

Climate change and long-run consequences of in utero exposure to natural disasters

Executive summary

Using full-count census data and a difference-in-differences identification strategy, we document that fetal exposure to hurricanes decreased educational attainment, geographic mobility, and lifecycle income of white males born in hurricane-prone southern U.S. states. Labor force participation was unaffected, while education and migration account for a small portion of the effects on income. We rule out alternative channels such as selective mortality, the persistent impact of damage to infrastructure or agricultural output, or flooding and the spread of waterborne diseases. Thus, we attribute the findings to lower health capital stemming from temporary disruptions and maternal stress in the aftermath of storms.

Introduction

A growing body of empirical evidence has shown that extreme weather events can have causal effects on economic activity (Dell et al. 2014), conflict (Burke et al., 2015), and longevity (Deryugina and Molitor, 2019). In the case of natural disasters such as tropical cyclones, effects have been ambiguous with negative consequences in some contexts and positive in others. At the macro-level, tropical cyclones have lowered a country's growth and productivity decades later (Hsiang and Jina, 2014). On the other hand, affected individuals may experience persistent increases in long-run earnings due to the economic expansion generated by recovery or government transfers (Deryugina, Kawano, and Levitt, 2018), while affected counties may provide insurance through net-positive fiscal transfers (Deryugina, 2017). What much of this literature has overlooked is the possibility for hidden costs of natural disasters through prenatal exposure to the tropical cyclones. For these cohorts, the consequences of exposure may not materialize until decades later.

Data and analysis

In a recent paper (Karbownik and Wray, 2019), we investigate the long-run impact of nearly 50 tropical cyclones that hit the US between 1885 and 1897. We assess the effects of in utero exposure to the storms on labor market outcomes and the potential mediating role of human capital and migration responses. The spatial analysis of historical US tropical cyclones is made possible by the National Oceanic and Atmospheric Administration's reconstruction of storm trajectories dating back over 150 years.

The primary challenge with estimating the long-run effects of historical tropical cyclones is identifying who was exposed to the storms and whether the exposure occurred during the critical prenatal period. Historical population censuses for the US typically only reported an individual's age in years on the day of enumeration and state of birth, which are insufficient for accurately measuring the birth cohorts and locations with in-utero exposure. A crucial innovation of our project is the use of the World War I Draft Registration Cards database, which is unique among historical US data sources in reporting the exact date of birth and city of birth. The coverage of the data set represents the near universe of males who survived until at least 1917.

A second challenge involves linking the storm exposure of individuals to long-run labor market outcomes and potential intermediate mechanisms. We implement the recently developed automated methods of historical data linkage to match individuals in the World War I draft cards to the 1940 census complete count file. Our sample cohorts were between the ages of 42 and 53 when enumerated in 1940, which provides information on their life-cycle

earnings. The 1940 population census is valuable since it is the only publicly available US census complete count to report years of education and annual wage and salary income.

We apply a difference-in-differences identification strategy to estimate the causal effects of in utero exposure to tropical cyclones on long-run labor market outcomes. The first difference compares individuals exposed in utero to those born before or conceived after a storm, while the second difference contrasts individuals born in locations exposed to a storm (0 to 30 km from the eye of a storm) to those born in surrounding locations (30 to 100 km from the eye of a storm).

Figure 1 displays these treatment (red) and control (green) locations from exposure to hurricanes that hit the US between 1885 and 1897. Each circle in the figure represents a geocoded location from the World War I draft cards and its size represents the number of observations at each location in the final estimation sample. Given that some of the findings in the literature are exclusive to severe natural disasters (Boustan et al. 2019), it is important to note that the vast majority of the tropical cyclones in our analysis were relatively mild with category 1 or 2 strength on the Saffir-Simpson scale.

