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Fertility after natural disaster: Hurricane Mitch in Nicaragua

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Abstract

This investigation evaluates the effect of Hurricane Mitch on women's reproductive outcomes throughout Nicaragua. This research aim is achieved by analyzing a unique Nicaraguan Living Standards Measurement Study panel dataset that tracks women's fertility immediately before and at two time points after Hurricane Mitch, combined with satellite-derived municipality-level precipitation data for the 10-day storm period. Results show higher odds of post-disaster fertility in municipalities receiving higher precipitation levels in the immediate post-Hurricane Mitch period. However, fertility normalizes between disaster and non-disaster areas four to six years after the storm. These findings suggest that the disruptive effects of a natural disaster such as Hurricane Mitch can have an initial stimulative effect on fertility but the effect is ephemeral.

Keywords

fertility; natural disaster; Hurricane Mitch; Nicaragua

Introduction

Fertility decision-making is a complex process even during stable times. For couples conception is not automatic; nor is bringing a successful conception to term. In contrast, at larger regional or national scales, short- and long-term fertility trends are less variable. There are, however, natural and human-caused events that can disrupt fertility, especially in the short-term and perhaps longer. Acute natural disasters including earthquakes and subsequent tsunamis (e.g., Carta et al., 2012; Hamilton, Sutton, Mathews, Martin, & Ventura, 2009; Nobles, Frankenberg, & Thomas, 2015), severe storm events (e.g., Buekens, Xiong, & Harville, 2006; Tong, Zotti, & Hsia, 2011), as well as anthropogenic war and acts to elicit terror (e.g., Agadjanian & Prata, 2002; Blanc, 2004; Heuveline & Poch, 2007; Lindstrom & Berhanu, 1999; Rodgers, John, & Coleman, 2005) force couples to reassess fertility timing and impede access to family planning services. More germane to this investigation, several post-hurricane fertility studies, all conducted in the United States, have found both fertility increases and decreases following storm events (Cohan & Cole, 2002; Evans, Hu, & Zhao, 2010; Hamilton et al., 2009). Given that all post-hurricane fertility research has been conducted in the developed world and even there the results are inconclusive, there is a need for similar research in the less developed world where families may be more sensitive to

resultant social and economic upheaval. Hurricane Mitch and the demographic and geographic data collected immediately before and after its onslaught provide a unique opportunity for addressing this research gap. Accordingly, this investigation determines the short- and medium-term effect of Hurricane Mitch, a major natural disaster, on fertility dynamics in Nicaragua. Specifically, pre- and post-Hurricane Mitch panel data provided by the Living Standards Measurement Study are combined and analyzed with municipality-level mean precipitation data for the 10-day storm period provided by the Tropical Rainfall Measuring Mission (TRRM) to evaluate the fertility impact on areas hardest hit by the storm.

Hurricane Mitch, considered one of the most destructive hurricanes to hit the Americas in recent centuries, originated as a tropical depression on October 22, 1998, in the Caribbean Sea, 580 kilometers south of Jamaica. Five days later, Mitch moved westward. Sitting 100 kilometers off of Honduras's northern coast, Mitch developed into a category five monster with maintained wind speeds of 180 mph and gusts measured at over 200 mph for a 33-hour period (Lott, McCown, Graumann, Ross, & Lackey, 1999). On October 28, Mitch made landfall in north-central Honduras where over three days it moved westward, skirting the Honduran-Nicaraguan border before exiting Central America through southern Mexico. Even though the eye of the storm never entered Nicaragua, its prolonged duration in close proximity had devastating effects on Nicaragua's infrastructure. Massive flooding and numerous landslides, including the partial collapse of Volcano Posoltega, resulted in numerous deaths and displacements (Lott et al., 1999). In total, an estimated 3,800 Nicaraguans died while another 867,000 were displaced by the storm – representing 20 percent of Nicaragua's population (Lott et al., 1999; United Nations, 1999).

Nicaraguan fertility dynamics at the end of the 20th century, just as Hurricane Mitch entered the scene, were rapidly declining. Between the years of 1980 and 2006, its total fertility rate (TFR) fell more than 50 percent, from 6.05 to 2.70 (Vatsia & Chowdhury, 2010). This end-of-century fertility decline coincided with a major upheaval in Nicaragua's national leadership with the successful Sandinista Revolution in 1979. As a whole, the Sandinistas and subsequent Nicaraguan administrations promoted policies and programs that elevated the role of women in society. For example, they furthered girl's education, women's employment opportunities, and primary health care knowledge and access – including family planning information and contraceptive method availability (Vatsia & Chowdhury, 2010). Furthermore, infant mortality (IMR) and under-five mortality rates (U5MR) dropped appreciably between 1990 and 2012 (IMR fell from 50 to 21; U5MR fell from 66 to 24) (UNICEF, 2014). The combination of these many fertility-lowering factors likely contributed to the just above replacement-level fertility present in Nicaragua today – TFR of 2.3 in 2014 (World Bank, 2015).

