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

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July, 2015

Abstract

We examine the impact of a magnitude-7.3 earthquake on fetal losses and birth outcomes in Taiwan. We compare the pregnancy outcomes and cohort sizes 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 a negative shock during the first trimester increases fetal losses by 4.4 percent and almost all the losses are due to the loss of male fetuses, whereas a later negative shock leads to worse pregnancy outcomes. We also find evidence of positive selection of the surviving fetuses.

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 NBER-HE, SOLE, PAA, NEUDC and SEA and seminar participants at IFPRI, National Taiwan University, UT-School of Public Health, Sam Houston State and University of Houston for their helpful comments and suggestions. We also thank Alan Barreca, Sandy Black, Jason Lindo, Erzo Luttmer, Nicholas Sanders, Mark Stabile, Wesley Yin for helpful conversation. We thank Professor Yih-Min Wu at National Taiwan University, Department of Geoscience and Professor Kohua Yap at National Sun Yat-sen University for providing us the earthquake intensity data.

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 with 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, known as survivor bias (Bozzoli, Deaton, and Quintana-Domeque 2009). This challenge posed by positive mortality selection is widely recognized in both economics and epidemiology. The main objectives of this paper are to understand the extent to which fetal losses occur as a result of poor *in utero* environment and to examine whether there is evidence of positive selection. We will also discuss the causes of fetal losses. 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 and one of the handful of papers that provides evidence of positive selection (Gørgens, Meng, and Vaithianathan 2012; Bozzoli et al. 2009; Bhalotra Valente, and van Soest 2010).

The closer examination of the impact of adverse events on fetal losses is of high importance for researchers. First, recent papers in this literature have tried to address the issue of *survivor bias* using a bounding exercise, following Lee's procedure (2009).[1] However, while the bounding exercise is appealing and informative, this method may not always be feasible since the size of culling 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

[1] Recent papers that use this exercise in the related literature include Bharadwaj, Loken, and Neilson (2013); Lin and Liu (2014); Halla and Zweimuller (2014); and Isen, Rosen-Slater, and Walker (2014).

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, and created aftershocks that lasted a month. We expect the earthquake to affect fertility outcomes and fetal mortality since recent papers have found that maternal stress caused by natural disasters is harmful to birth outcomes (e.g., Torche 2011, Currie and Rossin-Slater 2013, Simeonova 2011), but none of these papers examines the incidence of fetal losses. 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.

While fetal mortality that includes miscarriages and stillbirths is extremely common, the difficult part of estimating pregnancy losses is the issue of underreporting. Most existing papers that examine fetal losses often rely on the reporting of miscarriages/stillbirths in birth registries (Black, Devereux, and Salvanes. 2014; Laszlo et al. 2013; Persson and Rossin-Slater 2014). One caveat of using the record from birth registries is that most countries' administrative birth registries require reports of any outcomes of pregnancies of later gestation period.[2] Medical studies have found the incidence of fetal losses to be around 30% (Wilcox et al. 1988; Nepomnaschy 2006), but most fetal losses occur during the first trimester, which is before 12 weeks of gestational length (Nepomnaschy 2006; Goldhaber and Fireman 1991).[3] Early miscarriages will not be reported in administrative vital statistics. Other studies use household survey recall data reporting on miscarriages and fertility outcomes (Hernandez-Julian, Mansour,

[2] 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).

[3] 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, which happens within 20 weeks of gestation, and 80% of miscarriages happen during the first trimester 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 delayed 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 fetal losses rate of 31 percent of all pregnancies.

and Peters 2013). Recalling errors issue aside, according to the National Institutes of Health[4], which cites Michels and Tiu (2007), nearly half of fertilized eggs are aborted even before women realize that they are 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.

We use birth registries from 1998 to 2001 from Taiwan to construct cohort size. 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. We construct cohort size for each township and month of conception. After controlling for various fixed effects, the changes in cohort size could reflect the size of fetal losses as a result of the earthquake. Another advantage of the Taiwanese data is that 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 the location of the hospital. These health insurance 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 suggests 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 most earthquake-affected regions during the first and second trimesters, respectively. We find that almost all of the losses that occur during first-trimester exposure are due to the loss of male fetuses.

We also find reductions in birth weight of 13 and15 grams for females with *in utero* exposure to the earthquake during the first and third trimesters, respectively. There is no difference in birth weight for males who are exposed during the first trimester compared to those with no exposure to the earthquake. The lack of results for male birth weight can be due to the positive (fetal) selection. Next, we apply Lee's bounding technique to our analysis, and it paints a very different picture. We find that male exposure to the earthquake during the first trimester would lower birth weight by 48 grams, which is significantly higher than the impact of exposure

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

during the second and third trimesters and higher than the impact on females. 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.

Lastly, we discuss various channels of why this earthquake leads to an increase in miscarriages, and we provide some suggestive evidence that maternal stress caused by the earthquake may be a key reason for the increase in miscarriages and poor pregnancy outcomes.

The paper is organized as follows. Section 2 discusses Background and Data. Section 3 presents results from our empirical analysis. Section 4 discusses various channels of why the earthquake can lead to poor pregnancy outcomes. Section 5 concludes.

2. Background and Data

2.1 Background on the Earthquake Intensity

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.[5] 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 intensity scale ranged from 3 in the least severe area to 7 in the most affected area (see Figure 1). [6] 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.

[Insert Figure 1 about here]

[Insert Figure 2 about here]

2.2 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,

[5] While Taiwan is in an earthquake zone, most of the earthquakes occur on the east coast and cause little damage. The 9/21 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).

[6] The Richter Scale reflects the magnitude of an earthquake. Richter scale 7.3 is measured at the epicenter. Our dataset contains Shindo intensity scale, which reflects the intensity of the earthquake that is felt by humans. Unlike the Richter scale, the Shindo Intensity scale is ordinal, and the intensity is inversely related to the distance to the epicenter.

