September 2018

FONDAZIONE ENI ENRICO MATTEI

Working Paper

030.2018

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Economic Theory
Series Editor: Matteo Manera

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Summary

We study how prenatal maternal stress, caused by sustained seismic activity, affects birth outcomes in Chile during the period 2011-2015. A mother-fixed-effect model together with the spatiotemporal variation of earthquakes in Chile allow us to deal with identification issues that have obscured previous estimates. Our findings show that prenatal maternal stress seems to affect fetal growth, because infants born to mothers exposed to earth tremors in early and/or mid gestation are more likely to be large for gestational age. The estimates suggest that relatively poorer Chilean mothers are more vulnerable to earthquakes, because their babies seem to drive the reported impacts on fetal growth. We discuss and provide evidence that suggests a possible mechanism that explains the varying results across socioeconomic status. Mothers with diabetes and/or hypertension are more likely to have large-for-gestational-age babies. Exposure to earth tremors seems to increase the incidence of these afflictions among the affected population, with the observed impact on diabetes being relatively higher among women with lower socio-economic status.

Keywords: Maternal Stress, Birth Outcomes, Natural Disasters, Mother-Fixed-Effects

JEL Classification: C23, I12, J13

We wish to thank Enzo Cerletti for his computational assistance. Rocío Álvarez thanks the Universidad Central de Chile (CIP 16013) for financial support.

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Growing in the womb: The effect of seismic activity on fetal growth *†

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September 9, 2018

Abstract

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1 Motivation

Poor health at birth has important implications for public health and socioeconomic issues. According to WHO, more than 20 million babies are born with low birthweight (weight <2,500, LBW hereafter), globally, and an average of 12% of babies are preterm (before 37 weeks of gestation) in the poorest countries, whereas that figure falls to 9% in higher-income countries. Preterm and LBW infants are prone to serious health problems that may impede their physical growth and cognition development, as well as their accumulation of human capital and their prospects of future socioeconomic status (Lobel et al., 2000; Mancuso et al., 2004; Case et al., 2005; Johnson and Schoemi, 2007).

Scholars are concerned with understanding the factors and the mechanisms that drive the impacts on birth outcomes. From a public health point of view, this first step is an important one for designing policy interventions aiming to reduce or prevent negative consequences on health at birth. In this paper, we study the effects of prenatal maternal stress (PREMS, hereafter), caused by sustained seismic activity, on birth outcomes in Chile over the period 2011-2015.[1] We assess the impacts of PREMS on fetal growth, in addition to the typical outcomes related to the length of gestation used in the literature (i.e., birth-weight, gestational length, LBW and preterm birth), and we also try to identify which group of mothers, and at what stage in pregnancy, is more vulnerable to prenatal stress.

McEwan (2000) defines stress as a "real or interpreted threat to the physiological or psychological integrity of an individual that results in physiological and/or behavioral responses." Medical research has consistently documented that prenatal maternal stress does affect birth outcomes of newborns, and this relationship applies to women from different cultures, nationalities, and social classes (Mulder et al., 2002; Dunkel-Schetter, 1998; Rice et al., 2010). The exposure to a stressor activates the system of stress regulation, which generates changes in the concentration of many hormones during stress, causing negative effects on the length of gestation, fetal growth, and maturation (Lou et al., 1994; Mulder et al., 2002; Wadhwa et al., 2004; Wadhwa, 2005; Mancuso et al., 2004).

Low-birth-weight includes infants born preterm and newborns who suffered fetal growth restriction (Lee et al., 2013). Intra-uterine growth restriction (IUGR) is a process by which a fetus fails to reach her/his growth potential. Indirect measures for fetal growth, namely birth-weight adjusted for length of gestation, are typically used in the medical literature. Small for gestational age (SGA) refers to a newborn with a birth-weight lower than a predetermined threshold, and it is used as a diagnosis of IUGR. A fetus may also suffer accelerated growth. Large for gestational age (LGA), which refers to birth-weights larger than a predetermined cutoff value, is an indicator for this type of disorder. SGA and LGA are complex syndromes that affect different groups of infants and may have an important influence on them throughout their lives. SGA infants may be at an elevated risk of hypertension, stroke, and metabolic diseases in adulthood, among others health issues (Campbell et al., 2012), and LGA babies are at an increased risk of hypoglycemia, respiratory distress, and obesity in adolescence (Uptala et al., 2004).

[1] We borrow the acronym PREMS from Berghänel et al. (2017)

How women respond to an identical stressful stimulus depends on their personal characteristics, genetic factors, and previous experience. Because the interaction of several factors may confound the impact of prenatal stress on birth outcomes, some researchers have exploited natural experiments (man-made/natural disasters) to identify the causal relationship between PREMS and health at birth. Our work belongs to this strand of the literature. We use Chilean official birth records from 2011 to 2015, with information on newborns' birth outcomes, as well as parents' sociodemographic characteristics and information about mothers' fake IDs and their comuna of residence.[2] We also have information about whether a *comuna* was affected by an earthquake. We then combine this information with mothers' *comuna* of residence to determine whether they were exposed to an earthquake, and at what moment of the gestation that happened. Our empirical strategy consists of using mothers' fake IDs to construct a panel of mothers and control for mothers' fixed effects. In this way, we deal with identification issues, for example, endogeneity of maternal location, mothers' behavioral responses to exposure to negative events, and mothers' unobserved heterogeneity, that have obscured previous estimates.

The empirical approach based on natural experiments assumes the exposure to negative shocks is orthogonal to (observed and unobserved) maternal characteristics. Events are allocated at random within a particular population, and maternal characteristics should be balanced across the exposed and unexposed mothers. The difference in birth outcomes between groups should be explained by their different exposure to negative events. However, the definition of stress means mothers can react to the exposure to negative shocks (e.g., they may change their fertility plans and/or they move), which may hinder the identification of a causal link between stress and birth outcomes. Another identification problem is the presence of non-stress-related negative externalities that may follow man-made or natural disasters. The levels of pollution can increase dramatically during or after a terrorist attack; natural disasters (e.g., mega-earthquakes, tsunamis, or hurricanes) may cause a temporary loss of sources of employment, and disrupt the food-distribution system, electricity- and water-provision systems, and so on. Empirical evidence suggests that increased levels of air pollution or being unemployed are associated with adverse birth outcomes (Gray et al., 2014; Scharber, 2014). These externalities hence, have negative consequences on newborns' health, and they may confound the effects of PREMS caused by an unexpected shock.

Chile presents a suitable environment for studying the stress aftermath of seismic events on health at birth. The country is located in one of the most seismically active areas in the world, and earthquakes stretch almost the entire country. Few countries in the world exhibit the spatiotemporal variation in exposure to earthquakes Chile does (Calo-Blanco et al., 2017). The uncertainties related to the expected nature of the earthquakes and the strict Chilean building codes allow us to address some identification pitfalls presented in natural experiment studies of prenatal stress.

[2] A *comuna* is the smallest administrative subdivision in Chile. During the period of our analysis, the country was administratively divided into 15 regions, which were further divided into provinces (54 at the national level), and provinces were split into 346 *comunas*. In 2017, the country was re-organized from 15 to 16 regions. The new administrative division turned the Ñuble province into a region.

Mothers' behavioral responses. Because accurately predicting when and where an earthquake will occur is not possible, selective migration related to earthquakes is not an issue in our data. We show that Chilean mothers who were exposed to earthquakes during pregnancy are not more likely than others to move in response to earthquakes. However, we do observe that exposure to earth tremors affects mothers' fertility plans, which leads to changes in the composition of the affected groups. We tackle this issue by using mother fixed effects. This approach allows us to compare the birth outcomes of siblings born to the same mother who experienced different exposure to earth tremors across pregnancies.

Non-stress- related negative externalities. We consider earthquakes that occurred during March -2010 and December -2015, and that released enough energy to produce intense ground shaking in the affected area, generating stress among the affected population. Non-stress- related externalities, such as fatalities, economic losses, or resource shocks, were not reported for the vast majority of these events. Buildings, civil infrastructures, and so on generally performed well during these seismic events, because Chile has implemented seismic design into its strict building codes and building practices. National law enforces these norms and practices to make the country less vulnerable to earthquakes. However, we are particularly concerned with the non-stress- related negative externalities of the 2010 -Maule earthquake and the 2015 -Illapel earthquake.[3,4] These events are classified as mega-earthquakes because of the amount of energy they released at their epicenters. These earthquakes entailed important human and economic losses that may confound our estimates. To avoid the potential effects on birth outcomes caused by these externalities, we exclude those babies who were born in the most affected areas within the six months after these events.[5]

Correlation between the length of gestation and exposure to treatment. The longer the length of gestation, the more likely an unborn baby is to be exposed to a negative shock. This positive mechanical correlation upward biases the impacts of PREMS on birth outcomes (Curri and Rossin-Slatter, 2013). We use the instrumental variable estimator proposed by Curri and Rossin-Slatter to provide more accurate estimates of the impacts on the outcomes related to the length of gestation (i.e., weight, LBW, gestational length, and preterm). Regarding fetal growth, we provide evidence that shows that the impacts on measures of fetal growth are immune to this mechanical correlation, because these variables are already adjusted according to the length of gestation.

Our results show that exposure to earth tremors in the second trimester of gestation increases the incidence of LGA babies by 1.8 percentage points. The effect persists, and the magnitude is more pronounced, in the group of mothers who were affected during two successive trimesters, the first and second trimesters. For the traditional measures of birth outcomes, we find weak or no evidence of negative effects (in line with previous results

[3] Although the Maule earthquake occurred at the end of February-2010, and hence is not included in our seismic database, its negative consequences extended along the year 2010.

[4] In 2014, the epicenter of an earthquake of magnitude 8.2 was located in the Chilean sea, 89 km southeast of Cuya. No fatalities, economic losses, and/or resource shocks were reported for this event.

[5] Because babies who are excluded from our dataset represent roughly 4% of total births, we do not miss a significant part of the effect of stress on birth outcomes.

presented in Currie and Rossin-Slatter, 2013, and Black et al., 2016). For instance, exposure to PREMS in early gestation seems to increase the risk of preterm birth. We also find that the impacts on fetal growth vary across mothers with different socioeconomic status, with less affluent Chilean mothers being more vulnerable to prenatal stress. Their infants are more likely to be LGA. We do not find any significant effect on fetal growth for infants born to more affluent mothers. But, within this group, we observe a negative effect on birth-weight and LBW when exposure occurs in two successive trimesters late in gestation.

The direct mechanism that works through the releasing of stress hormones during the episodes of acute stress may explain the effects observed on preterm birth. But what are the mechanisms that may explain the varying effects on fetal growth across socioeconomic status? PREMS may trigger two indirect effects. On one hand, exposure to negative shocks may prompt health-enhancing behavior among affected pregnant women, which positively affects birth outcomes. On the other hand, exposure to negative shocks may change the incidence of afflictions such as diabetes and preeclampsia (Wadhwa, 2005), and infants born to mothers with diabetes and or preeclampsia are more likely to be larger than other babies (Xiong et al., 2000).[6] We assess whether these indirect effects vary across socioeconomic groups.

We present indirect evidence suggestive of these mechanisms. Exposure to earthquakes seems to encourage the use of antenatal care, especially among more affluent Chilean women in childbearing age. These women react to the stress caused by a seismic event, increasing the number of health- control visits. This positive behavioral response may cancel out any negative impact caused by physiological adjustments, thus leaving unchanged the percentages of SGA and LGA newborns among more affluent mothers. On the other hand, we observe that exposure to earthquakes is positively associated with the incidence of diabetes and hypertension, with the former effect being relatively more important for less affluent mothers. This varying effect may drive the observed impact on fetal growth within less affluent mothers, because infants born to mothers with diabetes are more likely to be LGA. We are very cautious with these results, because in these estimates, we cannot control for mothers' unobserved heterogeneity, and mothers' genetic factors or dietary/smoking habits may influence their predisposition to develop these afflictions.

