Fertility Following Natural Disasters and Epidemics in Africa

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September 22, 2020

Abstract

This paper documents average changes in fertility that followed nearly 2,000 droughts, floods, and other natural disasters in Africa between 1980 and 2016. Across dozens of large-scale household surveys, fertility falls by up to 5.1 percent after natural disasters. The decline in fertility is associated with changes in the fertility response to child mortality. Fertility typically rises after a child dies, but this replacement effect is diminished if the child dies during a natural disaster.

JEL codes: I15; J13; Q54

Keywords: Fertility; Natural Disasters; Epidemics; Africa

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1. Introduction

Global climate models project that recent changes in temperature, precipitation, and sea level will continue for at least the next several decades. These climate changes bring greater risk of droughts, floods, storms, disease, and other disasters, particularly for less developed countries, many of which are located in Africa (Intergovernmental Panel on Climate Change 2012; Dellink et al. 2019). Africa also has the highest fertility rate of any region of the world, and is projected to continue to have the highest fertility rate past 2050 (World Bank 2020). Understanding the relationship between natural disasters, epidemics, and fertility in Africa over the past several decades is therefore important for projecting the consequences of climate change for fertility in the coming decades.

In this paper, I document average changes in fertility following nearly 2,000 natural disasters in Africa between 1980 and 2016. I begin by drawing from the Emergency Events Database, a record of all natural disasters worldwide. I identify the district or districts in which each disaster in Africa occurred, and link this information to more than one million women in 34 countries whose place of residence and birth history are recorded by a Demographic and Health Survey. I then compare fertility following natural disasters to fertility in settings where a disaster did not occur. Fertility generally falls after natural disasters, by up to 5.1percent, but rises by 1.4 percent following epidemics.

This study contributes to two areas of research. First, several studies have documented changes in mortality and fertility following flooding in Bangladesh in 1974 (Hernández-Julián and Mansour 2014), drought in Ethiopia in the early 1970s (Lindstrom and Berhanu 1999), crop failure in Ireland in the late 1840s (Boyle and O Gráda 1986), droughts in Mali in the 1970s and

1980s (Pedersen 1995), hurricanes in the United States in the 1990s and 2000s (Evans et al. 2010, Seltzer and Nobles 2017), and the 1918 influenza epidemic in the United States (Fletcher 2018). Nobles et al. (2015) track fertility in coastal areas of Indonesia before and after the deadly 2004 Indian Ocean tsunami. Families that lost a child were more likely to have another child, as were families that did not lose a child, suggesting a community-wide repopulation effort. I similarly document an increase in fertility following natural disasters in Africa among families that lost a child, but fertility typically falls for families that experienced a disaster but did not lose a child. I show that these changes are consistent with a model in which changes in income, savings, and child survival during natural disasters in turn influence fertility. Only following epidemics did fertility increase for families that did not lose a child.

Second, while most studies of natural disasters focus on a single country, several explore the consequences of a single type of disaster across several countries, such as famines in Africa (Agbor and Price 2014) and earthquakes in Asia (Finlay 2009). Caruso (2016) compares the consequences of hundreds of floods, volcanic eruptions, earthquakes, cyclones, and landslides across Latin America during the twentieth century. For example, people who were children during a natural disaster, particularly a flood or landslide, complete fewer years of schooling. No study has yet conducted similar comparisons across multiple types of disasters in Africa. I find that the decline in fertility is greatest following tropical cyclones; more muted following droughts, earthquakes, tropical cyclones, and other storms; nearly zero following floods; and is substantially positive following epidemics.

2. Data

2.1 Natural disasters

A natural hazard is a naturally-occurring characteristic that could harm people, and a natural disaster happens when the harm occurs (Alexander 1993). For example, a geologic fault line is a natural hazard, and an earthquake at the fault line that damages a city is a natural disaster. Natural disasters are therefore not simply naturally-occurring events, but further require an effect on people. A cyclone that damages a populated coastline is a natural disaster; a cyclone in the empty ocean is not.

An epidemic is a rapid outbreak of disease in a well-defined geographic area and time period (Green et al. 2002). All types of natural disasters result from the interaction of natural events and social conditions, but epidemics especially so, because the spread of disease is strongly governed by available medicine, health facilities, and other public health conditions. Epidemics can also be more difficult to define or observe, and may therefore be recorded less consistently (Guha-Sapir et al. 2004).

The Centre for Research on the Epidemiology of Disasters draws on a variety of government, United Nations, and Red Cross/Red Crescent reports to maintain global database of disasters. This Emergency Events Database records the location and timing of more than 22,000 disasters around the world since 1900 (Guha-Sapir et al. 2018). Every disaster in the database satisfies one of the following criteria: at least 10 people died as a result of the disaster, at least 100 people were affected by the disaster, the affected country declared a state of emergency, or the affected country requested international assistance. About 8,000 of the disasters are industrial accidents, transportation accidents, or other technological disasters. The remaining 14,000 are natural disasters of geophysical, meteorological, hydrological, climatological, biological, or extraterrestrial origin. This database is the most comprehensive record of natural disasters in Africa.

The database records 2,577 natural disasters in Africa between 1900 and 2016. More than 90 percent occurred since 1980, and in this paper I focus on this recent period when disasters are more frequent or are recorded more completely. Because I compare fertility in places that experienced a natural disaster to places that did not, I further restrict focus to the 90 percent of disasters that have a location or locations recorded in the database. Additionally, several types of natural disasters are rare in Africa. For example, there were just 13 incidents of volcanic activity, and just 12 heat waves. I focus on more common disasters. These restrictions leave a final sample 1,977 natural disasters in Africa between 1980 and 2016: 196 droughts, 856 floods, 50 earthquakes, 98 tropical cyclones, 107 other storms, and 670 epidemics.

