# The Impact of a Natural Disaster on the Incidence of Fetal Losses and Pregnancy Outcomes

Elaine M. Liu[*]

University of Houston and NBER

Jin-Tan Liu

National Taiwan University and NBER

Tzu-Yin Hazel Tseng

University of Houston

November, 2014

## Abstract

We examine the impact of a magnitude-7.3 earthquake on fetal losses and birth outcomes in Taiwan. Our main identification strategy is difference-in-differences method. We compare the pregnancy outcomes and birth cohort size of those who resided in areas with high earthquake intensity to those who resided in areas with low earthquake intensity, before and after the earthquake. Our analysis suggests that the incidence of fetal losses increased by 4.4 percentage point in the most affected regions relative to the least affected regions for those who had exposure during the first trimester. Almost all the fetal losses are due to the loss of male fetuses. Exposure during the second or third trimester results in lower birth weights, but no significant impact on fetal losses. We do not find that women from lower socioeconomic status to be more affected by earthquake. Lastly, we suggest that the results are mainly driven by maternal stress.

JEL: I12, N35, I19

---

[*] Contacting Author. Email: emliu@uh.edu. We thank Aimee Chin, Willa Friedman, Reshmaan Hussam, Thomas Pullum, Joshua Wilde, conference participants at PAA, NEUDC and SEA and seminar participants at National Taiwan University, UT-School of Public Health, Sam Houston State, University of Houston for their helpful comments and suggestions. We also thank Alan Barreca, Sandy Black, Nicholas Sanders, Mark Stabile for helpful conversation. We thank Professor Yih-Min Wu at National Taiwan University, Department of Geoscience for providing us the earthquake intensity data at the township level.

# 1. Introduction

Studies have shown that *in utero* exposure to illness and adverse events is predictive of many negative outcomes such as shorter gestational length, low birth weight, higher infant mortality, lower education level, and higher likelihood of diabetes and cardiovascular disease. (See Almond and Currie 2011 and Currie and Vogl 2013 for an overview of recent literature.) Other than the randomized control trial experiments done on animals, much of this line of literature exploits natural experiments (e.g., the 1918 flu pandemic, famine, earthquake, and extreme weather events) to compare the health or cognitive outcomes of groups that are affected to those who are unaffected by negative shocks. One important thing to note is that these existing findings are estimated based on the surviving (fetus) population. If experiencing adverse events *in utero* increases fetal mortality and if there is positive selection of fetuses, such that the weakest are culled, then previous estimates of the impact provide a lower bound estimate of the true impact (Bozzoli, Deaton, Quintana-Domeque 2009). This challenge posed by positive mortality selection is widely recognized in both economics and epidemiology (Currie and Almond 2011).[1]

Fetal mortality that includes miscarriages and stillbirths is extremely common. Medical studies have found the incidence of fetal losses to be around 30% (Wilcox et al. 1988; Nepomnaschy 2006).[2] Thus, one might expect that had there been adverse intrauterine conditions, fetal mortality rates could be higher. The objective of this paper is to understand the

---

[1] This point is illustrated in Bozzoli et al. (2009) and also discussed by many of the authors in the aforementioned literature.

[2] This fetal loss rate (which includes both miscarriages and stillbirths) is highly variable. The American College of Obstetrics and Gynecologists (2002) suggests that an estimated 15-20 percent of *known pregnancies* result in miscarriage. But the rate of miscarriage can be even higher if one accounts for the *unknown pregnancies*. Early miscarriages that occur within the first couple weeks of conception have similar symptoms as the woman's period, and thus are often unknown to women. One of the studies that has tried to overcome the issue of under-reporting is Wilcox et al. (1988). They tracked women's hormone levels every day to detect very early pregnancy losses and found a total miscarriage rate of 31 percent of all detected pregnancies.

extent to which fetal losses occur as a result of poor *in utero* environment and whether parental socioeconomic background contributes to the differences in fetal mortality rates. To the best of our knowledge, this is one of the first papers that attempts to estimate the increasing likelihood of fetal losses caused by a natural disaster.[3]

The closer examination of the impact of adverse events on fetal mortality is of high importance. First, recent papers in this literature have tried to address the selective mortality issues using a bounding exercise, following Lee's procedure (2009).[4] The central idea of this exercise is that one first tries to estimate the size of culling ($x$) as a result of the adverse events. Then, one trims the left (right) tail of the distribution of the outcomes of interest by $x$ for the population that are unaffected by the adverse events and then re-estimates the impact of adverse events. This exercise could provide upper/lower bounds for the estimates. However, while the bounding exercise is appealing and informative, this method may not always be feasible since the size of culling ($x$) is often unknown to authors. The finding from this paper, which aims to estimate the size of culling as a result of a natural disaster, may be useful as a benchmark for future authors who wish to conduct similar bounding exercises. Second, from the policymaker's perspective, the true cost of a negative shock could be underestimated if pregnancy losses are unaccounted for.

In this project, we study the impact of the 1999 Taiwan earthquake on fetal mortality, pregnancy complications, and outcomes including birth weight, gestational lengths, and sex ratio. This earthquake caused more than 2,400 deaths[5], and created aftershocks that lasted a month. We

---

[3] There are few papers that examine  examine fetal loss from death of close relatives, such as  Laszlo et al. (2013) and Quintana-Domeque and Rodenas-Serrano(2014) (2014) using terrorist attacks as a shock. Almost all of these papers only study In a series of papers by Torche examining pregnancy outcomes, she did not look at fetal losses.

[4] Papers that use this exercise in this literature include Bharadwaj, Loken, Neilson (2013), Lin and Liu (2014), Halla and Zweimuller (2014), and Isen, Rosen-Slater, Walker (2014)

5 Given the magnitude of this earthquake, the earthquake causes relatively fewcasualties. Even in the highest intensity areas (level 6 and level 7), the fatality rate is less than 0.2%.

expect the earthquake to affect fertility outcomes and fetal mortality since recent papers have found that maternal stress caused by natural disasters (i.e., earthquakes, hurricanes, and other extreme weather events) are harmful to the birth outcomes (e.g., Torche 2011, Simeonova 2011, and Currie and Rossin-Slater 2013), but none of these papers examine the incidence of miscarriages. Our main identification strategy is a difference-in-differences method. We compare the pregnancy outcomes of women who resided in areas with high earthquake intensity (i.e., higher on the Seismic scale) to those who resided in areas with low earthquake intensity, and compare pregnancies that were exposed to the earthquake to those pregnancies that were not exposed to the earthquake.

The difficult part of estimating pregnancy losses is the issue of unreported fetal losses. Most existing papers that examine fetal losses often rely on the reporting of stillbirths in birth registries.[6] One caveat of using the stillbirths record from birth registries is that most countries' administrative birth registries require reports of any outcomes of pregnancies of at least 12 weeks of gestational length.[7] However, medical studies suggest that most fetal losses of *known pregnancies* occur during the first trimester, which is before 12 weeks of gestational length (Nepomnaschy 2006; Goldhaber and Fireman, 1991). Early miscarriages will not be reported in administrative vital statistics. Some studies use household survey recall data reporting on miscarriages and fertility outcomes (Hernandez-Julian, Mansour, and Peters 2013). Recalling errors issue aside, according to the National Institutes of Health[8], which cite Michels and Tiu (2007), nearly half of fertilized eggs are aborted even before women realize that they are

---

[6] For example, Black et al. (2014), Laszlo et al. (2013), and Persson & Rosen-Slater (2014) examine how stress to the mother from the death of a close relative affects the likelihood of stillbirths and various birth outcomes.

[7] For example, all births taking place at 12 weeks of gestation or later are registered in the Norwegian birth registry used by Black et al. (2014). All births taking place at 28 weeks of gestation or later in Sweden are recorded in the birth registry used by Laszlo et al. (2013).

[8] NIH. *Pregnancy loss*. Retrieved from http://m.nichd.nih.gov/topics/pregnancyloss/conditioninfo/Pages/risk.aspx

pregnant (Wilcox et al. 1988, Wang et al. 2006). The lack of knowledge of possible miscarriages could further dampen the issue of under-reporting of very early miscarriages. Our study tries to overcome this issue in the following ways.

First, we use birth registries from 1998 to 2001 from Taiwan. The birth registries data contains the universe of all births and information on the age, education, and permanent residence of the parents, and the birth county, birth date, gestational length, birth weight, and gender of the child. Using gestational lengths (reported in weeks) and birth date allows us to infer the week of conception and whether a given child was exposed to the earthquake or not.[9] We construct cohort size for each township and month of conception. This cohort size measure will be our main outcomes of interest. The township was identified based on the mother's permanent residence, not based on the birth location; thus, the issue of migration (as a result of the earthquake) is less of a concern.

Furthermore, we utilize detailed health insurance claim records of a 5 percent population sample from 1998 to 2001. The claim record provides information such as reason for visiting the hospital/clinic and location of the hospital. Since Taiwan provides universal health insurance, which covers ten free prenatal visits and a broad range of inpatient/outpatient visits (including stillbirths/miscarriages), a patient is much more likely to visit a hospital/doctor when a miscarriage occurs, which reduces issues with under-reporting. These health insurance claim records allow us to identify whether each pregnancy resulted in, labor complications, or a normal delivery, as long as these events occur in a hospital or clinic.