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.[7]

Having gestational age is extremely helpful. Based on gestational length and one's birth date, we can infer the week that one was conceived and the timing of exposure to earthquake. 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. We then collapse the data so that each unit of observation is at the conceiving-month-township level. We have birth records between January 1, 1998 and December 31, 2001, so conceiving year-months ranges from mid-1997 to the early part of 2001, with a total of 43 conceiving year-months. Table 1 shows the summary statistics at the cohort level. Townships with an intensity level of 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]

2.3 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 International Classification of Diseases (ICD-9) and Diagnosis-Related Group (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 the reason for their visit, and pregnancy outcome, with associated ICD-9 codes. Here pregnancy outcome is either normal delivery or delivery with complications (reported by physicians). Since health

[7] 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 mothers with missing age or education information tend to be of foreign origins. Based on a paper by Edlund, Liu, and Liu (2013) discussing foreign bride phenomenon in Taiwan, we would code those births from foreign mothers with missing age as aged between 25–34 and education level 9 years or below. If the birth is from domestic mothers, we replace the missing education level with 10–12 years of education and age between 25–34.

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.[8]

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 17-19% 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 a lower rate of labor complications. One should note that the difference could also be due to the differences in norm, to patient access to hospitals, and to 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]

3. Empirical Analysis

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 birth complications increases for those pregnancies that were exposed to the earthquake in high-intensity areas.

[8] While this dataset provides some information on miscarriages, we do not use it as an outcome for two reasons. First, as discussed in the introduction, most fetal losses occurred within a month of conception, and they are not known to mothers, so mothers might not visit hospitals/clinics for miscarriages. Second, as shown in Figure 4, immediately after the earthquake, there was a sharp drop in the number of outpatient visits. Those residing in high-intensity areas avoid visiting hospitals/clinics for less-urgent care as a result of the earthquake. For these two reasons combined, using post-earthquake miscarriages to proxy for fetal losses as a result of earthquake would underestimate the true impact of the earthquake.

3.1 Fetal Losses and 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 3.2). 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).

For a given cohort conceived in year-month t in township w, our primary specification is as follows:[9]

$$
\begin{aligned}
Y_{wt} = {} & \beta_1\, I(Intensity \geq 6)_w * I(Conceived\ in\ 0-3\ Months\ Before\ the\ earthquake)_t + \\
& \beta_2\, I(Intensity \geq 6)_w * I(Conceived\ in\ 4-6\ Months\ Before\ the\ earthquake)_t + \\
& \beta_3\, I(Intensity \geq 6)_w * I(Conceived\ in\ 7-9\ Months\ Before\ the\ earthquake)_t + \\
& \alpha_1\, I(Intensity = 5)_w * I(Conceived\ in\ 0-3\ Months\ Before\ the\ earthquake)_t \\
& + \\
& \alpha_2\, I(Intensity = 5)_w * I(Conceived\ in\ 4-6\ Months\ Before\ the\ earthquake)_t + \\
& \alpha_3\, I(Intensity = 5)_w * I(Conceived\ in\ 7-9\ Months\ Before\ the\ earthquake)_t \\
& + I(IntensityX)_w * I(Conceived\ in\ 1-3\ Months\ after\ the\ earthquake)_t. \\
& + I(IntensityX)_w * I(Conceived\ in\ 4-6\ Months\ after\ the\ earthquake)_t \\
& + I(IntensityX)_w * I(Conceived\ in\ 7-9\ Months\ after\ the\ earthquake)_t \\
& + I(IntensityX)_w * I(Conceived\ in\ 10-12\ Months\ after\ the\ earthquake)_t \\
& + v_w + \mu_t + \varepsilon \text{----(1)}
\end{aligned}
$$

v_w and μ_t capture the township and year-month fixed effects, respectively. β_1 , β_2 , β_3 capture the impact for exposure to the earthquake with intensity ≥ 6 during the first, second, and third trimesters, respectively; $\alpha_1, \alpha_2, \alpha_3$ capture the impact of the earthquake with intensity level 5 during the first , second, and third trimesters, respectively. Other coefficients capture the

[9] 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).

variation in outcomes for those conceived 1–3 months after the earthquake, 4–6 months after the earthquake, 7–9 months after earthquake, and 10–12 months after the earthquake. We include these post-earthquake dummies because there can be a negative selection issue for women who decide to conceive immediately 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 an intensity level of 7, 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. We decide not to use a continuous measure of earthquake intensity in our analysis, since the earthquake intensity scale we have is ordinal. 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.[10]

The regression results for fetal losses and sex ratio are shown in Table 3. We find that the cohort sizes for those who were exposed to the earthquake *in utero* during the first trimester (conceived 0–3 months prior to the earthquake) in a high-intensity area (level 6+) 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.[11] Impact on the third-trimester exposure, albeit negative, is not statistically different from zero. The size of fetal losses in the level 5 areas is smaller in magnitude compared to the level 6+ areas.

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 fetuses. This finding of a skewed sex ratio as a result of poor *in utero* environment is also supported by several papers, including Hernandez-Julian et al. (2013); Torche and Kleinhaus (2012); Trivers and Willard

[10] 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 with the average treatment effect for those who were born.

[11] 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. Valente (2015) finds civil conflict increases the likelihood of miscarriage by 12 percent.

(1973); Almond and Edlund (2007); Almond and Mazumder (2011); Mu and Zhang (2011); and Valente (2015).

[Insert Table 3 about here]

[Insert Table 4 about here]

Given that we find a difference in fetal mortality rates between genders, in Table 4, we will present birth outcomes 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 seem to be relatively unaffected by the earthquake. It might also appear that females are more affected by the earthquake since the effects in the first trimester are statistically greater for females than for males. This can be due to positive selection. Since nearly 4% of male fetuses in the left tail of health distribution may be culled, it is not surprising that we do not find much effect. In Section 4.2, we will perform a bounding exercise based on Lee's procedure, which will allow us to compare the impact for males versus for females.

We are also interested in exploring whether the fetal mortality rates can differ by the socioeconomic status of the mother or the age 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. In these regressions, we do not find mothers with lower socioeconomic status to be any more likely to experience fetal losses. These results are in the Appendix Table A1.