2.2 Administrative boundaries

The United Nations Food and Agriculture Administration's Global Administrative Unit Layers database records administrative boundaries in every country between 1990 and 2014 (FAO 2015). The database records the first and second sub-national administrative levels (generally provinces and districts, equivalent to states and counties in the United States), tracking any boundary changes over time. From these 25 years of boundaries, I construct harmonized district boundaries by joining any districts that overlap one another. There are 6,012 harmonized districts, an average of 105 per country. The districts have an average area of 4,972 square kilometers and an average population in 2010 of 171,324 people, comparable in size and population to the 39 counties in Washington state in the northwest United States. These harmonized boundaries allow me to control for unobserved district-specific characteristics in later regressions.

The natural disaster database identifies the sub-national location or locations in which each disaster occurred. For every disaster, I record the district or districts that contain each location where it occurred. (I assign disasters that occurred nationwide to every district in the country.) This approach may overstate the geographic reach of some disasters. For example, a flood occurred in four neighborhoods of Accra Metropolis district in Ghana in 2016. By recording all of the district as exposed to the flood, I include some neighborhoods that were not exposed. As indicated in Table 1, less than one quarter of each type of disaster similarly occurred at the sub-district level. Because some unaffected areas in these cases are recorded as exposed to disasters, the findings in this paper likely understate the actual consequences of natural disasters.

Table 1 additionally summarizes the districts in which disaster occurred. Droughts, floods, and epidemics are both the most numerous types of disasters and tend to occur over the largest area per disaster. For example, 95 percent of droughts occur in multiple districts, at an average of 34 districts and 296,821 square kilometers per drought (comparable in size and number of districts to the state of New Mexico in the United States). Tropical cyclones, other storms, and especially earthquakes tend to occur more locally. For example, less than half of earthquakes take place in multiple districts.

Figure 1 depicts the distribution of disasters. Droughts, floods, and epidemics are the most common types of disasters and have occurred widely across Africa. Although less frequent, storms have also occurred widely across much of the continent. Earthquakes are concentrated along the Mediterranean coast in Morocco and Algeria and near the 30-degree line of longitude from Egypt to South Africa. Tropical cyclones primarily strike Madagascar, Mauritius, and Mozambique. Except for parts of the Sahara and Kalahari deserts, nearly every district in Africa has experienced at least one natural disaster.

2.3 Demographic information

Vital registries of births would offer a comprehensive record of fertility, but are largely unavailable in Africa. Instead, I use birth history surveys, which record the timing of each of a parent's live births, as well as the dates that any children subsequently died. Because birth histories are collected overwhelmingly from women alone, all analyses in this paper focus on women. I use 69 Demographic and Health Surveys, administered in Africa between 1988 and 2017, that collect birth histories from women of childbearing age (generally, age 15 through 44 or 49), that record the latitude and longitude of the community in which each respondent lives, and that record how long the respondent has lived in this location (ICF International 1985–2017).

I restrict focus to geocoded surveys so that I can identify each respondent's district-level exposure to natural disasters. I restrict focus to surveys that record information about migration because migration is a common response to natural disasters. Eighty percent of the population of New Orleans left after Hurricane Katrina in 2005 (Gutman and Field 2010). In the interwar period in the United States, tornado-affected areas similarly experienced net emigration, while flood-affected areas experienced net immigration (Boustan et al. 2012). Berlemann and Steinhardt (2017) review several other studies of migration following natural disasters.

Immigration introduces people into a disaster-affected area who themselves did not experience the disaster, while emigration removes people who did live through the disaster. Both pose a challenge for identifying changes in fertility after natural disasters using retrospective birth history surveys. Unfortunately, the Demographic and Health Surveys do not record complete migration histories and places of previous residence, it is not possible to measure fertility changes among people who experience a disaster and then emigrate. However, I will use the basic information about duration of residence in current place to identify respondents plausibly affected by particular disasters.

Table 2 compares the full sample of 730,000 women to those who live in areas where each type of disaster has ever taken place. Women are observed at about age 29 on average. Women have lived at their current location for about 18 years on average. Where droughts, floods, and epidemics occur, women complete about 4.3 years of schooling on average, one year less than women who live where earthquakes, cyclones, and other storms occur. Women have given birth to between 3.0 and 3.2 children on average, except where tropical cyclones occur, where fertility is lower at 2.6 children per woman. About three-quarters of women have ever been married, and just over one-third live in an urban area. Where droughts, floods, and epidemics occur, between 15 and 17 percent of children die before reaching age 18; where earthquakes, cyclones, and other storms occur, child mortality is lower, at 12 to 14 percent. These comparisons indicate that demographic characteristics are generally similar across places affected by each type of disaster, although earthquakes, tropical cyclones, and other storms tend to affect areas with greater educational attainment and less child mortality.

The retrospective nature of birth history surveys introduces possible measurement error if a woman misreports a child's date of birth or, particularly for children who died at a young age long ago, omits mention of the child entirely. Although I cannot observe unreported children, at most 21 percent of children are recorded as having been born in a year ending in zero or five, barely above the expected 20 percent. This lack of heaping in children's reported years of birth suggests that misreporting of children's dates of birth may not be a substantial concern.