The rest of the paper is organized as follow: In section 2, we discuss the literature closely related to our work, whereas in section 3, we briefly describe the history of earthquakes in Chile. Section 4 describes the data, Section 5 presents our econometric approach and identification strategy, and in section 6, we report the results. In section 7, we discuss some possible mechanisms that may drive the results, in Section 8 we perform some robustness checks and in Section 9 we conclude.

[6] Horsch et al. (2016) find positive impacts of stress exposure (pregnancy-related major life events) on the development of gestational diabetes mellitus.

2 Literature Review

In this section, we provide a brief review of previous research on prenatal stress and birth outcomes. Prenatal maternal stress can trigger different mechanisms with opposing effects on newborns' health. Recently, Berghänel et al. (2017) presented a framework that explains when prenatal maternal stress impedes fetal growth. Exposure to stress late in gestation negatively affects fetal development, because affected mothers tend to invest less energy in their unborn offspring. Whereas exposure to stress during early in gestation causes the affected fetus to grow and mature faster than un-affected offspring to ensure it reproduces before it dies, this effect could cancel out the mother's lower energy investment, resulting in an unaffected growth rate while in the womb. Although Berghänel and colleagues present evidence for 21 mammal species that supports their proposed mechanism, they argue that their results could extend to humans.

Another mechanism not related to physiological changes involves women's preemptive responses. Mothers can change their behavior (e.g., dietary changes or use of antenatal care) to reduce harm caused by stress. In this vein, Torche and Villarreal (2014) provide empirical evidence that shows that exposure to growing local violence in early gestation triggers mothers' health- enhancing behavior to protect the unborn baby. They find that the use of antenatal care significantly increases among affected Mexican women.

To identify the causal relationship between PREMS and birth outcomes, some researchers have resorted to natural experiments and repeated-cross-section models. The works of Glynn et al. (2001), Torche (2011), and Kim et al. (2017) use earthquakes as a source of exogenous stress shocks. Quintana-Domeque and Ródenas-Serrano (2017), Eskenazi et al. (2007), and Brown (2013) use terrorist attacks, whereas Foureaux Koppensteiner and Manacorda (2016) use exposure to violence. These studies generally find that exposure to stress reduces birth-weight and gestational age and increases the incidence of LBW or the risk of preterm birth. The key assumption of their approach is that mothers are randomly assigned to the exposure of stressors during pregnancy. However, mothers' preemptive or adaptive responses to stress make this assumption difficult to hold. In addition, the negative externalities that may follow man-made or natural disasters can confound the negative effects on birth outcomes (Quintana-Domeque and Ródenas-Serrano, 2017).

The papers of Camacho (2008), Mansour and Rees (2012), Currie and Rossin-Slater (2013), and Black et al. (2016) use mother fixed effects to tackle the problems of mothers' behavioral responses to stress exposure. By using a panel of mothers, they compare the birth outcomes of siblings whose mother was exposed to different levels of stress shocks during pregnancy. These works use different sources to elicit prenatal stress, landmine explosions in Colombia (in Camacho), the number of fatalities during the al-Aqsa intifada (in Mansour and Rees), and exposure to hurricanes (in Currie and Rossin-Slater), and the work of Black et al. uses parental death during pregnancy. The works of Camacho and Mansour and Rees report a negative association between PREMS and birth-weight, whereas Currie and Rossin-Slater argue that the estimated impacts on birth-weight and gestational length are sensitive to econometric specification and measurement errors in the assignment of exposure in the corresponding trimester of gestation. Curri and Rossin-Slater and Black et al. find no effect or weak impacts of stress on birth outcomes. But Curri and Rossin-Slater do find that exposure to hurricanes during the first and the third trimesters increases the probability of abnormal conditions of the newborn.

Our work aims to contribute to this literature by providing new estimates of the impacts of prenatal stress, caused by sustained seismic activity, on fetal growth and on the commonly used measures of birth outcomes. Our database allows us to cope with the concerns presented in previous studies, that is, endogeneity of mother location, non-stress-related externalities, and how to measure exposure to stress.

Because of Chile's spatiotemporal variation in exposure to earthquakes, endogeneity of maternal location is not an issue in our data. On the other hand, we deal with the concern of compositional changes, by using a mother-fixed-effect model. With regard to the presence of non-stress-related externalities, for the vast majority of the earthquakes we consider, no fatalities, resource shocks, negative pollution, or structural or economic damages were reported. For the two seismic events that may cause this problem (the 2010 -Maule and the 2015 -Illapel mega-earthquakes), we drop all births that occurred in the most affected areas after these events. Because these observations only account for a small fraction of total observations, we believe we are not missing part of the relevant effect of stress on birth outcomes. Finally, we complement this literature by providing new evidence of the effects of PREMS on fetal growth. We discuss the potential mechanism for the increasing incidence of LGA infants in the affected group.

3 Earthquakes in Chile

We start this section with some background on measures of the severity of an earthquake. Then we present a brief description of the main seismic events Chile was exposed to, with a particular focus on March -2010 and December-2015 (what we call the earthquake -time -window).

Magnitude and Intensity. The magnitude of an earthquake measures the maximum energy released at its epicenter. Several scales are available, for example, the Richter magnitude (ML), the surface-wave magnitude (Ms), the body-wave (Mb), and the moment (Mw) magnitude, but all of them should yield approximately the same value for any given earthquake.[7] We report the available magnitudes, typically, Ms and Mw, and use the following notation: An earthquake of magnitude 6.0 according to Mw is denoted by $Mw6.0$, and all earthquakes of magnitudes 6 or higher as $Mw6.0+$.

The magnitude of an earthquake does not necessarily mirror the impact of the seismic event on humans, frame structures, and the natural environment. The Modified Mercalli scale (MMS) provides this information. Intensities allow us to quantify the effect of an earth tremor in affected areas, with the intensity of the same event decreasing as we move away from its epicenter. We use the scale provided by the U.S. Geological Survey, where

[7] U.S. Geological Survey available from https://earthquake.usgs.gov

the MMS ranges from I to X. Intensity values from I to V correspond with movements that go from "barely perceptible" to "felt by nearly everyone," but no damage on structural frameworks is produced. Movements felt by all, whereby many people are **frightened** and structures experience slight damage, are ranked with an intensity of VI. More powerful earthquakes have intensities between VII and X, and their damage ranges between "negligible in buildings of good design and construction" to "some frame structures destroyed."

Earthquakes in Chile. Chile is located in southern South America, bordering the South Pacific Ocean, between Peru, Bolivia, and Argentina. Chile has roughly 17.3 million inhabitants, who are unevenly distributed across the country. The vast majority of the population is located between the parallels 27° S and 42° S, with the far north and the extreme south regions of the country relatively underpopulated. Chile lies above the Nazca plate and the South American continental plate, one of the most seismically active areas in the World. The Nazca plate is subducting beneath the South American plate, causing massive earthquakes. The South- Central Chilean subduction zone caused the 1960 -Valdivia earthquake and the 2010 -Maule earthquake (Dzierma et al., 2012; Jaramillo et al. 2012).

The Valdivia earthquake is the world's largest recorded earthquake, with a magnitude of $Mw9.5$. The epicenter was located in Valdivia, approximately 850 km south of Santiago de Chile. More recently, in February 2010, the South-Central Chilean region of the Maule was hit by an $Mw8.8$ earthquake, the sixth- largest earthquake ever recorded globally. The epicenter was located 335 km south of Santiago de Chile and covered an area that extended at least 450 km along the Chilean coast, and its aftershocks extended from the coast to the trench for a length of over 600 km (Udías et al. 2012). The mega-earthquake triggered a tsunami. Both events damaged or destroyed 3,049 schools and 73 hospitals. At least 521 fatalities were reported, and 806,523 people were injured. Large areas of the most affected regions (the Maule and the Biobío) were left without electricity, gas, water supply, and telecommunication services for days. The economic losses were estimated to be about 17% of the Chilean GDP. Although approximately 336,079 homes were damaged and 86,917 destroyed, modern engineered buildings performed very well. Seventy percent of destroyed residences and 50% of residences with major damage were of "adobe," a building type that before the earthquake was not subject to building codes and did not follow building practices (ONEMI 2010; USGS 2011; Santa María Oyadenel and López García González 2012; Resumen Ejecutivo 2010).

During the earthquake -time -window, 5,057 seismic events were reported along the Chilean territory, with a median magnitude of 4.5. Sixty of these earth tremors had magnitudes of 6.0+ (the conditioned median magnitude was equal to 6.35), and only two of them had magnitudes above 8.0. Precisely, in April -2014, an Mw 8.2 -earthquake was registered in the Chilean sea, 89 km southeast of Cuya (1348 north to Santiago de Chile). The Chilean National Emergency Office, ONEMI, did not report fatal victims and/or economic losses due to this seismic event. In September -2015, an 8.4-earthquake hit the North-Central Chilean Zone, with its epicenter located 37 km southwest of Canela Baja (approx. 294 km north to Santiago de Chile) and affected a zone that extended 200-250 km along the Chilean cost. This earthquake triggered a tsunami that mainly affected the region of Coquimbo.

Namely, the *comunas* of Canela, Illapel, Salamanca, Coquimbo, and Cambarbalá were the most affected. Thousands of evacuated people from Chilean coastal areas returned home the day after the earthquake, when the authorities called off the tsunami alert across the Chilean coast (66,635 people were evacuated during the tsunami alert). Authorities estimated that 27,738 people were injured by the earthquake. In addition, 15 people were killed, 2,305 homes were destroyed, 2,743 houses suffered severe damage, and others 7,301 houses were damaged. The water and electric systems were disrupted, and the port of Coquimbo and 17 coves were closed because of structural damage. The tsunami affected 394 boats in the region of Coquimbo, with 131 boats completely destroyed. The estimated economic losses were about US$44 million (ONEMI, 2015).

4 Data and descriptive analysis

We use seismic data provided by the US Geological Survey,[8] the National Seismological Center,[9] and the ONEMI. The US Geological Survey and the National Seismological Center report magnitudes, the date of the seismic event, the depth of the event, and the location (latitude and longitude) of its epicenter, whereas the ONEMI reports information about the intensities (MMS) of an earthquake across Chilean comunas. This information is available for the years 2005 onwards. We use the data of earthquakes registered across the Chilean territory from March -2010 to December -2015.

Figure (1) presents the temporal distribution of earth tremors in Chile during the earthquake -time -window. The bars indicate the number of monthly earthquakes of magnitude $Ms/Mw6.0+$, and the curve shows the magnitudes of the earth tremors. Sixty seismic events (of magnitude $Mw/Ms6.0+$) were reported during this period, which represents an average number of 1.05 earthquakes. The frequency of earth tremors is quite volatile, because seismic activity is unevenly distributed across time. The peaks of earthquakes are in the months of March 2010 and September 2015 (with 9 and 15 earth tremors, respectively). These months comprise the majority of the aftershocks that followed the mega-earthquakes of Maule -2010 and Illapel -2015. For the remaining months, the number of earth tremors is lower than or equal to four, with the exception of April 2014, when an earthquake of magnitude 8.2 was registered in the Chilean Sea.

An earthquake can affect large areas, with both the intensity and the ability to cause stress decreasing as we move farther from its epicenter. To illustrate this point, consider the 6.7 -earthquake registered in the offshore of Valparaíso, in April 2012. Figure (2) shows the corresponding distribution of MMS intensities. The star denotes the location of the epicenter; the dark areas correspond to the most affected *comunas* where the event was felt with intensity higher than VI. Hijuelas (the red circle) was among the most affected *comunas*, with a reported intensity of VII. *Comunas* located farther from the epicenter, for example, Coquimbo (the green circle to the north) or Talcahuano (the green circle to the south), had intensities of III.

