Turmoil, Disaster, and Recovery:
Indonesian Fertility in the Context of the 2004 Tsunami

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On December 26, 2004, an earthquake measuring 9.3 on the Richter scale struck off of the coast of Indonesia. The quake, devastating in its own right, displaced over a trillion tons of water that slammed onto the Indonesian shoreline – and the shorelines of the other countries bordering the Indian Ocean – shortly afterward. The damage was vast. Over half a million Indonesians were displaced and over 130,000 were killed (Doocy et al. 2007).

Scientific analysis of the damage and the recovery process has slowly emerged in the ensuing half decade. Most studies have focused on the reconstruction of natural and economic resources, including land, housing, and the area's major industries (Kohl et al. 2005). A few studies have described the recovering mental and physical health trajectories of the population (e.g., Frankenberg et al. 2008; Guha-Sapir & Gijsbert van Panhuis 2009).

The present study will examine the progress of a different form of recovery – the repopulation of devastated families and destroyed communities through fertility. Although fertility remains the key determinant of population dynamics and accompanying resource needs in low income countries, it is often overlooked in the context of disaster. Lack of empirical research on the topic does not result from low scholarly interest but is instead a function of data collection difficulties in unstable environments (Hill 2004). Indeed, studies in the major demographic and health science journals have issued calls for research on fertility in the context of the 2004 disaster (e.g., Rogers et al, 2005; Carballo et al., 2007); to date these calls remain unanswered.

The planned research not only comprises the descriptive work necessary to document fertility trends in the context of the 2004 tsunami, but will - through the use of a novel, longitudinal data set – also examine the social, economic, physiological, psychological, and service-related mechanisms driving these effects.

BACKGROUND

In the past decade, nearly 4,000 disasters have resulted in significant economic costs and loss of human life worldwide (Vos et al. 2010). Although the disaster examined here was unusually devastating, similarly sized events have subsequently taken place in many parts of the world, including China, Pakistan, Myanmar, Turkey, and Haiti. Studying fertility in the context of disaster thus provides insight into the demographic patterns that follow the common experiences of damaging external shocks in the developing world. From a policy perspective, these patterns are particularly valuable because (a) fertility change will drive the changing public resource provision needed in these communities and (b) depending on the underlying mechanisms at play, fertility trends are likely to drive longer term economic recovery.

What do we know about fertility change in the presence of disaster, warfare, and economic downturn? Several studies have found that disastrous events are marked by concurrent fertility declines and followed later by fertility increases. This pattern was most famously demonstrated in the context of World War II (e.g., Rindfuss & Sweet 1978), but appears to extend across a heterogeneous set of events, including famine in Ethiopia and war in Angola (Lindstrom and Berhanu 1999; Agadjanian and Prata 2002). In the United States, births immediately increased following Hurricane Hugo in 1989 (Cohan and Cole 2002) and the Oklahoma City bombing in 1996 (Rogers et al. 2005). Fertility increases have also been documented following major earthquakes in India and Iran (Finlay 2008). Despite the similar direction of fertility change, the magnitude, timing, and duration of these changes - and thus, their ultimate social and economic significance - differ widely across experiences.

The origins of these differences are poorly understood and this gap in knowledge underscores two larger points. First, *how* disasters affect fertility is often theorized but remains, empirically, largely undocumented (Hill 2004). It is clear that all effects must operate through one of the three proximate fertility determinants (Davis and Blake 1956): intercourse, conception, and the survival of the fetus through gestation. More distal fertility determinants – e.g., individual health, household economies, community service provision – are likely affected in complicated ways and may well have offsetting effects on fertility. For example, most disasters reduce the physical and mental health of the population; on average, added stress and increased health threats will reduce fertility through each of the proximate determinants (e.g., Catalano and Bruckner 2005). At the same time, the death of children during disaster will increase fertility if parents seek to replace children who have died and/or seek to hedge newly increased uncertainty about the survival of living children (Hossain, Phillips, & LeGrand 2007). Reductions in economic security, assets, and access to credit may increase fertility if adults use children to navigate economic instability (e.g., Cain 1983, 1986; Pörtner 2001). Reductions in health care access will both reduce contraceptive access (increasing fertility) and reduce gestational survival (reducing fertility) (Cordero 1993, Hapsari et al. 2009). *A priori,* it is unclear which of these effects will dominate in the aftermath of a disaster. *Ex posteriori*, it is largely unclear which combination of factors has produced the post-disaster fertility trends described above.