Our analysis based on the birth registry data suggest that the incidence of fetal mortality increases by 4.4 and 3.2 percent for those who have *in utero* exposure to the earthquake in the

---

[9] Knowing the gestational length is important as the literature has found that poor intrauterine conditions can shorten gestational lengths, causing one to misidentify the timing of exposure to the earthquake.

most earthquake-affected regions during the first and second trimesters, respectively. There is no significant impact on fetal mortality if the exposure was during the third trimester: Interestingly, almost all of the losses that occur during first-trimester exposure are due to the loss of male fetuses. This finding provides evidence to the Trivers-Willard hypothesis, which suggests the fragility of the male fetus relative to the female fetus (Trivers and Willard 1973; Almond and Edlund 2007). We also find reductions in birth weight of 13 and15 grams for female with *in utero* exposure to the earthquake during the first and third trimesters, respectively. There is no difference in birth weight for male who are exposed during first trimester compared to those with no exposure of earthquake. This null results for male birth weight can be due to the positive selection.

Thus, we apply Lee's bounding technique to our analysis and it paints a very different picture. We find that for male exposure to earthquake during the first trimester would lower birth weight by 48 grams which is significantly higher than impact of exposure during second and third trimesters and higher than the impact on female. This is extremely important since this exercise illustrates how positive selection may bias our findings. In sum, exposure to the earthquake during the first trimester resulted in higher fetal mortality; exposure during later trimesters resulted in a lighter birth weight.

The paper is organized as follows. In Section 2, we provide a literature review. Section 3 discusses the empirical strategy. Section 4 describes data and provides summary statistics. In Section 5, we present our results. Section 6 discusses various channels of why earthquake can lead to poor outcomes. Section 7 concludes.

## 2. Literature Review

Our study is relevant for the general literature that tests fetal origins hypothesis, first proposed by Barker (1990), which suggests that adverse *in utero* events can lead to worse health conditions later in life. There is an extensive literature; thus, we will point our readers to Almond and Currie (2011) and Currie and Vogl (2013), both of which provide an overview of recent literature.

More specifically, this paper is related to the literature that examines maternal stress and pregnancies outcomes. In our analysis in later section, we find that this earthquake is a major source of psychological stress, which lasted months after the earthquake.[10] Medical literature points out an association between maternal stress and pre-term births. The hypothesized mechanism is that maternal stress activates a higher level of cortisol that stimulates the release of placental corticotrophin-releasing hormone(CRH) (Hobel and Culhane 2003; Copper et al. 1996; Dole et al. 2003; Wadhwa et al. 2001). There is further evidence suggesting a strong correlation between gestational length and the level of placental CRH (McLean et al. 1995). Based on the self-assessed stress levels among the pregnant women at a Danish hospital, Wisborg et al. (2008) provide some evidence on the positive association between maternal stress level and incidence of stillbirth.

However, the level of maternal stress can be endogenous. For example, women with low socio-economic status may tend to have worse birth outcomes and possibly have higher stress levels too. In order to deal with the endogeneity issues, researchers have exploited exogenous shocks to identify the effects of maternal stress, including extreme weather events (Simeonova 2011; Currie and Rossin-Slater 2013), natural disasters (Torche, 2011; Frankenberg et al. 2013; Glynn et al. 2001), threat of terrorist attacks (Camacho 2008; Ródenas-Serrano and

---

[10] There are various papers suggest that earthquake causes distress and worsen health outcomes including strokes (Dimsdale 2008; Leor et al. 1996; Siegel 2000).

Quintana-Domeque 2014; Brown 2012; Eccleston 2011), armed conflict (Mansour and Rees 2011), and post-911 treatment of Arabs women (Lauderdale 2006).[11] These studies provide evidence on the negative effects of adverse events on pregnancy outcomes including labor complications, birth weight, gestational length, education attainment, and labor market outcomes in later life. None of the above papers examines the effects on pregnancy loss, possibly due to limited data availability.

Several papers also try to examine the impact of other adverse events on fetal mortality. The ones most similar to ours in identification strategy are Torche (2011, 2012). In these two papers, the author examines various pregnancy outcomes as a result of a magnitude 7.2 Chilean earthquake using birth registry data. Although the author did not directly examine fetal losses, she finds a lower male-to-female sex ratio at birth for those cohorts that were *in utero* during the earthquake. This finding is similar to our finding, and we would interpret the skewed sex ratio as an evidence of fetal loss of male fetuses.

Using household-level survey recall data on fertility, Hernandez-Julian, Mansour, and Peters (2013) examine the effect of intrauterine exposure to a Bangladesh famine in 1974 and the post-famine fertility outcomes of women who were exposed to the famine. Similar to what we find, they also find that women are less likely to give birth to sons when there is a poor intrauterine environment. While they did not directly examine the impact of famine on miscarriages for those pregnancies during famine time, again one can infer from their findings of change of sex ratio at birth that there could be some fetal losses, resulting in the change in sex ratio.

---

[11] Aizer, Buka, and Stroud (2012) examine the causal relationship between maternal stress and long-term health and education attainment outcomes.

There are also few papers that examine the impact of the loss of a close relative on stillbirths/pregnancies outcomes. Using a Swedish registry that only contains stillbirth information during the last trimester, Laszlo et al. (2013) find the likelihood of stillbirth increases by 18 percentage points for women who lost a close relative during pregnancy or a year or less before. This measure is considerably higher than our finding, since we do not find any impact on fetal losses for those who were exposed during the third trimester. Using administrative data from Norway, Black, Devereux, and Salvanes (2014) find the death of the mother's parents has no effect on the likelihood of miscarriages/stillbirth when gestational age is longer than 12 weeks. As we discuss in the introduction and footnote, most fetal losses would occur before the 12 weeks, which could be a reason why Black et al.(2014) did not find much evidence of miscarriages/stillbirths.

## 3. Empirical Strategy

We exploit the variation in earthquake intensity and pregnancy timing and apply a difference-in-differences approach to investigate the effect of the earthquake. The first difference is between the outcomes of those residing in low-intensity regions and those residing in high-intensity regions. The second difference is based on the timing of pregnancy to determine whether there is *in utero* exposure to the earthquake or not. The key identifying assumption is that the pregnancy outcomes between high- and low-intensity areas would have followed similar trends had there not been an earthquake. In a later section, we will show some evidence of these assumptions.

Our analysis consists of two parts. First, we use birth registries to test whether cohort sizes are smaller and have worse outcomes for those who were exposed to the earthquake in high-intensity areas. Later, we use health insurance claim records to examine whether the likelihood of miscarriages/stillbirths increases for those pregnancies that were exposed to the earthquake in high-intensity areas.

### *3.1 Birth Outcomes using National Birth Registries*

We first examine the differences in birth outcomes across birth cohorts. Each birth cohort is defined by the month of conception and the township of the mother's permanent residence. This definition has two important features. First, we use the month of conception rather than the month of birth since gestational lengths can be shortened as a result of a negative shock: using the month of birth would misidentify the timing of exposure to the earthquake (Currie and Rossin-Slater 2013) (for the method of imputing month of conception see Section 4.2).[12] Second, earthquake intensity was defined based on the township of the mother's permanent residence (*hukou*) instead of the location of the birth place. This reduces the issue of endogenous migration discussed in Currie and Rossin-Slater (2013).[13]

For a given cohort conceived in year-month t in township w, our primary specification is as follows:[14]

$$Y_{wt} = \beta\, I(Intensity \geq 6)_w * I(Conceived\ in\ X\ Months\ Before/after\ the\ earthquake)_t$$

$$+\alpha I(Intensity = 5)_w * I(Conceived\ in\ X\ Months\ Before/after\ the\ earthquake)_t$$

$$+v_w + \mu_t + \varepsilon \text{----(1)}$$

---

[12] For example, suppose an individual was conceived in July 1999 (two months before the earthquake) and was born in February 2000. If we use birth months to identify the timing of earthquake exposure, we would infer that the person was exposed to the earthquake during the second trimester, instead of the first trimester. Given that gestational lengths in the birth registry are reported in weeks, we could infer the week of conception. However, we worry about measurement-error issues in gestational length, thus, we use months of conception.

[13] We also examine earthquake effects on individual birth outcome (regression results are available upon request). We find lower birth weight, shorter gestational length, higher probability of low birth weight and preterm birth, and lower likelihood of being male for individuals exposed to the earthquake during the early stage of pregnancy.

[14] We have birth records between 1998 and 2001, so conceiving year-months t ranges from the early part of 1997 to the early part of 2001, with a total of 43 conceiving year-months (specifically September of 1997 to March of 2001).