2.4 Risk of natural disasters

The United Nations Environment Programme maintains the Global Risk Data Platform, which records characteristics of risk of and exposure to many types of natural disasters around the world (United Nations Environment Programme 2019). When checking the sensitivity of the main findings to changes in specification, I use the platform's measure of physical exposure to natural disasters, which weights the risk of a natural disaster according by population density. Because a natural disaster requires both a natural hazard and a sufficiently populated area, this measure of exposure to natural disasters most accurately measures the likelihood that a natural disaster will occur. For convenience, I refer to physical exposure to natural disasters as the risk of disasters.

The Global Risk Data Platform records risk for droughts, floods, earthquakes (of strong intensity, Modified Mercalli Intensity scale seven or higher), and high winds associated with tropical cyclones. Risk is recorded at a grid resolution of 2.5 arc-minutes. For each harmonized district, I identify the highest risk of any grid cell that overlaps the district. (The findings below are all similar if I instead calculate the average risk value within each district, weighted by the surface area of the district and each overlapping grid cell.) I then order the districts from greatest to least risk, and divide the districts into above and below-median risk groups. The distribution of districts at above-median risk for drought overlaps closely with the distribution of districts, depicted in Figure 1, that actually experienced drought. Risk of floods, earthquakes, and tropical cyclones similarly closely coincides with actual incidence of these disasters.

3. Main findings: changes in fertility following natural disasters

I estimate the relationship between natural disasters and fertility using the following specification:

$$Births_{idy} = \alpha + \beta Disaster_{dy} + \boldsymbol{X}'_i\theta + \delta_d + \gamma_y + \eta_{d\times y} + \varepsilon_{idy}. \quad (1)$$

There is one observation per woman each year she was between the ages of 15 and 44. *Births* records the number of children that woman *i*, surveyed while living in district *d*, gave birth to in the five years following year *y*. *Disaster* equals one if a natural disaster occurred in year *y* in district *d*. The coefficient of interest β measures the average number of children per woman born in the five years following natural disasters minus average fertility at other times. The regression also includes a vector, $\boldsymbol{X}$, of dummy variables that record demographic characteristics of the woman that could affect fertility: age in year *y*, total number of children born by *y*, an indicator variable equal to one if the woman had ever been married by year *y*, years of schooling completed when surveyed, and urban location when surveyed. (Educational attainment and urban residence are observed later in life and are therefore potentially influenced by disaster exposure. The findings presented below change little if they are excluded from the regression.)

As discussed in section 2, disasters do not occur evenly across Africa and, particularly for earthquakes and tropical cyclones, average fertility is different in areas affected and unaffected by disasters. Average fertility may also change over time. The regression therefore additionally includes district and year fixed effects, δ and γ, to account for district or year-level differences in fertility. Finally, the regression includes district-specific linear time trends η to account for any differences in how fertility changes over time across districts. Because natural disasters are recorded at the district and year level, standard errors are clustered by district-by-year in this and all subsequent regressions in this paper. Because there are multiple observations per woman, standard errors are also clustered by woman.

As discussed in section 2.3, the Demographic and Health Surveys record how long each woman has lived at her current location. For each woman, I restrict focus to only the years in which she has lived at her current location. This restriction allows me to identify the relationship between natural disasters and fertility among women who did not subsequently emigrate. Unfortunately, because the surveys do not record complete migration histories and places of previous residence, it is not possible to measure fertility changes among people who experience a disaster and then emigrate. The final sample consists of 4.3 million person-year observations.

Panel (a) of Table 3 provides the estimates of equation 1. When no drought occurs, women give birth to 1.18 children over the following five years on average. After a drought, this value falls by 0.0059 children, or 0.5 percent. Although small, this difference is statistically significant. The remaining columns of Table 3 repeat equation 1 for each other type of disaster. Fertility is 0.9 percent lower following earthquakes compared to times that an earthquake did not appear, 5.1 percent lower following tropical cyclones, and 0.5 percent lower following other storms. Fertility rises by a negligible 0.003 percent following floods, and a larger 1.4 percent following epidemics. The largest of these differences are substantial: for every 1,000 women, there are 60 fewer children born on average following a tropical cyclone than at other times, and 17 more children born following an epidemic.

These changes are generally consistent across different empirical specifications. The first row of panel (b) of Table 3 presents estimates of equation 1, but including only observations located in district-year combinations that either had a disaster or were located next to a district that had a disaster that same year. This restriction compares people who experienced a disaster to those who lived adjacent to a district that experienced a disaster. For example, this restriction removes districts located throughout much of Africa from the tropical cyclone regression, focusing on just districts in southeast Africa, the horn of Africa, and Western Sahara. Compared to the main specification, the estimated coefficients change magnitude but remain the same sign: fertility is lower after droughts, earthquakes, tropical cyclones, and other storms, and is higher after floods and epidemics.

The second row of panel (b) presents estimates of equation 1 with all demographic controls and fixed effects replaced by a single, person-level fixed effect. People who never experienced a natural disaster, or who experienced one in each year since turning 15, are excluded from the sample. This regression therefore compares average fertility following natural disasters to the same person's average fertility in other years. The magnitudes of the changes in fertility again vary compared to the main specification, but the signs remain the same.

The remaining rows of Table 3 compare estimates using women between the ages of 15 and 29, women between the ages of 30 and 44, women living in urban areas, women living in rural areas, large-scale disasters that affected 500,000 or more people, smaller disasters, areas at above-median risk of each type of disaster, and areas at low risk of disaster. The magnitudes of the estimated changes in fertility again very by specification, but the main findings mostly hold: fertility generally falls after natural disasters, especially tropical cyclones, and it is only following epidemics that a consistent increase in fertility is apparent across specifications. In the remainder of this paper, I investigate whether these changes in fertility are associated with changes in income, savings, and child survival during natural disasters.