Investigating the effects of natural disasters – particularly hurricanes – on demographic factors such as fertility is instructive given the predicted rise in the frequency and intensity of these storms in an era of global climate change (Elsner, Kossin, & Jagger, 2008; Knutson et al., 2010; Webster, Holland, Curry, & Chang, 2005). Dramatic alterations in fertility patterns in response to natural disasters can have both short-, medium- and long-term ramifications for local resources and national economies. For example, local area health

resources may be either nonexistent or overly taxed during the recovery process. Thus, women in natural disaster areas may not have access to comprehensive pregnancy and post-partum care in the near term. This is especially relevant to Hurricane Mitch where it damaged and destroyed hundreds of rural health centers (United Nations, 1999). Additionally, livelihoods especially in rural areas, may take a short-term economic hit due to the loss of crops and other productive assets, and indirectly influence couples to delay childbearing until economic stasis has resumed. Research shows that Hurricane Mitch *did not* have an appreciable long-term impact on consumption levels (Premand, 2010) or overall productive asset holdings in Nicaragua (Jakobsen, 2012). However, it was noted that the storm's impact disproportionately struck the poorest households in the region (Jakobsen, 2012; Morris et al., 2002). In the medium and longer terms, educational infrastructure and employment dynamics may be disrupted if schools and/or local economies do not have sufficient space or resources to accommodate anomalous spikes (or drops) in population. Such isolated cohort-level fertility aberrations can be particularly acute when combined with other population shifts attributable to natural disaster-induced mortality and migration change.

Theoretical approaches to fertility change in response to natural disasters

The influence of natural disasters on fertility is multifaceted with counteracting forces that facilitate and hinder reproductive activity and success. From the reproduction disruption perspective, the disaster itself may result in physical harms (including miscarriages, preterm births), deaths and displacements, along with a long period of cleanup and reconstruction that can act to hinder reproductive activity. Additionally, the immediate diminishing of a household's livelihood may force couples to reassess short-term reproductive planning – essentially leading to delays in childbearing (tempo-effect) while not necessarily a long-term decline in the total of desired or actual children born (quantum-effect) (Bongaarts & Feeney, 1998).

From a reproductive promotion perspective, physical as well as psychological dynamics may hold sway in the back and forth of higher or lower fertility. Just as the disruptive influence of a disaster can hinder fertility, it can also contribute to higher coital frequency especially when couples hunker down in place for long periods of time during storm events (Cohan & Cole, 2002). Furthermore, a barrier to modern contraceptive access can occur during a storm and for a time afterward (Evans et al., 2010). Natural disasters also create a tribal effect where family members come together. From the psychology literature, attachment theory argues that during times of elevated stress, couples seek support and physical closeness/reassurance from loved ones and friends (Belsky, 1999; Hazan & Zeifman, 1999). Such reassuring behavior is thought to increase coital frequency between couples with a concomitant increase in fertility. Cohan and Cole (2002) found evidence for attachment theory in the aftermath of Hurricane Hugo in South Carolina. An additional natural disaster-evoked behavioral response is encapsulated by replacement theory. Replacement theory argues that in the aftermath of a natural disaster with a high death count, couples increase their near-term desire for children as a means to replace lives lost (Rodgers et al., 2005). This theory becomes more relevant in the event of family member deaths, particular one's own children. Strong empirical evidence for replacement theory was found in a study of the

2004 Indian Ocean Tsunami and from post-earthquake fertility research in India, Pakistan and Turkey (Finlay, 2009; Nobles et al., 2015).

Natural disasters and fertility

The effect of natural disasters on demographic factors has been well studied in the mortality, and to a lesser extent, migration arenas. In both contexts, but especially when lives and property are lost, the effects of natural disasters are not distributed equally. A host of socioeconomic factors, particularly access to human and material resources, pose unique risks to women over men and the poor over the wealthy (Blaikie, Cannon, Davis, & Wisner, 2014; Dilley, 2005; Girard & Peacock, 1997; Neumayer & Plümper, 2007). This is particularly applicable to the Hurricane Mitch case in Central America (Cupples, 2007; Morris et al., 2002). In a review of the natural disaster and migration literature, Hunter (2005) described a continuum of effects where major events such as massive floods led to the complete relocation of villages while cyclical cyclone-induced floods in places such as Bangladesh elicited only temporary displacements but subsequent returns. In post-Hurricane Mitch Nicaragua, Loebach (2016) did not find differential international migration patterns between areas of high and low storm-related damage.