We perform robustness checks using alternative proxies for earthquake intensity. First, the Shindo intensity level we use has one decimal point. In our main specification, we round it to the closest integer. As a robustness check, we round down the number to the integer, and the results are presented in Table 5, Column 2. In Column 3, we have measures of building collapsed rates in each township. We define highest intensity as those townships with 5% or more of the buildings collapsed, and 2nd highest intensity for those townships with greater than 0 to 5% of buildings collapsed. Across these alternative specifications, we can see that the magnitudes of fetal loss for first-trimester earthquake exposure in high-intensity areas are quite consistent.

[Insert Table 5 about here]

3.2 Labor Complication Using Health Insurance Claim Records

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

Unlike the birth registry data, we do not know the gestational length, we only observe the timing of diagnosis. If a pregnant woman 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, unlike the birth registry data, we show results based on the timing of the diagnosis rather than the timing of the conception.

Our main regression specification is listed as below, for a birth delivery *i* from mother who resides in township *w* at year-month *t*:

$$I(Labor\ Complication)_{iwt} = \sum_{k=1998M2}^{k=2001M12} I(YearMonth = k)_t + \sum_{k=1998M2}^{k=2001M12} \beta_k * I(YearMonth = k)_t * I(Intensity \geq 5)_w + (Age)_{it} + \delta_w + \varepsilon_{iwt} \text{---(2)}$$

$I(Labor\ Complication)_{iwt}$ equals 1 if a physician reported a labor complication during delivery. The coefficients β_k capture the differences in labor complication in areas with an intensity of 5 and above relative to areas with an intensity of 4 or below and relative to the omitted month (1998M1). We decided to combine all areas with an intensity of 5 or more as one group since there are only 4,752 observations in areas with intensity levels of 6 and 7.

[Insert Figure 3 about here]

The regression results of specification (2) are presented in Figure 3. The shaded areas indicate those who probably had *in utero* exposure to the earthquake and its month-long aftershock. 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 analysis. In the period immediately after the earthquake (October–November, 1999), the likelihood of complications increases by 7.4–9.5 percentage points (approximately 30% increase) in areas with intensity of 5 and above relative to low-intensity areas, but this impact disappears after two months. Combining this result with the previous results on fetal losses suggests that exposure to the earthquake during the third trimester increases the likelihood of pregnancy/labor complications, whereas exposure during the first and second trimesters increases the likelihood of fetal losses.

3.3 Evidence of Positive Selection

In this section we examine whether there is evidence of positive selection. We will attempt to do so by examining subgroups that potentially experience greater treatment from the earthquake and compare the pregnancy outcomes of these groups. If we find that the ones that experience more fetal losses have better outcomes than those that do not, then it could be supporting evidence for positive selection.

First, we examine the likelihood of labor complications in level 6+ areas compared to level 5 areas. We rewrite Equation 2 as below. For a birth delivery *i* from a mother who resides in township *w* at year-month *t*,

$$I(Labor\ Complication)_{iwt} = \pi_1 I(Intensity \geq 5)_w * I(< 3\ months\ post\ equarthquake)_t + \sum_{k=1998M2}^{k=2001M12} I(\ YearMonth = k)_t + (Age)_{it} + \delta_w + \varepsilon_{iwt} \quad \text{------ (3a)}$$

$$I(Labor\ Complication)_{iwt} = \pi_1 I(Intensity \geq 5)_w * I(< 3\ months\ post\ equarthquake)_t + \pi_2 I(Intensity \geq 6)_w * I(Intensity \geq 5)_w * I(< 3\ months\ post\ equarthquake)_t) \sum_{k=1998M2}^{k=2001M12} I(\ YearMonth = k)_t + (Age)_{it} + \delta_w + \varepsilon_{iwt} \quad \text{------ (3b)}$$

[Insert Table 6 about here]

Results can be found in Table 6. Column 1 shows the regression results of Equation 3a. We only focus on less than 3 months after the earthquake since in Figure 3, we find that this short-term effect π_1 captures the causal effect of the earthquake on labor complications within the first two months post-earthquake, which is an increase of about 4.0 percentage points. Column 2 presents the regression results of Equation 3b. In Column 2, we can see that most of the negative effects on labor complications are being driven by women residing in the intensity 5 areas, rather than those from the intensity 6 areas. In particular, $\pi_2 + \pi_1$, the total earthquake effect on level 6+ intensity area is not statistically different from zero. This is not surprising, given that in the earlier analysis, we find that most fetal losses occur in the level 6+ areas (instead of level 5 area). This pattern is consistent with the positive selection in level 6+ areas. Appendix Figure A1 illustrates this pattern of positive selection.

Second, we identify those pregnant women with chronic conditions prior to the earthquake.[12] In general, we find that women with chronic conditions are more susceptible to miscarriages, thus has a higher rate of fetal losses even without the presence of the earthquake.[13] We examine whether they are more likely to experience labor complications as a result of earthquake in the regression specification below.

$$I(Labor\ Complication)_{iwt} = I(Chronic)_{it} + I(Chronic)_{it} * I(Intensity \geq 5)_w$$
$$+\pi_1 I(Intensity \geq 5)_w * I(< 3\ months\ post\ equarthquake)_t$$
$$+\pi_3 I(Chronic)_{it} * I(Intensity \geq 5)_w * I(< 3\ months\ post\ equarthquake)_t$$
$$\sum_{k=1998M2}^{k=2001M12} \beta_k * I(YearMonth = k)_t + (Age)_{it} + \delta_w + \varepsilon_{iwt} \quad \text{------ (4)}$$

Results are shown in Table 6, Column 2. Similar to before, π_1 is the causal estimate of the impact of the earthquake on labor complications is positive and significant. The casual impact of the earthquake on women with chronic condition is $\pi_1 + \pi_3$, which is not statistically different from zero. Again similar to the finding before, given that women with chronic conditions probably experience more fetal losses as a result of the earthquake, the pattern in Column 3 is consistent with a positive selection of fetuses. We illustrate this pattern in Appendix Figure A2.

4. Discussion of Channels and Bounding Exercise

4.1 Channels

There can be many reasons why a major earthquake could increase the likelihood of fetal losses and worsen pregnancy outcomes. Following is a list of reasons that we try to tackle them one by one: the earthquake could destroy health infrastructure or increase the overall

[12] Patients with chronic conditions have been identified by the National Health Insurance Bureau. It is recorded in our dataset. The chronic conditions include diabetes, hypertension, hyperlipidemia, cancer, mental illness, cardiovascular disease, chronic renal failure, chronic obstructive pulmonary disease, etc. Being identified with chronic conditions would allow the patients to pick up drugs for their conditions for longer duration.