4. Theoretical relationship between natural disasters and fertility

In this section, I present a model of how changes in income, savings, and child survival can lead to changes in fertility. The objective of this model is to understand why fertility changes following natural disasters. The model is most similar to one introduced by Finlay (2009), who also measures the fertility response to natural disasters. I discuss the predictions of the model in the context of natural disasters when income declines, savings decline, and existing children are more likely to have died. Finally, I discuss other potential channels, not accounted for in the model, that could link natural disasters to changes in fertility.

4.1 A model of income, savings, child mortality, and fertility

The model has two periods. In the first period, parents receive utility from the number of composite goods they consume, G_1, and the number of children they have, C_1. The two terms are additively separable, each term takes a log functional form that captures diminishing marginal utility of goods and children, and $\alpha>0$ and $\beta>0$ weight the two terms:

$$U_1 = \alpha ln(G_1) + \beta ln(C_1). \qquad (2)$$

Parents are subject to a budget constraint:

$$Y_1 = p_g G_1 + p_c C_1 + s_1. \qquad (3)$$

Each good costs p_g, and each child costs p_c to raise. Income earned in the first period, Y_1, can either be spent on goods, spent raising children, or carried forward to the next period as savings, s_1. I assume that goods and children are normal: $\partial G/\partial Y>0$ and $\partial C/\partial Y>0$.

In the second period, parents receive utility from the number of goods they consume, G_2, and new children they have, C_2, as well as older children from the previous period, C_1:

$$U_2 = \alpha ln(G_2) + \beta ln(C_1 + C_2). \quad (4)$$

Parents are again subject to a budget constraint:

$$Y_2 + (1 + r)s_1 + w_c C_1 = p_g G_2 + p_c C_2. \quad (5)$$

Parents earn income Y_2 in period 2, savings from period 1 grow at an interest rate $r\geq 0$, and each child born in period 1 earns a wage w_c in period 2. This money is spent on consuming goods or raising the young children born in period 2. The model allows for differential costs of raising younger and older children. Young children are costly to raise if $p_c>0$. In many developing country settings where the survey data were collected, older children often work in market, agricultural, or other forms of labor, suggesting that w_c could be positive.

Assuming no intertemporal discounting, parents choose how many goods to buy and children to have in each period in order to maximize the sum of first period utility and second period utility:

$$\begin{aligned} U &= U_1 + U_2 \\ &= \alpha \ln\left(\frac{Y_1 - p_c C_1 - s_1}{p_g}\right) + \beta ln(C_1) + \\ &\alpha \ln\left(\frac{Y_2 + (1 + r)s_1 + w_c C_1 - p_c C_2}{p_g}\right) + \beta ln(C_1 + C_2). \end{aligned} \quad (6)$$

Setting the first order condition with respect to the number of children born in period 2 equal to zero, $\partial U/\partial C_2=0$, yields the optimal number of children born in the second period:

$$C_2 = \frac{\beta Y_2 + \beta(1+r)s_1 + \beta w_c C_1 - \alpha p_c C_1}{\alpha p_c + \beta p_c} \tag{7}$$

I focus on how second period fertility responds to changes in second period income, first period savings, and the number of older children who survive to the second period. If young children are costly to raise (p_c>0), then an increase in second period income allows parents to afford to not just buy more goods but also to have more children in the second period:

$$\frac{\partial C_2}{\partial Y_2} = \frac{\beta}{(\alpha + \beta)p_c} > 0. \tag{8}$$

Similarly, if young children are costly to raise (p_c>0), then an increase in accrued savings allows parents to afford to not just buy more goods but also to have more children in the second period:

$$\frac{\partial C_2}{\partial s_1} = \frac{\beta(1+r)}{(\alpha + \beta)p_c} > 0. \tag{8}$$

Finally, an increase in the number of children born in the first period who survive to the second period is associated with lower fertility in the second period:

$$\frac{\partial C_2}{\partial C_1} = \frac{\beta w_c - \alpha p_c}{(\alpha + \beta)p_c} < 0. \tag{9}$$

Alternatively, as older children die, parents respond by increasing fertility in the second period. This change again relies on the condition that young children are costly to raise (p_c>0). The change further relies on the condition that the numerator is negative ($w_c/p_c>\alpha/\beta$). This final condition is satisfied when older children remain costly to support (negative w_c), or when older children's earnings are small relative to the cost of raising younger children (small w_c and large p_c) and parents especially value goods relative to children (large α and small β).

4.2 Predictions following natural disasters

I consider the situation when a natural disaster occurs between the two periods. Droughts can kill crops and cause food shortages. Earthquakes, floods, tropical cyclones, and other storms may damage or destroy homes, businesses, and infrastructure. Disease can particularly harm young children and other vulnerable groups. It is therefore plausible that economic disruption and physical destruction due to natural disasters lowers income, reduces savings, and worsens child survival (in section 5, I test these relationships). If so, then the model yields three predictions, which I also test in section 5.

Fertility decreases for parents who experience the lower income and reduced savings associated with a natural disaster. If these parents do not also have a child die, they do not experience the corresponding positive fertility response to a child's death. Therefore, the model first predicts that, among all parents who do not have a child die, those who experience a natural disaster have lower fertility than those who do not experience a natural disaster.

Conversely, fertility increases for parents who have a child die. If the child died when a disaster did not occur, the parents do not experience the corresponding fertility decline due to a drop in income and savings. Therefore, the second prediction of the model holds that, among parents who do not experience a disaster, parents who have a child die have lower fertility than those who do not have a child die.