$v_w$ and $\mu_t$ capture the township and year-month fixed effects, respectively. X months include 0–3 months before the earthquake (exposed during the first trimester), 4–6 months before the earthquake (exposed during the second trimester), 7–9 months before the earthquake (exposed during the third trimester), 1–3 months after the earthquake, 4–6 months after the earthquake, 7–9 months after earthquake, and 10–12 months after the earthquake. Outcomes of interest include natural log of cohort size, cohort male-to-female ratio, average gestational length and birth weight. There are only 9 townships with level 7 intensity, so we group townships with level 6 intensity and level 7 intensity together. The reference groups in this regression are those in townships with the lowest intensity level, i.e. intensity levels of 4 or below, and those births that were not exposed to the earthquake. Each observation may have a very different sample size, so we adjusted it by weighting the cell by township female population at the end of December 1998 or the cohort size.[15] In Figure 1 we provide the residual cohort size over time by earthquake –intensity level. Those who were conceived before Dec 1998 never experience the earthquake, and the trends for Level 4, 5 and 6 appear to be quite noisy, but one can see a very clear drop for those who were conceived in September 1999 in Level 6 intensity areas.

[Figure 1 About Here]

We are also interested in exploring whether the fetal mortality rates can differ by the socioeconomic status of the mother. In the birth registry data, we do not have household income information, thus, we examine the variation in outcomes by mother's education level.

---

[15] In the regression with log cohort size/sex ratio as outcomes, we do not weight it by cohort size since cohort size is endogenous and is an outcome of interest. Hence, we use a pre-earthquake township female population as the weight. For other birth outcomes such as gestational lengths and birth weight, we use cohort size as weight since it will provide us the average treatment effect for those who were born.

### *3.2 Labor Complication using Health Insurance Claim Records*

We examine the impact of the earthquake on incidences of pregnancy complications. using the health insurance claim records. The advantage of this dataset is that it provides us the International Classification of Diseases (ICD-9) codes and Diagnosis-Related Group (DRG) codes, which allow us to identify the reason for the woman's visit (labor delivery) and the physician diagnostic codes for relevant pregnancies outcome (e.g., labor/pregnancy complications).

There are also some caveats and advantages of this dataset. First, it does not include any information on individual characteristics other than women's age. We have to identify one's residence based on the township of the most frequently visited hospital/clinic before the earthquake strikes. [16] On the other hand, we do know one's health condition prior to the earthquake, thus we can examine the impact of earthquake by mother's health condition. Second, unlike the birth registry data, we do not know the gestational length, we only observe the timing of diagnosis. If someone went to the hospital eight months after the earthquake for a delivery, we would not be able to know whether the pregnancy was conceived before or after the earthquake. Thus, in the following specification, we show an event study results (month by month after the earthquake).

Our main regression specification is listed as below, for each delivery *i* in township *w* in month *t*,

---

[16] Even though we do know the location of the hospital where a pregnancy outcome took place, we worry about migration as a result of the earthquake; thus, we prefer to use the identified township prior to the earthquake. In Appendix table 2, we show that migration occurs more frequently among women residing in high-intensity areas relative to low-intensity areas immediately after the earthquake.

$$I(Labor\ Complicatoin)_{iwt} = \sum_{k=1998M2}^{k=2001M12} I(YearMonth = k)_t + \sum_{k=1998M2}^{k=2001M12} \beta_k * I(YearMonth = k)_t * I(Intensity \geq 5)_w + (Age)_{it} + \delta_w + \varepsilon_{iwt}$$

(2)

. $I(Labor\ Complication)_{iwt}$ equals to 1 if the physician reported a labor or pregnancy complication. We further identify whether a woman has pre-existing health conditions include heart conditions, hypertension, stroke, diabetes, asthma, cancer and high cholesterol and examine whether those with poor health conditions prior to the earthquake are more likely to have labor complications. The coefficients $\beta_k$ capture the differences in labor complication in areas with intensity 5 and above relative to areas with intensity 4 or below and relative to the omitted month (1998M1). We decided to combine all areas with intensity of 5 or more as one group since there are very few observations in areas with intensity levels of 6 and 7 and also in the cohort analysis we do not find statistical differences between level 5 and level 6 areas in most cases.[17]

(3)

# 4. Data

### *4.1 Earthquake Intensity*

---

[17] We had also tried to separate areas with intensity of 5 and areas with intensity 6+ (relative to intensity 4). The coefficients on intensity 6 areas are not statistically different from those coefficients on intensity 5 areas; thus, we combine them as one treated group. The results for separating level 5 and level 6 are available upon request.

On September 21, 1999, the most destructive earthquake in the past few decades struck central Taiwan. 2,415 people were killed and 11,305 injured, with 51,711 buildings destroyed.[18] The earthquake had a magnitude of 7.3 on the Richter scale and was classified as a major earthquake. Townships experienced the earthquake at various levels of intensity. The magnitudes ranged from 3 in the least severe area to 7 in the most affected area (see Figure 1). As indicated in Figure 2, the aftershocks from this earthquake persisted for a month. Figure 2 shows the distribution of the number and maximum Richter scale reading of detectable earthquakes before and after the earthquake.

### *4.2 Birth Registries*

One of the main datasets we use in this study is the national birth registries from 1998 to 2001 in Taiwan. The records include birth weight, gestational age, gender, county of birth, multiple birth, birth order, parental education levels, age, township of permanent residence (*hukou)* and marital status. We focus on only singleton births in this study.[19]

Having gestational age is extremely helpful. Based on gestational length and one's birth date, we can infer the week that one was conceived. We collapse the data so that each unit of observation is at the conceiving-month-township level. Table 1 shows the summary statistics at the cohort level for the period between 1998 and 2001. Townships with intensity level 6 have lower birth weights even prior to the earthquake. The time-invariant characteristics would be absorbed by township fixed effects in our analysis later.

[Insert Table 1 about here]

---

[18] While Taiwan is in an earthquake zone, most of the earthquakes occur on the east coast and cause little damage. The 921 earthquake was one of the most catastrophic earthquakes since the epicenter was in the center of Taiwan, and the western part of the island, which is densely populated, was much more affected (Earthquake Engineering Research Institute 1999).

[19] We also restrict the sample to births with birth weight between 500 g and 6,000 g and gestational length between 20 and 44 weeks. We find that mother's with missing age or education information tend to be of foreign origins. Based on a paper by Edlund, Liu & Liu (2013) discussing foreign bride phenomenon in Taiwan, we would code those with missing age as age between 25-34 and education level 9 years or below.

### *4.3 Health Insurance Claim Records*

The second main dataset we use in this study are the detailed claim records of a sample of 5 percent of the Taiwanese population from 1998 to 2001. After implementing universal health insurance in 1995, Taiwan's coverage rate reached 96% by 1997. The claim data records include outpatient and inpatient visits and drug prescriptions that were covered by government insurance during this period. We use ICD-9 and DRG codes to identify the reasons for their visits. We construct a dataset of women between the ages of 16 and 45 in which each pregnancy contains their reasons for visits, and pregnancy outcome, with associated ICD-9 codes. Here pregnancy outcome is either normal delivery or delivery with complication (reported by physicians). Since health claim records do not contain residence information for individuals, we infer their pre-earthquake residences based on the township of their most frequently visited outpatient hospitals/clinics prior to the earthquake.

Table 2 shows the summary statistics of insurance claim records. Earthquake intensity levels are based on the township of the most frequently visited hospital prior to the earthquake. Conditional on giving birth, about one third of them experienced labor complications (Currie and Rossin-Slater 2013 reported a rate of 16% in their sample). Upon first examination, pregnant women in level 5+ areas seem to be healthier, with lower rate of labor complications. One should note that the difference can also be due to the differences in norm, in patient access to hospitalsand physicians' billing practices. As long as these differences in patient/physician behaviors remain time-invariant, it would not threaten our identification.

[Insert Table 2 about here]

## 5. Empirical Results

### *5.1 Birth Outcomes using National Birth Registries*

The regression results of specification (1) for cohort size and sex ratio are shown in Table 3.[20] We find that the cohort sizes for those who were exposed to the earthquake *in utero* during first trimester (conceived 0–3 months prior to the earthquake) in a high-intensity area (level 6 or above) are about 4.4% smaller relative to those who experienced the earthquake in the low-intensity areas (level 4 or below). Exposure to the earthquake (in level 6) during the second trimester would cause a 3.2% drop in cohort size.[21] Impact on the third-trimester exposure, albeit negative, is not statistically different from zero. The magnitude of fetal losses in the level 5 areas are smaller compare to the level 6+ areas. Interestingly, the cohort conceived at 1–3 months (in level 6) after the earthquake also has worse outcomes. It can be due to a negative selection on mother's socioeconomics status or to the lasting effect of maternal stress (as suggested in Laszlo et al. 2013).[22]

The differences in cohort size in the birth registry reflect the size of the conceiving cohort minus the number of fetal losses that are not recorded in the birth registry. It is unlikely that parents were planning to avoid births because of an unexpected earthquake; thus, our findings suggest that the shrinking cohort size among cohorts conceived prior to the earthquake is most likely a result of pregnancy loss, not due to difference in conception.

Our finding that the exposure during first trimester results in most fetal losses suggest that maternal stress maybe the main cause of fetal mortality in our study. If fetal mortality is due to a disruption in infrastructure or access to medical care, we would expect the cohort born

---

[20] We also perform a similar specification based on birth month cohort, instead of conception-month cohort. The results (reported in Appendix Table 1) are in line with Table 3.

