sample mean. In column (2) of Table 2, we show that the increase in prenatal hospitalizations is driven entirely by visits for emergency or urgent reasons rather than scheduled appointments, which implies a deterioration in underlying maternal health as opposed to an improvement in health care access or utilization.

Next, we document that this average effect masks important heterogeneity by geography, timing of prenatal hospitalization, and maternal race.

Adaptation and Heterogeneity Across Historically Cooler and Hotter Counties. To examine the role of adaptation to extreme heat, we study differences between mothers residing in counties with below- and above-median daily mean temperatures averaged over the whole data period. Table 3 and Figure 2(d)-(i) show that the effect of extreme heat on maternal pregnancy hospitalization is driven entirely by women residing in *cooler* rather than hotter counties. Specifically, an additional day with above-90-degree temperature increases the likelihood of an emergency or urgent hospitalization during pregnancy by 0.11 percentage points (or 4.4 percent) for mothers in below-median counties. For mothers in above-median counties, the corresponding estimate is much smaller and statistically insignificant. Moreover, the difference in the effects on emergency/urgent hospitalizations between mothers in below-median and above-median counties is statistically significant (p-value: 0.009).

Timing of Hospitalization and Differences by Maternal Race. We investigate the timing of prenatal hospitalization in Table 4 and find that extreme heat exposure during the first trimester has both immediate and latent effects on prenatal hospitalization for mothers. Specifically, Panel B of Table 4 suggests that additional day with above-90-degree heat in the first trimester increases the likelihood of hospitalization in the first trimester by 0.01 percentage points and hospitalization in the third trimester by 0.02 percentage points.

Further, we find that the effect of exposure to extreme heat is much more pronounced for black than for white mothers. Table 5 shows that an additional day with above-90-degree heat increases first trimester hospitalizations by 0.04 percentage points (or 3.2 percent) and third trimester hospitalizations by 0.08 percentage points (2.3 percent) for black mothers. By contrast, we find no significant relationship between heat exposure and prenatal hospitalizations in any trimester for white mothers. The differences in effects are statistically significant (p-values are 0.014 and 0.077, respectively, for first and third trimester hospitalizations).[10]

Table 6 additionally shows that the increases in prenatal hospitalizations for black mothers are much larger in historically cooler counties for all three trimesters, highlighting once again the importance of adaptation. The differences in estimated coefficients are statistically significant with p-values close to zero.

On the whole, these results suggest that temperature exposure may be an important determinant of the widely documented black-white gap in maternal pregnancy-related health. In particular, as black mothers are on average exposed to more days with extreme heat than white mothers, our estimates imply that disparities in both the levels of extreme heat exposure and the magnitudes of the effects of exposure could help explain the racial gap in maternal health.

Diagnoses at Prenatal Hospitalization. In Figure 3, we present estimates and 95% confidence intervals from regression models that use indicators for various diagnoses codes associated with prenatal hospitalization as outcomes. We find that the increase in maternal hospitalizations in response to extreme heat during the first trimester is driven by hospitalizations due to pregnancy complications (ICD-9 codes 640-649). Specifically, these include hospitalizations due to hemorrhage in early pregnancy (ICD 640), antepartum hemorrhage (ICD 641), excessive vomiting (ICD 643),

[10]When we estimate our models separately for black and white mothers, we drop counties that have fewer than 50 black or white mothers. This sample restriction allows us to identify the effects for each subgroup by providing sufficient variation in temperature exposure conditional on a large set of fixed effects and trends.

early or threatened labor (ICD 644), and infectious and parasitic conditions (ICD 647). The effect sizes are larger in cooler than in hotter counties (Appendix Figure A.1) and for black than for white mothers (Appendix Figure A.2).

Maternal Health at and after Childbirth. Table 7 presents results for maternal length of hospital stay at the time of childbirth and readmission to the hospital after childbirth. Column (1) of Table 7 shows that an additional day with above-90-degree heat in the first trimester leads to a significant 0.006 day increase in the average length of stay (0.2 percent). Consistent with our results on prenatal hospitalizations, Table 8 shows that the increase in maternal length of stay is larger in historically cooler than in hotter counties, and the difference is marginally significant at the 10% level (p-value: 0.063). However, unlike the results for prenatal hospitalizations, Table 9 shows that the effect on maternal length of stay is larger for white than for black mothers (although the difference is not statistically significant at conventional levels). This pattern provides suggestive evidence that white mothers may be better able to compensate for adverse health effects by staying longer in the hospital at childbirth, reflecting racial disparities in women's ability to access health care resources.