[8] http://earthquake.usgs.gov
[9] www.sismologia.cl

We need to choose a cutoff value for the MMS intensity above which people interpret the seismic event as a real or potential threat to their integrity. In Chile, earth tremors of magnitudes lower than 6 typically involve intensities lower than or equal to V. An earthquake felt with an intensity of V may not cause stress on affected people, because not everyone feels it, and its shaking is moderate and does not injure humans and/or damage structures. We focus on earthquakes of magnitudes larger than $Ms/Mw6.0$, and we set the cutoff value for MMS at VI. In affected areas, with intensities of VI or higher, earth tremors are felt by all and are strong enough to frighten people.[10]

Does exposure to earth tremors with intensities higher than or equal to VI cause stress? Unfortunately, for the period 2011-2015, we do not have empirical evidence about the impacts of the seismic activity on mental health. But we provide some evidence on post-traumatic stress disorder caused by the 2010 -Maule earthquake to illustrate our point regarding the cutoff value of VI. Although this event was the sixth-largest earthquake ever recorded worldwide and, naturally, it caused stress, its impacts were unevenly distributed across the Chilean territory. During May and June of -2010, the Chilean government conducted a survey aimed at assessing the impact of the earthquakes on the mental health of the affected population. The earthquake struck the regions of Maule, Biobío, and O'Higgins. In some *comunas* within these regions, the earthquake was felt with intensities higher than or equal to $VIII$. In areas of the regions of Valparaíso and Región Metropolitana (the Chilean Central Zone), the event was felt with intensities between VI and $VIII$. In the rest of the country, the earthquake was felt with intensities lower than VI or not at all. Empirical evidence collected in this survey shows that 11.3% of Chilean people exhibited symptoms of post- traumatic stress disorder related to the earthquake (that percentage was 6.1% for men and 13.7% for women). This figure dramatically increases in the regions where the event was felt with intensities $\geq VIII$, with 24.3% in the region of O'Higgins, 22.5% in Maule, and 25.7% in the region of Biobío. In Valparaíso and Región Metropolitana, the percentages were 9.3% and 7.1%, respectively, and the figure for the rest of the country was 4.5%. The impacts on mental health were more severe for women, approximately 30% of whom exhibited post-traumatic stress disorder in the most affected regions. In Valparaíso and Región Metropolitana, the percentages were 11.5% and 8.8%, respectively. In the rest of the country, only 6% of women reported some trauma related to the earthquake (Díaz, 2010).

Data on birth outcomes and parents' characteristics come from the Chilean Ministry of Health, with 1,228,665 official birth certificates for the period of January -2011 to December -2015 (what we call birth -time -window). The database has information on birth outcomes and sociodemographic variables. For each birth record, we have information on the newborn's *date of birth* (month-day-year), *weight* (measured in grams), *height* (in centimeters), *gestational age* (measured in weeks), gender, medical attention (whether the delivery was attended by a professional and whether the delivery took place in a health care center (99.2%) or in another place), and the mother's number of previous live births (total and still living). It also provides socio-demographic information about both parents: age, job status, level of

[10] We check the robustness of our results when lowering the cutoff value for MMS to V (see section 8).

educational achievement, marital status, and the mothers' region and *comuna* of residence. Since 2011, the Ministry of Health has collected information about mothers' national identification number, and the database links each mother to a fake identification code. We identify siblings using this fake identification code to construct a panel of mothers.

We focus on single births and exclude multiple births (24,915), those observations with birth weights under 500 grams or above 9000 grams (2,754 cases), as well as those cases with gestational age below 26 weeks (1,992), and exclude those newborns whose mothers younger than 15 or older than 49, giving us 4,426 observations (Currie and Rossin-Slater, 2013; Quintana-Domeque and Ródenas-Serrano, 2017). Some births that occurred during the first months of 2011 may correspond to babies exposed to non-stress- related externalities of the 8.8 -Maule mega-earthquake. Hence, we exclude all infants conceived within the six months after February 27, 2010, and whose mothers lived in either the *comunas* affected by the tsunami or *comunas* that reported at least one fatality related to the earthquake. This approach leaves us with 48,926 fewer observations (3.9% of the total number of observations). For the $Mw8.4$ -Illapel mega-earthquake, the most affected *comunas* were Canela, Illapel, Salamanca, Coquimbo, Cambarbalá, and Los Vilos. We exclude those infants born in these *comunas* after the seismic event (1,368 observations), thus rendering a repeated "cross-sectional" database with 1,144,284 observations.

To construct our panel of mothers, we use the fake identification code to link observations of the same women. In 7,337 cases (0.5% of the total number of observations), women are not properly identified; hence, these observations are lost. We keep those observations corresponding to women who gave birth to more than one baby throughout the birth -time -window. Because in some cases there are missing values for gestational age, some mothers who gave birth to more than two babies could have at least one missing value for gestational age. We decided to exclude these cases from the panel of mothers, leaving us with an unbalanced panel of mothers composed of 97,877 mothers (96.9%) who gave birth to two babies within 2011-2015, there are 3,080 mothers (3.05%) who had three babies during this period, 51 mothers (0.05%) who had four babies, and one (∼0%) with one birth per year. The total number of observations is equal to 205,205.

The accuracy of a gestational- length measurement plays a key role in properly identifying the group of mothers who were exposed to earthquakes, and at what stage of the pregnancy. Chilean official statistics for gestational length are reliable because healthcare professionals estimate the gestational age (in weeks) as the period between the date of the first date of the last menstrual cycle (i.e., the estimated conception date) and the date of birth. The estimated conception date -not reported in the database- is determined at the beginning of prenatal care, and according to national guidelines, if that estimate is not reliable, the conception date is then determined by means of an ultrasound during the first trimester. In addition, before official statistics are publicly available, the information is validated by comparison with hospitals records (López and Bréart, 2012). Chilean households have guaranteed access to universal healthcare coverage, and all pregnant women have access to prenatal care and to professional care during childbirth. In our data, 99.87% of births took place in hospitals, with healthcare professionals (45.39% obstetricians and

54.56% midwives) who collected the information of birth outcomes on a birth certificate.

By using the reported gestational age and the date of birth, we recover the estimated conception date and construct the estimated dates of each trimester of gestation. The first trimester (FT) is measured from the estimated conception date, totaling 13 weeks; the second trimester (ST) includes weeks 14- 26 of gestation; and the third trimester (TT) spans from week 27 to the birth.[11]

To identify mothers exposed to earthquakes, we construct a dummy variable, EQ, that equals 1 if a mother lived in a *comuna* with a reported intensity greater than or equal to VI after an earthquake of magnitude $Ms/Mw6.0+$. We combine information about the dates and location of earthquakes, mothers' pregnancy timing, and their *comuna* of residence. We form eight disjoint groups, labeled 1 to 8. Groups 1- 3 include those mothers who were exposed to earthquakes in only one trimester of gestation (either the first, the second, or the third trimester, respectively). Group 4 comprises mothers affected by earth tremors in two successive trimesters (the first and the second); group 5 includes those cases in which mothers were affected in the second and third trimesters; group 6 includes those mothers exposed to earthquakes in the first and third trimesters; group 7 includes those mothers who were exposed to earth tremors (at least once) in each trimester; and group 8 corresponds to non-exposed mothers.

Table (1) presents the number of observations in each group, for both the all-Chilean-births sample and the panel- of- mothers sample. The majority of the mothers who were exposed to seismic events are in groups 1 - 3, whereas some mothers suffered earthquakes in more than one trimester (groups 4 and 5). We have only one observation in group 6 (which we exclude from both samples), and no observation in group 7. In this manner, we construct five dummy variables. Let $EQ^g_{i,m,c,t}$ equal 1 if infant i was born to mother m, with *comuna* of residence c, at date (year-month-day) t, was exposed to (at least) one earth tremor in trimester(s) g; and $EQ^g_{i,m,c,t}$ is zero otherwise, with $g \in \{1, 2, 3, 1\&2, 2\&3\}$. The mean values of $EQ^1_{i,m,c,t}$, $EQ^2_{i,m,c,t}$, and $EQ^3_{i,m,c,t}$ are approximately 3%, whereas for variables $EQ^{1\&2}_{i,m,c,t}$ and $EQ^{2\&3}_{i,m,c,t}$, the mean values are 0.2% each.

Table (2) presents the descriptive statistics for Chilean birth records during the period 2011-2015. During these years, the average birth-weight was 3,344 grams and the average gestational age was 38.5 weeks, close to the full gestation period (39 weeks). The incidences for low -birth-weight and pre-term birth are 50 and 60 per 1,000 live births, respectively. The majority of mothers, 47%, are between 25 and -34 years old, 56% with secondary and post-secondary non-tertiary education and 46% are employed. Approximately 100 per 1,000 newborns were exposed to earth tremors while in utero. Exposed newborns are 13 grams heavier than un-exposed newborns and are less likely to be LBW or premature. No significant difference is present in the gender composition between the exposed and un-exposed groups. Note that the mothers who live in an urban area account for more than 90% of the cases regardless of their exposure to earth tremors. This observation is a

[11] For a baby born in February 2, 2015, with gestational age of 38 weeks, the estimated conception date is May 19, 2014. The FT is the period between May 19th to August 18th; the second trimester is from August 19th to November 18th; and TT starts in November 19th, 2014 and ends the date of birth.

consequence of how an urban area is defined in Chile.[12] The descriptive statistics of the panel of mothers generally mirrors the pattern and values of the all-Chilean births sample. For the panel of mothers, we can also compute the variable *Birth Spacing* that measures the temporal distance (in weeks) between two pregnancies. The mean for this variable is 43.37 weeks for all mothers, and exposed mothers delay the next pregnancy for roughly 14 weeks longer than other mothers.

Figure (3) plots the monthly averages of birth weight and gestational age during 2011 - 2015. Bold vertical lines denote months with earthquakes of magnitudes $Ms/Mw7.0+$: January -2011 ($Mw7.2$), March -2012 ($Mw7.1$), April -2014 ($Mw8.2$ and $Mw7.7$), and September- 2015 ($Mw8.4$), whereas dotted vertical lines correspond to months with earthquakes of magnitudes between 6 and 7. The solid curve corresponds to all newborns, the square-dotted curve corresponds to un-exposed newborns, and the dashed curve measures the average birth outcome of exposed infants. Comparing these figures, we can provide some important insights about earthquakes and birth outcomes in Chile. First, the monthly average birth-weight remains relatively constant over time, around its mean value of 3,344 grams, decreasing slightly during the second semester of 2015 (see Figure (3a)), whereas the monthly average gestational age (shown in Figure (3b)) exhibits a moderately downward trend, converging to the value of 38.5 weeks of gestation. Second, in each figure, the dashed curve has a discontinuity from December -2013 to April -2014. The seismic nature of the country is such that within the birth -time -window, in only five months were infants not exposed to earthquakes while in the womb. Third, both figures suggest the effects of PREMS on birth-weight seems to be mediated through changes in gestational age, as the curves in each figure resemble each other.

Comparing birth outcomes before and after a particular (big) earthquake in the affected area can be problematic in a country like Chile. Measures of exposures to earthquake may not be well computed, and treated and control groups may not be well specified. To illustrate this point, assume we only consider the earth tremor of magnitude $Mw7.1$ of March-2012 in the region of Maule (this is the second bold vertical line in both graphs). Some babies born during March to- May of 2012 may be treated as exposed to the earthquake in the third trimester. However, some of these babies could also have been exposed to earthquakes earlier in gestation, because in January- 2012, an earthquake of magnitude $Mw/Ms6.0+$ hit in the bordering region of Biobío, and during 2011, two important earthquakes hit the north of the country (in June, $Mw6.4$, and in December, $Mw6.1$). Hence, whether the abrupt drop in the monthly birth-weight within the four months after the 7.1 earthquake in -March -2012 is a consequence of that event or a consequence of the other seismic events or a combination of all them is unclear. In addition, the control group (of non-exposed babies) could include newborns who were exposed to earthquakes at the beginning of 2012 or during 2011, thus affecting the comparison between groups. Finally, because of the volatility of the temporal variation of earthquakes, infants can be exposed to earth tremors in one or more trimesters of gestation.

[12] An area is classified as urban if it has more than 2,000 inhabitants or between 1,001 and 2,000 inhabitants, with 50% of them employed or actively seeking employment.