[13] We use only 1998 health insurance claim data to estimate the relationship between chronic illness and miscarriages that are recorded in health insurance claims. We find that those with chronic illnesses are associated with a 9 percentage point increase in miscarriage and a 1.8 percentage point increase in labor complications even without the presence of the earthquake.

crowdedness of hospitals; the earthquake could damage public infrastructure, affecting the food and water supplies; the earthquake could affect the frequency of prenatal visits; and lastly, a major earthquake could increase maternal stress.

[Insert Figure 4 about here]

The increase in fetal loss may be due to the crowdedness of the hospitals or the closure of the hospitals. In Figure 4, we plot the residual of inpatient and outpatient visits by earthquake intensity level after the township dummies and the month and year dummies included in our models have been controlled for. Surprisingly, we find a dramatic drop in the use of outpatient visits immediately following the earthquake. It is likely that individuals are avoiding going to hospitals for less urgent care post-earthquake. In addition, given the magnitude of this earthquake, this particular earthquake caused relatively few casualties compared to other earthquakes of similar intensity level (e.g., the Turkish earthquake in 1999 had approximately 17,000 deaths, and the Kobe earthquake in Japan in 1995 had 6,400 reported deaths). Even in the highest-intensity areas, with intensity levels of 6 and 7, the fatality rates are 1.0/1000 and 2.4/1000, respectively.[14] Thus, hospitals may not be as crowded as one expects. Our data also allows us to observe the number of hospitals that are actively treating patients. In Figure 5, we do not see evidence of hospital closures following the earthquake.

[Insert Figure 5 about here]

[Insert Table 7 about here]

Next, we examine whether the results are being driven by infrastructure damages. There are a lot of variations in the share of building collapses even within the same intensity level. Among level 6 and 7 intensity areas (41 townships), some have no building collapses in the township while some townships have nearly half of their buildings collapsed.[15] To distinguish whether the effect is from the damaged infrastructure, we focus on the subgroups that have high intensity (level 6 and level 7) but little damage (less than 5% buildings completely collapsed). The results are presented in Table 7, Column 2. We do observe that the coefficient has shrunk

[14] We do not have the breakdown of injuries by townships, so we do not know the rate of casualties by earthquake intensity. However, there are about 5 times more casualties than deaths resulting from this earthquake. If we assume the proportions between intensity levels is the same between casualties and deaths, it suggests that level 7 areas have about a 12/1000 casualty rate and level 6 areas have casualty rates of about 5/1000.

[15] One might worry that within a given earthquake intensity, townships with higher income may have fewer buildings collapsed. We run a regression and township average education level is not predictive of the share of buildings collapsed. This suggests that the share of buildings collapsed could be random within a given intensity level.

compared to the original specification, which is expected since we dropped all the most-severely damaged areas, but in this relatively undamaged and high-intensity area, the rate of fetal loses is still statistically different from zero. In addition, one possible channel is dirty water as a result of infrastructure damages. We examine gastrointestinal-related visits to hospitals/clinics using Equation 2, and we do not find a statistical significant increase in these visits. Overall, the finding seems to point to the reason beyond the infrastructure damages.[16]

Given that we find fewer non-urgent outpatient visits, it is possible that pregnant women may go to the hospital for prenatal visits fewer times as a result of the earthquake. Universal health insurance in Taiwan covers 10 free prenatal visits per pregnancy, and every prenatal visit is recorded in the health insurance claim data (but cannot be linked to the birth registry). Thus, for every birth/delivery, we can impute the number of prenatal visits. In Figure 3, we show that births in October–November 1999 are more likely to have labor complications. One possibility is that these births had fewer prenatal visits, which may result in a higher likelihood of labor complications. So we use the same specification as Equation 2: for each delivery i in township w and year-month t, we examine a number of prenatal visits as an outcome, and coefficients β_k are presented in Appendix Figure A3. We do not find any statistical difference in the number of prenatal visits (among those births immediately following the earthquake). This suggests that missing prenatal visits is not a reason for the increase in labor complications for those who had earthquake exposure during the third trimester. On the other hand, can missing prenatal visit explain the fetal losses that occurred for those with first-trimester exposure?[17] We think it is unlikely since the medical literature suggests that most fetal losses occur within the first two weeks of conception, which is earlier than the first prenatal visit—occurring around 8 weeks into pregnancy.

We propose that one of the main explanations is due to maternal stress. First, there is an existing literature suggesting an association between maternal stress and gestational lengths and

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[16] We tried to use a repeated-cross-section dataset on labor force participation to examine the earthquake's effects on labor participation and hours of work. We find no significant impacts on unemployment, hourly wages, and working hours. It is possible that the dataset does not have enough power to detect the impact.

[17] We can look at frequencies of prenatal visits by intensity level; this is illustrated in Figure 6. Similar to the non-urgent outpatient visits, the number of prenatal visits immediately dropped after the earthquake for those who reside in intensity 6+ and this drop lasted for few quarters. There can be a few reasons of this drop. One is that for each given birth, pregnant women visiting the OB/GYN less frequently post-earthquake, and another possibility is that there are simply fewer births (either due to changes in conception or fetal losses). We cannot distinguish one reason from the other.

birth outcomes. The hypothesized biological mechanism is that maternal stress activates a higher level of cortisol that stimulates the release of placental corticotrophin-releasing hormone (CRH), which could affect birth outcomes (Hobel and Culhane 2003; Copper et al. 1996; Dole et al. 2003; Wadhwa et al. 2001; McLean et al. 1995; and Wisborg et al. 2008). Some economists have exploited exogenous shocks to identify the effects of maternal stress on birth outcomes, including natural disasters (Torche 2011; Frankenberg et al. 2013; and Glynn et al. 2001), the threat of terrorist attacks (Camacho 2008; Quintana-Domeque and Ródenas-Serrano 2014; Brown 2012; and Eccleston 2011), armed conflict (Mansour and Rees 2011), and post-9/11 treatment of Arab women (Lauderdale 2006).