[21] Dinkleman (2013) finds drought exposure reduces cohort size by 2 percent. Laszlo et al. (2013) show that maternal bereavement increases the probability of stillbirth by 18 percent.

[22] In regressions not show, we find that college educated mothers are less likely to be giving birth in level 6 + areas months after earthquake. This supports the negative selection story.

immediately after the earthquake (conceived 6–9 months before) to have the worst health outcomes, rather than those who were born months after the earthquake.

Next we examine the male-to-female ratio of birth cohorts. Recently, there have been some works suggesting that male fetuses can be more fragile than female fetuses under poor intrauterine conditions (Kraemer 2000; Almond and Edlund 2007). If the earthquake caused more loss of male fetuses, we would see a decrease in the male-to-female ratio for the affected cohorts. Table 3 Column 2 suggests that almost all the losses that occurred during the first trimester were caused by the loss of male fetus (evident in the drop of male-to-female sex ratio). This finding is also supported by Hernandez-Julian, Mansour, and Peters (2013) and Torche, (2012).

[Insert Table 3 about here]

Given that we find a difference in fetal mortality rates between genders, in Table 4, we will present results separated by gender. Table 4 shows that birth weights are lower for both male and female infants. Females with first- and third-trimester exposure are about 16 g lighter (0.5% reduction), and gestational length is only marginally shorter (0.07 weeks) in high-intensity areas (relative to low intensity areas). The impact on gestational lengths is extremely small.

Interestingly, we find that males with first-trimester exposure to the earthquake have similar birth weights and gestational lengths as those that are unaffected by the earthquake. This can be due to positive selection. Since, near 5% male fetus in the left tail of health distribution may be culled, it is not surprising that we do not find much effect. In Section 7, we will perform bounding exercise based on Lee's procedure, then we can compare the impact for male versus for female.

[Insert Table 4 about here]

Next, we examine the differences in male cohort size by mother's education level and mother's age in Tables 5 and 6. Surprisingly, most of the results in fetal mortality are driven by mothers with a high school education or more (Columns 2 and 3). Those with lower education levels are only affected through lower birth weight and slightly shorter gestational lengths. Furthermore, those mothers between ages 25–34 have higher fetal mortality and lower birth weights, compared to people who are age 35 above or 24 and below. These results together are somewhat surprising, since one might expect women from lower social economic status (proxy by education) to be less protected by income or older women to have more difficulty to carry pregnancy to full term in case of adverse events. This result is informative in helping for us to think about the how and why earthquake affect pregnancy outcome. If the reason we found that pregnancy worsen was due to disruption in food or medical access, one might expect that a higher socioeconomic status can protect the fetus from the shock (those with more resources can move out of the earthquake zone easier).

[Insert Tables 5 and 6 about here]

### *5.2 Labor Complication during Childbirth using Health Insurance Claim Records*

The regression results of specification (2) are presented in Figure 3. The shaded areas indicate those who have probably had *in utero* exposure to the earthquake and its month-long aftershock. In order to deal with the issue of multiple hypothesis testing, the reported p-values are adjusted based on Simes' method (1986).[23] In the period leading up to the earthquake, we do not find any systematic differences between the high-intensity areas and the low intensity areas, which provide evidence to the parallel trends assumption required by difference-in-differences

---

[23] For example, 20 hypotheses are being tested simultaneously. The probability of having at least one significant result at the 95% level is 0.64 (=1-(1-0.05)$^{20}$) instead of 0.05.

analysis. In the period immediately after the earthquake (1999M11), we the likelihood of complications increases by 5.6 percentage points (not statistically significant) and two months after earthquake it increase by 10.8  percentage points in areas with intensity 5 and above relative to low-intensity areas. Similar to our finding in Section 5.1, those who experienced higher earthquake intensity had worse pregnancy outcomes in Table 7. The average probability of complication is about 28%, which is equivalent to a 38% increase in the likelihood of complication.

Next, we examine whether the impact are different by women's health condition In Table 7. In our dataset, about 20 percent of women had been diagnosed with various health conditions prior to the earthquake.  In Figure 4, we present the coefficients from Equation 2 by health status. In other words, these coefficients reflect the change in likelihood of labor complication in a given month, relative to 1998M1 and relative to the areas with no earthquake. The estimates are extremely noisy with lots of fluctuation from month to month. However, one can see that around the time of earthquake, the coefficients on poor health conditions is also greater than the coefficients on healthy condition. In the first two months after the earthquake, the coefficients for both health and unhealthy women experience a small increase in labor complication. But 3-5 months after the earthquake, the likelihood of labor complication of those women with poor health conditions continue to rise while women with good health stay rather constant throughout the period.  It suggests that the earthquake seem to have a lasting impact on women with poor health conditions.

[Insert Table 6 and 7 about Here]

[Insert Figure 3 about Here]

## 6. Discussion

There can be several reasons why a major earthquake could increase the likelihood of fetal losses and worsen pregnancy outcomes: e.g., the earthquake destroys health infrastructure; ,leading to worse *in utero* nutritional environment; and the earthquake increases maternal stress.

As we have discussed before, if the increase in fetal loss is due to damaged infrastructures or crowdedness of the hospitals, one might not expect that we would find that those with first trimester exposure experience the most fetal losses. Since those with trimester 3 exposures are much more likely to be born in a poor health facility (rather than those with trimester 1 exposure who will be born 6-8 months after the earthquake.

We have information on the share of collapsed building at township level. Therefore, we can examine whether it is the damaged infrastructure or the earthquake itself that affect the health outcome. In regression not shown, we leave out the areas where 10% of the buildings collapsed and examine only those in areas with less destruction and we still find a strong and significant effect on fetal losses outcomes.

We propose that one of the main explanations is due to maternal stress. First, there is an existing literature suggesting that a major earthquake like this can increase one's stress level (Dimsdale 2008; Leor et al. 1996; Siegel 2000). We examine the psychiatric visit post-earthquake for male who are between age 16-45, and we find that those reside in areas with high intensity are likely to increase their psychiatric related outpatient visits in the first half year after the earthquake (figures provided in Web Appendix).

Nian (2014) examines the earthquake's effects on labor participation and hours of work. Her results suggest no significant impacts on unemployment and working hours, although hourly wages are lower for residents of high-intensity counties. Figure 3 shows the numbers of hospitals and clinics over time by intensity level. There does not seem to be any change in numbers of health care facilities opened in high intensity areas right after the earthquake. Overall, the fact that we find more fetal losses during first trimester exposure also suggests that it may not be related to change in infrastructures. It can be due to longer exposure to poor nutritional environment or maternal stress.

## 7. Conclusion

We use a major earthquake in Taiwan to examine the effects of a natural disaster on birth outcomes and incidences of pregnancy loss. We find evidence that the earthquake increases pregnancy loss by 4.4% for those who experienced the earthquake during early stage of pregnancy and resided in high-intensity areas relative to those who resided in low-intensity areas. Almost all the pregnancy losses were driven by loss of male fetus. We find that labor complication probability increases by 10 percentage points in the months right after the earthquake. We also find evidence of positive selection.

We perform Lee's bounding method to examine how much a positive selection (culling of 4.5% of male sample) would affect our regression estimates. The results are presented in Appendix Table 3. We find that birth weight for males who were exposed to the earthquake during the first trimester in high-intensity areas compared to those in low-intensity areas would drop by 48gram, which is a lot higher than the impact on female.

In sum, our findings on fetal losses suggest that the existing literature based on surviving past a certain gestational length is likely to have underestimated the impacts of natural disasters on pregnancy outcomes. Without the bounding exercise and the results on fetal losses, some may mistakenly conclude that the earthquake has bigger impact on female fetus health. The bounding exercise in this paper demonstrates that if poor intrauterine environment substantially affects the likelihood of miscarriages/stillbirths of certain gender/subgroups, it can lead to bias in findings.

# References

A. Aizer, L. Stroud, and S. Buka. “Maternal Stress and Child Outcomes: Evidence from Siblings”. NBER Working Papers 18422. National Bureau of Economic Research, Inc, Sept. 2012.

D. Almond. “Is the 1918 Influenza Pandemic Over? Long-Term Effects of In Utero Influenza Exposure in the Post-1940 U.S. Population”. *Journal of Political Economy* 114.4 (2006), pp. 672–712.

D. Almond and J. Currie. “Human Capital Development before Age Five”. In: ed. by O. Ashenfelter and D. Card. Vol. 4. Handbook of Labor Economics. Elsevier, 2011. Chap. 15, pp. 1315–1486.

D. Almond and L. Edlund. “Trivers-Willard at Birth and One Year: Evidence from US natality data 1983-2001”. *Proceedings of the Royal Society B: Biological Sciences*, 274 (2007), pp. 2491-2496.

D. Almond et al. “Long-Term Effects of Early-Life Development: Evidence from the 1959 to 1961 China Famine”. In: *The Economic Consequences of Demographic Change in East Asia, NBER-EASE Volume 19*. NBER Chapters. National Bureau of Economic Research, Inc, 2010, pp. 321–345.