In contrast to the well-studied effects of natural disasters on mortality and migration, relatively little complementary research has been undertaken on demography's third process: fertility. The handful of studies in this domain have investigated fertility changes in response to earthquakes, tsunamis, floods, and hurricanes. The directional effect of these natural disasters on fertility vary among and occasionally within disaster types but the majority show positive fertility effects.

All three of the post-earthquake fertility studies identified during a review of the literature largely conform to this norm (Carta et al., 2012; Finlay, 2009; Hosseini Chavoshi & Abbasi-Shavazi, 2015). Specifically, in a 2009 case study documenting post-earthquake fertility in the Italian village of L'Aquila, researchers found a 27 percent jump in births nine to 15 months following the earthquake (Carta et al., 2012). The authors argued that many of the disaster victims sought motherhood as a means to normalize their lives following an emotionally traumatic experience. In another earthquake study, the 2003 Bam earthquake in south-central Iran that caused over 33,000 deaths, investigators noted a decrease in the local fertility rate in 2004 followed by a recuperative fertility rise in 2006–2007 (Hosseini Chavoshi & Abbasi-Shavazi, 2015). Finally, in a more extensive post-earthquake fertility study spanning three countries (India, Pakistan and Turkey), a higher fertility response was found in earthquake-exposed areas compared with similar areas in other parts of their respective countries (Finlay, 2009). Higher fertility was also noted for mothers who lost children to a natural disaster.

Only one contemporary study evaluated the effect of an earthquake-induced tsunami on fertility: the 2004 Indian Ocean Tsunami that struck Aceh Province in northwestern Indonesia. Similar to the earthquake studies, this examination found elevated fertility rates in the disaster zone one to four years following the tsunami (Nobles et al., 2015). This study also found strong evidence to support the idea that the death of one's child prompts a higher

fertility response. Additionally, it was noted that first-time mothers who resided in the disaster zone initiated childbearing at a higher rate compared with similar women outside the disaster zone. Contrary to these findings, a historic study of Italian and Japanese fertility change in response to earthquakes and tsunamis only found negative natural disaster-related fertility effects (Lin, 2010).

In contrast to nearly all the earthquake and tsunami studies, the only investigation of fertility in the wake of a catastrophic flood – 1997 Red River flood in South Dakota – identified a significant state-wide post-disaster fertility decline (Tong et al., 2011). However, fertility comparisons between the six counties most affected by the flood and the rest of the state did not identify substantial differences.

Within the post-hurricane fertility literature, the results are mixed. For instance, in a study prepared in the aftermath of Hurricane Katrina, Hamilton et al. (2009), noted a 19 percent fertility decline in the 12-month post-storm period compared to the 12-month pre-storm period for the 14 Federal Emergency Management Agency designated disaster counties and parishes. In contrast, in the year following the arrival of Hurricane Hugo in South Carolina, a rise in statewide fertility occurred compared with pre-storm fertility trends (Cohan & Cole, 2002). Furthermore, higher fertility was also observed in South Carolina counties that received the brunt of Hurricane Hugo's impact compared to less impacted counties. In a unique study that sought to determine whether catastrophic storm events were correlated with baby boomlets or busts, Evans et al. (2010) analyzed storm advisory data, as a proxy for hurricane severity, in relation to birth outcomes 38 weeks following storms in U.S. Atlantic and Gulf Coast counties. They found a positive fertility effect following low-intensity storm warnings but a negative fertility effect following high-intensity storm warnings.

Research methods

To generally assess the effect of Hurricane Mitch on national-level Nicaraguan fertility, age-specific fertility rates (ASFRs) and TFRs are calculated for the pre-storm period (1998) and two post-storm periods (2001 and 2005) from the *Encuesta Nacional de Hogares Sobre Medicion de Niveles de Vida* (ENMV) dataset. To more specifically assess the municipality-level effect of the storm on fertility, multivariate logistic regression is used. Specifically, the influence of the storm's intensity on the odds that a reproductive-aged women (aged 15–49) had a birth is assessed during two time periods: (1) the two-year post-hurricane conception period (1999–2001) and (2) a two-year period, five to seven years after the hurricane (2003–2005). To achieve these ends, three paneled waves (1998, 2001 and 2005) of the ENMV are combined with mean rainfall levels during the 10-day Hurricane Mitch storm period. The ENMV data, collected by the Nicaraguan Institute of Statistics and Census with assistance from the World Bank, have many advantages for assessing the effect of a natural disaster on fertility including: (1) three paneled survey waves that narrowly bracket the storm event in time; (2) national representativeness, including fertility histories, for over 2,000 reproductive-aged women in each of the three survey waves; and (3) the inclusion of a suite of individual- and household-level variables that control for differences in demographic, geographic and socioeconomic characteristics. The 1998 survey wave was collected from

April through September – less than one month before Hurricane Mitch struck the Central American Isthmus. Survey waves 2001 and 2005 were collected between May-August and July-October for their respective survey years. The two post-Hurricane Mitch waves allow for both short- (zero to two years after) and medium- (four to six years after) term assessments of Hurricane Mitch's effect on Nicaragua's fertility dynamics.¹ One limitation of this approach relates to attrition (further described below), with women falling out of the 1998/2001 analysis if they were not encountered in both 1998 and 2001; and falling out of the 1998/2005 analysis if they were not encountered in 1998 and either 2001 or 2005. Specifically, 5,676 women with complete information on relevant measures are retained in the 1998 sample; 3,235 (57%) of these women are retained for analysis in 2001 and 2,144 (38%) are retained for analysis in 2005.