For parents who both experience a natural disaster and have a child die, the change in fertility is ambiguous. Income and savings declines lead to lower fertility, while child mortality leads to higher fertility. Therefore, the third prediction of the model holds that these parents have more children than parents who experience a disaster but do not have a child die, and fewer children than parents who do not experience a disaster but have a child die.

4.3 Limitations of the model

The model in section 4.1 explains how changes in income, savings, and child mortality following natural disasters could influence fertility. There are several additional ways in which natural disasters could affect fertility that are not accounted for in the model. First, changes in income may influence not just the number of children that parents want but also their choices for investments in each child. Lower income (such as following a natural disaster) may lead parents to shift from having a few "high quality" to having more children on whom they spend less on schooling, health, and other investments (Becker and Lewis 1973).

Second, a natural disaster that causes substantial child mortality may accelerate fertility even among families that did not have a child die. Nobles et al. (2015) document such a communitywide repopulation effort in coastal areas of Indonesia following the 2004 Indian Ocean tsunami. A communitywide increase in fertility could also occur if a disaster-related increase in child mortality changes expectations about the likelihood of future disasters, leading even people who did not lose a child to increase their target number of children.

Finally, earthquakes and other natural disasters may damage infrastructure and health facilities, reducing access to contraception or other family planning services. Because contraception reduces the cost of averting births, unplanned births could increase after natural disasters (Evans et al. 2010, Seltzer and Nobles 2017). On the other hand, rebuilding after a disaster may be both costly and time-consuming, raising the opportunity cost of having children (Evans et al. 2010).

5. Test of model predictions

In section 4, I present a model that links natural disasters to fertility via changes in income, savings, and child mortality. In this section, I first document how labor market activity, wealth, and child mortality vary during natural disasters. I then test the model's predicted changes in fertility.

5.1 Natural disasters, labor market activity, wealth, and child mortality

The Demographic and Health Surveys unfortunately do not record income, but they do record whether each woman is employed at the time of observation. Three-quarters of the surveys also record an index of each household's wealth, composed of asset ownership, dwelling characteristics, and access to sanitation and other services (USAID 2020). The index takes values between –1.8 and 5.3, with a median and mean of zero. Finally, the surveys record the date of death for each child that has died.

I measure the relationship between natural disasters and employment, wealth, and child mortality using the following specification:

$$Outcome_{idy} = \alpha + \beta Disaster_{dy} + \boldsymbol{X'}_i\theta + \delta_d + \gamma_y + \eta_{d\times y} + \varepsilon_{idy}. \qquad (10)$$

Outcome is one of three variables: a dummy variable equal to one if woman *i*, surveyed while living in district *d*, is employed when surveyed; the woman's wealth index when surveyed; or the number of children born to the woman who died in year y. The employment and wealth regressions have one observation per woman. Because child mortality is available retrospectively, the child mortality regression has one observation per woman each year she was between the ages of 15 and 44 and lived at her current location. *Disaster* equals one if a natural disaster occurred in year y in district d. The specification includes the same vector of demographic characteristics $\boldsymbol{X}$, district and year fixed effects δ and γ, and district-specific linear time trend η as in equation 2.

The first three panels of Table 4 present the estimated coefficients β on *Disaster* from equation 10. When droughts, floods, earthquakes, or tropical cyclones occur, women are between 2.0 percent and 6.4 percent less likely to be employed than at other times. Only when other storms or epidemics occur are women more likely to be employed. Wealth is higher during floods, earthquakes, tropical cyclones, other storms, and epidemics than at other times, but these differences are all statistically insignificant. Wealth is lower, and statistically-significantly so, during droughts. Finally, child mortality is less than four percent higher or lower during each type of disaster except storms, when women lose 15.0 percent more children than at other times. These findings (that employment generally falls during natural disasters, wealth changes little or falls, and child mortality changes little or rises) weakly support the assumptions from section 4.1 that natural disasters lower income, wealth, and child survival – assumptions that drive the predictions from section 4.2 that I test in the next section.

5.2 Changes in fertility

I test the model's predicted relationship between natural disasters, child mortality, and fertility using the following specification:

$$Births_{idy} = \alpha + \beta_1 DisNoDeath_{idy} + \beta_2 NoDisDeath_{idy} + \beta_3 DisDeath_{idy} + \boldsymbol{X'}_i\theta + \delta_d + \gamma_y + \eta_{d\times y} + \varepsilon_{idy}. \quad (11)$$

There is one observation per woman each year she was between the ages of 15 and 44 and lived at her current location. *Births* records the number of children that woman *i*, surveyed while living in district *d*, gave birth to in the five years following year *y*. *DisNoDeath* equals one if, in year *y*, a natural disaster occurred in district *d* and the woman did not have a child die. *NoDisDeath* equals one if a disaster did not occur and the woman had a child die. *DisDeath* equals one if both a disaster occurred and the woman had a child die. The coefficients of interest, β_1 through β_3, measure the average number of children per woman born within five years for each group, relative to the omitted category of women who neither experience a disaster nor have a child die. Again, the model predicts lower fertility for people who experience a natural disaster ($\beta_1<0$), higher fertility for people who have a child die ($\beta_2<0$), and fertility somewhere in between for people who both experience a disaster and have a child die ($\beta_1<\beta_3<\beta_2$).