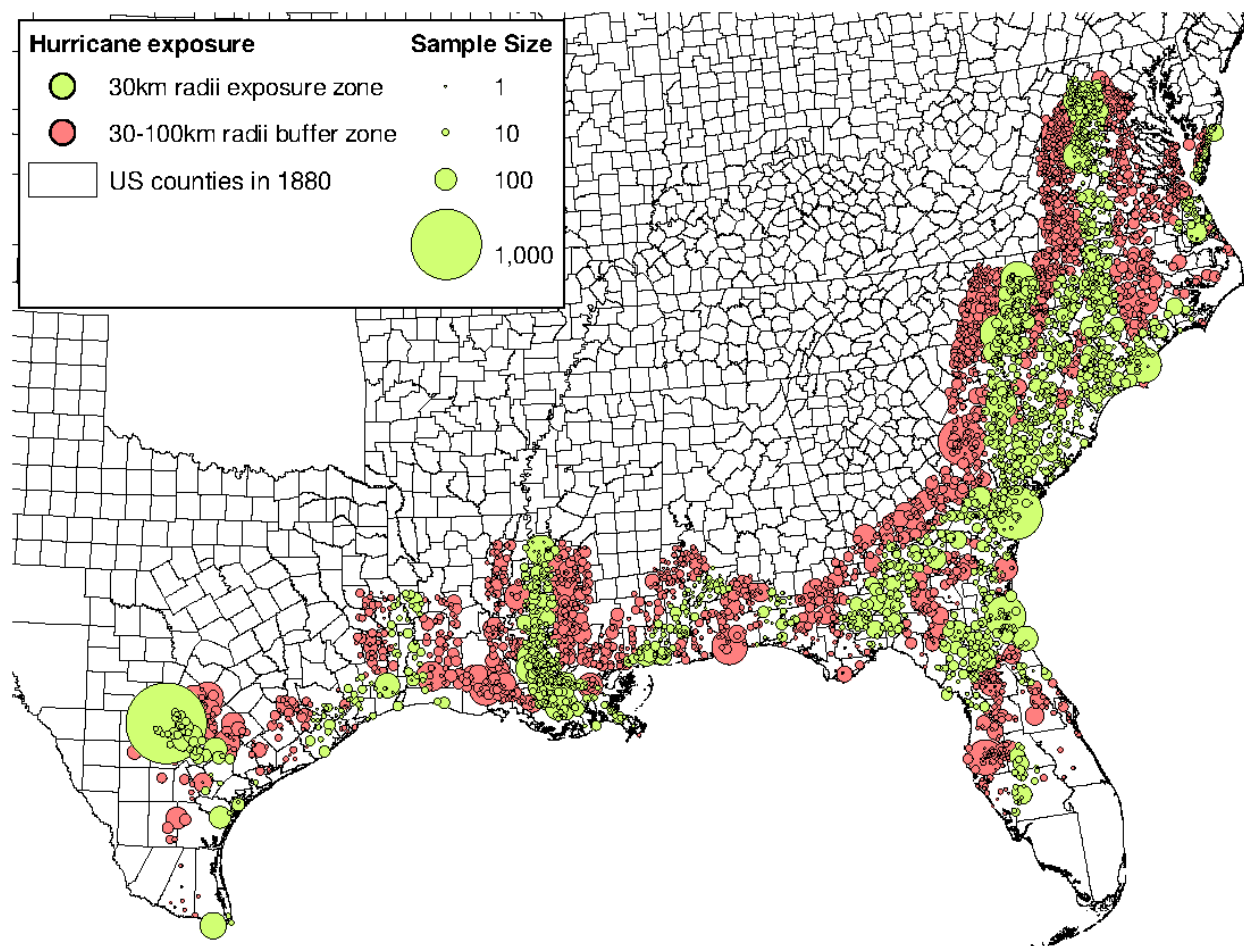


Figure 1

Given that our data have variation at the sub-county level, we include birth location, state-by-year, and conception week fixed effects and account for correlated errors across birth locations within a county through the clustering of standard errors at county-of-birth level. The estimates of interest are interpreted as effects of in utero exposure relative to the excluded

group of individuals born before a hurricane, conceived after a storm, or born in neighboring locations (30-100 km), who we assume were unaffected by the storm.

Findings

Figure 2 presents our main findings for four labor-market outcomes of white males at ages 42 to 53 from the difference-in-differences specification. In utero exposure to hurricanes has negative effects on intensive margin labor market outcomes, leading to 5.3% and 2.2% lower total income and occupational income, respectively. On the other hand, it has no effect on extensive margin labor market outcomes with statistically insignificant effects of 0.6% and 1.5%, respectively. The lack of extensive margin effects is consistent with finding a relatively smaller effect on occupational income. Taken together, we interpret the results as effects on individual productivity within occupations rather than large effects on occupational sorting.