5 Empirical strategy

Women may change their behavior or their decisions in response to a situation they interpret as a threat to their physical or psychological integrity. For instance, women may move in response to an earthquake, as they look for a safer place to live, or for employment reasons. Mothers who were exposed to an earth tremor may also change their fertility plans. If these behavioral changes are heterogenous among the affected population, the identification of the causal effect of PREMS can be problematic. In this section, we study whether our database there provides evidence supporting either (or both) of these situations.

5.1 Migration decisions.

The cross-regional variation of seismic activity in Chile, in addition to a lack of an earthquake-prediction method, renders domestic migration in response to earthquakes unlikely. Earthquakes are widespread throughout almost the entire country; see Figure (4). Seismic activity is more frequent and intense in the most populated areas of the country, namely, the metropolitan region, and the North and South-Central regions, whereas in the southernmost region of the country, earthquakes are extremely rare and are rarely perceived. Short-term earthquake prediction is a scientific challenge because of the absence of an earthquake-prediction method that clearly states the geographical area, the time interval, and the magnitude range of upcoming earthquakes in the short term. Hence, Chilean mothers have difficulty anticipating these natural events and adopting preemptive responses.

Let $R_{i,m,t}$ be a dummy variable that switches from 0 to 1 if mother m of child i changes her *comuna* of residence between pregnancies. We estimate the following migration- response model:

$$R_{i,m,t} = \beta_0 + \beta_1 EQ_{m,t} + X'_{i,m,t}\beta_2 + EQ_{m,t} \times X'_{i,m,t}\beta_3 + \alpha_c + \alpha_t + \alpha_c \times \alpha_t + \alpha_{month} + \epsilon_{i,m,t}, \tag{1}$$

where $X_{i,m,t}$ is a vector of the mother's time-varying characteristics (e.g., dummies for age category, educational attainment, and missing educational attainment, and dummies for birth order, birth spacing, marital status, urban area, employment status, and missing employment status) and the father's time-varying characteristics (dummies for age category, education, and employment status). First *comuna* of residence, birth-year, and month-year fixed effects are indicated by α_c, α_t, and α_{month}, respectively. Because of the effect of *comuna* fixed effects on migration decisions could change over time, we interact first *comuna* of residence with birth -year. Standard errors are clustered at the level of the mother's first *comuna* of residence. The included interaction of mothers' observable characteristics with exposure to earthquakes aims to capture differential responses. Table (3) shows the estimated values for β_1 and for the vector of coefficients β_3. The estimated β_1 is negative but not statistically significant. We observe that mothers with missing employment status who were exposed to earth tremors are less likely to move (at 5% of significance level). However, these mothers account for only 0.02% of the sample of interest. We also observe that affected families in which fathers are less educated are less likely to move. But the corresponding $p-$value is equal to 0.10.

Overall, we are confident that endogenous migration is not an issue in our data; hence, the benchmark estimations are presented assuming that mothers do not move in response to earthquakes exposure. In section 8, as a robustness check, we present additional estimates that control for possible migration endogeneity.

5.2 Compositional changes

Because seismic events occur at random, mothers should be randomly allocated across exposed and non-exposed groups, and their unobservable and observable characteristics should be balanced between these two groups. This is the key assumption of the empirical approach used in much of the literature. A potential threat to this assumption, however, is that women may change their fertility plans if they are exposed to negative events. If these changes in family plans vary among women, the composition of the exposed and non-exposed groups changes, thus hindering identification of the causal effect of prenatal stress. For instance, older women may postpone their fertility plans if they are more psychologically vulnerable to earthquakes than younger women. If these women give birth to lighter-weight babies, newborns are positively selected and we can mistakenly attribute this positive impact on birth-weight to PREMS.

To assess whether these compositional changes take place in our data we estimate the following model:

$$MC_{i,m,c,t} \quad = \quad \beta_0 + \sum_{g=1}^{5} \beta_g EQ^g_{i,m,c,t} + \alpha_c + \alpha_t + \alpha_c \times \alpha_t + \alpha_{month} + \epsilon_{i,m,c,t}, \qquad (2)$$

where $MC_{i,m,c,t}$ is a maternal characteristic (age category, parity, educational attainment, marital and employment statuses) of a mother m who lives in *comuna* c and gave birth child i at date t; $EQ^g_{i,m,c,t}$ is our dummy variable that we defined above, with $g \in \{1, 2, 3, 1\&2, 2\&3\}$. The *comuna*, birth-year, and birth-month fixed effects are denoted by α_c, α_t, and α_{month}, respectively. If women are allocated at random across groups, the estimated β_g's should not be significantly different from zero, and the differences in birth outcomes across groups could be explained by their different exposure to earthquakes. If self-selection takes place, groups are not equivalently comparable.

Table (4) presents the estimates for both all-Chilean- births and the panel- of- mothers samples. In both cases, we find evidence of changes in the composition of groups. For instance, exposure to earthquakes in the third trimester of gestation increases the proportion of mothers younger than 25, whereas exposure to earth tremors in two successive trimesters (the first and the second) leads to a higher fraction of mothers who are married. For the all-Chilean- births sample, we even find some additional effects. Exposure to PREMS during the first trimester of gestation decreases the percentage of mothers with low educational attainment and the percentage of married women, whereas the percentage of mothers with secondary schooling increases when they are exposed to earthquakes in the third trimester of gestation. Hence, how these compositional changes could affect estimates is unclear, because some of them lead to positive selection, whereas others lead to negative selection of newborns. However, *comuna* and birth-year fixed effects clearly do not control for compositional changes, and the use of mother -fixed -effects is necessary to control for mothers' behavioral responses.

Before leaving this section, we look for a potential source of bias, in addition to the demographic and socioeconomic composition studied above. If exposure to earth tremors increases the incidence of miscarriages or stillbirths in affected areas, the composition of the population of interest would be altered, because we would find a positive selection of newborns. As a result, the impact of PREMS on birth outcomes would be underestimated. We regress the number of fetal deaths (and the log of fetal deaths + 1) in *comuna* c (at year-month t) on three dummy variables (one for each trimester) that indicate whether pregnant women in that *comuna* were exposed to an earthquake of $MMS \geq VI$. These regressions control for *comuna* and for year and month fixed effects (with comuna interacted with year). To run these regressions, we append the database of fetal deaths (from the Chilean Ministry of Health) to the database of live births. Table (10), in Appendix B, shows that exposure to earthquakes in the first trimester of gestation significantly increases the incidence of fetal deaths in affected *comunas* (we only find this effect when we use log of (fetal deaths + 1) and not when we use number of fetal deaths). This finding further justifies the use of the mother-fixed-effect model.

5.3 Econometric model

Our empirical strategy consists of comparing birth outcomes of newborns exposed to seismic activity with those who were not exposed, controlling for mothers' fixed effects. We estimate the following linear reduced form:

$$BO_{i,m,c,t} = \beta_0 + \sum_{g \in \{1,2,3,1\&2,2\&3\}} \beta_g EQ^g_{i,m,c,t} + X'_{i,m,t}\gamma + \alpha_m + \alpha_c + \alpha_t + \alpha_c \times \alpha_t + \alpha_{month} + \epsilon_{i,m,c,t}, \tag{3}$$

where $BO_{i,m,c,t}$ is the birth outcome corresponding to infant i born at date t and whose mother m resides in *comuna* c. α_c, α_t, and α_{month} are the same as those defined in (2), and α_m denotes the mother's fixed effects. The parameters β_g's capture the causal link between exposure to earthquakes and birth outcomes. The omitted group is the group of newborns who were not exposed to earth tremors while in utero.[13]

We consider birth-weight as well as indicators of low birth-weight and pre-term birth, because they are the typical markers of health at birth, as tested in the literature. We also assess whether PREMS has an impact on fetal growth and, if so, how. We use SGA

[13] In our regressions, we do not control for the newborn's gender, because gender can be a potential outcome of exposure to negative events while in the womb (e.g., Brown, 2012; Quintana-Domeque and Ródenas-Serrano, 2017). However, we have run estimates including gender as a control, and the results do not change. These estimates are available upon request.

indicator as a proxy of intrauterine growth retardation (Lee et al., 2013). The failure to attain optimal fetal growth not only refers to IUGR problems, but also to excessive fetal growth; and we use large- for- gestational- age as an indicator of accelerated fetal growth. AGA denotes a condition of an infant with adequate fetal growth (adequate weight for gestational age).

We use the international standards for newborn size for each gestational age provided by the INTERGROWTH-21st Project.[14] The project computes standards that capture how fetuses everywhere should optimally growth in the presence of minimum constraints. The standards are aimed to be universal and time invariant because they are population -based, multiethnic, based on several countries, and are sex- specific. A newborn is small for her/his gestational age when her/his birth-weight is two standard deviations below the median birth-weight for gestational age. LGA is defined as a birth-weight two standard deviations above the median birth-weight for gestational age, and AGA are newborns with birth-weight within two standard deviations of the median birth-weight for gestational age.[15]

Measures of exposure to negative shocks may embody a positive mechanical correlation between gestational length and the probability of being exposed. Longer gestation entails potentially better birth outcomes (e.g., heavier babies), which may generate a positive bias in the estimated impacts of stress exposure (Currie and Rossin-Slater, 2013; Black et al., 2016). To address this issue, we use the IV-strategy proposed in Currie and Rossin-Slater.

We use the conception dates (see section 4) to construct the predicted gestation period, assuming full gestation term (39 weeks of gestation). For each mother, we compute measures of exposures to earth tremors that would have occurred, in each predicted trimester, had the pregnant mother had a full- term pregnancy. We then instrument the actual measures of exposure, explained in section 4, by the predicted ones.

Because the measures of fetal growth are already adjusted by the length of gestation, the estimated impacts on these variables should not be affected by the mechanical correlation. Note that these measures cover the full spectrum of infants, from preterm to post-term infants. Post-term infants can be small-, adequate-, or large for- gestational- age; and within post-term babies, the three types of infants are equally likely to be affected by earth tremors. Hence, the discussed mechanical correlation between gestational length and the probability of being affected is not an issue for the measures of fetal growth. However, we expect that the estimated impacts on birth weight, LBW, gestational length, and preterm are sensitive to the implementation of the IV-mother-fixed-effect estimator.

[14] For more information, see https://intergrowth21.tghn.org

[15] Small-, large- and adequate-for-gestational-age are also defined in terms of percentile categories. Severe -SGA are newborns with weights for gestational age below the third percentile; the majority of those infants who are severely -SGA are IUGR (Campbell et al., 2012). Because measures of SGA based on z-score are even tighter than those measures based on percentiles, we use the indicators provided by the INTERGROWTH-21st Project.

6 Results

Table (5) reports our estimates. Each column of the table corresponds to a regression for a birth outcome. All regressions include controls for parity categories, mothers' age categories, mothers' educational attainment, mothers' marital and employment statuses, an indicator for urban area, and fathers' sociodemographic variables. Birth spacing is another factor that can determine birth outcomes, such as low -birth-weight. When we use the panel- of-mothers sample, we include birth spacing as an additional control variable.[16] Table (5) is composed of three panels. Panel A shows the estimates for the all-Chilean- births sample, whereas the other two (B and C) report the results for the panel- of- mothers sample.[17]

We first discuss the results of an OLS regression that assumes mothers are randomly allocated to the varios exposure categories (Panel A). We see that being exposed to earthquakes during any trimester of gestation has significant consequences on birth outcomes, with the exception of accelerated fetal growth. These results, however, are contaminated by compositional changes as well as by the positive mechanical correlation between gestational length and the probability of being exposed. Note that in all instances where the impacts are significant, PREMS has "positive" consequences on the birth outcomes of exposed babies.

