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journal homepage: www.elsevier.com/locate/econbaseWeathering the storm: Hurricanes and birth outcomes[☆]Janet Currie^{a,b,*}, Maya Rossin-Slater^c^a Princeton University, United States^b NBER, United States^c Columbia University, United States

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ABSTRACT

A growing literature suggests that stressful events in pregnancy can have negative effects on birth outcomes. Some of the estimates in this literature may be affected by small samples, omitted variables, endogenous mobility in response to disasters, and errors in the measurement of gestation, as well as by a mechanical correlation between longer gestation and the probability of having been exposed. We use millions of individual birth records to examine the effects of exposure to hurricanes during pregnancy, and the sensitivity of the estimates to these econometric problems. We find that exposure to a hurricane during pregnancy increases the probability of abnormal conditions of the newborn such as being on a ventilator more than 30 min and meconium aspiration syndrome (MAS). Although we are able to reproduce previous estimates of effects on birth weight and gestation, our results suggest that measured effects of stressful events on these outcomes are sensitive to specification and it is preferable to use more sensitive indicators of newborn health.

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Health at birth is predictive of important child outcomes including educational attainment and adult earnings. Hence, economists are increasingly concerned with understanding the impacts of conditions during pregnancy on birth outcomes.¹ One

intriguing hypothesis is that stress during pregnancy could have negative effects on the fetus through neuroendocrine changes, changes in immune function, and/or through behavioral channels (Dunkel-Schetter, 2011). Extreme weather events represent an unpredictable and unusual source of stress during pregnancy.

This paper analyzes the effects of severe storms and hurricanes on birth outcomes in Texas over the period 1996–2008. In principle, hurricanes could also subject pregnant women to other negative conditions including injury, disruptions in the supply of clean water, inadequate access to safe food, exposure to environmental toxins, interruption of healthcare, or crowded conditions in shelters (Callaghan et al., 2007). However, in the U.S., with the notable exception of hurricane Katrina, such direct threats to health from hurricanes affect only very small numbers of people. The primary threat to pregnant women in the path of a hurricane is the stress that is generated by the fear of the hurricane, as well as by the property damage and disruption that follows it.

The existing empirical literature on disasters and infant health is generally limited to studies comparing birth outcomes before and after a disaster in the area of occurrence (Glynn et al., 2001;

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¹ Black et al. (2007) offer some of the most convincing evidence in this regard. See Currie (2011) and Almond and Currie (2010, 2011) for surveys of this literature.

Lauderdale, 2006; Eskenazi et al., 2007; Simeonova, 2009; Tan et al., 2009; Eccleston, 2011). Such comparisons can be problematic if people respond to disasters by moving. Additionally, many previous studies are based on small samples and use self-reported measures of stress exposure, which could exacerbate measurement error bias. A third issue is that many previous studies count exposure backwards from the date of birth rather than forwards from the date of conception. Such a procedure could bias the estimated relationship between exposure to the stressful event, gestation, and other outcomes that depend on gestation length. A related issue is that there is a mechanical correlation between length of gestation and the probability of having been exposed to a disaster in the third trimester of pregnancy. Although these measurement issues sound arcane, we show below that they have a significant impact on the estimated effects of disaster exposure.

We use a confidential version of all Texas birth records from 1996 to 2008 with information on mothers' names, dates of birth, and residential addresses. This information allows us to link siblings born to the same mother and to identify mothers who were in the path of major tropical storms and hurricanes using data from the Weather Underground Hurricane Archive. We compare mothers who lived in the path of the hurricane to those who lived further away, and use mother fixed effects and an instrumental variables strategy to control for time-invariant maternal characteristics that might be correlated both with residential location and birth outcomes. We also explore issues related to measurement of gestation, and the mechanical correlation of gestation length with probability of exposure.

We show that estimated effects on birth weight and gestation are sensitive to econometric specification, and especially to measurement issues. This is not simply a matter of power since we see precisely estimated and extremely robust effects of disaster exposure on more subtle measures of infant health: mothers living within 30 km of the hurricane path during their third trimester are 60% more likely to have a newborn with abnormal conditions (including meconium aspiration syndrome, and being on a ventilator more than 30 minutes), and 30% more likely to have any complications during labor and/or delivery. The medical literature suggests that infants with these conditions are significantly more likely to experience adverse long term consequences, including developmental delays, compared to other infants.