Dependent and independent variables

The 2001 and 2005 survey waves contain demographic and fertility panels from which the study's dependent variables were created: whether at least one child was *conceived and born alive* (yes/no) during a two-year period by each of the study's reproductive-aged women (1) after Hurricane Mitch and by mid-2001 (August 1999–July 2001) and (2) in the two-year period preceding the 2005 survey wave (November 2003–October 2005). Figure 1 provides a timeline of events including when Hurricane Mitch struck Central America, the months of data collection for the three paneled ENMV survey waves and the two respective two-year birth hazard periods. It should be noted that the first two-year birth hazard period is lagged by nine-months following Hurricane Mitch to account for the post-conception to birth period immediately following the storm. Following a similar methodology used by Nobles et al. (2015), this approach maximizes the amount of time that a reproductive-aged woman can contribute a birth hazard to the analysis following Hurricane Mitch, prior to the end of data collection for the second ENMV survey wave in 2001. For consistency, a similar two-year birth hazard period is analyzed between the second and third data collection periods. These two-year birth hazard dependent variables provide information on whether, among other conditions and constraints, women of reproductive age across Nicaragua initiated or deferred fertility decision-making in the immediate aftermath of the hurricane in response to its destructiveness or due to assistance resources that were brought into the disaster zone for coping and recovery purposes.

The primary predictor of fertility is a measure that captures Hurricane Mitch's intensity at the municipality level (standard errors are clustered at this level). Specifically, this variable represents mean rainfall totals measured in millimeters for the 10-day storm period (October 22–31, 1998). Figure 2 displays measured Hurricane Mitch mean rainfall intensity by Nicaraguan municipality ranging from 55 to 1,040 mm. In the analyses, mean rainfall totals are natural log (ln) transformed to better approximate a linear relationship with fertility. Mean storm rainfall was derived from 0.25 degree spatial resolution daily rainfall totals measured by the Tropical Rainfall Measuring Mission (TRMM) project. Accumulated rainfall totals were computed using Geographic Information System (GIS) software for each

¹To clarify, even though the medium-term post-Hurricane Mitch fertility period assessed is five to seven years after the storm, the actual effect period is four to six years post-Hurricane Mitch when accounting for the nine-month conception to birth period.

Nicaraguan municipality. Due to coarse spatial data grid spacing, resampling methods were used to more accurately estimate mean rainfall accumulation for the storm event.

Using cumulative mean rainfall as a measure of a storm's destructiveness and ultimately as a proxy for its overall effect on post-storm fertility has its limitations. While higher levels of rainfall may adequately capture the destructive effect of a hurricane that is attributable to landslides or immediate area flooding, they may not accurately reflect the harm caused by other storm-related forces such as high winds or downstream flooding. However, this continuous cumulative mean rainfall measure, arguably, represents a more accurate estimate of the storm's local area impact compared to other methodologies that dichotomize storm-affected counties or municipalities as affected/unaffected (e.g., Hamilton et al., 2009; Jakobsen, 2012; Van den Berg, 2010). There are also a host of post-disaster responses that may influence research outcomes, including the infusion of resources to both cope with the immediate impact of the storm and longer-term recovery efforts. These resources may have counteracting influences on the outcomes of interest if a storm's harms are outweighed by its benefits by, for example, the creation of employment opportunities or increases in access to healthcare such as family planning resources that were less available prior to the disaster.

The investigation's control variables were derived from pre-Hurricane Mitch conditions obtained from the 1998 survey wave. A suite of individual-level demographic control variables common to most quantitative fertility studies are included: woman's age, woman's age-squared, marital status (unmarried/married), woman's educational attainment (grouped into none, some primary, secondary or more), and total children ever born by 1998. A variable designating whether an own-child had died within the 12-month period following Hurricane Mitch and nine months prior to a birth was created. However, because of the limited number of births that met this condition (three out of 504 births), this variable was excluded from the final analyses. Individual-level variables are included for each reproductive-aged woman (between the ages of 15 and 49 years) surveyed during the respective time points (1998 and 2001 or 1998 and 2005).