Results presented in Panel B are cleaned of compositional issues, because these estimates control for mother -fixed -effects. The majority of the effects on birth outcomes vanish, but we still find some "positive" impacts on birth-weight and on LBW when the exposure occurs during mid or late gestation. The effect on SGA disappears, but we now observe an impact on LGA outcome. The shift toward LGA, which comes at the expense of AGA, reflects the fact that exposure to earthquakes in the second trimester of gestation explains more of the variation in newborns' LGA birth outcome than AGA.

In Panel C, we cope both with the concerns of compositional changes and with those of the mechanical relationship between the length of pregnancy and the probability of suffering an earthquake. We find that only the impacts on fetal growth remain, as we expected. Infants born to mothers exposed to earth tremors in the second trimester are 1.8% more likely to be LGA. The impact almost doubles (3.2%) for the group of mothers who were exposed in two successive trimesters. As for the other birth outcomes, we now observe that infants are more likely to be preterm if mothers were exposed to earthquakes in the first trimester of gestation or when they were exposed to the stressor in the second trimester of gestation. Finally, we observe a significant negative impact on birth-weight in the group of mothers who suffered earth tremors in two successive trimesters late in gestation (in the second and third trimesters).

The reported positive impacts for birth-weight and for LBW (in Panel B) vanish because the IV -estimator corrects the "upward" bias of the OLS estimates. The instrument of exposure to earthquakes based on the predicted gestational length gives less weight to the

[16] In all regressions, we also include dummy variables that indicate whether a data point is missing. These variables correspond to educational attainment (for both mothers and fathers) and to employment status (for both mothers and fathers), because in some cases, data in these variables were missing.

[17] In all cases where we use the IV -estimator, we run regressions with the command *xtivreg2* by Schaffer, M.E. (2010).

observations with higher birth-weight due to the positive mechanical correlation.

Before leaving this section, we assess the impacts of PREMS on birth outcomes when we consider the number of earthquakes a mother was exposed to in each trimester of gestation. Let $NEQ^{g}_{i,m,c,t}$ (with $g \in \{1, 2, 3\}$) denote the number of earthquakes infant i born to mother m (with *comuna* of residence c) at date t was exposed to in trimeter g. Table (6) shows the distribution of these variables for the panel of mothers.

Although earthquakes are not rare events in Chile, the fraction of the affected mothers is relatively small (approximately 10%). For a given trimester, the probability of been exposed to one earthquake is significantly higher than the probability of being exposed to more than one earthquake. Note that the number of mothers who suffered one earthquake is slightly tilted toward the third trimester. The reason is that in September- 2015, the number of monthly earthquakes increased to 15 earth tremors because of the 8.4 -Illapel mega-earthquake. Because we have information for infants born no later than December -2015, for this seismic event, we can only observe those mothers who were in the third trimester of gestation at the time the event occurred.

Table (7) presents the estimates of the impacts of the number of seismic events on birth outcomes. In Panel A, we report the results for the OLS mother -fixed -effect. Estimates present the same pattern (in terms of sign and significance) as those in Panel B of Table (5). Consider the results of the IV-mother-fixed-effect model. The effects on the distribution of AGA and LGA infants remain. Being exposed to an additional earth tremor during the second trimester of gestation reduces the probability of being AGA by 1.2% while increasing the probability of LGA by 1.1 percentage points (both effects are significant at the 1% level). We do not find any significant impact on birth-weight or LBW, but we do observe that an additional earth tremor seems to reduce the length of gestation when exposure to earth tremors occurs during mid and late gestation. Finally, estimates also show that exposure to an additional earthquake early or in mid gestation increases the probability of being born before 37 weeks (preterm).

6.1 Impacts on birth outcomes by socioeconomic status

In this subsection, we assess whether relatively poorer Chilean mothers are more vulnerable to prenatal stress caused by sustained seismic activity. To this end, we use women's educational attainment as an indicator of affluence or socioeconomic advantages. Private resources are a key component in financing educational investments. Chile has the largest share of private expenditure through all education stages among OECD countries. At the basic education level (primary, secondary, and post-secondary non- tertiary education), 79% of education expenditures are from public resources and the remaining 21% is from private financing, which comes from households. However, for higher education, this picture reverses. The percentage of public resources for the tertiary education stage drops to 38%, with the remaining 62% of spending coming from private sources (51% from households, the rest from other private sources). Individuals with higher education, on average, earn 160% more than individuals with lower educational attainment. Individuals with post-graduate studies (master or PhD) receive 444% more on average than upper secondary graduates

(OECD, 2017).

We split Chilean mothers into two subgroups. The first includes those with primary, secondary, or post-secondary -non-tertiary educational attainment, which we denote by LAM (less affluent mothers). They represent 63.9% of the observations. The other subgroup includes those mothers with higher educational attainment, denoted by MAM (more affluent mothers), which represents 36.1% of the observations.

The estimates we report in this subsection correspond to the IV-mother-fixed-effect model. The impacts of exposure to seismic activity on birth outcomes vary between LAM and MAM mothers (see Table (8)). We first describe the impact of PREMS on the variables birth-weight, LBW, and gestational length. Infants born to LAM -mothers who were exposed to earthquakes in the third trimester are on average 1.3% more likely to be preterm, whereas we find some (weak) effects on LBW and gestational length only for infants in the MAM group. In this group, we find an important effect on birth-weight for infants who were exposed to earth tremors in two successive trimesters in late gestation. The reduction in birth weight is about 106 grams, which translates into a higher probability of being LBW. As for the effects on fetal growth, the LAM group appears to drive the results reported in Table (5). Exposure to earth tremors (either in the second trimester or in two successive trimesters) increases the incidence of LGA within the LAM group.

In the next section, we elaborate on some possible mechanisms that may explain our findings.

7 Possible mechanisms

Overall, our empirical evidence suggests the consequences of PREMS exposure on birth outcomes vary in at least two dimensions: the timing of the stressor and mothers' socioeconomic status. Infants exposed to earth tremors in the first and/or second trimester are more likely to be preterm than non-exposed infants. As for the consequences on fetal growth, we observe that LAM- mothers are more vulnerable to seismic activity, because PREMS increases the incidence of LGA -babies within this group. In this section, we explore some possible mechanisms that may explain these results.

Exposure to earthquakes triggers different mechanisms with opposing consequences on birth outcomes. The medical literature has provided theoretical explanations and empirical evidence that show that neuroendocrine changes may have negative effects on the fetus. Much of the literature documents this effect. This mechanism provides a rationale for the negative effects we observe among MAM -infants. In addition, the recent findings of Berghänel et al. (2017) could explain the lack of significant effects on birth weight and on SGA when exposure to PREMS happens in early gestation. However, these mechanisms do not explain the observed varying impacts on the incidence of LGA infants.

We consider two possible channels with opposing indirect effects on birth outcomes. Prenatal stress can encourage health-enhancing behavior among affected women. Mothers exposed to acute stress caused by un-expected shocks can change their nutritional habits or their use of prenatal care, leading to positive effects on birth outcomes (Torche and

Villarreal, 2014). The other channel involves changes in the incidence of diabetes and hypertension. Because mothers with diabetes and/or hypertension and preeclampsia are more likely to deliver larger babies, if PREMS increases the incidence of these afflictions among women of childbearing age, the risk of LGA babies may increase.

Our database does not have information about mothers' health- behavior and health conditions. Hence, we cannot directly test whether exposure to earthquakes encourages health-enhancing behavior or whether it triggers the incidence of diabetes and/or hypertension among affected groups. However, we can use the Socioeconomic National Survey (*Encuesta de Características Socioecnómicas Nacionales*, CASEN) to provide some indirect evidence on this issue. We study changes in health conditions and antenatal healthcare use among women of childbearing age (i.e., women aged between 15 and 49 years of age).

We use data from the 2011, 2013, and 2015 waves of the CASEN, which provides information about Chilean households. The health module of the survey is of particular interest to us. This module contains questions about health status, mothers' nutritional conditions (only for waves 2011 and 2013), pregnancy, parity, diabetes, hypertension, and use of antenatal care (healthcare controls ($HC - visits$), sonograms ($Sonograms$), and supplemental nutrition assistance, SNA). Because we are interested in studying the effects of earthquake exposure on indicators of Chilean women's behaviors and health conditions, we drop all male respondents and all women younger than 15 years or older than 49 years. This step reduces our sample to 77,395 women in 2011, 56,484 in 2013, and 62,588 in 2015.

We use data in relation to pregnancy information; we observe whether a woman was pregnant at the moment of the survey, although we do not have information about the stage of gestation. Let $Preg_{i,c,w}$ be a dummy variable that equals 1 if woman i, who lived in *comuna* c, was pregnant in the year -wave w ($Preg$ has a mean equal to 0.03 and a standard deviation 0.169). We also have information about the number of children she had, the birth order, her self- reported physical and mental health conditions, whether she suffers from diabetes and/or hypertension, information about her nutritional condition, health insurance coverage, use of antenatal care, and supplementary nutritional assistance (a more detailed description of all the variables are provided in Appendix A).

To determine women's exposure to earthquakes, we consider the period of time in which interviews were collected, the locations of the earthquakes that occurred during the months previous to the field period of each wave, and women's *comuna* of residence. For each wave, to determine the earthquake -time -window, we count nine months backwards from the last day of the field period. In this way, we can measure the exposure to earthquakes of a mother who was in her final stage of gestation by the end of the field period. The problem with this criterion is that we could mistakenly assign to the affected group those mothers who were at the beginning of the first trimester of gestation during the field period. However, we would still have similar problems if we were to limit the earthquake -time -window to the month before the field period. That being said, for the 2011 -wave, interviews were conducted from November 26, 2011, through January 22, 2012; hence, the earthquake -time -window is the period between May -2011 and January -2012. Precisely, in June- 2011, an $Ms/Mw6.4$ earthquake struck the northern region of Antofagasta, in which three *comunas* reported an intensity equal to VI. For the 2013 -wave (with field period between November 11, 2013, and February 2, 2014), two earthquakes happened within its earthquake- time -window: the 6.5 -earthquake of October 30, 2013, and the 5.8 -earthquake of October 29, 2013. In both events, the most affected *comunas* reported intensities equal to V. Although the intensity V is just below our threshold of VI, we decided to include these events because otherwise we could not use the 2013 wave. Finally, for the 2015 -wave (with field period between November 2, 2015, and January 31, 2016), we consider the 8.4 -mega-earthquake of September -2015. For this seismic event, several *comunas* reported intensities greater than or equal to VI. The dummy variable $EQ_{i,c,w}$ takes the value 1 if woman i lived in comuna c that was affected by the earthquake considered in the wave w (with $w = \{2011, 2013, 2015\}$). This variable has a mean of 0.079 and a standard deviation equal to 0.271.

We construct the dummy variable MAW (for more affluent women) that equals 1 if woman i has complete or incomplete tertiary education, and the variable LAW (for less affluent women) is equal to $1 - MAW$.

We estimate the following model:

$$\begin{aligned} Y_{i,c,w} &= \beta_0 + \beta_1 MAW_{i,c,w} + \beta_2 Preg_{i,c,w} + \beta_3 EQ_{i,c,w} + \beta_4 Preg_{i,c,w} \times EQ_{i,c,w} + \\ & \quad \beta_5 Preg_{i,c,w} \times MAW_{i,c,w} + \beta_6 EQ_{i,c,w} \times MAW_{i,c,w} + \beta_7 Preg_{i,c,w} \times MAW_{i,c,w} \times EQ_{i,c,w} \\ & \quad + \gamma' X_{i,c,w} + \alpha_c + \alpha_w + \alpha_c \times \alpha_w + \epsilon_{i,c,w}, \end{aligned} \tag{4}$$

where $Y_{i,c,w}$ denotes the outcome variable of woman i, who lives in *comuna* c in the year-wave w; the vector $X_{i,c,w}$ includes women's sociodemographic characteristics (income, age categories, marital status, birth parity, type of health insurance, poverty, health and mental health statuses, and area of residence- urban or rural); *comuna* of residence and year-wave fixed effects are indicated by α_c and α_w, respectively. Our outcome variable measures antenatal care utilization (i.e., SNA, $HC - visit$, and $Sonogram$) and health conditions (i.e., $Diabetes$ and $Hypertension$). In all regressions, non-pregnant LAW are in our reference group. Table (9) presents the results.