We do not find any evidence that prenatal heat exposure raises the likelihood that a mother is readmitted to the hospital in the postpartum period. If anything, Table 7 shows that third trimester exposure to extreme heat reduces the risk of postpartum readmission on average. That said, the negative effect on postpartum readmission is driven entirely by white mothers (Table 9), while the coefficient for black mothers is positive (albeit insignificant). This pattern is again consistent with the idea that white mothers are able to compensate for prenatal health insults by staying longer at the hospital at the time of childbirth, which may avert the need for postpartum hospital readmission.

4.1 Additional Results

Placebo Temperature Exposure. To assess the possibility of bias due to differential trends in temperature exposure that are not controlled for in our main regression models, we test the robustness of our results to including two-year leads of temperature exposure. In particular, for every birth-county$\times$birth-year-month, we calculate the hypothetical exposure to temperature assuming that the child had been born two years prior. We use a two-year (instead of a one-year) lead to avoid confounding our estimates with possible effects of temperature on conception or fertility (Lam et al., 1994; Barreca et al., 2015; Wilde et al., 2017). Appendix Table B.2 shows that our main results are robust to the inclusion of this placebo control.

Controlling for Air Pollution. Lastly, since prior research shows that pollution is highly correlated with weather and affects population health (e.g., Ye et al., 2012), we have estimated our main models, controlling for the air quality index (AQI) as measured by the Environmental Protection

Agency. Since AQI is not available for all counties and year/months in our analysis sample, we have re-run our main specifications using a subsample of the data with non-missing AQI measures. We find that our estimates are similar and robust to including pollution controls (see Appendix Table B.3).

5 Conclusion

Scientists predict that global average temperatures will rise over the next 50 to 100 years, mostly due to a shift to the right in the upper tail of the temperature distribution. For instance, the number of days with mean temperature above 90°F in the average American county is forecasted to increase from about 1 to approximately 43 per year by 2070-2099 (Intergovernmental Panel on Climate Change, 2014). Understanding the health consequences of this increase in extreme heat is critical for informing discussions about the costs of climate change and the possible benefits of mitigating policies. Moreover, the growing literature that demonstrates heterogeneity in effects of heat across regions with different average temperatures and the importance of adaptation (Deschênes and Greenstone, 2011; Graff Zivin et al., 2014; Barreca et al., 2015; Barreca et al., 2016; Carleton et al., 2018) suggests that extreme *deviations* from typical weather may be particularly damaging.

In this paper, we contribute to the evidence on the costs of exposure to extreme heat by documenting maternal health impacts. We use the universe of inpatient discharge records from three states and find that exposure to extreme heat in the first trimester of pregnancy leads to an increase in women's emergency and urgent prenatal hospitalizations for pregnancy-related complications. We further find that prenatal exposure to extreme heat raises maternal length of hospital stay at the time of childbirth, which may in part represent a compensatory response for prenatal health insults. The fact that the adverse impacts on hospitalizations during pregnancy are larger in historically cooler than hotter counties highlights the importance of adaptation, and the larger effects for black than for white mothers suggest that climate change may exacerbate the already large racial gap in maternal health.

An important limitation of our study is that we are not able to measure health impacts not captured by the hospitalizations data. Just like measures of maternal health in birth records may miss effects on other aspects of health that we *do* measure, our estimates based on hospitalizations cannot capture potential impacts on more minor health insults that do not lead to hospital encounters. Future research may expand our understanding of these effects with better data on other health conditions.

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6 Figures

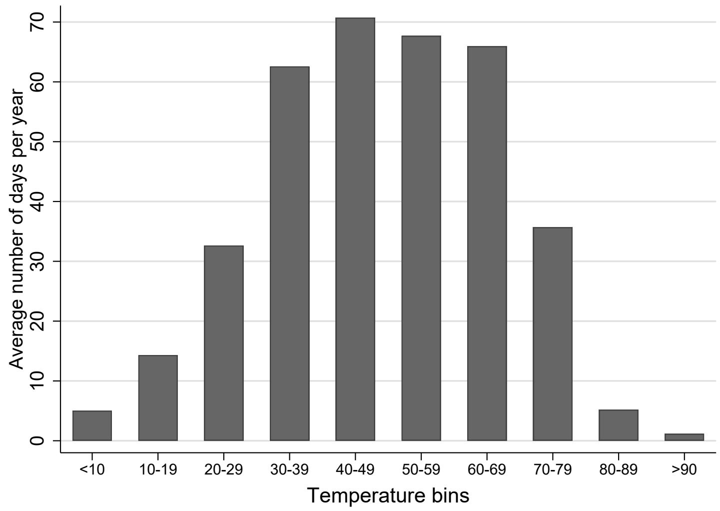
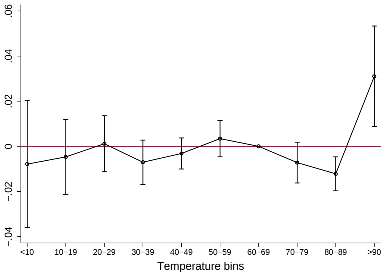
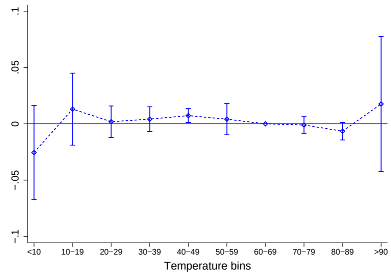