American College of Obstetrivians and Gynecologists. “ACOG Practice Bulletin. Management of Recurrent Pregnancy Loss. Number 24, February 2001”. *Int J Gynaecol Obstet* 78 (2010), pp. 179–190.

D. J. Barker. “The Fetal and Infant Origins of Adult Disease”. *BMJ* 301.6761 (1990), p. 1111.

P. Bharadwaj, K. V. Loken and C. Neilson. “Early Life Health Interventions and Academic Achievement”. *American Economic Review* 103.5 (2013), pp. 1862–1891.

S. E. Black, P. J. Devereux, and K. G. Salvanes. “Does Grief Transfer Across Generations? In-Utero Deaths and Child Outcomes”. NBER Working Papers 19979. National Bureau of Economic Research, Inc, Mar. 2014.

R. Brown, “The Intergenerational Impact of Terror: Does the 9/11 Tragedy Reverberate into the Outcomes of the Next Generation?” 2012.

C. Bozzoli, A. Deaton, and C. Quintana-Domeque. “Adult Height and Childhood Disease". *Demography* 46.4 (2009), pp. 647–669.

A. Camacho. "Stress and Birth Weight: Evidence from Terrorist Attacks". *American Economic Review* 98.2 (2008), pp. 511–15.

R. L. Copper et al. "The Preterm Prediction Study: Maternal Stress is Associated with Spontaneous Preterm Birth at Less than Thirty-Five Weeks' Gestation. National Institute of Child Health and Human Development Maternal-Fetal Medicine Units Network". *Am. J. Obstet. Gynecol*. 175.5 (1996), pp. 1286–1292.

J. Currie, M. Neidell, and J. F. Schmieder. "Air Pollution and Infant Health: Lessons from New Jersey". *Journal of Health Economics* 28.3 (2009), pp. 688–703.

J. Currie and M. Rossin-Slater. "Weathering the Storm: Hurricanes and Birth Outcomes". *Journal of Health Economics* 32.3 (2013), pp. 487–503.

J. Currie and T. Vogl. "Early-Life Health and Adult Circumstance in Developing Countries". *Annual Review of Economics* 5.1 (2013), pp. 1–36.

T. Dinkelman. Mitigating Long-run Health Effects of Drought: Evidence from South Africa. NBER Working Papers 19756. National Bureau of Economic Research, Inc, Dec. 2013.

N. Dole et al. "Maternal Stress and Preterm Birth". *Am. J. Epidemiol*. 157.1 (2003), pp. 14–24.

Earthquake Engineering Research Institute, 1999. "The Chi-Chi, Taiwan Earthquake of September 21, 1999"

M. Eccleston. "In Utero Exposure to Maternal Stress: Effects of the September 11th Terrorist Attackes in New Yorl City on Birth and Early Schooling Outcomes". 2011.

E. Frankenberg et al. "Child Height After a Natural Disaster". 2013.

L. M. Glynn et al. "When Stress Happens Matters: Effects of Earthquake Timing on Stress Responsivity in Pregnancy". *Am. J. Obstet. Gynecol*. 184.4 (2001), pp. 637–642.

M. K. Goldharber and B. H. Fireman. "The Fetal Life Table Revisited: Spontaneous Abortion Rates in Three Kaiser Permanente Cohorts". Epidemiology. 2.1 (1991), pp. 33–39.

M. Halla and M. Zweimuller. Parental Response to Early Human Capital Shocks: Evidence from the Chernobyl Accident. IZA Discussion Papers 7968. Institute for the Study of

Labor (IZA), Feb. 2014.

Health and Vital Statistics. Department of Health, R.O.C. 2004.

R. Hernandez-Julian, H. Mansour, and C. Peters. The Effects of Intrauterine Malnutrition on Birth and Fertility Outcomes: Evidence from the 1974 Bangladesh Famine. IZA Discussion Papers 7692. Institute for the Study of Labor (IZA), Oct. 2013.

C. Hobel and J. Culhane. “Role of Psychosocial and Nutritional Stress on Poor Pregnancy Outcome”. *J. Nutr*. 133.5 Suppl 2 (2003), 1709S–1717S.

A. Isen, M. Rossin-Slater and W. R. Walker. “Every Breath You Take – Every Dollar You’ll Make: The Long-Term Consequences of the Clean Aie Act of 1970”. NBER Working Papers 19858. National Bureau of Economic Research, Inc, Jan. 2014.

S. Jayachandran. “Air Quality and Early-Life Mortality: Evidence from Indonesia’s Wildfires”. *Journal of Human Resources* 44.4 (2009) , pp.916–954.

E. Kelly. “The Scourge of Asian Flu: In utero Exposure to Pandemic Influenza and the Development of a Cohort of British Children”. *Journal of Human Resources* 46.4 (2011), pp. 669–694.

S. Kraemer. “The Fragile Male”. *BMJ*. 321 (2000), pp.1609-1612.

K. D. Laszlo et al. “Maternal Bereavement During Pregnancy and the Risk of Stillbirth: a Nationwide Cohort Study in Sweden”. *Am. J. Epidemiol*. 177.3 (2013), pp. 219–227.

D. Lauderdale. “Birth Outcomes for Arabic-named Women in California Before and After September 11”. *Demography* 43.1 (2006), pp. 185–201.

D. S. Lee. “Training, Wages, and Sample Selection: Estimating Sharp Bounds on Treatment Effects”. *Review of Economic Studies* 76 (2009), pp. 1071–1102.

H. Mansour and D. I. Rees. “Armed conflict and birth weight: Evidence from the al-Aqsa Intifada”. *Journal of Development Economics* 99.1 (2012), pp. 190–199.

T. C. Michels and A. Y. Tiu. “Second Trimester Pregnancy Loss”. *American Family Physician* 76.9 (2007), pp. 1341–1346.

M. McLean et al. “A Placental Clock Controlling the Length of Human Pregnancy”. *Nat.Med*. 1.5 (1995), pp. 460–463.

H. Nian. “The Effects of the 921 Taiwan Earthquake on the Labor Market Outcomes and on the Birth Outcomes”. 2014.

C. Quintana-Domeque and P. Rodenas. “Fear in the Womb: The Effects of Terrorism on Birth Outcomes in Spain”. 2014.

M. Rutter, T. E. Moffitt, and A. Caspi. “Gene-Environment Interplay and Psychopathology: Multiple Varieties but Real Effects”. *J Child Psychol Psychiatry* 47.3-4 (2006), pp. 226–261.

R. J. Simes. An Improved Bonferroni Procedure for Multiple Tests of Significance. *Biometrika*. 73 (1986) pp. 751–754

E. Simeonova. “Out of Sight, Out of Mind? Natural Disasters and Pregnancy Outcomes in the USA”. *CESifo Economic Studies* 57.3 (2011), pp. 403–431.

F. Torche. “The Effect of Maternal Stress on Birth Outcomes: Exploiting a Natural Experiment”. *Demography* 48.4 (2011), pp. 1473–1491.

F. Torche and K. Kleinhaus. “Prenatal Stress, Gestational Age and Secondary Sex Ratio: the Sex-specific Effects of Exposure to a Natural Disaster in Early Pregnancy”. *Human Reproduction* 27.2 (2012), pp. 558–567.

P. D. Wadhwa et al. “Stress and Preterm Birth: Neuroendocrine, Immune/Inflammatory, and Vascular Mechanisms”. *Matern Child Health* J 5.2 (2001), pp. 119–125.

X. Wang et al. “Conception, early pregnancy loss, and time to clinical pregnancy: a population-based prospective study”. *Fertility and Sterility* 79.3 (2003), pp. 577–584.

K. Wisborg et al. “Psychological Stress During Pregnancy and Stillbirth: Prospective Study”. *BJOG: An International Journal of Obstetrics & Gynaecology* 115.7 (2008), pp. 882–885.

A. J. Wilcox et al. “Incidence of Early Loss of Pregnancy”. *N Engl J Med* 319 (1988), pp. 189–194.

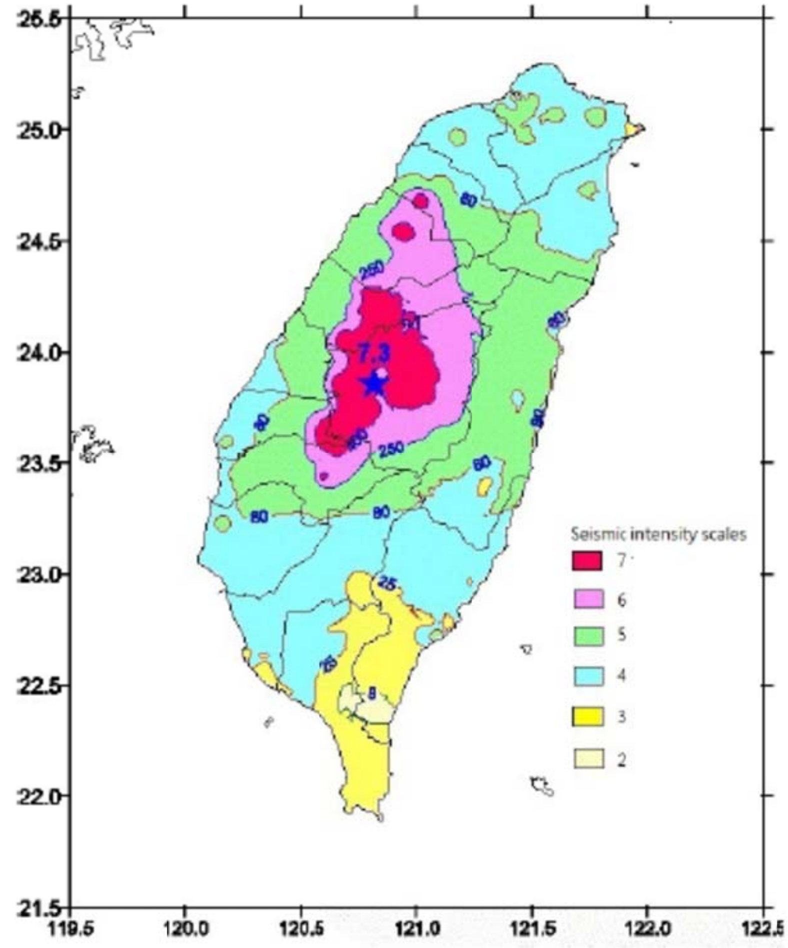


Figure 1: Isomap of the earthquake of Sept. 21, 1999
*Source: Central Weather Bureau, Taiwan*