The first three columns of Table (9) capture possible changes in women's behavior. Exposure to earthquakes seems to increase the use of antenatal care, because exposed women are more likely to have access to supplementary nutrition assistance as well as to increase the use of sonograms (or X-rays) and the use health-care visits. These estimates suggest preemptive responses vary between women with different socioeconomic status. Pregnant MAW are more likely to use antenatal care controls (sonograms and health-care visits) than pregnant LAW. On the other hand, pregnant LAW are more likely to have access to supplementary nutrition assistance (e.g., Milk) than pregnant MAW. Columns (4) and (5) suggest the stress caused by seismic activity may increase the incidence of diabetes and hypertension among affected women of childbearing age. In particular, the impact on the incidence of diabetes is lower for MAW. Pregnant MAW who were exposed to an earthquake are less likely to have diabetes than exposed, pregnant LAW. Finally, being exposed to an earthquake and being pregnant increase the probability of suffering hypertension. These results may be suggestive of the channels discussed above.

We start with the effects on LGA mediated through changes in the incidence of diabetes and hypertension. Exposure to seismic activity seems to increase the proportion of diabetes and hypertension among exposed women of childbearing age. The effect varies by socioeconomic status, with pregnant MAW being relatively less affected in the case of diabetes. Mothers with diabetes and/or hypertension (and preeclampsia) are more likely to give birth LGA. We argue that the differential impacts on the incidence of these afflictions could explain the increase in the proportion of LGA babies among less affluent mothers. The other mechanism operates through mothers' preemptive responses. Exposure to a stressor triggers the use of antenatal care, especially among pregnant MAW. This behavioral response may cancel out any negative effect the prenatal stress may have on fetal growth.

We are very cautious about the results presented in this section, because some factors limit the validity and scope of the estimates. First, we cannot control for mothers' unobserved heterogeneity such as genetic predisposition to develop diabetes or to have hypertension. As a result, our estimates could be picking up the effects of these omitted variables. Second, exposure to earth tremors can trigger behavioral responses among affected women; for example, they might change their sleeping habits, dietary habits, and so on. Because these changes alter the composition of the affected population, we cannot claim that differences in the outcome variable between affected and non-affected groups can be explained by differences in the exposure to stress. Third, our variable EQ is likely to have measurements errors. Because we do not observe mothers' gestational stage, our treated group might include some women who were not pregnant when the earth tremor occurred. On the other hand, the control group might also include some mothers who were pregnant and affected by the earthquake but delivered their babies before the interviews were conducted. Finally, medical research documents a positive association between hypertension **and preeclampsia** and the risk of LGA babies. Our estimates only include information about hypertension, because we do not observe whether women suffer preeclampsia during pregnancy.

8 Robustness Check

In this section, we report several robustness check. First, we assess the sensitivity of the results to the assumed cutoff value for the Modified Mercalli Scale. Second, we study whether endogenous mobility is an issue in our estimates. Finally, we report the results of a placebo test in which we randomly distribute the value of EQ^g to different Chilean mothers. For reasons of space, in this section, we discuss the results, and the corresponding tables with the estimates are gathered in Appendix B.

8.1 Re-defining exposed groups with a cutoff value of $MMS = V$

We test whether our results are sensitive to the chosen cutoff value for the Modified Mercalli Scale. Recall that an intensity of V may not cause stress to affected people, because its shaking is moderate and does not injure humans and/or damage structures, whereas a seismic event with an intensity of VI has the potential to cause stress because it is felt by all and many might be frightened. In our benchmark models, the group of Chilean mothers who were exposed to earthquakes with intensities of V were classified into the control groups. We re-define the dummy variables $EQ^{g}_{i,m,c,t}$, with $g \in \{1, 2, 3, 1\&2, 1\&3, 2\&3, 1\&2\&3\}$. $EQ^{g}_{i,m,c,t}$ equals 1 if infant i born to mother m, with *comuna* of residence c, at date (year-month-day) t, was exposed to (at least) one earth tremor, felt with intensity $\geq V$, in trimester(s) g. Note that under this cutoff value, more mothers are affected by earth tremors. The number of observations in each of the affected groups, that is, groups 1 to 7 of Table (1), increases. Hence, under this specification, we include the dummy variables $EQ^{1\&3}_{i,m,c,t}$ and $EQ^{1\&2\&3}_{i,m,c,t}$.

We still find that PREMS caused by seismic activity -cutoff V- has important effects on fetal growth. Mothers exposed to earthquakes in the second trimester of gestation face increased risks of delivering LGA babies. The estimated impact is 1.2%, significant at the 1% level. The estimated impact on LGA for those mothers who were exposed to earth tremors in two successive trimesters vanishes, but we now find a (weak) impact on the incidence of SGA. Infants born to mothers who suffered earthquakes during the first trimester are 0.2% less likely to be SGA. For the other variables, we still find the same impact on preterm (for those mothers exposed to PREMS in the second trimester), and we now find a significant negative effect on gestational length for those mothers exposed to earth tremors in the second trimester. Finally, the effect on birth weight (for those mothers who suffered earthquakes in two successive trimesters in late gestation) disappears.

8.2 Endogenous mobility

In section 5, we argue that mothers exposed to earth tremors are not more likely than others to move. Table (3) presents evidence on this respect. Because a small fraction of mothers, namely, those whose employment status is missing, and families with fathers with low educational attainment (the p-value for this group is exactly 10%) seem to be less likely to move in response to earthquakes, we perform additional estimates where we use the instrument proposed by Curri and Rossin-Slatter (2013).

We modify the instrument of section 5. We still assume full gestation term to construct the predicted gestation period. For each mother, we compute measures of exposure to earth tremors that would have occurred in each predicted trimester had the pregnant mother had a full- term pregnancy and had she remained in her first *comuna* of residence. We use these constructed variables to instrument for the current measures of exposure to earth tremors, i.e. $EQ^{g}_{i,m,c,t}$, with $g = \{1, 2, 3, 1\&2, 2\&3\}$.

The estimates reported in Table (12) confirm our main results. Endogenous mobility is not an issue in our data, because the reported impacts are virtually the same as those presented in Panel C of Table (5). We observe that infants born to mothers exposed to earthquakes during the second trimester of gestation are more likely to be preterm and also more likely to be LGA. Mothers who suffer earth tremors in two successive trimesters in early and mid gestation are more likely to give birth to LGA babies, whereas those mothers exposed to earth tremors in successive trimesters in mid and late gestation are more likely to give birth to lighter-weight babies.

8.3 Placebo test

In this section, we randomly distribute the value of $EQ^g_{i,m,c,t} = 1$, with $g = \{1, 2, 3, 1\&2, 2\&3\}$ to different mothers, maintaining the number of instances $EQ^g_{i,m,c,t} = 1$ appears in the observed data. We reestimate our models to see whether a random distribution of earthquake exposure generates the same estimates as the observed exposure. We repeat this exercise 600 times and record how often such a random distribution of exposure reproduces our results. If the reported impacts are driven by PREMS, we should obtain an average null effect under this ”fake” exposure. In all cases, the average value of the estimated coefficients of variables $EQ^g_{i,m,c,t}$ are not significantly different from zero (see Table (13)).

9 Concluding Remarks

We assess the impacts of acute prenatal stress, caused by sustained seismic activity, on birth outcomes in Chile. We pay particular attention to the effects of prenatal maternal stress on fetal growth, in addition to the typical measures considered in the literature, namely, birth-weight, low -birth weight, and gestational length. Our data come from the Chilean official birth certificates over the period 2011-2015. The mother-fixed-effect model with full- term- gestation exposure instrument together with the spatiotemporal variation of earthquakes in Chile allow us to cope with identification issues, for example, endogeneity of maternal location, changes in the composition of the affected population, and the mechanical link between length of gestation and the probability of being exposed, that obscured the identification of the causal effect of prenatal stress in previous estimates.

Our main findings show that exposure to sustained seismic activity has an impact on fetal growth (and this result is robust to several checks). Exposure to prenatal stress increases the incidence of large- for- gestational- age babies, and the effect is most pronounced in the group of mothers with low socioeconomic status. We elaborate the possible mechanism that explains our results. We claim that exposure to negative shocks increases the incidence of afflictions such as diabetes and hypertension among the affected population. Medical literature shows that infants born to mothers with diabetes or hypertension and preclampsia are more likely to be large for gestational age.

We provide some empirical evidence that is suggestive of the discussed mechanism in action. Exposure to earth tremors seems to increase the incidence of diabetes and hypertension, and the effect on diabetes is relatively higher among the group of mothers with low socioeconomic status. However, we are very cautious about the validity and scope of this result. Our estimates can capture the (unobserved) predisposition of women of childbearing age to develop these afflictions, and our variables of treatments are likely to have measurement errors. Further research with more detailed data, such as mothers' health conditions, maternal behavior during pregnancy, and so on, will be needed to verify whether exposure to un-expected negative shocks has an impact on fetal growth through changes in mothers' health.

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Appendix: Tables

Group	Trimester			*All-Chilean Births*		*Panel of Mothers*	
	FT	*ST*	*TT*	Frequency	(%)	Frequency	(%)
1	**X**	–	–	34,829	3.04%	6,132	2.99%
2	–	**X**	–	31,642	2.77%	5,457	2.66%
3	–	–	**X**	39,024	3.41%	6,774	3.30%
4	**X**	**X**	–	1,978	0.17%	317	0.15%
5	–	**X**	**X**	2,160	0.19%	352	0.17%
6	**X**	–	**X**	1	∼0%	1	∼0%
7	**X**	**X**	**X**	0	0%	0	0%
Total Exposed				109,634	9.58%	19,033	9.28%
8 (Not-exposed)	–	–	–	1,034,651	90.42%	186,172	90.72%
Total				1,144,284	100%	205,205	100%

Table 1: Cells with **X** indicate that mothers were exposed to (at least) one earthquake in the first, second and/or third trimester of gestation; "-" indicates that mothers were not exposed to a seismic event in the corresponding trimester.