Figure 1: Distribution of Daily Average Temperature

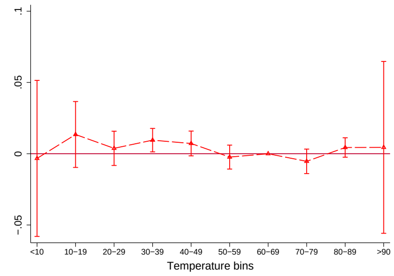
Sources: NOAA weather data.
Notes: This figure shows the overall average number of days per year falling into each of the temperature bins (°F) denoted on the $x-$axis. We compute daily average temperature by taking the average of minimum and maximum temperature in a given day measured at weather stations in Arizona 2003 to 2007, New York 2003 to 2013, and Washington 2003 to 2013.



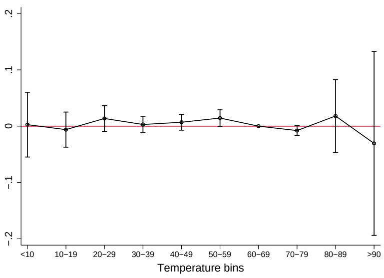
(a) Hospitalization during pregnancy, trimester 1 exposure



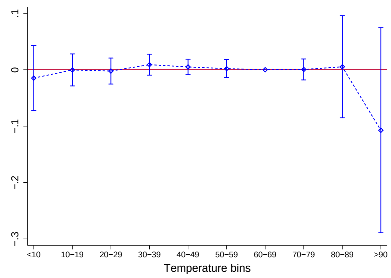
(b) Hospitalization during pregnancy, trimester 2 exposure



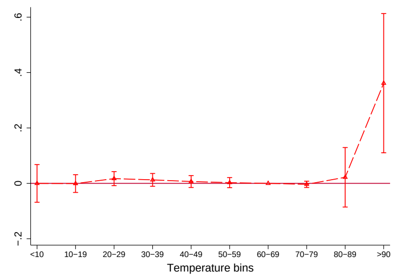
(c) Hospitalization during pregnancy, trimester 3 exposure



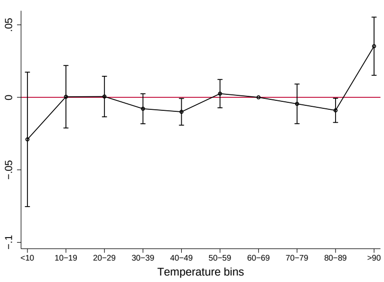
(d) Hospitalization during pregnancy, trimester 1 exposure, colder counties



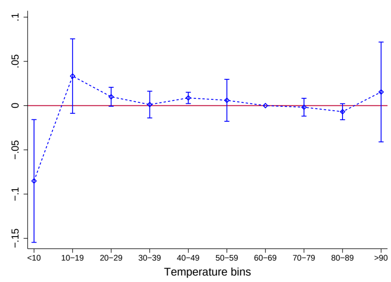
(e) Hospitalization during pregnancy, trimester 2 exposure, colder counties



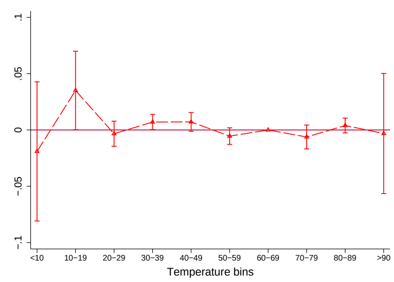
(f) Hospitalization during pregnancy, trimester 3 exposure, colder counties



(g) Hospitalization during pregnancy, trimester 1 exposure, hotter counties



(h) Hospitalization during pregnancy, trimester 2 exposure, hotter counties



(i) Hospitalization during pregnancy, trimester 3 exposure, hotter counties

Figure 2: **Effects of Temperature During Pregnancy on Any Prenatal Hospitalization**

Notes: The figures plot regression coefficients, $\beta_{t,j}$, from equation (1) for each temperature bin (j) for each trimester (t) with 95% confidence intervals. Outcome is rescaled by multiplying by 100. Standard errors are clustered by the commuting zone level. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used.