A major earthquake like this can increase one's stress level. Constant fear of aftershocks could last for months and the traumatic experience could even lead to post-traumatic stress disorder (Dimsdale 2008; Leor et al. 1996; and Siegel 2000). We examine psychiatric-related visits post-earthquake for males who are between age 16–45, and we find that those who reside in areas with high intensity increase depression-related outpatient visits by about 10% within half a year after the earthquake. It suggests that maternal stress could be a possible explanation for our findings.

We cannot rule out the difference in nutrition intake: the first trimester, especially, is a critical period for the formation of organs. Overall, the fetal losses we estimate can possibly be due to the exposure to poor nutritional environment or maternal stress.

Last, one might suspect that the differences in cohort size in the birth registry could be due to the change in conception or even selective abortion post-earthquake. However, it is unlikely that parents were planning to avoid giving birth because of an unexpected earthquake. Furthermore, either of the alternative hypotheses would not be able to explain the drop in male-to-female sex ratio we find in Column 2.

4.2 Bounding exercise

[Insert Table 8 about here]

As we have discussed before, a positive selection of survivors would lead to an underestimate of the true impact of the earthquake. We try to address the issue of *survivor bias* using a bounding exercise, following Lee's procedure (2009). In previous sections, we find that nearly 4.4% of fetuses who had first trimester–exposure to a high-intensity earthquake were culled and they are almost all male, and we show some evidence of positive selection. In the exercise, we drop the bottom 5% of observations by birth weight for each township-conception month cohort for males and females separately (males who had first-trimester exposure in intensity 6+ areas are excluded from this exercise) and rerun the regressions. The results are presented in Table 8, Columns 3 and 4. 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 48 grams and see their gestational length shorten by 0.10 week, both of which are higher than the impact on females. In Table 8, we also present the results without bounding exercise in Columns 1 and 2 for easy comparison. Before the bounding exercise, one might conclude that the earthquake has a greater impact on females, but once we correct for the survivor bias, it would suggest that the earthquake has a stronger, if not similar, impact on males.

5. 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 early *in utero* exposure to the earthquake led to fetal losses and that exposure to the earthquake during the last trimester led to more labor complications and worse pregnancy outcomes. Almost all the pregnancy losses were driven by loss of a male fetus. We find evidence of positive selection on health.

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 a bigger impact on female fetus health, and draw the wrong conclusion, e.g. female fetuses suffer more because the son preference in Taiwan. The bounding exercise in this paper demonstrates that it is extremely important to consider survivor bias especially if poor intrauterine environment substantially affects the likelihood of fetal losses of one subgroup more than others.

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Figure 1: Seismic Intensity Map of the Earthquake on September 21, 1999

Map source: Central Weather Bureau, Taiwan

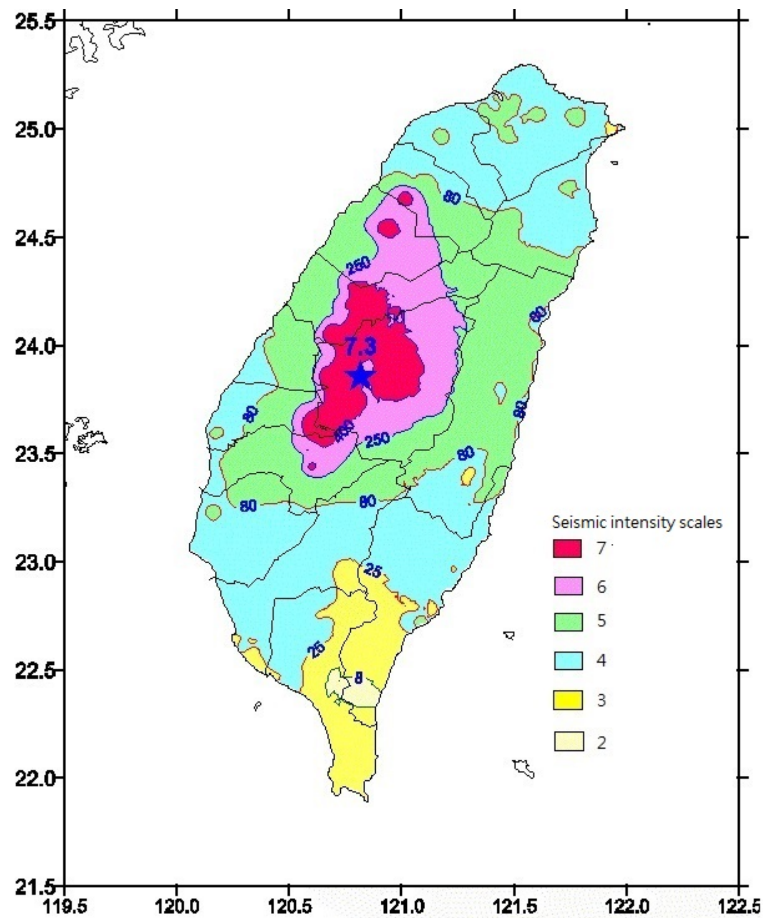
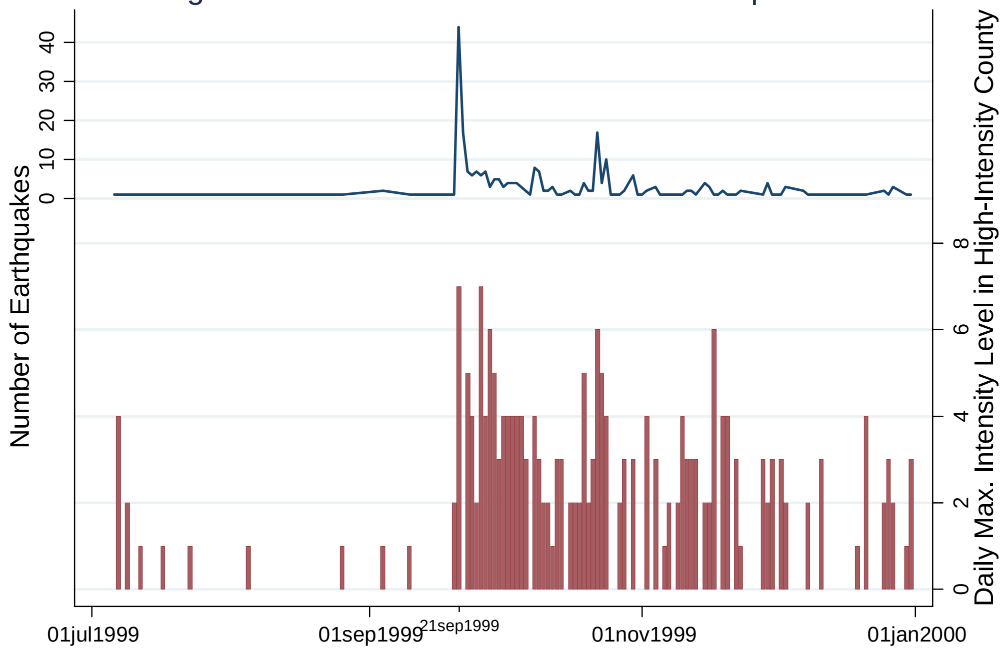
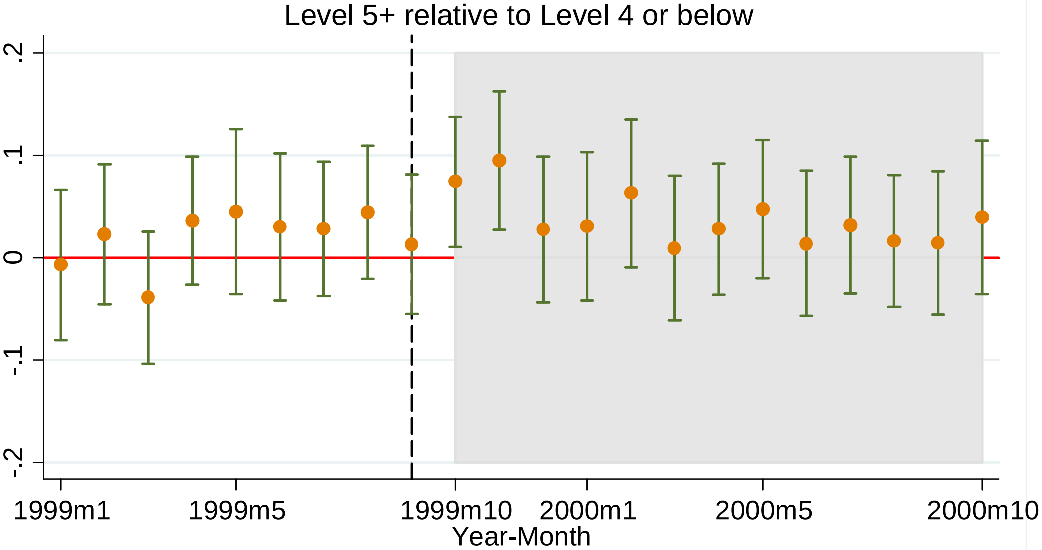