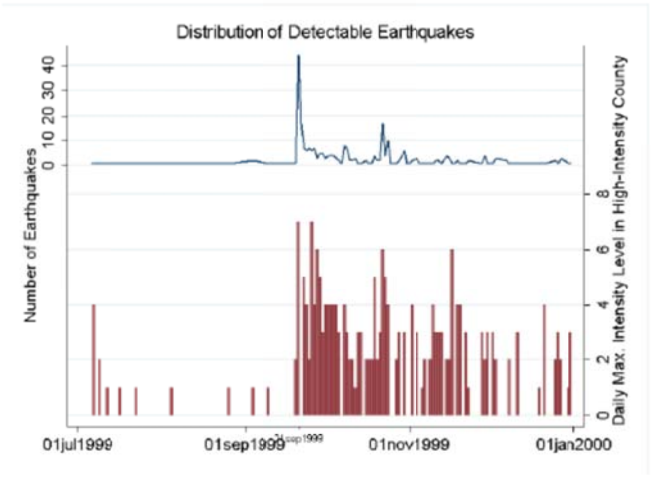
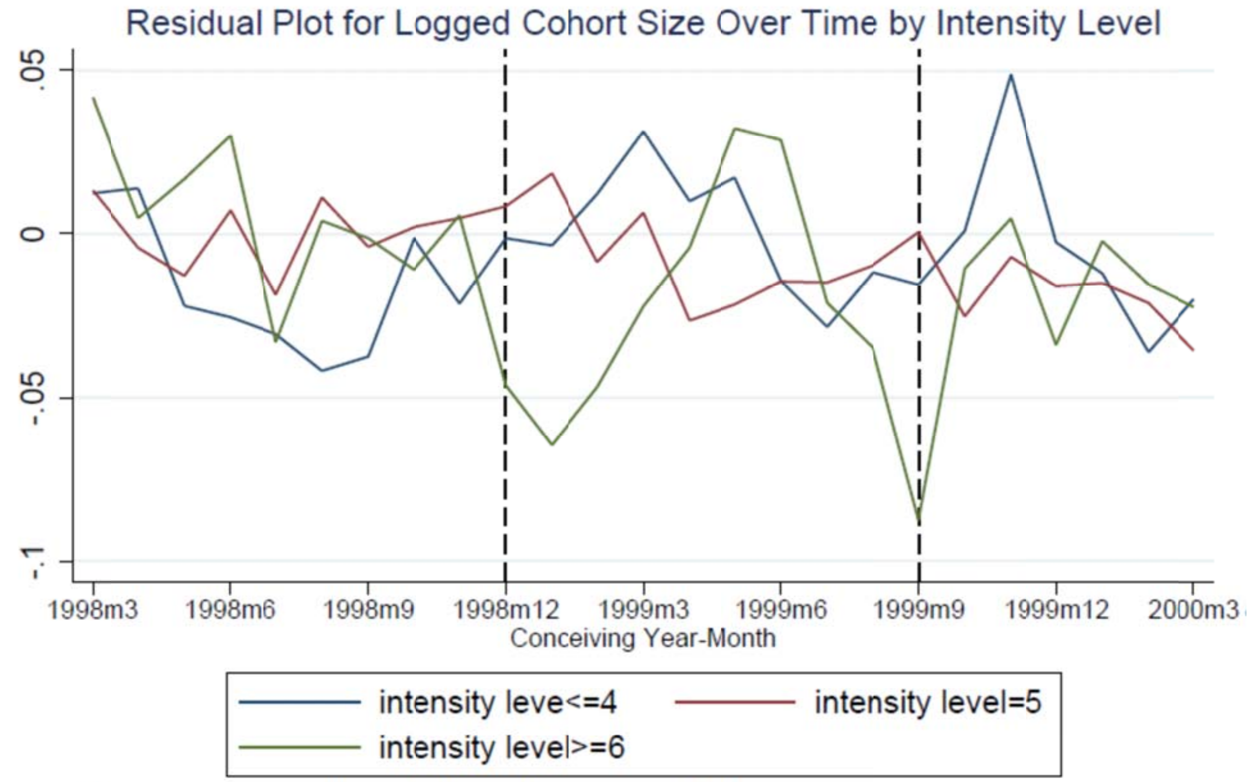


Figure 2: Distribution of Detectable Earthquakes between July 1999 and August 2000
*Source: All data was obtained from Central Weather Bureau and calculated by authors.*

Figure 3



Note: Cohort size is collapsed at township-conceiving level.
Regression includes township FE and conceiving month FE.

Figure 4

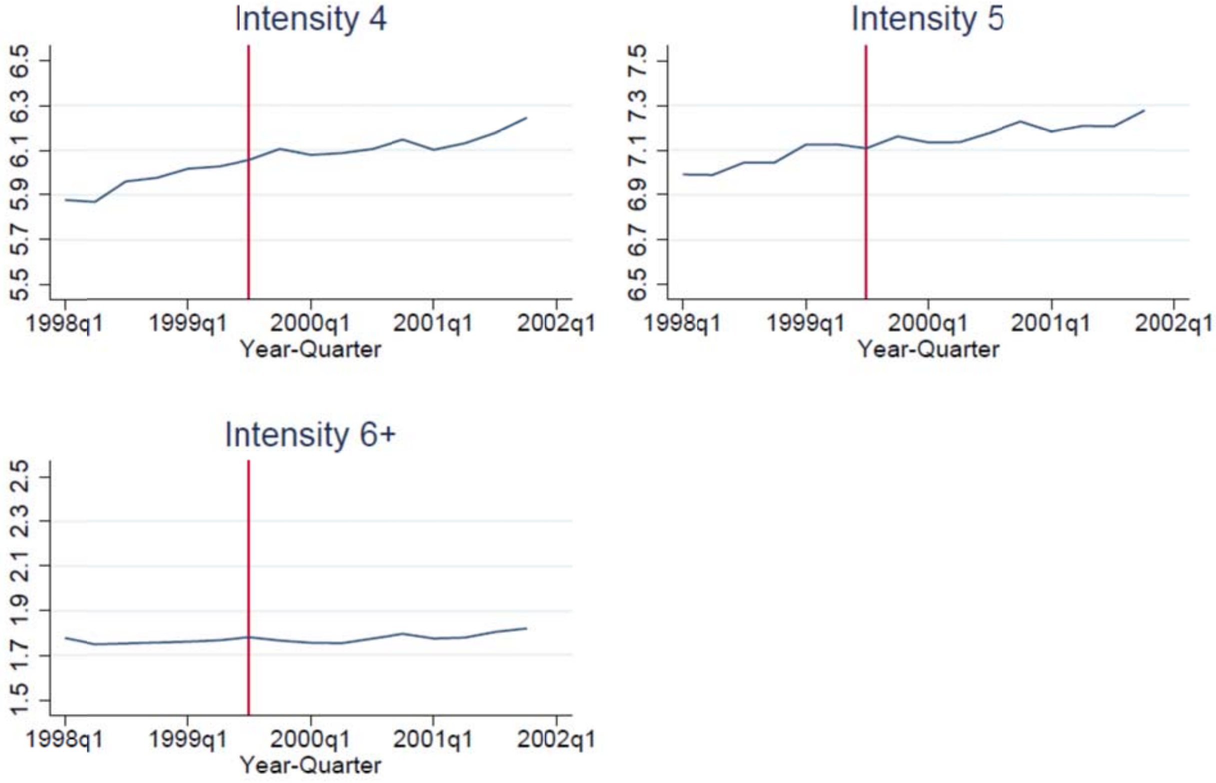


Figure 3: Number of Hospitals/Clinics by Intensity Level, 1998-2001
*Source: Authors calculated from health insurance claim records.*

Table 1: Descriptive Statistics of Birth Registry By Township Earthquake Intensity Level, 1998-2001

| Intensity level | 4<br>(1) | 5<br>(2) | 6+<br>(3) |
|---|---|---|---|
| Cohort size | 56.336 | 76.803*** | 56.157 |
| | (65.744) | (80.044) | (54.371) |
| Male-to-female ratio | 1.064* | 1.082 | 1.088 |
| | (0.459) | (0.382) | (0.443) |
| Infant mortality rate | 6.006 | 6.36 | 6.337 |
| (per 1000 live births) | (20.172) | (17.520) | (16.988) |
| Preterm | 0.068 | 0.066 | 0.067 |
| ( less than 37 weeks) | (0.063) | (0.050) | (0.055) |
| Birth weight | 3132.328*** | 3139.275*** | 3121.117 |
| | (117.803) | (98.570) | (103.816) |
| Gestational length | 38.633 | 38.638 | 38.627 |
| | (0.450) | (0.358) | (0.381) |
| Number of townships | | | |
| Number of observations (conceiving month-township) | | | |

Note: Data source: Birth Registry, 1998-2001. Earthquake intensity level is based on the township of mother's permanent residence registration (hukou). Intensity 6+ includes 9 townships with level 7 earthquake shock and intensity 4 includes 17 townships with level 3 earthquake shock. Standard deviation are reported in parentheses. *, **, *** denotes the p-values at 1%, 5%, 10% level from t-test of the equality between the given number and the reported number for level 6.