Panel (d) of Table 4 presents the estimates of equation 11. Women who do not experience a drought and do not have a child die have 1.17 children on average over the next five years. When a disaster occurs, fertility falls by 0.0049 children. When a child dies, fertility rises by 0.23 children. When both occur, fertility rises by 0.21 children. These changes are consistent with the model's predictions. Changes following earthquakes, tropical cyclones, and other storms are also consistent with the model's predictions. It is only following floods and epidemics that fertility rises among women who did not have a child die, in violation of the model's prediction that $\beta_1<0$. Still, as expected, fertility rises following the death of a child when a flood or epidemic does not occur, $\beta_2>0$.

Women who have a child die when a disaster does not occur have 0.23 or 0.24 additional children over the following five years, depending on the type of disaster. The magnitude of this change in fertility is much larger than the smaller changes associated with experiencing a disaster without the death of a child. An individual woman's experience of losing a child has a much larger average effect on fertility than the typical natural disaster. However, few women have a child die in any particular year, and the estimates in section 5.1 suggest that child mortality changes little during natural disasters. It is rather the smaller disaster-related declines in fertility across all women in a place and time that drive the overall decline in fertility following droughts, earthquakes, tropical cyclones, and other storms. When the disaster-related change in fertility is positive, following floods and epidemics, the overall change in fertility is also positive.

For floods and epidemics, the estimated interaction effect of a disaster occurring and a child dying (β_3) is additionally notable. For these disasters, both the disaster and the death of a child are associated with increased fertility ($\beta_1>0$ and $\beta_2>0$), yet the combination of these two changes (β_3) is less than their sum. Floods and epidemics have a dampening effect on the positive fertility response to children who die during them ($\beta_3<\beta_2$). Such a dampening effect may hold for the other types of disasters, although, as predicted by the model, the finding that $\beta_1<\beta_3<\beta_2$ could instead be explained by declines in income or savings.

5. Discussion

This paper measures the changes in fertility following six types of natural disasters in Africa between 1980 and 2016. Women who experience droughts, earthquakes, tropical cyclones, and other storms have between 0.5 percent and 5.1 percent fewer children over the following five years than do women who do not experience these disasters. These decreases account for up to 60 fewer births per 1,000 women and are consistent with a model in which natural disasters affect fertility decisions through changes in income, savings, and child survival. There is little change in fertility following floods, and epidemics are associated with a 1.4 percent increase in fertility, or 17 additional births per 1,000 women. For every type of disaster, the positive fertility response to losing a child is muted when the child dies during a disaster.

Fertility declined following the 2009 Great Recession in the United States (Cherlin et al. 2013), particularly for women most exposed to economic hardship (Schneider and Hastings 2015). Across recessions more broadly, fertility decreases as output falls and unemployment rises in the United States (Buckles et al. 2018) and in a larger group of developed countries (Kondo 2016). The finding in this paper that fertility falls even when there is little measurable change in child mortality suggests that the consequences of natural disasters resemble the broad, macro changes associated with recessions.

This study adds to a body of prior evidence documenting changes in fertility following natural disasters. Fertility increased substantially following large-scale earthquakes in Turkey in 1999, India in 2001, and Pakistan in 2005 (Finlay 2009); following the 2004 Indian Ocean tsunami in Indonesia (Nobles et al. 2015); and following the 1974 flooding and subsequent famine in Bangladesh (Hernández-Julián et al. 2014). On the other hand, fertility declined on average following severe tropical storms in the United States between 1995 and 2001 (Evans et al. 2010), and among black residents of New Orleans following Hurricane Katrina in 2004 (Seltzer and Nobles 2017). The generally small declines in fertility following natural disasters in Africa are consistent with observed declines in employment accompanied by little change in child mortality. Further study should continue to explore mechanisms (such as damage to infrastructure, limitations on access to health care, and an influx of domestic or international aid) by which natural disasters, and the response to natural disasters, influences fertility.

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Table 1: Characteristics of natural disasters

	Number	Occurred at the sub-district level (%)	Occurred in a single district (%)	Average number of districts per disaster	Average land area per disaster (km^2)
Droughts	196	5	5	34	296,821
Floods	856	13	29	20	124,822
Earthquakes	50	24	54	14	13,684
Tropical cyclones	98	5	18	16	86,033
Other storms	107	18	45	17	62,975
Epidemics	670	16	25	17	116,182

Notes: See section 2.2. *Data sources*: Emergency Events Database (Guha-Sapir et al. 2018), Global Administrative Unit Layers (FAO 2015).

Table 2: Characteristics of demographic survey data

	All women	Women who live in a district that, between 1980 and 2016, experienced a Drought	Flood	Earthquake	Tropical cyclone	Other storm	Epidemic
Countries	31	28	31	10	6	18	30
Surveys	69	60	69	22	13	41	68
Number of women	729,618	465,437	602,031	22,448	41,269	237,471	610,080
Average age	28.8	28.2	28.5	30.2	28.4	29.8	28.6
Average years lived at current location	18.0	17.4	17.6	19.0	17.9	19.8	17.7
Average years of completed schooling	4.5	4.3	4.4	5.4	5.4	5.3	4.3
Average number of children	3.0	3.0	3.0	3.2	2.6	3.0	3.0
Share ever been married	0.75	0.76	0.75	0.77	0.74	0.76	0.76
Share live in an urban area	0.35	0.30	0.35	0.40	0.30	0.35	0.35
Share of children died age before age 18	0.15	0.17	0.16	0.13	0.12	0.14	0.16
Share of children born in year ending 0 or 5	0.21	0.21	0.21	0.21	0.20	0.20	0.21