Second, a disaster provides powerful analytical leverage toward studying the mechanisms that underlie fertility change more broadly. A large-scale disaster presents an opportunity to measure the demographic effects of uncertainty, stress, relocation, child mortality, and economic vulnerability - each of these characteristics has long been a debated mechanism in the production of fertility in developing countries (Cain 1983, 1986; Robinson 1986; Pörtner 2001; Hossain, Phillips, & LeGrand 2007). When these disasters are largely unexpected - as was the 2004 tsunami - they introduce changes into social settings and relationships that are certainly external but occasionally exogenous to the processes under consideration, providing a natural experiment.

Harnessing the disaster as an analytical tool has a long history in social science, yet has rarely been used to study the mechanisms underlying fertility - largely because of the data required to do so. As such, nearly all existing studies on fertility in the context of disaster rely on macro-level data and attempt to use descriptive differences between two or three geographic regions to make inference about the mechanisms driving these processes. By drawing from a novel multilevel data set with information collected before and after the event, we aim to better understand the relative contributions of psychological, physiological, economic, and social causes of fertility.

Our approach relies in part on features specific to the Indonesian context; we describe the setting and before turning to the proposed methods.

THE INDONESIAN SETTING

The Indonesian population, now over 220 million persons, has witnessed dramatic social and economic change over the past four decades. Sustained economic growth between the mid-60s and the present period was accompanied by marked declines in fertility, increases in education, and expansions in health care. In 1965 life expectancy was 43 years for men and 45 for women; by 2008 it had extended to 68 and 72 years for men and women, respectively (World Bank 2010). Over this period, the total fertility rate fell from 6 to 2.4 (Gubhaju 2008). The timing of these declines was experienced with considerable regional heterogeneity (e.g., Hull and Hatmadji 1988) though most provinces had achieved near-replacement fertility by the time of the 2004 disaster (BPS, 2010).

The immediate physical impacts of the tsunami have been described at length (Kohl et al. 2005; UN 2005). Estimates suggest that as many as 700,000 survivors were displaced and some 600,000 lost their source of livelihood as a result of the earthquake and tsunami. Of particular importance to this study is the considerable local level variation in the disaster's impact. Parts of Aceh were only 40 kilometers from the earthquake's epicenter, and so tsunami waves reached some coastal communities only a few minutes after the quake. The height and inland reach of water from the tsunami on shore was a complicated function of slope, wave type, water depth, and coastal topography (Ramakrishnan 2005). In many cases, communities a short distance apart experienced markedly different levels of destruction. In some areas the water scoured the earth's surface, removing all buildings and almost all vegetation. In other areas the water left deposits of mud and sand but structures largely remained intact. Other communities experienced little physical damage at all (McAdoo, Richardson, Borrero 2007; Umitsu et al. 2008).

A few previous findings have particular implications for the examination of fertility in this context. Reproductive-age women were significantly more likely to be killed in the disaster than were reproductive-age men (Frankenberg et al. 2010). For those surviving women, the disaster had clear deleterious effects on reproductive health. Carballo et al. (2005) argue that 133,318 fecund women were displaced by the tsunami – an estimated 11,300 were pregnant at the time of displacement – and the change in living conditions caused significant physical stress. An estimated 1600 Indonesian midwives (a common source of pre- and antenatal care) were killed during the tsunami, further compromising the health of existing and subsequent pregnancies. At the same time, contraceptive demand dramatically outstripped supply; Aceh's provincial capital, Banda Aceh, acquired less than a fifth of needed contraceptive units in the months following the disaster (Carballo et al. 2005).