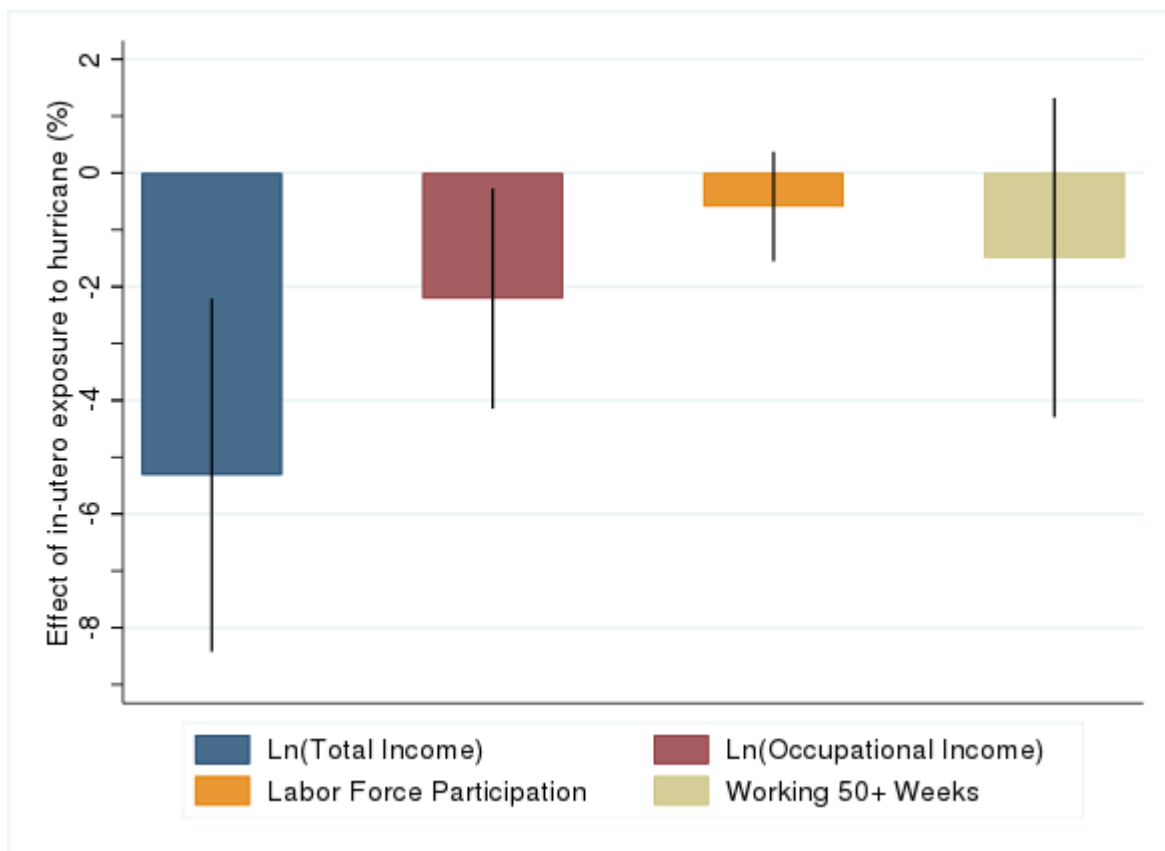


Figure 2

Our preferred estimate is a 5.3% reduction in income, which is comparable to the lower bound of the negative effects of in utero exposure to the 1918 flu pandemic (Almond, 2006), smaller than the 9% reduction in earnings from in utero exposure to seasonal influenza (Schwandt, 2018), and about twice as large as penalties for exposure to low doses of radiation and airborne pollution, which are estimated using contemporary data (Black et al. 2013; Isen, Rossin-Slater, and Walker, 2017).