The investigation also includes household-level geographic and socioeconomic control variables. In particular, an asset index was created to address inter-household socioeconomic variability. Following the methodology of Filmer and Pritchett (2001), McKenzie (2005) and Filmer and Scott (2012), principal components analysis was used to generate an index variable (ranging from zero to 10) based on a number of household attributes including home composition, access to utilities and infrastructure, and ownership of durable goods. The asset index is used in lieu of a direct measure of household income because the latter has been shown to be highly variable and difficult to measure, while the former better reflects relative household wealth, which can influence household decision-making (Acosta, 2011). Two geographic variables are included to capture household rurality and whether study participants resided along the Atlantic Coast of Nicaragua. The "Atlantic region" variable is included to separate historically high fertility experienced in the remote, rural areas of the North Atlantic Autonomous Region (RAAN), South Atlantic Autonomous Region (RAAS) and the Rio San Juan area that contain high proportions of indigenous peoples and descendants of African slaves (Vatsia & Chowdhury, 2010).

Results

Descriptive findings

To provide a general sense of national-level fertility change during the 1998 to 2001 to 2005 study periods, ASFRs and TFRs were calculated for all reproductive-aged women in each survey cross-section and are exhibited in Panel I of Table 1.² Panels 2 and 3 display similar ASFR and TFR information for the subset of women residing in below and above median Hurricane Mitch precipitation zones, respectively. Regarding ASFRs, all three survey waves show fertility rising and peaking within the 20–24 year age group and declining thereafter. Regarding TFRs and corresponding with longer-term fertility trends reported elsewhere (see Vatsia & Chowdhury, 2010), the three survey waves show a downward fertility trend, moving from a TFR of 3.01 to 2.81 to 2.75 between 1998, 2001 and 2005, respectively. A similar downward TFR time trend is seen in the below median Hurricane Mitch precipitation zones (Panel II), while for women residing in above median precipitation zones, TFRs drop initially from 2.62 to 2.36 between 1998 and 2001, but stalls by 2005 (Panel III). Not shown, calculated TFRs for reproductive-aged women that remained in the study between the survey waves are consistently lower overall and within the below and above median precipitation subsamples, compared with the full cross-sectional samples.

Summary statistics of common fertility-related characteristics for the study's reproductive-aged women are presented in the first column of Table 2. On average, pre-storm reproductive-aged women in the study were 28.0 years old, had 2.6 children and completed 5.5 years of schooling and just over half were married by 1998. Additionally, less than half of these women resided in rural communities in relatively poor households.

One potential form of bias inherent in this investigation is differential fertility outcomes by rainfall intensity between women remaining in the study compared with women forced/prompted to leave the study by Hurricane Mitch or some other factor prior to the 2001 and 2005 resurvey periods. As mentioned above, research findings on the effect of natural disasters on migration vary by the extent and intensity of the disaster event (Hunter, 2005). The one study that specifically assesses the influence of Hurricane Mitch on Nicaraguan international out-migration did not find a significant effect (Loebach, 2016). Nevertheless, to explore the possibility of differential fertility among women remaining and dropping out of the study, further precipitation and fertility comparisons between women retained and lost to follow-up for the 2001 and 2005 data panels are presented in columns two and three and five and six of Table 2, respectively. Additionally, two-sided t-test p-values that reflect precipitation and fertility differences between women retained and lost to follow-up for their respective years are displayed in columns four and seven. Women lost to follow-up are defined for the 2001 sample as those that appeared in 1998 but not in 2001; for the 2005 sample as those that appeared in 1998 but not in either 2001 or 2005. Women lost to follow-

²Conceptually, to maintain as large a sample size as possible from which to calculate TFRs and ASFRs and given no justifiable reason to exclude women lost to follow-up in these calculations, all reproductive-aged women by study year (1998, 2001 and 2005) were evaluated. This differs from the sub-set of reproductive-aged women – accounting for women lost to follow-up – that were used in the respective longitudinal logistic regression findings displayed in Table 3.

up could have fallen out of the study for a number of reasons including out-migration, local moves not tracked by survey enumerators, or refusals.

The descriptive statistics shown in Table 2 show differences among women who remained versus those that dropped out of the study between 1998 and 2001 or 2005. The first notable difference is women lost to follow-up compared to those that remained in the study in both 2001 and 2005 were from areas that received lower average precipitation during the Hurricane Mitch storm event. This is important because it suggests that the storm's intensity was *not* an important migration push factor that led to higher rates of attrition. Regarding fertility characteristics, women that remained in the study were older, had more children to date, were more likely to have been married, and had higher levels of completed education by 1998. Additionally, retained women were more likely to be from rural areas and to possess slightly lower household assets than women lost to follow-up for both survey waves. In total these fertility differences, with the exception of the percentage of women from rural areas which was non-significant, argue that had the women that were lost to follow-up remained in the study that their fertility as described in the next section's logistic regression results would have been even higher than currently displayed. This is based on the fact that the mean age of women lost to follow-up was closer to the 20–24 age group (the age group with the highest ASFR) than for the women retained in the study. Additionally, the lower total children born to date and the percentage married for women lost to follow-up during the pre-storm 1998 period suggests that they would have likely increased these characteristics at a higher rate compared to their retained women counterparts, thus leading to higher fertility among study women. Additionally, having lower years of completed education and household assets are also consistent with higher fertility.