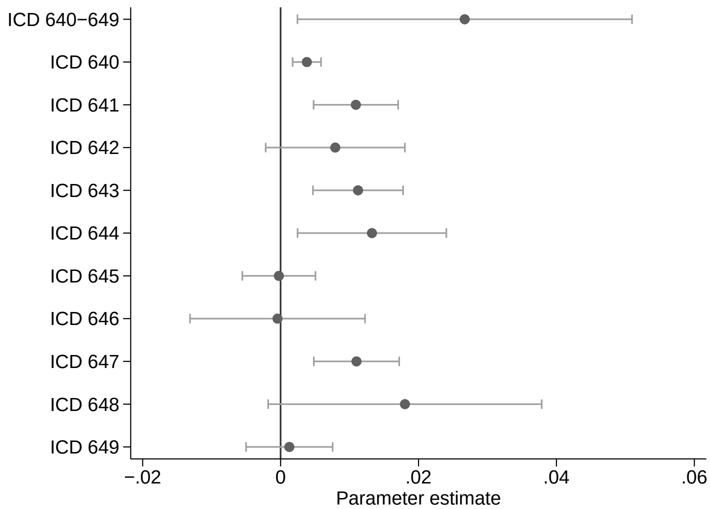


Figure 3: **Effects of Temperature Above 90 Degrees During the First Trimester on Diagnoses at Prenatal Hospitalization**

Notes: The figure plots separate regression coefficients, $\beta_{1,10}$, from equation (1) for temperature above 90-degrees for the first trimester with 95% confidence intervals for each diagnosis category. Outcomes are rescaled by multiplying by 100. ICD codes 640-649 indicate "complications mainly related to pregnancy." The definition of each sub-category is as follows. ICD 640: Hemorrhage in early pregnancy; ICD 641: Antepartum hemorrhage abruptio placentae and placenta previa; ICD 642: Hypertension complicating pregnancy childbirth and the puerperium; ICD 643: Excessive vomiting in pregnancy; ICD 644: Early or threatened labor; ICD 645: Late pregnancy; ICD 646: Other complications of pregnancy not elsewhere classified; ICD 647: Infectious and parasitic conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 648: Other current conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 649: Other conditions or status of the mother complicating pregnancy, childbirth, or the puerperium. Standard errors are clustered by the commuting zone level. All regressions control for mother's race/ethnicity$\times$birth-county$\times$birth-month fixed effects, zip code level income quartiles, birth-state$\times$birth-year fixed effect, a quadratic time at the county$\times$calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race$\times$birth-county$\times$birth-year-month level. Cell size weights are used.

7 Tables

Table 1: Summary Statistics

	(1) Combining three states	(2) Arizona	(3) New York	(4) Washington
A. Exposure to temperature extremes				
Annual days with mean temperature				
$[80^oF, 90^oF)$	5.206	38.907	3.324	1.612
$\geq 90^oF$	1.178	16.533	0.046	0.003
B. Maternal health outcomes (per 100 mothers)				
Any hospitalization during pregnancy	3.995	3.645	4.032	4.022
Emergency/urgent hospitalization during pregnancy	2.571	2.945	2.601	2.335
Diagnoses at prenatal hospitalization				
Pregnancy-related complication (ICD 640-649)	3.722	3.501	3.771	3.659
Hemorrhage in early pregnancy (ICD 640)	0.048	0.043	0.053	0.035
Antepartum hemorrhage (ICD 641)	0.284	0.270	0.294	0.257
Hypertension complications (ICD 642)	0.489	0.526	0.464	0.551
Excessive vomiting in pregnancy (ICD 643)	0.227	0.154	0.251	0.184
Early or threatened labor (ICD 644)	1.451	1.654	1.437	1.415
Late pregnancy (ICD 645)	0.239	0.105	0.255	0.243
Other complications (ICD 646)	0.869	0.961	0.855	0.876
Infectious and parasitic conditions (ICD 647)	0.158	0.112	0.151	0.197
Other current conditions (ICD 648)	2.031	1.778	2.129	1.837
Other conditions (ICD 649)	0.273	0.032	0.279	0.351
Timing of prenatal hospitalization				
Trimester 1	0.546	0.279	0.606	0.468
Trimester 2	1.212	0.880	1.261	1.195
Trimester 3	2.562	2.685	2.505	2.683
Maternal outcomes at and after childbirth				
Length of stay at childbirth	2.691	2.568	2.819	2.354
Any readmission	1.979	1.518	1.973	2.174
Readmission within 28 days	1.144	0.908	1.157	1.198
Observations	44349	3902	30347	10100

Sources: NOAA weather data and HCUP databases.