Figure 2: Distribution of Detectable Earthquakes



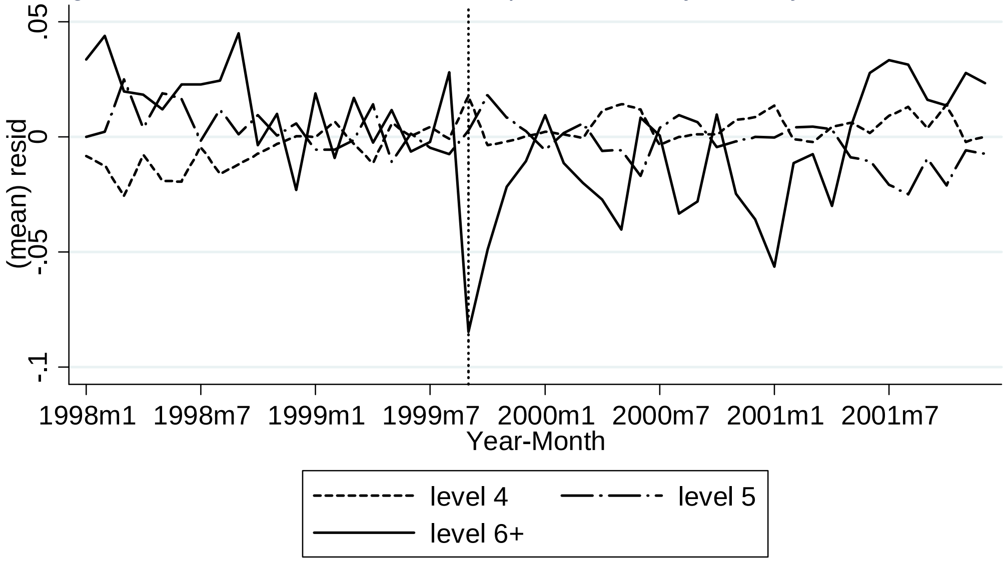
Note: Data source Central Weather Bureau, Taiwan.

Figure 3: Impact of Earthquake on the Likelihood of Labor Complications
Level 5+ relative to Level 4 or below