Longitudinal logistic regression findings

Logistic regression results are displayed in Table 3. The primary finding in this study is a positive effect of Hurricane Mitch on fertility in the nearly two-year period following its Central American landfall. Specifically, a one-unit increase in logged cumulative rainfall (172% increase in cumulative rainfall) correlates with a 39 percent increase in the odds that a reproductive-aged woman in the study would have conceived and given birth to a child by mid-2001 when all other variables are held constant. To put this result into perspective, a reproductive-aged woman that lived in the northwest corner of Nicaragua where mean cumulative rainfall was about 1,000 mm had a 195 percent higher odds of giving birth compared with a similar woman that lived in the southeastern corner where mean cumulative rainfall was about 200 mm over the 10-day Hurricane Mitch period. A notable additional finding is that the disruptive hurricane effect on fertility dissipates in the medium-term as indicated by the smaller and statistically insignificant odds ratio for $\ln(\text{mm})$ precipitation by 2005.

As a test of model robustness, I also analyzed the correlation between birth hazards between May 1996 and April 1998 – a two-year time period that falls completely before Hurricane Mitch – and mean Hurricane Mitch precipitation totals by Nicaraguan municipality. This test provides an indication of whether Hurricane Mitch disproportionately struck areas that were predisposed to higher fertility. Results displayed in Table 3 demonstrate a lower and

insignificant correlation between $\ln(\text{mm})$ rainfall and pre-Hurricane Mitch fertility (odds ratio 0.99, p-value 0.93). This test suggests that the main study results detailed above accurately reflect a stimulative effect of Hurricane Mitch on the two-year post-storm fertility in Nicaragua.

The main study's control variables are largely statistically significant and align with expectations for the 1999 to 2001 study period. In particular, a one-year increase in a woman's age is correlated with a 27 percent increase in the odds of child birth while the age-squared term redirects this trend downward at older ages. Interestingly, the point at which the age-squared term hits its maximum point and starts to trend downward is 22.7 years of age in 2001 (further discussed below). Additionally, women married in 1998 had a 120 percent higher odds of giving birth by mid-2001 compared with non-married women. In contrast, women with more education are less likely to have had children in the roughly two-year period after Hurricane Mitch. However, only women with some primary school education are significantly different (26% lower odds) than women without any education. Of the household-level variables, only residence along the Atlantic coast and the 1998 asset scores are significant. Specifically, women living in the Atlantic region have an 89 percent higher odds of giving birth, while a one-unit change in a household's asset score is associated with a 21 percent lower odds of giving birth by a reproductive-aged woman after Hurricane Mitch.

Only a few notable control variable differences between the two survey waves exist. In particular, having been married in 1998 does not have a significant influence on the odds of birth between mid-2003 and mid-2005, while rurality becomes statistically significant during the second birth hazard period. Specifically, residing in a rural household is correlated with a 59 percent higher odds of giving birth compared with residing in an urban household between 2003 and 2005. Perhaps more noteworthy, the correlation between 1998 household assets and birth during the second time period is not statistically significant. This latter finding contrasts with the strongly significant 1999–2001 survey period finding. Finally, the point at which the age-squared term bends the rise in births downward as women's age increases occurs at 25.0 years of age in 2005.

Discussion

This investigation capitalizes on a unique opportunity to combine national-level demographic panel data that tracks women's reproduction immediately prior to and at two time points after Hurricane Mitch with mean cumulative rainfall derived from satellite imagery to determine the post-storm effect on fertility. The study's findings show that Hurricane Mitch, one of the most powerful Atlantic storms of record, had a stimulative effect on fertility in the two-year post-storm period. This conclusion is supported by a significantly higher odds of a child being born in areas with higher mean precipitation. This conclusion is further strengthened by the fact that Hurricane Mitch disproportionately impacted Nicaragua's more developed areas – areas that also expressed the lowest fertility rates in the country – including the major metropolitan areas of Managua and Leon.

Study results align with many general natural disaster-related fertility findings (Carta et al., 2012; Finlay, 2009; Hosseini Chavoshi & Abbasi-Shavazi, 2015; Nobles et al., 2015). However, only one of three published post-hurricane studies reported a similar fertility effect; that of the aftermath of Hurricane Hugo in South Carolina (Cohan & Cole, 2002). Considering that higher death tolls, physical displacements, levels of infrastructure destruction, and much longer recovery periods are more common in developing world natural disaster situations compared with their more developed world counterparts, it was not a given that fertility effects would be similar between the two regions. Results from this investigation thus provide evidence that a substantial hurricane event can have a stimulative fertility effect in a developing world situation similar to that witnessed in the more developed world.