Notes: We use the data collapsed at the race×birth-county×birth-year-month level.

Table 2: Effects of Exposure to Above-90-Degree Heat on Prenatal Hospitalization

	(1)	(2)
	Prenatal hospitalization	
	Any	Emergency/urgent
Panel A. Exposure during pregnancy		
# Days above-90-degree during pregnancy	0.021	0.010
	(0.021)	(0.014)
Observations	44336	44336
Adjusted R^2	0.465	0.489
Mean	3.995	2.571
Panel B. Exposure separately by each trimester		
# Days above-90-degree in trimester 1	0.031***	0.032***
	(0.011)	(0.008)
# Days above-90-degree in trimester 2	0.018	0.001
	(0.029)	(0.024)
# Days above-90-degree in trimester 3	0.004	-0.007
	(0.030)	(0.023)
Observations	44342	44342
Adjusted R^2	0.466	0.490
Mean	3.995	2.571

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity$\times$birth-county$\times$birth-month fixed effects, zip code level income quartiles, birth-state$\times$birth-year fixed effect, a quadratic time at the county$\times$calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race$\times$birth-county$\times$birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 3: Effects of Exposure to Above-90-Degree Heat on Prenatal Hospitalization, by Historic Average Daily Mean Temperature

	(1)	(2)
	Prenatal hospitalization	
	Any	Emergency/urgent
Panel A. Below median counties		
# Days above-90-degree during pregnancy	0.073	0.109***
	(0.051)	(0.038)
Observations	21816	21816
Adjusted R^2	0.204	0.181
Mean	3.876	2.476
Panel B. Above median counties		
# Days above-90-degree during pregnancy	0.019	0.006
	(0.021)	(0.013)
Observations	22520	22520
Adjusted R^2	0.573	0.595
Mean	4.111	2.663
P-value from testing the difference	0.297	0.009

Source: HCUP SID merged with NOAA weather data

Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 4: Effects of Exposure to Above-90-Degree Heat on the Timing of Prenatal Hospitalization

	(1) Trimester 1	(2) Trimester 2	(3) Trimester 3
Panel A. Exposure during pregnancy			
# Days above-90-degree during pregnancy	0.001	0.007	0.017**
	(0.005)	(0.013)	(0.008)
Observations	44336	44336	44336
Adjusted R^2	0.225	0.327	0.324
Mean	0.546	1.212	2.562
Panel B. Exposure separately by each trimester			
# Days above-90-degree in trimester 1	0.009**	0.007	0.023**
	(0.005)	(0.008)	(0.009)
# Days above-90-degree in trimester 2	0.003	-0.001	0.015
	(0.010)	(0.021)	(0.011)
# Days above-90-degree in trimester 3	-0.006	0.004	0.009
	(0.007)	(0.019)	(0.007)
Observations	44342	44342	44342
Adjusted R^2	0.225	0.327	0.324
Mean	0.546	1.212	2.562

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 5: Effects of Exposure to Above-90-Degree Heat on the Timing of Prenatal Hospitalization, by Race

	(1) Trimester 1	(2) Trimester 2	(3) Trimester 3
Panel A. White mothers			
# Days above-90-degree during pregnancy	0.007	-0.004	0.030
	(0.007)	(0.010)	(0.018)
Observations	9835	9835	9835
Adjusted R^2	0.242	0.315	0.328
Mean	0.514	1.146	2.489
Panel B. Black mothers			
# Days above-90-degree during pregnancy	0.035***	0.055	0.084*
	(0.009)	(0.066)	(0.043)
Observations	4923	4923	4923
Adjusted R^2	0.162	0.369	0.273
Mean	1.093	2.246	3.637
P-value from testing the difference	0.014	0.288	0.077

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 6: Effects of Exposure to Above-90-Degree Heat on the Timing of Prenatal Hospitalization, by Historic Average Daily Mean Temperature & Race