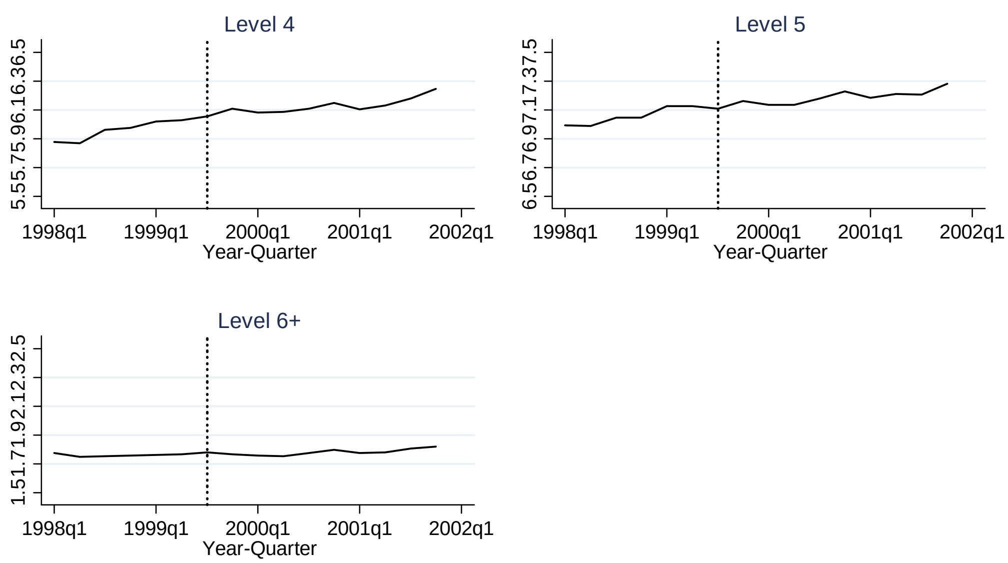
Notes: Regression estimates from Equation 2 are plotted. The dot and the bar correspond to the coefficient estimates with 90% confidence intervals. The shaded areas indicate those who probably had in utero exposure to the earthquake and its month-long aftershock. The dotted vertical line indicates the month when the earthquake occurred. Regression estimates are plotted. The covariates include year-month fixed effects, township fixed effects, and a set of age dummies.

Figure 4: Residuals of Numbers of Outpatient Visits by Intensity Level, 1998–2001



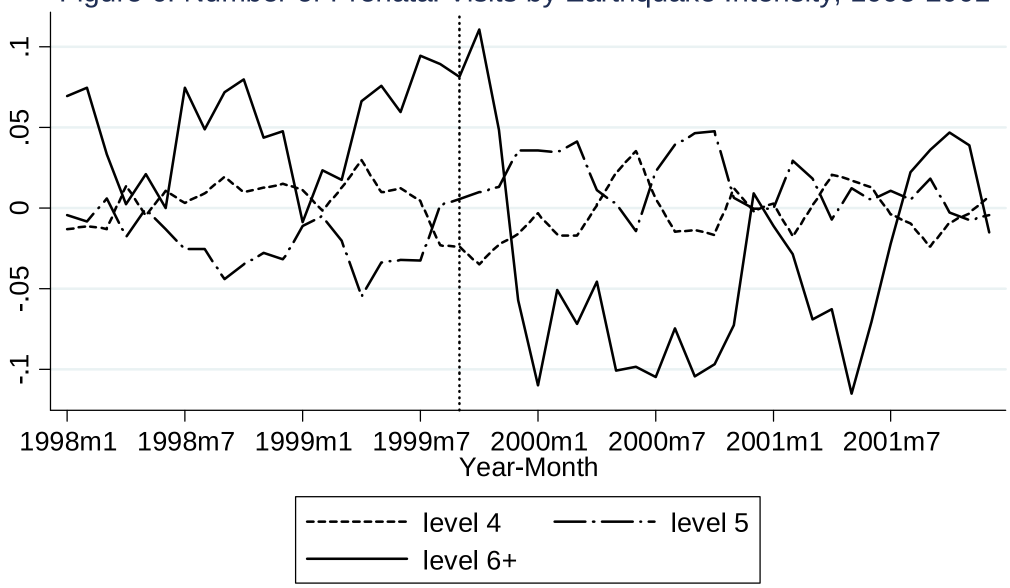
Note: This figure plots residual levels of log number of outpatients visits after the township dummies, month and year dummies included in our models have been controlled for. Unit of observations: township-months. We exclude OBGYN and prenatal visits. The vertical dotted line correspond to the month when the earthquake occur. Level 6+ include both townships with level 6 and level 7 intensity. Level 4 include those townships with intensity level 4 or below.

Figure 5: Number of Hospitals/Clinics by Earthquake Intensity (in Thousands), 1998-2001



Note: Data source Health Insurance Claim from 1998–2001. The vertical dotted line correspond to the month when the earthquake occur. Level 6+ include both townships with level 6 and level 7 intensity. Level 4 include those townships with intensity level 4 or below.

Figure 6: Number of Prenatal Visits by Earthquake Intensity, 1998-2001



Note: This figure plots residual levels of log number of prenatal visits by township intensity level after month and year dummies have been controlled for. The vertical dotted line correspond to the month when the earthquake occur. Level 6+ include both townships with level 6 and level 7 intensity. Level 4 include those townships with intensity level 4 or below.

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

Intensity level	4	5	6+
	(1)	(2)	(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 1,000 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	170	142	41
Number of observations (conceiving month-township)	7,310	6,106	1,763

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 deviations are reported in parentheses. *, **, *** denote the p-values at 1%, 5%, 10% levels 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 Earthquake Intensity Level, 1998–2001

Intensity level	<=4	>=5
	(1)	(2)
Mother with pre-existing health conditions	0.233***	0.258
	(0.423)	(0.437)
Conditional on giving birth:		
Complications during delivery	0.172***	0.190
	(0.378)	(0.393)
Age of mother	28.004***	27.722
	(4.819)	(4.817)
Number of observations (pregnancy)	16,240	24,825

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 the township of the mother's residence. *, **, *** denote the p-values at 1%, 5%, 10% levels from t-test of the equality between the given number and the reported number for level 6.