	All Chilean Births				Panel of Mothers			
	All Mothers	Exposed	Not-Exposed	Difference	All Mothers	Exposed	Not-Exposed	Difference
Birth-weight	3343.99	3356.06	3342.71	-13.35***	3348.53	3369.85	3346.35	-23.50***
Height	49.33	49.33	49.33	-0.00	49.33	49.34	49.33	-0.01
Gestational weeks	38.53	38.60	38.53	-0.07***	38.49	38.54	38.49	-0.05***
LBW	0.05	0.04	0.05	0.01***	0.05	0.04	0.05	0.01***
Preterm birth	0.06	0.06	0.07	0.01***	0.07	0.06	0.07	0.01***
SGA	0.01	0.01	0.01	0.00	0.01	0.01	0.01	-0.00
AGA	0.93	0.93	0.93	0.00	0.93	0.92	0.93	0.01**
LGA	0.06	0.06	0.06	-0.00	0.07	0.07	0.06	-0.01**
Gender (Male=1)	0.51	0.51	0.51	-0.00	0.51	0.51	0.51	0.00
First child	0.44	0.45	0.44	-0.01***	0.27	0.22	0.28	0.06***
Second child	0.34	0.33	0.34	0.01***	0.43	0.46	0.43	-0.03***
Third child	0.15	0.15	0.15	0.00*	0.20	0.22	0.20	-0.02***
Mother's age $<$ 25	0.36	0.36	0.36	0.00	0.37	0.37	0.37	0.00
Mother's age 25-34	0.47	0.48	0.47	-0.01***	0.50	0.51	0.50	-0.00
Mother's age 35-44	0.17	0.16	0.17	0.01***	0.13	0.12	0.13	0.00
Mother's age $>$ 45	0.00	0.00	0.00	0.00*	0.00	0.00	0.00	0.00*
Mother's age missing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Married	0.29	0.28	0.29	0.02***	0.35	0.33	0.36	0.02***
Mother's educ. $\leq$ Primary	0.10	0.09	0.11	0.01***	0.12	0.12	0.12	0.00
Mother's educ. Secondary	0.56	0.56	0.56	-0.00*	0.52	0.54	0.52	-0.02***
Mother's educ. Tertiary	0.34	0.34	0.33	-0.01***	0.36	0.34	0.36	0.02***
Mother's education level missing	0.00	0.00	0.00	-0.00	0.00	0.00	0.00	0.00
Mother's employment status	0.46	0.46	0.46	0.00	0.45	0.43	0.46	0.03***
Mother's employment status missing	0.00	0.00	0.00	-0.00***	0.00	0.00	0.00	0.00***
Urban	0.91	0.94	0.90	-0.03***	0.92	0.94	0.91	-0.02***
Father's age $<$ 25	0.22	0.22	0.22	0.00**	0.20	0.20	0.20	0.01*
Father's age 25-34	0.42	0.43	0.42	-0.01***	0.46	0.47	0.46	-0.01**
Father's age 35-44	0.22	0.21	0.22	0.01***	0.21	0.20	0.21	0.01*
Father's age $>$ 45	0.14	0.14	0.14	-0.00	0.13	0.13	0.13	-0.00
Father's age missing	0.10	0.10	0.10	-0.00***	0.10	0.10	0.10	-0.00
Father's educ. $\leq$ Primary	0.10	0.08	0.10	0.02***	0.09	0.09	0.10	0.01**
Father's educ. Secondary	0.48	0.49	0.48	-0.01***	0.44	0.46	0.44	-0.03***
Father's educ. Tertiary	0.32	0.33	0.32	-0.01***	0.37	0.35	0.37	0.02***
Father's education level missing	0.10	0.10	0.10	-0.00***	0.10	0.10	0.10	-0.00
Father's employment status	0.84	0.84	0.84	0.00***	0.87	0.86	0.87	0.00
Father's employment status missing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
EQ^1	0.03	0.32	0.00	-0.32***	0.03	0.32	0.00	-0.32***
EQ^2	0.03	0.29	0.00	-0.29***	0.03	0.29	0.00	-0.29***
EQ^3	0.03	0.36	0.00	-0.36***	0.03	0.36	0.00	-0.36***
$EQ^{1\&2}$	0.00	0.02	0.00	-0.02***	0.00	0.02	0.00	-0.02***
$EQ^{2\&3}$	0.00	0.02	0.00	-0.02***	0.00	0.02	0.00	-0.02***
NEQ^1	0.04	0.43	0.00	-0.43***	0.04	0.44	0.00	-0.44***
NEQ^2	0.04	0.43	0.00	-0.43***	0.04	0.43	0.00	-0.43***
NEQ^3	0.05	0.53	0.00	-0.53***	0.05	0.55	0.00	-0.55***
Birth Spacing					43.37	55.84	42.09	-13.75***
Num. of observations	1144318	109634	1034684		205203	19032	186171	

Table 2: Descriptive statistics Chilean births, 2011-2015. The column labeled "Difference" shows the differences in mean (and their significance level, (***) 1%, (**) 5%, (*) 10%) between Not-Exposed and Exposed mothers.

Controls	Migration
EQ	-0.031
(s.e.)	(0.051)
$EQ\times$ Birth 1	0.005
(s.e.)	(0.021)
$EQ\times$ Birth 2	0.001
(s.e.)	(0.020)
$EQ\times$ Birth 3	0.009
(s.e.)	(0.020)
$EQ\times$ Mother's age < 25	0.027
(s.e.)	(0.033)
$EQ\times$ Mother's age $25-34$	0.014
(s.e.)	(0.027)
$EQ\times$ Mother's age $35-44$	0.000
(s.e.)	(-)
$EQ\times$ Mother's educ. primary	0.009
(s.e.)	(0.020)
$EQ\times$ Mother's educ. secondary	0.008
(s.e.)	(0.014)
$EQ\times$ Mother's educ. tertiary	0.199
(s.e.)	(0.183)
$EQ\times$ Mother's educ. missing	0.199
(s.e.)	(0.183)
$EQ\times$ Married	0.010
(s.e.)	(0.017)
$EQ\times$ Employment	-0.000
(s.e.)	(0.014)
$EQ\times$ Empl. missing	-0.457**
(s.e.)	(0.210)
$EQ\times$ Urban	0.011
(s.e.)	(0.019)
$EQ\times$ Father's age < 25	-0.021
(s.e.)	(0.044)
$EQ\times$ Father's age 25-34	-0.008
(s.e.)	(0.040)
$EQ\times$ Father's age 35-44	0.000
(s.e.)	(0.038)
$EQ\times$ Father's age missing	-0.030
(s.e.)	(0.047)
$EQ\times$ Father's educ. primary	-0.032*
(s.e.)	(0.019)
$EQ\times$ Father's educ. secondary	0.005
(s.e.)	(0.016)
$EQ\times$ Father's educ. tertiary	0.000
(s.e.)	(-)
$EQ\times$ Father's educ. missing	0.000
(s.e.)	(-)
$EQ\times$ Father's educ. employment	0.003
(s.e.)	(0.020)
Constant	-0.026
(s.e.)	(0.047)
Number of observations	104195
Number of clusters	342

Table 3: Dependent variable: $R_{i,m,t}$ that equals 1 if mother m changes her *comuna* of residence between pregnancies. Regression includes birth-month fixed effects, fixed effects of the mother's first *comuna* of residence, interacted with birth-year fixed effects, and controls for birth order (first, second, third child and four or more children), mother's age (<25, 25-34, 35-44, $\geq$45), mother's education (primary, secondary, tertiary and missing), mother's marital status, employment status (employed and employment missing) and fathers' characteristics. Omitted categories are: mothers' age > 44, mothers with higher educational attainment, birth ≥ 4, father's age > 44, and fathers with higher educational attainment. In the table, we report the coefficients of EQ and the coefficients of each covariate interacted with EQ. Standard errors (in parentheses) are clustered at the level of mother's first *comuna* of residence. Significance level: (***) at $p < 0.01$, (**) at $p < 0.05$, and (*) $p < 0.10$.

	All Chilean Births							
	Mothers' characteristics							
	Age $\leq$ 25	Age $\geq$ 45	Primary education	Secondary education	Education missing	Married	Employment status	Employment missing
EQ^1	0.002	-0.000	-0.004***	0.005	-0.000	-0.005*	-0.001	0.000
(s.e.)	(0.003)	(0.000)	(0.002)	(0.004)	(0.000)	(0.003)	(0.003)	(0.000)
EQ^2	-0.000	-0.000	0.001	-0.003	-0.000	-0.001	-0.001	0.000
(s.e.)	(0.003)	(0.000)	(0.002)	(0.005)	(0.000)	(0.003)	(0.003)	(0.000)
EQ^3	0.010***	-0.000	0.003	0.008**	-0.000	-0.010***	-0.009***	0.000
(s.e.)	(0.003)	(0.000)	(0.002)	(0.003)	(0.000)	(0.003)	(0.003)	(0.000)
$EQ^{1\&2}$	-0.019	-0.001	0.001	0.001	-0.000*	0.036***	-0.001	0.000
(s.e.)	(0.013)	(0.002)	(0.005)	(0.013)	(0.000)	(0.008)	(0.009)	(0.000)
$EQ^{2\&3}$	0.010	-0.001	0.001	-0.015	-0.000	-0.001	0.004	0.000
(s.e.)	(0.009)	(0.001)	(0.005)	(0.013)	(0.000)	(0.008)	(0.010)	(0.000)
Number of observations	1144284	1144284	1144284	1144284	1144284	1144284	1144284	1144284
Number of clusters	346	346	346	346	346	346	346	346
	Panel of Mothers							
	Mothers' characteristics							
	Age $\leq$ 25	Age $\geq$ 45	Primary education	Secondary education	Education missing	Married	Employment status	Employment missing
EQ^1	0.007	-0.000	0.001	0.006	-0.000*	-0.002	0.003	-0.000
(s.e.)	(0.007)	(0.000)	(0.006)	(0.008)	(0.000)	(0.008)	(0.007)	(0.000)
EQ^2	0.003	-0.000	0.002	-0.005	-0.000	-0.003	-0.000	-0.000
(s.e.)	(0.007)	(0.000)	(0.006)	(0.007)	(0.000)	(0.007)	(0.008)	(0.000)
EQ^3	0.016***	-0.000*	0.006	0.002	-0.000	-0.002	-0.005	-0.000
(s.e.)	(0.006)	(0.000)	(0.004)	(0.007)	(0.000)	(0.006)	(0.007)	(0.000)
$EQ^{1\&2}$	-0.022	-0.000	0.014	0.018	-0.000*	0.058**	0.007	-0.000
(s.e.)	(0.026)	(0.000)	(0.011)	(0.029)	(0.000)	(0.024)	(0.037)	(0.000)
$EQ^{2\&3}$	0.030	-0.000	0.013	-0.042	-0.000*	0.049**	0.006	-0.000
(s.e.)	(0.029)	(0.000)	(0.014)	(0.027)	(0.000)	(0.024)	(0.029)	(0.000)
Numb. of observations	205203	205203	205203	205203	205203	205203	205203	205203
Numb. of clusters	342	342	342	342	342	342	342	342

Table 4: Mothers' fertility response. Each column is a regression that controls for *comuna*, birth-year, and birth-month fixed effects. *Comuna* and birth-year fixed effects are interacted with each other. Standard errors are clustered at the level of *comuna* and are in parentheses. Significance level: (***) at $p < 0.01$, (**) at $p < 0.05$, and (*) $p < 0.10$.

	Panel A: All-Chilean Births Sample - OLS-Model						
	Birth Weight	Gestational Age	LBW	Preterm	SGA	AGA	LGA
EQ^1	19.362***	0.090***	-0.007***	-0.010***	-0.001	-0.000	0.001
(s.e.)	(4.778)	(0.015)	(0.002)	(0.001)	(0.000)	(0.002)	(0.002)
EQ^2	12.484***	0.030*	-0.001	-0.001	-0.001	-0.001	0.002
(s.e.)	(3.833)	(0.016)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)
EQ^3	57.088***	0.290***	-0.023***	-0.030***	-0.001*	-0.001	0.002
(s.e.)	(3.961)	(0.013)	(0.002)	(0.002)	(0.000)	(0.002)	(0.002)
$EQ^{1\&2}$	15.739	0.061**	-0.011***	-0.013***	-0.001	0.004	-0.003
(s.e.)	(12.164)	(0.028)	(0.004)	(0.004)	(0.001)	(0.004)	(0.004)
$EQ^{2\&3}$	27.989***	0.145***	-0.009	-0.020***	0.002	-0.004	0.002
(s.e.)	(9.276)	(0.039)	(0.005)	(0.006)	(0.002)	(0.005)	(0.005)
Number of observations	1144283	1144283	1144283	1144283	1144250	1144250	1144250
Number of clusters	346	346	346	346	346	346	346
	Panel B: Panel- of -Mothers Sample - OLS-Mother-Fixed-Effect Model						
	Birth Weight	Gestational Age	LBW	Preterm	SGA	AGA	LGA
EQ^1	6.826	0.037	0.001	0.002	-0.002	-0.001	0.003
	(8.780)	(0.031)	(0.004)	(0.005)	(0.002)	(0.005)	(0.005)
EQ^2	24.091***	0.048	-0.004	0.002	-0.000	-0.018***	0.018***
	(9.147)	(0.033)	(0.005)	(0.005)	(0.002)	(0.005)	(0.005)
EQ^3	42.633***	0.192***	-0.019***	-0.018***	-0.001	-0.003	0.004
	(8.290)	(0.028)	(0.004)	(0.005)	(0.002)	(0.005)	(0.005)
$EQ^{1\&2}$	-0.048	0.120	-0.009	-0.004	0.002	-0.035*	0.033*
	(31.676)	(0.110)	(0.015)	(0.019)	(0.005)	(0.019)	(0.019)
$EQ^{2\&3}$	-39.512	0.104	0.006	-0.007	0.003	-0.025	0.022
	(30.270)	(0.104)	(0.015)	(0.018)	(0.006)	(0.019)	(0.018)
Number of observations	205203	205203	205203	205203	205191	205191	205191
Number of clusters	101009	101009	101009	101009	101003	101003	101003
	Panel C: Panel- of -Mothers Sample - IV-Mother-Fixed-Effect Model						
	Birth Weight	Gestational Age	LBW	Preterm	SGA	AGA	LGA
EQ^1	-6.133	-0.032	0.006	0.010**	-0.001	-0.001	0.002
	(8.812)	(0.031)	(0.004)	(0.005)	(0.002)	(0.005)	(0.005)
EQ^2	9.659	-0.030	0.002	0.010*	0.000	-0.018***	0.018***
	(9.143)	(0.032)	(0.005)	(0.005)	(0.002)	(0.005)	(0.005)
EQ^3	-1.281	-0.044	-0.000	0.008	-0.001	-0.003	0.003
	(9.025)	(0.032)	(0.004)	(0.005)	(0.002)	(0.005)	(0.005)
$EQ^{1\&2}$	-19.651	0.015	-0.001	0.007	0.002	-0.035*	0.032*
	(31.665)	(0.109)	(0.015)	(0.019)	(0.005)	(0.019)	(0.019)
$EQ^{2\&3}$	-57.405*	0.008	0.014	0.003	0.003	-0.025	0.022
	(30.293)	(0.104)	(0.015)	(0.018)	(0.006)	(0.019)	(0.018)
Number of observations	205203	205203	205203	205203	205191	205191	205191
Number of clusters	101009	101009	101009	101009	101003	101003	101003