	(1) Trimester 1	(2) Trimester 2	(3) Trimester 3
Panel A1. Below median counties, white mothers			
# Days above-90-degree during pregnancy	-0.062**	0.046	0.067
	(0.021)	(0.038)	(0.054)
Observations	5602	5602	5602
Adjusted R^2	0.220	0.173	0.225
Mean	0.546	1.111	2.426
Panel A2. Above median counties, white mothers			
# Days above-90-degree during pregnancy	0.011	-0.008	0.030
	(0.009)	(0.006)	(0.021)
Observations	4233	4233	4233
Adjusted R^2	0.275	0.451	0.399
Mean	0.471	1.193	2.574
P-value from testing the difference	0.003	0.160	0.513
Panel B1. Below median counties, black mothers			
# Days above-90-degree during pregnancy	0.560**	0.703***	0.892***
	(0.192)	(0.220)	(0.079)
Observations	2250	2250	2250
Adjusted R^2	-0.001	0.154	0.137
Mean	1.156	2.081	3.106
Panel B2. Above median counties, black mothers			
# Days above-90-degree during pregnancy	0.033***	0.053	0.086*
	(0.009)	(0.066)	(0.048)
Observations	2673	2673	2673
Adjusted R^2	0.270	0.461	0.316
Mean	1.040	2.384	4.083
P-value from testing the difference	0.008	0.007	0.000

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 7: Effects of Exposure to Above-90-Degree Heat on Maternal Health at and after Childbirth

	(1)	(2)	(3)
	Length of stay at childbirth	Any readmission	Readmission within 28 days
Panel A. Exposure during pregnancy			
# Days above-90-degree during pregnancy	0.003**	-0.009	-0.008***
	(0.002)	(0.007)	(0.003)
Observations	44336	44336	44336
Adjusted R^2	0.551	0.086	0.056
Mean	2.691	1.979	1.144
Panel B. Exposure separately by each trimester			
# Days above-90-degree in trimester 1	0.006***	-0.008	-0.007
	(0.001)	(0.007)	(0.005)
# Days above-90-degree in trimester 2	0.005	-0.005	-0.009
	(0.003)	(0.009)	(0.006)
# Days above-90-degree in trimester 3	-0.001	-0.020***	-0.010***
	(0.002)	(0.007)	(0.002)
Observations	44342	44342	44342
Adjusted R^2	0.551	0.086	0.055
Mean	2.691	1.979	1.144

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each binary outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth county×birth month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 8: Effects of Exposure to Above-90-Degree Heat on Maternal Health at and after Childbirth, by Historic Average Daily Mean Temperature

	(1)	(2)	(3)
	Length of stay at childbirth	Any readmission	Readmission within 28 days
Panel A. Below median counties			
# Days above-90-degree during pregnancy	0.016**	-0.059	-0.004
	(0.007)	(0.044)	(0.030)
Observations	21816	21816	21816
Adjusted R^2	0.280	0.040	0.015
Mean	2.691	1.979	1.155
Panel B. Above median counties			
# Days above-90-degree during pregnancy	0.003**	-0.009	-0.007**
	(0.001)	(0.007)	(0.003)
Observations	22520	22520	22520
Adjusted R^2	0.590	0.129	0.092
Mean	2.691	1.979	1.134
P-value from testing the difference	0.063	0.229	0.908

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each binary outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth county×birth month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table 9: Effects of Exposure to Above-90-Degree Heat on Maternal Health at and after Childbirth, by Race