When examining fertility, our study must appropriately address fertility changes that arise from mortality- and migration-related shifts in the number of women at-risk of a birth. Further, a consideration of the links between disaster and fertility cannot be limited to the social, psychological, and economic pathways theorized in studies of less-destructive events (Lauderdale 2006, Rodgers et al. 2005, Torche forthcoming) but must also seriously consider the role of the compromised health service environment.

METHOD

Data

Data for the study come from STAR, the Survey of Tsunami Aftermath and Recovery, a longitudinal, population-representative data set of households in the North Sumatra and Aceh provinces of Indonesia collected by a team of researchers in the United States and in Indonesia (Frankenberg et al. 2008). STAR was designed as a follow-up to a large, high quality, and population representative socioeconomic household survey, SUSENAS, collected each year in Indonesia. STAR targeted 2004 SUSENAS respondents from 11 districts (*kabupaten*) in Aceh and 8 districts in North Sumatra; in combination over 40,000 individuals from 526 villages were targeted for face-to-face reinterview. The data are thus highly unusual for disaster research in that they are representative of a population that was in place *prior* to the disaster, that they include data collected from individuals prior to the disaster, and that those same individuals are re-interviewed at five different points (roughly a year apart, on average) between 2005 and 2009 after the disaster. The STAR data are also exceptionally rich; information is collected at the individual, household, and community level on demographic, socioeconomic, health, employment and migration characteristics, among others.

In the present study, we will rely on data collected through 2008. We refer to these rounds as STAR A (the 2004 pre-disaster interview), B (2005-2006), C (2006-2007), and D (2007-2008).

Recontact rates in STAR are high, particularly given the level of devastation that occurred. Mortality and displacement status was established for 99% of targeted adults, with slightly more success in damaged areas because of exhaustive documentation efforts there by government and non-governmental organizations. Among those for whom survival status at the first wave could be ascertained, almost 7% died, leaving about 25,400 adult to be reinterviewed as part of STAR B. Of these respondents, 91% were members of interviewed households, so that some information on the details of their lives after the tsunami is known. Of the remainder 1% refused and 8% couldn't be located, despite intensive tracking efforts.

Analysis

(I) Did the tsunami affect fertility?

We begin the analysis by describing two data series from January 2000 through June 2007[1]: month-specific birth counts and month-specific marital GFR values. We use ARIMA models to identify shifts in the trends of the two series that appear when appropriately accounting for secular trends, seasonality, and other sources of autocorrelation in fertility. The discrete nature of the disaster helps facilitate attribution of the trends to the event itself. Nevertheless, we will also look for a proportional response to the disaster by relying on regional variation in the degree of destruction caused by the tsunami (measures described below). Mechanically this amounts to the inclusion of period-destruction interactions in the ARIMA specifications.

Finally, comparison between the discontinuities observed in the birth count series and those observed in the marital GFR series allows us to assess the proportion of fertility change that can be attributed to *exposure* differences arising from disaster-related female mortality and marital delay. The remaining proportion of fertility change can reasonably be assumed to have resulted from disaster-induced behavioral and/or physiological changes among the *exposed* – here, fecund-age married women.

(II) What social, economic, and physiological processes drive the disaster effects?

The second part of the analysis uses pooled person-month data on women ages 10-49 to pinpoint the behavioral and physiological origins of these trends. We use repeated-event discrete-time hazard models to predict post-disaster births as a function of time-varying and time-invariant covariates.

In these specifications the "comparison" group is comprised of the women living in communities that were not damaged by the tsunami.