Notes: See section 2.3. *Data source*: Demographic and Health Survey (ICF International 1986–2018). The surveys were administered in the following countries and years: Angola (2015), Benin (1996, 2001, 2017), Burkina Faso (1993, 1998, 2003), Burundi (2016), CAR (1994), Cameroon (1991, 2004,), Cote d'Ivoire (1994), DRC (2007), Egypt (1992, 1995, 2000, 2003, 2005, 2008), Eswatini (2006), Ethiopia (2000, 2005, 2016), Ghana (1993, 1998, 2003, 2008), Guinea (2005), Kenya (2003, 2008), Lesotho (2004, 2009), Liberia (2007, 2009), Madagascar (1997, 2008), Malawi (2000, 2004, 2010, 2015), Mali (1995, 2001, 2006), Morocco (2003), Namibia (2000, 2006), Niger (1992, 1998), Nigeria (1990, 2003, 2008), Rwanda (2005), Senegal (1992, 1997, 2005, 2008), Sierra Leone (2008), Tanzania (1999, 2015), Togo (1988, 1998), Uganda (2000, 2006, 2016), Zambia (2007, 2013), Zimbabwe (1999, 2005, 2015).

Table 3: Changes in fertility following natural disasters

	(1) Drought	(2) Flood	(3) Earthquake	(4) Tropical cyclone	(5) Other storm	(6) Epidemic
(a) Main specification						
Disaster occurred	-0.0059** (0.0026)	0.000029 (0.0023)	-0.011 (0.0092)	-0.060*** (0.0085)	-0.0053 (0.0088)	0.017*** (0.0023)
Average births after no disaster	1.18	1.18	1.18	1.18	1.18	1.18
Percent change after a disaster	-0.5**	0.003	-0.9	-5.1***	-0.5	1.4***
(b) Percentage change under alternative specifications						
Only districts with or next to a disaster	-1.0	0.7	-6.4***	-2.2	-2.9	2.5***
Person fixed effects	-1.9***	0.5*	-2.5**	-7.0***	-0.2	1.9***
Ages 15–29	-0.5**	0.01	-1.3	-5.1***	1.0	1.3***
Ages 30–44	-1.0**	0.03	0.006	-2.7*	-4.2***	2.3***
Urban areas	-0.1	-0.1	0.4	-5.5***	0.5	1.0***
Rural areas	-0.7***	-0.02	-2.5*	-4.7***	-0.8	1.5***
Everyone regardless of migration status						
Disasters that affected ≥500,000 people	-0.9***	1.6***		-2.5*		3.6***
Disasters that affected <500,000 people	1.3***	-0.2	-0.9	-5.9***	-0.5	1.4***
Area at high risk of disaster	-1.8***	0.2	-0.4	1.5		
Area at low risk of disaster	-1.5**	1.1*	-3.0***	1.2		

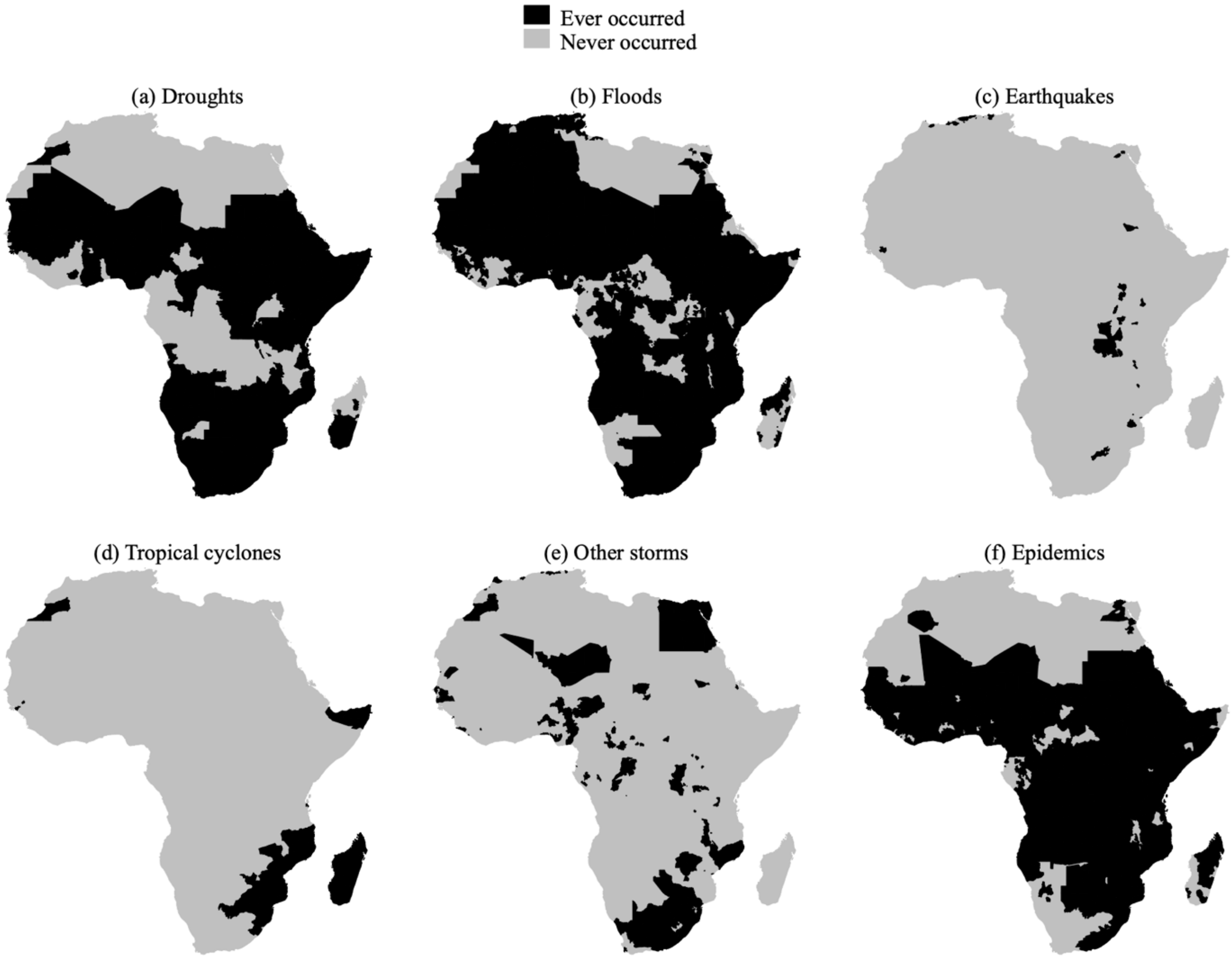
Notes: Regressions are performed according to equation 1. The dependent variable is number of children born within the following five years. Each regression includes demographic controls (age in the year, number of children born by the year, an indicator variable equal to one if the woman had ever been married by the year, years of schooling completed when surveyed, and urban location when surveyed), district fixed effects, year fixed effects, and district-specific linear time trends. For the main specification, there are 4,346,001 observations (one per woman per year she was aged 15–44 and lived at her current location) and R^2 is 0.21 in each regression. Estimates are missing in panel (b) for the following reasons: there were no large earthquakes or other storms, and risk is not measures for other storms or epidemics. Standard errors are clustered by district-by-year and by woman. Statistical significance at the 10%, 5%, and 1% levels denoted by *, **, and ***. See section 3. *Data sources*: Emergency Events Database (Guha-Sapir et al. 2018), Global Administrative Unit Layers (FAO 2015), Demographic and Health Survey (ICF International 1986–2018), Global Risk Data Platform (United Nations Environment Programme 2019).