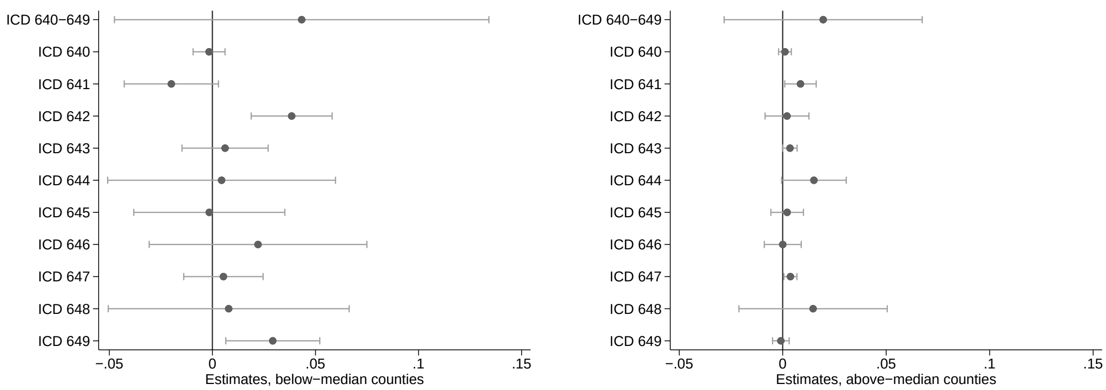
	(1)	(2)	(3)
	Length of stay at childbirth	Any readmission	Readmission within 28 days
Panel A. White mothers			
# Days above-90-degree during pregnancy	0.005**	-0.019***	-0.014**
	(0.002)	(0.005)	(0.006)
Observations	9835	9835	9835
Adjusted R^2	0.719	0.079	0.036
Mean	2.565	1.894	1.068
Panel B. Black mothers			
# Days above-90-degree during pregnancy	-0.001	0.014	0.004
	(0.005)	(0.019)	(0.027)
Observations	4923	4923	4923
Adjusted R^2	0.324	-0.009	0.028
Mean	2.879	3.069	1.900
P-value from testing the difference	0.352	0.096	0.386

Source: HCUP SID merged with NOAA weather data

Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each binary outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity$\times$birth county$\times$birth month fixed effects, zip code level income quartiles, birth-state$\times$birth-year fixed effect, a quadratic time at the county$\times$calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race$\times$birth-county$\times$birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Online Appendix

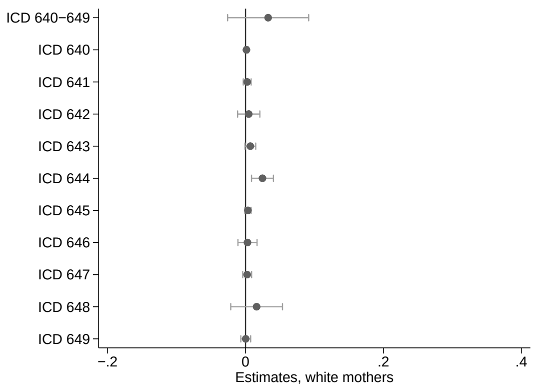
Appendix A. Appendix Figures



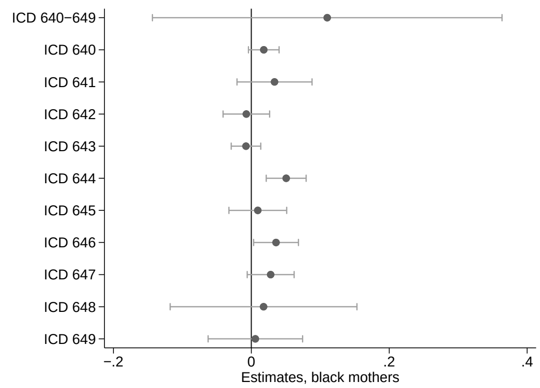
(a) Below median counties (b) Above median counties

Figure A.1: **Effects of Temperature Above 90 Degrees During Pregnancy on Diagnoses at Prenatal Hospitalization by Historic Temperature**

Notes: The figure plots separate regression coefficients, $\beta_{1,10}$, from equation (1) for temperature above 90-degrees for the first trimester with 95% confidence intervals for each diagnosis category. Outcomes are rescaled by multiplying by 100. ICD codes 640-649 indicate "complications mainly related to pregnancy." The definition of each sub-category is as follows. ICD 640: Hemorrhage in early pregnancy; ICD 641: Antepartum hemorrhage abruptio placentae and placenta previa; ICD 642: Hypertension complicating pregnancy childbirth and the puerperium; ICD 643: Excessive vomiting in pregnancy; ICD 644: Early or threatened labor; ICD 645: Late pregnancy; ICD 646: Other complications of pregnancy not elsewhere classified; ICD 647: Infectious and parasitic conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 648: Other current conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 649: Other conditions or status of the mother complicating pregnancy, childbirth, or the puerperium. Standard errors are clustered by the commuting zone level. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used.