We test for differences in the fertility hazards by degree of destruction. We then assess whether these differences can be attributed to a set of individual, household, and community covariates. We emphasize several classes of characteristics described in existing research as

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[1] June 2007 represents the month prior to data collection for STAR D, or, the latest month for which the full wave D sample is at-risk of a birth.

potential mechanisms linking disaster exposure to fertility outcomes. These include household demographics (the number of living children, the recent death of children, household relocation), material resources (assets, expenditures), physiological functioning (food security, traumatic stress, anxiety), access to care (availability of contraceptives, presence of midwives, functioning health facilities), access to risk-management (proximity to extended family, access to formal sources of credit), and subjective perceptions of future wellbeing.
All of the above characteristics are measured approximately annually in the STAR data.

Measuring Regional Variation in Disaster Exposure
In the STAR data, destruction can be measured in several ways: community-level administrative records on deaths; village leader reports of destruction to roads, bridges, homes, water sources and other community facilities, aggregated individual information about destruction to personal property; and photographs taken by the survey team to verify this information. This project will rely in particular on satellite imagery. Members of the STAR research team have matched satellite images from NASA's MODIS sensor taken on December 17, 2004 and December 29, 2004 for each of the 526 communities surveyed in STAR. With a reprojection tool, Gillespie and colleagues (2009) developed a pixel-based codification of the amount of ground cover destroyed by the disaster. This indicator is particularly valuable because the error with which it is measured should be uncorrelated with the outcome of interest in this study (versus, for example, a respondent-provided retrospective account of destruction that may directly or indirectly take into account the post-disaster fertility climate).

Descriptive Statistics
Table 1 demonstrates several sample characteristics that are central to the proposed analysis. First, the STAR survey includes communities which experienced considerable variation in exposure to the disaster. The survey interviews over 17,000 individuals from more than 200 communities that experienced no tsunami-related destruction. Second, the satellite data described above appear to capture meaningful variation in destruction; it is highly correlated with indicators of damage collected from STAR interviews of village residents and of village leaders. (Third, the communities affected by the tsunami are not identical to those affected by political insecurity prior to the disaster, suggesting that it will be possible to delineate between the effects of the two processes.)

Finally, a tabulation of the relative abundance of young children in STAR communities suggests that the proportion of young children rose in the years following the disaster. The increases were largest in the worst hit communities, though interestingly, the pace of increase was slower in hardest hit areas than the pace of increase in lightly damaged communities. Though it is certainly true that several concurrent demographic processes might lead to these findings,[2] they are at minimum suggestive of fertility patterns worth further exploration.

[2] Disproportionately high mortality among adults over 50 (relative to adult females) paired with unchanged fertility rates could result in a similar pattern. However, previous studies have emphasized the largely flat nature of the female age-specific mortality rates during the disaster (Frankenberg et al. 2010)

Table 1: Sample Characteristics by Degree of Tsunami Damage, STAR

	Damage Zone as Determined by Satellite Imagery			
	None	Light	Some	Heavy
Tsunami Damage				
From Aggregated Individual Interviews:				
Average % of respondents who felt the earthquake	98.8	98.1	99.5	99.4
Average % of respondents who died between STAR A & B	1.8	2.7	2.8	28.5
From Village Leader Interviews:	*Percent of Communities*			
Water supply was contaminated	1	4	40	83
Problems with debris in the roads	0	2	20	79
Five or more families relocated	1	3	27	36
Relative Abundance of Young Children				
From Aggregated Individual Interviews:				
Average % of community under the age of 4:				
STAR A *(2004 pre-tsunami)*	8.4	7.4	8.5	6.9
STAR B (*2005-6*)	9.7	8.9	9.4	7.2
STAR C (*2006-7*)	9.8	9.3	10.6	8.3
STAR D *(2007-8)*	9.3	9.0	10.7	9.3
Difference: STAR D – STAR A	*0.9*	*1.6*	*2.2*	*2.4*
Number of communities in STAR	213	136	83	94
Total number of adults interviewed in STAR A	17,053	10,269	7,197	6,659
Total number of women age 10-49 interviewed in STAR A	5,610	3,453	2,318	2,307

Source: Study of Tsunami Aftermath and Recovery, 2004-2008.

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