Table 2: Descriptive Statistics of Health Insurance Claim Records By Township Earthqu

| Intensity level | <=4<br>(1) | >=5<br>(2) |
|---|---|---|
| Mother with pre-existing health conditions | 0.211 | 0.213 |
| | (0.408) | (0.410) |
| Conditional on giving birth: | | |
| Complications during pregnancy/delivery | 0.289 | 0.284 |
| | (0.453) | (0.451) |
| Age of mother | 28.3*** | 28.050 |
| | (5.552) | (5.472) |
| Number of observations (pregnancy) | | |

Note: Data source: 5% Health Insurance Claim Records, 1998-2001. Pre-existing conditions include heart conditions, hypertension, stroke, diabetes, asthma, cancer and high cholesterol. We use all outpatient visits prior to the earthquake to identify the most-frequently visited township as mother's residence. Earthquake intensity is based on township of mother's residence. *, **, *** denotes the p-values at 1%, 5%, 10% level from t-test of the equality between the given number and the reported number for level 6.

Table 3: Impact of Earthquake Exposure on Fetal Losses and Sex Ratio

| Dependent Variable | Log Cohort Size | M/F Ratio |
|---|---|---|
| Mean across Cohort Average | 3.665 | 1.08 |
| | (1) | (2) |
| (Intensity≥6) *(Conceived 7-9M before Earthquake) | -0.027 | -0.028 |
| | (0.018) | (0.038) |
| *(Conceived 4-6M before Earthquake) | -0.032* | -0.024 |
| | (0.017) | (0.029) |
| *(Conceived 0-3M before Earthquake) | **-0.044*** ** | **-0.082*** ** |
| | **(0.013)** | **(0.027)** |
| *(Conceived 1-3M after Earthquake) | -0.034** | -0.048 |
| | (0.015) | (0.040) |
| *(Conceived 4-6M after Earthquake) | -0.017 | 0.000 |
| | (0.013) | (0.039) |
| *(Conceived 7-9M after Earthquake) | 0.008 | -0.105*** |
| | (0.015) | (0.030) |
| *(Conceived 10-12M after Earthquake) | -0.014 | -0.031 |
| | (0.019) | (0.034) |
| (Intensity= 5)*(Conceived 7-9M before Earthquake) | -0.002 | -0.000 |
| | (0.009) | (0.020) |
| *(Conceived 4-6M before Earthquake) | -0.024** | -0.008 |
| | (0.010) | (0.018) |
| *(Conceived 0-3M before Earthquake) | -0.007 | -0.021 |
| | (0.009) | (0.017) |
| *(Conceived 1-3M after Earthquake) | -0.018* | -0.005 |
| | (0.009) | (0.018) |
| *(Conceived 4-6M after Earthquake) | -0.007 | 0.011 |
| | (0.009) | (0.019) |
| *(Conceived 7-9M after Earthquake) | 0.019* | -0.047** |
| | (0.010) | (0.021) |
| *(Conceived 10-12M after Earthquake) | 0.028** | 0.065*** |
| | (0.011) | (0.019) |

Note: N=15,179. Data source: Birth Registry, 1998-2001. This table presents the estimation results of specification (1). Cohort is defined as conceived in the same month and same township. Each column is from a single regression, weighted by township population size. All regressions include conceiving month FE and township FE. Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Impact of Intrauterine Exposure to Earthquake on Birth Outcomes by Gender

| Dependent Variable | Birth Weight | | Gestational Length | |
|---|---|---|---|---|
| | Male | Female | Male | Female |
| Mean across Cohort Average | 3178.518 | 3085.831 | 38.563 | 38.712 |
| | (1) | (2) | (3) | (4) |
| (Intensity≥6)*(Conceived 7-9M before Earthquake) | -6.273 | -15.744** | 0.015 | -0.031 |
| | (7.353) | (7.015) | (0.036) | (0.034) |
| * (Conceived 4-6M before Earthquake) | -25.378*** | -11.295 | -0.047 | -0.068** |
| | (8.870) | (8.342) | (0.035) | (0.033) |
| * (Conceived 0-3M before Earthquake) | -3.887 | -13.654* | 0.003 | -0.022 |
| | (7.987) | (7.949) | (0.028) | (0.030) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -8.614 | -4.776 | -0.008 | -0.019 |
| | (5.496) | (6.237) | (0.019) | (0.025) |
| * (Conceived 4-6M before Earthquake) | -7.461 | -3.525 | -0.050** | -0.040* |
| | (5.697) | (6.117) | (0.022) | (0.021) |
| * (Conceived 0-3M before Earthquake) | -7.558 | -9.138* | -0.042** | -0.009 |
| | (4.753) | (5.012) | (0.019) | (0.018) |

Note: Data source: Birth Registry, 1998-2001. This table presents the estimation results of specification (1). Cohort is defined as conceived in the same month and same township. Each column is from a single regression, weighted by cohort size. All regressions include conceiving month FE and township FE and a set of interaction terms between township intensity level and conceived X months after earthquake (same as Table 3). Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Impact of Earthquake on Male Cohort Birth Outcomes by Mother's Educational Attainment

| Mother's Education Attainment | Middle school and below | High school | Some college or above |
|---|---|---|---|
| | (1) | (2) | (3) |
| Panel A: Dep Variable Log(Cohort Size) | | | |
| (Intensity≥6)*(Conceived 7-9M before Earthquake) | 0.005 | -0.056** | -0.005 |
| | (0.021) | (0.024) | (0.033) |
| * (Conceived 4-6M before Earthquake) | 0.023 | -0.065** | -0.077** |
| | (0.023) | (0.031) | (0.031) |
| * (Conceived 0-3M before Earthquake) | -0.003 | -0.078*** | -0.059** |
| | (0.026) | (0.026) | (0.029) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -0.005 | -0.021 | 0.069*** |
| | (0.017) | (0.017) | (0.024) |
| * (Conceived 4-6M before Earthquake) | -0.020 | -0.026* | 0.003 |
| | (0.019) | (0.016) | (0.022) |
| * (Conceived 0-3M before Earthquake) | -0.003 | -0.015 | -0.012 |
| | (0.016) | (0.018) | (0.022) |
| Panel B: Dep Variable Birth Weight (grams) | | | |
| (Intensity≥6)*(Conceived 7-9M before Earthquake) | -14.360 | -14.011 | 2.460 |
| | (10.471) | (8.830) | (13.344) |
| * (Conceived 4-6M before Earthquake) | -31.849*** | -7.131 | -6.535 |
| | (9.405) | (10.620) | (15.459) |
| * (Conceived 0-3M before Earthquake) | -3.015 | -9.364 | -23.111* |
| | (8.109) | (8.139) | (13.797) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -5.010 | -10.849 | -4.103 |
| | (6.075) | (6.919) | (9.516) |
| * (Conceived 4-6M before Earthquake) | -11.032* | -2.903 | 0.626 |
| | (5.983) | (7.470) | (8.412) |
| * (Conceived 0-3M before Earthquake) | -4.517 | -10.774* | -10.708 |
| | (5.528) | (5.760) | (6.744) |
| Panel C: Dep Variable Gestational Length (weeks) | | | |
| (Intensity≥6 )*(Conceived 7-9M before Earthquake) | -0.019 | -0.011 | 0.025 |
| | (0.037) | (0.039) | (0.057) |
| * (Conceived 4-6M before Earthquake) | -0.087** | 0.008 | -0.133*** |
| | (0.036) | (0.036) | (0.046) |
| * (Conceived 0-3M before Earthquake) | 0.037 | -0.047 | -0.040 |
| | (0.033) | (0.036) | (0.052) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | 0.002 | -0.012 | -0.044 |
| | (0.023) | (0.024) | (0.033) |
| * (Conceived 4-6M before Earthquake) | -0.061** | -0.022 | -0.056* |
| | (0.024) | (0.022) | (0.031) |
| * (Conceived 0-3M before Earthquake) | -0.012 | -0.032 | -0.043 |
| | (0.022) | (0.022) | (0.028) |

Note: Each panel reports different outcomes. Column 1 include only women whose education is below middle school or reported missing level of education. Column 2 includes women who receive some high school education or high school diploma. Column 3 includes women who have some college education or beyond. All regressions include conceiving-birth-month fixed effects, township fixed effects, a set of interaction terms between intensity and X months after earthquake (similar to Table 4). Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1. There are about 680,000 births for middle school/below, 780,000 births for high school and 530,000 births for some college and above.