(a) White mothers



(b) Black mothers

Figure A.2: **Effects of Temperature Above 90 Degrees During Pregnancy on Diagnoses at Prenatal Hospitalization by Race**

Notes: The figure plots separate regression coefficients, $\beta_{1,10}$, from equation (1) for temperature above 90-degrees for the first trimester with 95% confidence intervals for each diagnosis category. Outcomes are rescaled by multiplying by 100. ICD codes 640-649 indicate "complications mainly related to pregnancy." The definition of each sub-category is as follows. ICD 640: Hemorrhage in early pregnancy; ICD 641: Antepartum hemorrhage abruptio placentae and placenta previa; ICD 642: Hypertension complicating pregnancy childbirth and the puerperium; ICD 643: Excessive vomiting in pregnancy; ICD 644: Early or threatened labor; ICD 645: Late pregnancy; ICD 646: Other complications of pregnancy not elsewhere classified; ICD 647: Infectious and parasitic conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 648: Other current conditions in the mother classifiable elsewhere but complicating pregnancy childbirth or the puerperium; ICD 649: Other conditions or status of the mother complicating pregnancy, childbirth, or the puerperium. Standard errors are clustered by the commuting zone level. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used.

Appendix B. Appendix Tables

Table B.1: Placebo Outcome: Race and Zip-Code-Level Income

	(1) White	(2) Black	(3) Hispanic	(4) Asian
A. Race				
# Days above-90-degree during pregnancy	-0.025	-0.012	0.165**	-0.008
	(0.049)	(0.013)	(0.064)	(0.028)
Observations	10121	10121	10121	10121
Adjusted R^2	0.962	0.972	0.934	0.889
Mean	76.614	4.547	11.286	2.305
	Q1	Q2	Q3	Q4
B. Zip-code-level income quartiles				
# Days above-90-degree during pregnancy	-0.223	0.144	0.291*	-0.212
	(0.387)	(0.367)	(0.147)	(0.138)
Observations	8978	8978	8978	8978
Adjusted R^2	0.958	0.919	0.915	0.985
Mean	25.033	41.301	22.978	10.688

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. All regressions control for birth-county×birth-month fixed effects, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation. We use the data collapsed at the birth-county×birth-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table B.2: Robustness to Including Two-Year Leads in Temperature Exposure

	(1)	(2)
	Prenatal hospitalization	
	Any	Emergency/urgent
Panel A. Main specification in the subsample with two-year leads		
# Days above-90-degree during pregnancy	0.108***	0.069***
	(0.019)	(0.021)
Observations	35775	35775
Adjusted R^2	0.448	0.476
Mean	3.995	2.571
Panel B. Adding two-year leads		
# Days above-90-degree during pregnancy	0.150***	0.100***
	(0.021)	(0.021)
# Days above-90-degree during pregnancy (placebo)	0.046	0.068***
	(0.035)	(0.012)
Observations	35775	35775
Adjusted R^2	0.448	0.477
Mean	3.995	2.571

Source: HCUP SID merged with NOAA weather data
Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions controls for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.

Table B.3: Effects of Exposure to Above-90-Degree Heat on Prenatal Hospitalization, Robustness to AQI Controls

	(1)	(2)	(3)	(4)	(5)	(6)
	Full sample		Colder counties		Hotter counties	
	Any	Emergency/urgent	Any	Emergency/urgent	Any	Emergency/urgent
Panel A. Main specification in the subsample with AQI measures						
# Days above-90-degree during pregnancy	0.022	0.011	0.129***	0.137***	0.021	0.008
	(0.020)	(0.014)	(0.043)	(0.042)	(0.020)	(0.012)
Observations	28717	28717	12450	12450	16267	16267
Adjusted R^2	0.523	0.561	0.229	0.211	0.616	0.642
Mean	4.113	2.603	4.049	2.519	4.162	2.668
Panel B. Adding AQI measures						
# Days above-90-degree during pregnancy	0.023	0.007	0.130***	0.140***	0.024	0.004
	(0.019)	(0.013)	(0.041)	(0.042)	(0.019)	(0.011)
Observations	28717	28717	12450	12450	16267	16267
Adjusted R^2	0.523	0.561	0.229	0.211	0.617	0.643
Mean	4.113	2.603	4.049	2.519	4.162	2.668

Source: HCUP SID merged with NOAA weather data

Notes: This table reports regression coefficients, $\beta_{t,10}$, from equation (1). Robust standard errors, clustered by commuting zone, are in parentheses. Each outcome is rescaled by multiplying by 100. All regressions control for mother's race/ethnicity×birth-county×birth-month fixed effects, zip code level income quartiles, birth-state×birth-year fixed effect, a quadratic time at the county×calendar month level, and a series of indicators for terciles of precipitation in each trimester. In panel B, we include a series of indicators for AQI categories ("good," "moderate," "unhealthy for sensitive groups," "very unhealthy," with "hazardous" as a reference group) separately for each trimester. We use the data collapsed at the race×birth-county×birth-year-month level. Cell size weights are used. * p<0.10, ** p<0.05, *** p<0.01.