Although fertility spikes upward in the short-term (two-year post-disaster), the rise in fertility is short-lived. In as little as six years after the storm event, individual-level fertility differences between high and low impact municipalities normalize. An interesting direction of future research based on these findings would be to determine if children born in the immediate aftermath of the storm represent a shift in the timing (tempo) of childbearing – having children sooner than originally planned – or whether couples that endured Hurricane Mitch have more children (quantum) over their lifetimes than if they had not been impacted by the storm.

Additional research results are worthy of discussion. One anomaly pertains to the exceptionally young average age (22.7 years in 2001) at which the odds that a woman gives birth begins to decline – this figure roughly approximates the mean age of childbearing in the 2001 sample. For comparison, the United Nations (2011) reported a mean age of childbearing to be 26.7 years for Nicaragua in 2005. Furthermore, for 175 countries with populations above 100,000, the mean age of childbearing ranged from 25.1 to 32.7 with an average of 28.7 years and a standard deviation of 1.4 years. This result suggests that relatively young reproductive-aged women contributed the bulk of childbearing in the years that immediately followed Hurricane Mitch. The ASFRs, which only capture one year of birth data (mid-2000 and mid-2001), are less supportive of this point by suggesting that most births in 2001 were to women between the ages of 20 and 29.

A second noteworthy finding is the substantial difference between the effect of 1998 household assets on respective 2001 and 2005 fertility. In general, more affluent women/couples have, on average, fewer children during their lifetimes and thus at any given point in time are less likely to have children compared with less affluent women/couples (G.S. Becker & Lewis, 1974; G. S. Becker & Tomes, 1976). However, the fact that the 1998 asset score has a strong and statistically significant association with lower fertility in the immediate post-hurricane period that disappears four to six years after the hurricane suggests that wealth empowers some women to more strongly control their fertility timing by postponing childbearing until more stable times have returned. This result might also reflect the fact that wealth can rapidly change within a seven-year period, especially if reproductive-aged women are moving between singlehood and marriage.

The study's results conform to post-disaster attachment and replacement fertility theories. It is possible that aspects of these theories, in addition to a likely disruption in the provision of family planning services in high-disaster areas and the possible fertility response to a rise in storm-induced miscarriages, conspired to drive up fertility after the hurricane. Unfortunately, the ENMV does not provide information on whether couples became closer, lacked access to modern contraceptives in the storm's immediate aftermath or had more miscarriages to credibly test attachment theory or the family planning disruption/physical harm scenarios. Regarding replacement theory, given the limited number of own-child deaths preceding births identified in the 2001 ENMV data wave, it does not appear that this theory adequately explains the study's elevated post-disaster fertility findings.

This investigation has some limitations that should be disclosed. First, individuals and entire households that left the study area between 1998, 2001 and 2005 were not followed – signifying a high level of attrition. Specifically, as shown in Table 3, the number of women lost to attrition by 2005 represents a third (1,073 out of 3,207) of the women analyzed between 1998 and 2001. This is a concern because reproductive-aged women lost to follow-up could be fundamentally different in their fertility behavior compared with women remaining in the study. However, as detailed above, the differences in both rainfall and fertility characteristics between women retained and those lost to follow-up suggest that had the latter group of women remained in the study, that they would have only strengthened the logistic regression fertility findings. Second, spatial autocorrelation is a concern because Hurricane Mitch's footprint was not random in its relation to Nicaraguan fertility. Rather, higher levels of rainfall are correlated with more affluent, urban Nicaraguan municipalities that also, on average, express lower fertility levels compared to lesser-impacted areas – this represents another form of potential bias and a limitation of this study.

In summary, results from this study provide evidence that fertility disruption following Hurricane Mitch, while substantial and significant, was short lived. From a long-term human resource and budgetary standpoint, this finding perhaps offers a silver lining to a very traumatic event.