We argue that these findings are consistent with having poorer health due to maternal stress from experiencing the storms and temporary disruptions in the immediate aftermath. In the paper, we provide additional evidence that there is no effect of prenatal exposure to a storm location during the nine months after a hurricane and rule out the possibility that persistent

economic shocks or waterborne disease associated with persistent disruption in the aftermath of a hurricane represent channels leading to the observed reduction in income.¹

Figure 3 examines the role of education and geographic mobility as pathways leading to the observed productivity differences. The figure plots four pairs of coefficients from interactions of in utero exposure with indicators for above- and below median socioeconomic status (SES) during childhood.² Individuals with lower-SES backgrounds who were exposed in utero to a hurricane experienced a 9.9% decline in the probability of graduating high school and had 3.8% fewer years of education. Additionally, their geographic mobility was constrained as they were 13.3% less likely to move between states and 25.3% less likely to migrate outside the South as adults. These results suggest that having a poorer background may have limited opportunities to mediate the in-utero shock, either through compensating investments in education or moving to locations with better paying jobs. Conversely, we find larger negative effects on earnings among individuals coming from lower-SES backgrounds.

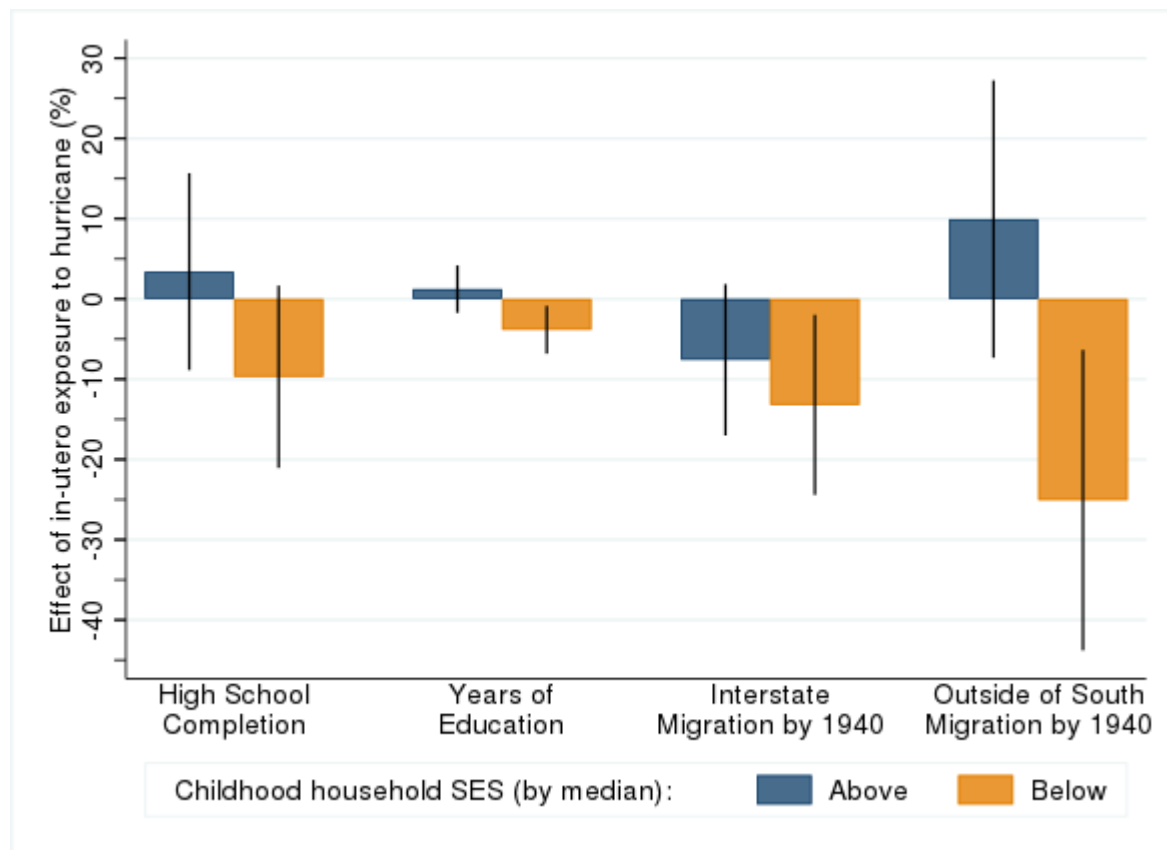


Figure 3

¹ We expand our basic specification, in which treatment is defined as in utero exposure, into one that includes exposure up to 9 months pre-conception and up to 9 months after birth. The post storm conception term can be thought of as a placebo to the extent that fetuses are not directly affected by a storm prior to conception but could, theoretically, be affected by selective fertility or migration. Importantly, for all outcomes we find a point estimate of zero for individuals conceived in the 9 months after a hurricane, and for both income measures standard errors are small enough that we can statistically reject the equality with the in-utero coefficient.