Table 6: Impact of Earthquake on Male Cohort Birth Outcomes by Mother's Age

| Mother's Age | Age< 25 | 25-34 | >34 |
|---|---|---|---|
| | (1) | (2) | (3) |
| Panel A: Dep Variable Log(Cohort Size) | | | |
| (Intensity=6)* (Conceived 7-9M before Earthquake) | 0.001 | -0.038** | 0.029 |
| | (0.031) | (0.019) | (0.034) |
| * (Conceived 4-6M before Earthquake) | 0.024 | -0.047** | -0.005 |
| | (0.033) | (0.019) | (0.040) |
| * (Conceived 0-3M before Earthquake) | -0.006 | -0.060*** | -0.005 |
| | (0.032) | (0.013) | (0.032) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -0.011 | 0.000 | 0.015 |
| | (0.023) | (0.010) | (0.022) |
| * (Conceived 4-6M before Earthquake) | -0.025 | -0.031*** | 0.023 |
| | (0.025) | (0.011) | (0.023) |
| * (Conceived 0-3M before Earthquake) | -0.010 | -0.017 | 0.036* |
| | (0.021) | (0.010) | (0.018) |
| Panel B: Dep Variable Birth Weight (grams) | | | |
| (Intensity=6)*(Conceived 7-9M before Earthquake) | 2.418 | -13.666* | -2.805 |
| | (13.480) | (7.056) | (16.611) |
| * (Conceived 4-6M before Earthquake) | 14.297 | -26.367*** | -1.582 |
| | (13.321) | (8.048) | (22.753) |
| * (Conceived 0-3M before Earthquake) | -14.188 | -14.049* | 8.140 |
| | (10.761) | (7.877) | (20.269) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -8.795 | -9.373* | 7.558 |
| | (10.227) | (4.968) | (13.264) |
| * (Conceived 4-6M before Earthquake) | 19.486* | -6.908 | -5.877 |
| | (11.348) | (5.028) | (12.221) |
| * (Conceived 0-3M before Earthquake) | -5.403 | -6.805 | -25.737** |
| | (10.143) | (4.224) | (12.907) |
| Panel C: Dep Variable Gestational Length (weeks) | | | |
| (Intensity=6)* (Conceived 7-9M before Earthquake) | 0.064 | -0.033 | 0.021 |
| | (0.061) | (0.028) | (0.078) |
| * (Conceived 4-6M before Earthquake) | -0.011 | -0.067*** | -0.115 |
| | (0.065) | (0.026) | (0.076) |
| * (Conceived 0-3M before Earthquake) | -0.006 | -0.025 | 0.041 |
| | (0.043) | (0.026) | (0.062) |
| (Intensity=5)* (Conceived 7-9M before Earthquake) | -0.001 | -0.035* | 0.011 |
| | (0.045) | (0.018) | (0.049) |
| * (Conceived 4-6M before Earthquake) | -0.055 | -0.049** | -0.027 |
| | (0.049) | (0.020) | (0.047) |
| * (Conceived 0-3M before Earthquake) | 0.004 | -0.024 | -0.047 |
| | (0.040) | (0.015) | (0.046) |

Note: Column 1 includes only women less than 25; Column 2 includes women between age 25-34; Column 3 includes women who are age 35+ . Each panel reports different outcomes. All regressions include conceiving-birth-month fixed effects, township fixed effects, a set of interaction terms between earthquake intensity and conceived X months after earthquake (similar to Table 4). Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1. There are about 1.4 million births by mothers between age 25-34; 300,000 births each for age<25 and age>34.

Table 7: Complication over time, 1998 to 2001

| | Complication during pregnancy/delivery (N=41,132) (2) | |
|---|---|---|
| VARIABLES | coef. | adj. p-value |
| **1999m1** | 0.032 | 0.524 |
| **1999m2** | 0.070 | 0.205 |
| **1999m3** | -0.015 | 0.730 |
| **1999m4** | 0.060 | 0.232 |
| **1999m5** | 0.062 | 0.253 |
| **1999m6** | 0.014 | 0.792 |
| **1999m7** | 0.046 | 0.332 |
| **1999m8** | 0.051 | 0.317 |
| **1999m9** | 0.033 | 0.506 |
| **1999m10** | 0.056 | 0.295 |
| **1999m11** | 0.108*** | 0.010 |
| **1999m12** | 0.030 | 0.563 |
| **2000m1** | 0.067 | 0.173 |
| **2000m2** | 0.097* | 0.057 |
| **2000m3** | 0.026 | 0.587 |
| **2000m4** | 0.044 | 0.336 |
| **2000m5** | 0.069 | 0.193 |
| **2000m6** | 0.035 | 0.493 |
| **2000m7** | 0.049 | 0.287 |
| **2000m8** | 0.073* | 0.123 |
| **2000m9** | 0.061 | 0.179 |
| **2000m10** | 0.014 | 0.783 |
| **2000m11** | 0.022 | 0.616 |
| **2000m12** | 0.056 | 0.232 |

Note: Data source: 5% Health Insurance Claim Records, 1998-2001. This table presents the estimation result of specification (2) and (3). Pregnancy loss includes miscarriages and stillbirths. Health insurance claim records between 1998 and 2001 is used to impute the dependent variables, i.e. pregnancy loss. We use all outpatient visits prior to the earthquake to identify the most-frequently visited township as mother's residence. All regressions include mother's age FE, township FE, month FE and a set of interaction terms between high intensityX(1998M1-1998M12, 2001M1-2001M12) (not reported here). Adjusted p-values are calculated by Simes' procedure. Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1.

Table 8: Complication by Pre-existing conditions over time, 1998 to 2001

| | Pre-existing conditions | | | |
|---|---|---|---|---|
| | No<br>(N=32,503)<br>(1) | | Yes<br>(N=8,629)<br>(2) | |
| VARIABLES | coef. | adj. p-value | coef. | adj. p-value |
| **1999m1** | 0.017 | (0.760) | 0.038 | (0.837) |
| **1999m2** | 0.019 | (0.760) | 0.101 | (0.503) |
| **1999m3** | -0.065 | (0.156) | 0.060 | (0.660) |
| **1999m4** | 0.035 | (0.514) | 0.132 | (0.266) |
| **1999m5** | 0.040 | (0.472) | 0.041 | (0.820) |
| **1999m6** | 0.005 | (0.910) | 0.014 | (0.944) |
| **1999m7** | 0.057 | (0.212) | -0.031 | (0.854) |
| **1999m8** | 0.031 | (0.525) | 0.109 | (0.541) |
| **1999m9** | -0.003 | (0.952) | 0.049 | (0.806) |
| **1999m10** | 0.039 | (0.441) | 0.088 | (0.587) |
| **1999m11** | 0.088** | (0.064) | 0.110 | (0.430) |
| **1999m12** | 0.009 | (0.861) | 0.093 | (0.609) |
| **2000m1** | 0.032 | (0.536) | 0.153* | (0.172) |
| **2000m2** | 0.078 | (0.170) | 0.149 | (0.304) |
| **2000m3** | 0.043 | (0.438) | -0.042 | (0.812) |
| **2000m4** | 0.056 | (0.219) | 0.022 | (0.901) |
| **2000m5** | 0.050 | (0.340) | 0.099 | (0.493) |
| **2000m6** | 0.016 | (0.754) | -0.075 | (0.698) |
| **2000m7** | 0.022 | (0.662) | 0.074 | (0.609) |
| **2000m8** | 0.031 | (0.527) | 0.062 | (0.736) |
| **2000m9** | 0.023 | (0.662) | 0.059 | (0.700) |
| **2000m10** | 0.015 | (0.785) | 0.108 | (0.438) |
| **2000m11** | -0.007 | (0.876) | 0.034 | (0.843) |
| **2000m12** | 0.045 | (0.389) | -0.101 | (0.569) |

Note: Data source: 5% Health Insurance Claim Records, 1998-2001. This table presents the estimation result of specification (2) and (3). Pregnancy loss includes miscarriages and stillbirths. Health insurance claim records between 1998 and 2001 is used to impute the dependent variables, i.e. pregnancy loss. We use all outpatient visits prior to the earthquake to identify the most-frequently visited township as mother's residence. All regressions include mother's age FE, township FE, month FE and a set of interaction terms between high intensityX(1998M1-1998M12, 2001M1-2001M12) (not reported here). Adjusted p-values are calculated by Simes' procedure. Std. Errors are clustered at township level. *** p<0.01, ** p<0.05, * p<0.1.