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Fig. 1.
Timeline of three LSMS survey periods and two birth hazard periods

Fig. 2.
Hurricane Mitch mean accumulated rainfall in Nicaragua, October 22–31, 1998

Table 1

Age-specific and total fertility rates for Nicaragua by survey wave

Panel I – All Women		Survey Wave			
		1998		2001	
Age group		Women	Births/1000 women	Women	Births/1000 women
15–19		1468	104.22	1384	82.37
20–24		792	166.67	824	150.49
25–29		848	129.72	808	139.85
30–34		736	104.62	713	91.16
35–39		656	70.12	648	60.19
40–44		506	23.72	539	31.54
45–49		418	2.39	37	6.86
Total Women			5,424		5,353
Total Fertility Rate			3.01		2.81
Panel II – Below Median Hurricane Mitch Precipitation					
		Survey Wave			
		1998		2001	
Age group		Women	Births/1000 women	Women	Births/1000 women
15–19		734	121.25	714	99.44
20–24		398	195.98	398	163.32
25–29		433	136.26	395	159.49
30–34		344	133.72	348	112.07
35–39		335	65.67	316	69.62
40–44		248	28.23	267	41.20
45–49		194	0	216	9.26
Total Women			2,686		2,654
Total Fertility Rate			3.41		3.27
Panel III – Above Median Hurricane Mitch Precipitation					
		Survey Wave			
		1998		2001	
Age group		Women	Births/1000 women	Women	Births/1000 women
15–19		734	121.25	714	99.44
20–24		398	195.98	398	163.32
25–29		433	136.26	395	159.49
30–34		344	133.72	348	112.07
35–39		335	65.67	316	69.62
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30–34		344	133.72	348	112.07
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40–44		248	28.23	267	41.20
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Total Women			2,686		2,654
Total Fertility Rate			3.41		3.27

Panel I – All Women	Survey Wave					
	1998			2001		
	2005			2001		
	Women	Births/1000 women	Births/1000 women	Women	Births/1000 women	Births/1000 women
Age group	Women	Births/1000 women	Births/1000 women	Women	Births/1000 women	Births/1000 women
15–19	734	87.19	64.18	670	831	79.42
20–24	394	137.06	138.50	426	596	132.55
25–29	415	122.89	121.07	413	577	124.78
30–34	392	79.08	71.23	365	476	79.83
35–39	321	74.77	51.20	332	416	36.06
40–44	258	19.38	22.06	272	369	18.97
45–49	224	4.46	4.52	221	360	0
Total Women	2,738		2,699		3,625	
Total Fertility Rate	2.62		2.36		2.36	

Comparisons of Hurricane Mitch precipitation and 1998 fertility-related characteristics among (1) 2001 study women vs. 2001 women lost to follow-up and (2) 2005 study women vs. 2005 women lost to follow-up

Table 2

	1998 Full Sample	2001 Retained	2001 Lost to Follow-up	Two-sided t-test (Retained vs. Lost to Follow-up)	2005 Retained	2005 Lost to Follow-up	Two-sided t-test (Retained vs. Lost to Follow-up)
Hurricane Mitch precipitation	537.4	557.2	511.1	<0.001	566.4	519.8	<0.001
Individual-level							
Mean age	28.0	29.4	26.1	<0.001	29.7	27.0	<0.001
Total children ever born	2.6	2.9	2.3	<0.001	3.0	2.4	<0.001
% married	53.6	55.6	51.0	<0.001	58.8	50.5	<0.001
Mean years of schooling	5.5	5.6	5.4	0.03	5.7	5.4	0.02
Household-level							
% rural	43.6	42.7	44.8	0.12	43.3	43.8	0.75
Mean asset score	2.6	2.7	2.5	<0.001	2.7	2.6	0.055
<i>N</i>	5,676	3,235	2,441		2,144	3,532	

Table 3

Effect of Hurricane Mitch on the odds of a birth

	Pre-Hurricane Study Period (Robustness Check)		Post-Hurricane Study Period (Main Results)			
	1996–1998		1999–2001		2003–2005	
	Odds Ratio	Robust SE	Odds Ratio	Robust SE	Odds Ratio	Robust SE
Ln(Mean Mitch Precipitation)	0.99	0.13	1.39 [*]	0.21	1.16	0.22
Individual-level						
Age 1998	1.27 ^{***}	0.06	1.27 ^{***}	0.07	1.39 ^{***}	0.14
Age-squared 1998	0.99 ^{***}	0.00	0.99 ^{***}	0.001	0.99 ^{***}	0.002
Children ever born 1998	1.53 ^{***}	0.06	1.06	0.04	1.09	0.07
Married 1998	2.41 ^{***}	0.33	2.21 ^{***}	0.30	1.17	0.14
Schooling level 1998 (none – ref.)						
Some primary	1.46 ^{**}	0.21	0.74 [*]	0.10	0.88	0.20
Secondary or more	1.53 [*]	0.28	0.889	0.17	0.95	0.24
Household-level						
Rural	0.93	0.13	1.18	0.14	1.59 [*]	0.33
Atlantic region	1.21	0.30	1.89 [*]	0.51	2.20 [†]	0.98
Asset score 1998	0.87 ^{**}	0.04	0.79 ^{***}	0.03	0.95	0.06
Constant	0.02 ^{***}	0.02	0.003 ^{***}	0.004	0.002 ^{***}	0.005
N	3,207		3,207		2,134	

Level of significance:

p 0.001,**
p 0.01,*
p 0.05,†
p 0.10