² We measure socioeconomic status using the average occupational income score of fathers with children having the same given name (Olivetti and Paserman, 2015).

Conclusion

We conclude that for milder tropical cyclones, the effects of in utero exposure manifested decades later in the form of lower labor productivity. We suggest that low socioeconomic status limited opportunity to mediate the effects through human capital accumulation or migration to higher-earning areas. Although fetal-origins arguments may not factor into the cost-benefit analysis of disaster prevention plans, our findings suggest that the individual and societal costs of in utero exposure should not be overlooked. The impact of natural disasters on these individuals may be hidden from the view of policymakers and not materialize until decades later in the form of a less productive labor force.

In any given year roughly 100 tropical cyclones occur around the world and over the course of a lifetime nearly one-third of the global population will be exposed to a cyclone (Hsiang and Narita 2012). Of even greater concern is the ongoing urbanization of coastal areas that has brought larger populations to locations at risk of these extreme weather events, including vulnerable groups such as infants and pregnant women. Our results suggest that consequences of these changes, which are unaccounted for in analyses of contemporaneous outcomes, could manifest decades after the initial exposure.

References

- Almond, Douglas. 2006. Is the 1918 influenza pandemic over? Long-term effects of in utero influenza exposure in the post-1940 U.S. population. *Journal of Political Economy* 114, no. 4:672–712.
- Black, Sandra E., Aline Bütikofer, Paul J. Devereux, and Kjell G. Salvanes. 2013. This is only a test? Long-run impacts of prenatal exposure to radioactive fallout. NBER Working Paper no. w18987, National Bureau of Economic Research, Cambridge, MA.
- Boustan, Leah Platt, Matthew E. Kahn, Paul W. Rhode, and Maria Lucia Yanguas. The Effect of natural disasters on economic activity in US counties: A century of data. NBER Working Paper no. w23410, National Bureau of Economic Research, Cambridge, MA.
- Burke, Marshall, Solomon M. Hsiang, and Edward Miguel. 2015. Climate and conflict. *Annual Review of Economics* 7:577–617.
- Dell, Melissa, Benjamin F. Jones, and Benjamin A. Olken. 2014. What do we learn from the weather? The new climate-economy literature. *Journal of Economic Literature* 52, no. 3:740–98.
- Deryugina, Tatyana. 2017. The fiscal cost of hurricanes: Disaster aid versus social insurance. *American Economic Journal: Economic Policy* 9, no. 3:168–98.
- Deryugina, Tatyana, Laura Kawano, and Steven Levitt. 2018. The economic impact of Hurricane Katrina on its victims: Evidence from individual tax returns. *American Economic Journal: Applied Economics* vol. 10, no. 2:202–33.
- Deryugina, Tatyana and David Molitor. 2019. Does when you die depend on where you live? Evidence from Hurricane Katrina? Working Paper.

- Hsiang, Solomon M., and Amir S. Jina. 2014. The causal effect of environmental catastrophe on long-run economic growth: Evidence from 6,700 cyclones. NBER Working Paper no. 20352, National Bureau of Economic Research, Cambridge, MA.
- Hsiang, Solomon M., and Daiju Narita. 2012. Adaptation to cyclone risk: Evidence from the global cross-section. *Climate Change Economics* 3, no. 2:1–28.
- Isen, Adam, Maya Rossin-Slater, and W. Reed Walker. 2017. Every breath you take—every dollar you’ll make: The long-term consequences of the Clean Air Act of 1970. *Journal of Political Economy* 125, no. 3:848–902.
- Karbownik, Krzysztof, and Anthony Wray. 2019. Long-Run Consequences of Exposure to Natural Disasters. *Journal of Labor Economics* 37, no. 3: 949-1007.
- Olivetti, Claudia, and M. Daniele Paserman. 2015. In the name of the son (and the daughter): Intergenerational mobility in the United States, 1850-1940. *American Economic Review*, 105, 8:2695-2724.
- Schwandt, Hannes. 2018. The lasting legacy of seasonal influenza: In-utero exposure and labor market outcomes. CEPR Discussion Paper no. 12563, Centre for Economic Policy Research, London.