We find no placebo effects of exposure to hurricanes six months after birth, which provides support for the validity of our identification strategy. We also find little consistent evidence of effects on maternal behaviors including smoking, weight gain, and use of prenatal care that could explain our findings. Further, our results suggest that the effects on abnormal conditions of the newborn are not due to changes in medical care which might be associated with the hurricane.

There are many possible ways for hurricane exposure to affect pregnancy outcomes. In this paper, we believe we have ruled out some important potential pathways including changes to migration, medical care, and maternal behavior. Therefore, while stress is a "residual explanation" in our context, we believe that our results may reflect the effects of stress itself during pregnancy. Our results suggest that the effects of stress on fetal health, while important, may be more subtle than previous research has suggested.

The rest of the paper proceeds as follows. Section I presents a review of the existing literature, while Section II discusses the data, sample, and presents summary statistics. The empirical methods are discussed in detail in Section III, while Section IV presents the main results. Several robustness checks are presented in Section V, and Section VI concludes.

1. Background

A growing literature in public health (such as Glynn et al., 2001; Xiong et al., 2008; Tan et al., 2009) studies the effects of disasters on birth outcomes. These studies typically involve small samples, and few if any control variables making it difficult to assess their causal claims. In a large-scale study, Simeonova (2009) uses county-level data on all births in the United States over 1968–1988 and a range of natural disasters and finds that exposure to a disaster during pregnancy increases the likelihood of a preterm birth by about 1.3%. She finds little effect on birth weight. One difficulty with using county-level data is that one must *defacto* assume that babies born in month t were conceived at month $t-9$. As we show below, correcting this simple measurement issue can have a large effect on the estimates. Torche (2011) uses individual level data with correctly measured exposure to study the effects of the 2005 earthquake in Chile and finds that exposure to the worst shaking during the first trimester of pregnancy increased the risk of low birth weight and short gestation (though more moderate shaking had no significant effect). Our study improves on hers by including maternal fixed effects and accounting for the possibility of maternal mobility.²

Another strand of literature has studied the impacts of the September 11 terrorist attacks. These studies typically compare women living or working in the area around the World Trade Center to women in another area, under the maintained assumption that women further away experienced less stress (Berkowitz et al., 2003; Lipkind et al., 2010). Other studies conduct an analysis comparing birth outcomes of New York City women pregnant before and after 9/11 (Lederman et al., 2004; Eskenazi et al., 2007; Eccleston, 2011). The results from this literature are mixed.³

As discussed above, one possible problem with these studies is that the population of women may change in an affected area following disasters. Changes in composition may decrease birth weight if those left behind are more disadvantaged, but the effect could also work the other way. For instance, after Hurricane Katrina, New Orleans lost a large part of its black population and gained Hispanics and Asians, trends that are likely to increase mean birth weight (Plyer, 2011). Deschênes and Moretti (2009) document the fact that migration is an important determinant of a population's exposure to extreme weather events over time. Data like ours that follows individual mothers over time can be used to control for such changes in the composition of mothers.

Camacho (2008) uses an identification strategy close to ours, and exploits the variation in the number of landmine explosions in Colombia by municipality and quarter over 1998–2003 on births using a design with mother fixed effects. She finds that living near a landmine explosion during pregnancy reduces birth weight by approximately 9 g (on a mean of 3153 g) but finds no significant effect on the incidence of low birth weight and a very small impact on prematurity.

Mansour and Rees (2011) examine the effect of the intensity of the Intifada-related conflict in the West Bank and Gaza to gauge

² Another potential issue with Torche (forthcoming) is that she does not cluster the standard errors in her analysis, but it is unclear how much this would change her qualitative findings.

³ Another problem with some of the 9/11 studies is that maternal characteristics and birth outcomes may differ significantly by month of birth (Buckles and Hungerman, 2008). In one of the more compelling 9/11 studies, Lauderdale (2006) uses California birth records for 2000–2002 and finds that women with Arab names were 34% more likely to have a low-birth-weight baby and 1.5 times more likely to have a preterm birth in the six months after 9/11 relative to women who gave birth between October 2000 and March 2001. She found no such effects for other ethnic groups. She attributes the effects to stress due to discrimination against individuals of Arabic origin post-9/11.

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