Table 3: Impact of Intrauterine 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)**
(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)

Note: N=15,179. Data source: Birth Registry, 1998-2001. This table presents the estimation results of specification (1). Cohort is defined as those conceived in the same month and same township. Each column is from a single regression, weighted by township female population size. All regressions include a set of post-earthquake dummies interacting with intensity level, 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 those 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: Robustness Check for Impact of Earthquake Exposure on Fetal Losses
Using Alternative Definition of High Intensity

	Original	Alternative I	Alternative II
	(1)	(2)	(3)
(Highest Intensity Level) *(Conceived 7-9M before Earthquake)	-0.027	-0.026*	-0.032*
	(0.018)	(0.013)	(0.017)
*(Conceived 4-6M before Earthquake)	-0.032*	-0.017	-0.026*
	(0.017)	(0.018)	(0.016)
*(Conceived 0-3M before Earthquake)	**-0.044*** **	**-0.059*** **	**-0.049*** **
	(0.013)	**(0.016)**	**(0.017)**
(2^{nd} Highest Intensity Level)*(Conceived 7-9M before Earthquake)	-0.002	-0.000	0.001
	(0.009)	(0.011)	(0.011)
*(Conceived 4-6M before Earthquake)	-0.024**	-0.023**	-0.002
	(0.010)	(0.012)	(0.012)
*(Conceived 0-3M before Earthquake)	-0.007	-0.006	0.005
	(0.009)	(0.009)	(0.009)

Note: N=15,179. Data source: Birth Registry, 1998-2001. This table presents the estimation results of specification (1). Cohort is defined as those conceived in the same month and same township. Each column is from a single regression, weighted by township population size. Column 1 reports the results of original specification from Table 3 Column 1. As an alternative measure I use the rounding down of the intensity level. Highest intensity is still those areas with level 6.0 and higher and second-highest intensity level includes those townships with intensity between 5.0–5.9. A1All 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 6: Impact of Intrauterine Exposure to Earthquake on Labor Complication

	(1)	(2)	(3)
I(<3 months Post Eqk)*I(Intensity≥5) (π1)	0.040***	0.043**	0.045***
	(0.015)	(0.017)	(0.017)
I(<3 months Post Eqk)*I(Intensity≥6)*I(Intensity≥5) (π2)		-0.012	
		(0.027)	
I(<3 months Post Eqk)*I(Chronic illness)*I(Intensity≥5) (π3)			-0.027
			(0.046)
I(Chronic illness)*I(Intensity≥5)			0.012
			(0.011)
I(<3 months Post Eqk)*I(Chronic illness)			0.023
			(0.035)
Chronic Illness			-0.002
			(0.009)
H0: π1+π2=0		0.19	
H0: π1+π3=0			0.673

Note: N=41,065. Data source: 5% Health Insurance Claim Records, 1998–2001. This table presents the estimation result of specifications 3a, 3b and 4 in Columns 1, 2 and 3, respectively. I(Chronic Illness) indicates whether one has chronic illness prior to earthquake. I(<3 months Post Eqk) indicates whether a birth occurred within three months after earthquake.I(Intensity≥X) indicates whether one resides in areas with earthquake intensity greater or equal to X level. 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. Std. Errors are clustered at the township level. *** p<0.01, ** p<0.05, * p<0.1.

Table 7: Robustness Check for Impact of Intrauterine Earthquake Exposure on Fetal Losses

	Original (1)	Dropping>5% (2)
(Intensity Level 6+) *(Conceived 7-9M before Earthquake)	-0.027	-0.014
	(0.018)	(0.026)
*(Conceived 4-6M before Earthquake)	-0.032*	-0.022
	(0.017)	(0.027)
*(Conceived 0-3M before Earthquake)	**-0.044*** **	-0.028*
	(0.013)	(0.015)
(Intensity Level 5)*(Conceived 7-9M before Earthquake)	-0.002	-0.002
	(0.009)	(0.009)
*(Conceived 4-6M before Earthquake)	-0.024**	-0.024**
	(0.010)	(0.010)
*(Conceived 0-3M before Earthquake)	-0.007	-0.008
	(0.009)	(0.008)
N	15,179	14,276

Note: Data source: Birth Registry, 1998–2001. This table presents the estimation results of specification (1). Column 1 is the same as Table 3 Column 1. Column 2 drops all townships with more than 5% of building collapsed.Cohort is defined as those 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 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 8: Impact of Intrauterine Exposure to Earthquake on Birth Outcomes with Bounding Exercise

	Male original	Female original	Male Bounding	Female Bounding
	(1)	(2)	(3)	(4)
Panel A: Dependent Variable Birth Weight (grams)				
(Intensity≥6)*(Conceived 7-9M before Earthquake)	-6.273	-15.744**	-11.047	-21.017**
	(7.353)	(7.015)	(9.705)	(8.141)
* (Conceived 4-6M before Earthquake)	-25.378***	-11.295	-16.035	-9.343
	(8.870)	(8.342)	(10.830)	(11.582)
* (Conceived 0-3M before Earthquake)	-3.887	-13.654*	-48.375***	-20.887**
	(7.987)	(7.949)	(11.950)	(8.664)
(Intensity=5)* (Conceived 7-9M before Earthquake)	-8.614	-4.776	-11.883*	-9.348
	(5.496)	(6.237)	(6.332)	(6.157)
*(Conceived 4-6M before Earthquake)	-7.461	-3.525	-9.206	-9.452
	(5.697)	(6.117)	(6.392)	(7.589)
*(Conceived 0-3M before Earthquake)	-7.558	-9.138*	-15.113***	-11.879**
	(4.753)	(5.012)	(5.097)	(5.543)
Panel B: Dependent Variable Gestation Length (weeks)				
(Intensity≥6)*(Conceived 7-9M before Earthquake)	0.015	-0.031	-0.014	-0.090**
	(0.036)	(0.034)	(0.040)	(0.036)
* (Conceived 4-6M before Earthquake)	-0.047	-0.068**	-0.037	-0.076**
	(0.035)	(0.033)	(0.036)	(0.036)
* (Conceived 0-3M before Earthquake)	0.003	-0.022	-0.105***	-0.037
	(0.028)	(0.030)	(0.036)	(0.039)
(Intensity=5)* (Conceived 7-9M before Earthquake)	-0.008	-0.019	0.016	-0.081***
	(0.019)	(0.025)	(0.022)	(0.022)
*(Conceived 4-6M before Earthquake)	-0.050**	-0.040*	-0.065***	-0.048**
	(0.022)	(0.021)	(0.023)	(0.024)
*(Conceived 0-3M before Earthquake)	-0.042**	-0.009	-0.021	-0.028
	(0.019)	(0.018)	(0.021)	(0.021)

Note: Data source: Birth Registry, 1998–2001. We apply Lee's bounding method (2008) in Columns 3/4 by dropping the bottom 5% of observations by birth weight for each cohort (the only exception are males in Intensity 6*Conceived 0–3M before earthquake). 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