Table 4: Changes in employment, wealth, and child mortality, and test of model predictions

		(1) Drought	(2) Flood	(3) Earthquake	(4) Tropical cyclone	(5) Other storm	(6) Epidemic
(a) Dependent variable: Employed							
Disaster occurred		-0.023**	-0.013	-0.041**	-0.019	0.043**	0.0055
		(0.011)	(0.0085)	(0.019)	(0.017)	(0.019)	(0.0093)
Mean of dep. var. when no disaster occurred		0.64	0.64	0.64	0.64	0.64	0.64
Percent change after disaster		-3.6	-2.0	-6.4	-3.0	6.7	0.9
(b) Dependent variable: Wealth index							
Disaster occurred		-0.52***	0.14	0.029	0.092	0.0034	0.017
		(0.19)	(0.11)	(0.13)	(0.058)	(0.45)	(0.073)
Mean of dep. var. when no disaster occurred		0.21	0.12	0.14	0.14	0.14	0.13
Percent change after disaster		-247.6	116.7	20.7	65.7	2.4	13.1
(c) Dependent variable: Num. of children died							
Disaster occurred		-0.00052	-0.00063	0.00055	-0.0015	0.0057***	0.00040
		(0.00042)	(0.00042)	(0.0014)	(0.0014)	(0.0020)	(0.00043)
Mean of dep. var. when no disaster occurred		0.038	0.038	0.038	0.038	0.038	0.038
Percent change after disaster		-1.4	-1.7	1.4	-3.9	15.0	1.1
(d) Test of model predictions	Prediction						
Avg. num. of births after no disaster occurred and did not have a child die		1.17	1.17	1.17	1.17	1.17	1.17
Additional births after a disaster occurred and no child died (β_1)	$\beta_1<0$	-0.0049*	0.0018	-0.010	-0.060***	-0.0050	0.018***
		(0.0026)	(0.0023)	(0.0099)	(0.0084)	(0.0084)	(0.0024)
Additional births after no disaster occurred and a child died (β_2)	$\beta_2>0$	0.23***	0.24***	0.23***	0.23***	0.23***	0.23***
		(0.0028)	(0.0028)	(0.0027)	(0.0027)	(0.0027)	(0.0028)
Additional births after a disaster occurred and a child died (β_3)	$\beta_1<\beta_3<\beta_2$	0.21***	0.19***	0.19***	0.20***	0.17***	0.22***
		(0.0084)	(0.0092)	(0.068)	(0.046)	(0.051)	(0.0094)

Notes: Regressions are performed according to equation 10 in panels (a), (b), and (c), and equation 11 in panel (d). Each regression includes the same demographic controls, district fixed effects, year fixed effects, and district-specific linear time trends as in Table 3. In panel (a), there are 903,058 observations, one per woman. In panel (b), there are 800,311 observations, one per woman. In panels (c) and (d), there are 4,346,001 observations, one per woman per year she was aged 15–44 and lived at her current location. For each type of disaster, R^2 is 0.19 in panel (a), 0.24 in panel (b), 0.04 in panel (c), and 0.21 in panel (d). Standard errors are clustered by district-by-year and by woman. Statistical significance at the 10%, 5%, and 1% levels denoted by *, **, and ***. See section 5.1. *Data sources*: Emergency Events Database (Guha-Sapir et al. 2018), Global Administrative Unit Layers (FAO 2015), Demographic and Health Survey (ICF International 1986–2018).

Figure 1: Location of natural disasters



Notes: Each map records the districts where a disaster occurred anytime between 1980 and 2016. See section 3.2.
Data sources: International Disasters Database (Guha-Sapir et al. 2018), Global Administrative Unit Layers (FAO 2015).