Table 5: Relationship between prenatal stress and birth outcomes. Each column is a regression that corresponds to a birth outcome. Panel A presents the estimates that correspond to all-Chilean birth records, which assume mothers are randomly allocated between exposed and un-exposed groups. Panels B and C correspond to the panel- of -mothers sample. All regressions control for mothers' and fathers' sociodemographic characteristics. Standard errors (reported in parentheses) are clustered at the mothers' comuna- of -residence level (in Panel A) and at the level of mothers (in Panels B and C). All regressions include *comuna* (interacted with) birth-year and birth-month fixed effects. Significance level at (***) 1%, (**) 5%, and (*) 10%.
Panel C: in all cases, we cannot reject the null hypothesis that the instruments are valid instruments (Sargan-Hansen test), and we reject the null hypothesis of both underidentification (with p-value = 0.000, LM version of Kleibergen-Paap's rk-statistic) and weak-identification (Kleibergen-Paap Wald rk F-statistic$> 7.8e + 04$)

Panel of Mothers						
Number of Earthquakes	FT		ST		TT	
	Frequency	(%)	Frequency	(%)	Frequency	(%)
0	198,754	98.86	199,067	97.01	198,077	96.53
1	5,377	2.62	4,881	2.38	5,425	2.64
2	695	0.34	795	0.39	974	0.47
3	167	0.08	220	0.11	339	0.17
4	22	0.01	26	0.01	23	0.01
5	188	0.09	189	0.09	204	0.10
6	0	0	15	0.01	161	0.08
Number of of observations	205,203	100	205,203	100	205,203	100

Table 6: Number of seismic events in each trimester of pregnancy. We exclude mothers younger than 14 and older than 49, infants born in the most affected areas during the six months after the 8.8 -Maule earthquake, as well as those infants born in the most affected areas after the 8.4 -Illapel earthquake, newborns with birth-weight < 500 or $> 9{,}000$, and newborns with gestational weeks less than 26.

	Panel A: Panel- of -Mothers Sample - OLS-Mother-Fixed-Effect Model						
	Birth Weight	Gestational Age	LBW	Preterm	SGA	AGA	LGA
NE^1	3.735	0.031	-0.002	0.001	-0.001	-0.001	0.002
	(5.773)	(0.020)	(0.003)	(0.003)	(0.001)	(0.004)	(0.003)
NE^2	6.679	0.001	-0.003	0.003	0.000	-0.011***	0.011***
	(5.674)	(0.020)	(0.003)	(0.003)	(0.001)	(0.004)	(0.003)
NE^3	17.182***	0.084***	-0.009***	-0.008***	-0.000	-0.003	0.003
	(4.407)	(0.015)	(0.002)	(0.002)	(0.001)	(0.003)	(0.003)
Number of observations	205203	205203	205203	205203	205191	205191	205191
Number of clusters	101009	101009	101009	101009	101003	101003	101003
	Panel B: Panel- of -Mothers Sample - IV-Mother-Fixed-Effect Model						
	Birth Weight	Gestational Age	LBW	Preterm	SGA	AGA	LGA
NE^1	-4.831	-0.016	0.001	0.006**	-0.001	-0.001	0.002
	(5.746)	(0.020)	(0.003)	(0.003)	(0.001)	(0.004)	(0.003)
e NE^2	-0.898	-0.041**	0.000	0.008**	0.000	-0.012***	0.011***
	(5.638)	(0.020)	(0.003)	(0.003)	(0.001)	(0.004)	(0.003)
NE^3	-2.839	-0.028*	-0.000	0.004	0.000	-0.003	0.003
	(4.726)	(0.017)	(0.002)	(0.003)	(0.001)	(0.003)	(0.003)
Number of observations	205203	205203	205203	205203	205191	205191	205191
Number of clusters	101009	101009	101009	101009	101003	101003	101003

Table 7: Relationship between prenatal stress and birth outcomes. Each column is a regression that corresponds to a birth outcome. Panel A presents the OLS-mother-fixed-effect model, whereas Panel B presents the estimates of the IV-mother-fixed-effect model. All regressions control for mothers' and fathers' sociodemographic characteristics. Standard errors (reported in parentheses) are clustered at the level of mothers. All regressions include *comuna* (interacted with) birth-year and birth-month fixed effects. Significance level at (***) 1%, (**) 5%, and (*) 10%.

Panel B: In all cases, we cannot reject the null hypothesis that the instruments are valid instruments (Sargan-Hansen test), and we reject the null hypothesis of both underidentification (with p-value = 0.000, LM version of Kleibergen-Paap's rk-statistic) and weak-identification (Kleibergen-Paap Wald rk F-statistic$> 2.1e+04$)

Panel A: Less Affluent Group of Mothers - IV-Mother-Fixed-Effect Model							
	Birth Weight	Gestational Age	LBW	Pre-term birth	SGA	AGA	LGA
EQ^1	7.416	-0.002	-0.001	0.006	-0.002	-0.006	0.009
(s.e.)	(11.540)	(0.041)	(0.005)	(0.006)	(0.002)	(0.007)	(0.007)
EQ^2	2.033	-0.036	0.007	0.013**	0.002	-0.020***	0.018**
(s.e.)	(11.989)	(0.043)	(0.006)	(0.007)	(0.003)	(0.007)	(0.007)
EQ^3	9.434	-0.025	-0.003	0.009	-0.002	-0.001	0.003
(s.e.)	(11.943)	(0.043)	(0.006)	(0.007)	(0.003)	(0.007)	(0.007)
$EQ^{1\&2}$	0.792	0.032	-0.004	0.003	0.002	-0.050*	0.048*
(s.e.)	(42.783)	(0.154)	(0.019)	(0.026)	(0.006)	(0.026)	(0.025)
$EQ^{2\&3}$	-34.177	-0.050	-0.012	0.021	0.002	-0.022	0.021
(s.e.)	(40.973)	(0.152)	(0.021)	(0.025)	(0.009)	(0.027)	(0.025)
Number of observations	123139	123139	123139	123139	123127	123127	123127
Number of clusters	60552	60552	60552	60552	60546	60546	60546

Panel B: More Affluent Group of Mothers - IV-Mother-Fixed-Effect Model							
	Birth Weight	Gestational Age	LBW	Pre-term birth	SGA	AGA	LGA
EQ^1	-14.374	-0.086*	0.013*	0.011	-0.000	0.006	-0.006
(s.e.)	(15.188)	(0.052)	(0.008)	(0.009)	(0.002)	(0.008)	(0.008)
EQ^2	24.948	-0.005	-0.010	0.003	-0.002	-0.009	0.012
(s.e.)	(15.582)	(0.054)	(0.008)	(0.010)	(0.002)	(0.009)	(0.008)
EQ^3	-14.085	-0.094*	0.006	0.005	0.003	-0.011	0.008
(s.e.)	(15.284)	(0.050)	(0.008)	(0.009)	(0.003)	(0.009)	(0.008)
$EQ^{1\&2}$	-69.470	-0.194	0.002	0.043*	-0.003	0.034	-0.032
(s.e.)	(48.456)	(0.133)	(0.023)	(0.026)	(0.003)	(0.029)	(0.029)
$EQ^{2\&3}$	-106.145**	-0.005	0.055**	0.007	0.007	-0.026	0.019
(s.e.)	(51.236)	(0.152)	(0.023)	(0.026)	(0.009)	(0.032)	(0.031)
Number of observations	66670	66670	66670	66670	66670	66670	66670
Number of clusters	32909	32909	32909	32909	32909	32909	32909

Table 8: Relationship between prenatal stress and birth outcomes by socioeconomic status. Chilean women are split into two groups: Less Affluent Mothers (LAM), which includes women with intermediate or lower educational attainment, and More Affluent Mothers (MAM), which includes women with tertiary education. Estimates in both panels correspond to the IV-mother-fixed-effect model. All regressions control for mothers' and fathers' sociodemographic characteristics. Standard errors (reported in parentheses) are clustered at the level of mothers. All regressions include *comuna* (interacted with) birth-year and birth-month fixed effects. Significance level at (***) 1%, (**) 5%, and (*) 10%.
In Panels A and B, in all cases, we cannot reject the null hypothesis that the instruments are valid instruments (Sargan-Hansen test), and we reject the null hypothesis of both underidentification (with p-value = 0.000, LM version of Kleibergen-Paap's rk-statistic) and weak-identification (Kleibergen-Paap Wald rk F-statistic$> 2.4e + 04$)

	SNA	Sonogram	HC_visits	Diabetes	Hypertension
	(1)	(2)	(3)	(4)	(5)
MAW	0.009	0.002	-0.022***	-0.003	0.001
	(0.029)	(0.003)	(0.004)	(0.008)	(0.009)
Preg.	0.221***	0.398***	0.606***	-0.001	-0.004
	(0.026)	(0.018)	(0.013)	(0.004)	(0.010)
EQ	0.430***	0.040***	0.075***	0.019*	0.020*
	(0.034)	(0.003)	(0.004)	(0.010)	(0.012)
Preg.×EQ	-0.011	-0.032	0.007	0.029	0.035*
	(0.047)	(0.070)	(0.035)	(0.021)	(0.021)
MAW×Preg.	-0.222***	0.116***	0.044*	-0.006	-0.001
	(0.036)	(0.030)	(0.024)	(0.010)	(0.009)
MAW×EQ	0.044	0.000	-0.012	0.007	-0.005
	(0.079)	(0.009)	(0.012)	(0.021)	(0.010)
Preg.×EQ×MAW	-0.040	0.043	0.047	-0.046**	0.042
	(0.133)	(0.089)	(0.043)	(0.021)	(0.046)
Number of observations	11844	176702	176690	9129	9129
Number of clusters	323	323	323	323	323
CASEN Wave	2011-13-15	2011-13-15	2011-13-15	2011-13	2011-13

Table 9: OLS-estimates. Each regression controls for women's sociodemographic characteristics and indicators of health and mental health status. Regressions presented in the last two columns include controls for women's nutritional status. Because variables about mothers' nutritional conditions are available for waves 2011 and 2013, these regressions do not include observations of the 2015 wave. Standard errors (in parentheses) clustered at the level of *comuna*. Significance at (*) p<0.10, (**) p<0.05, (***) p<0.01

Appendix: Figures

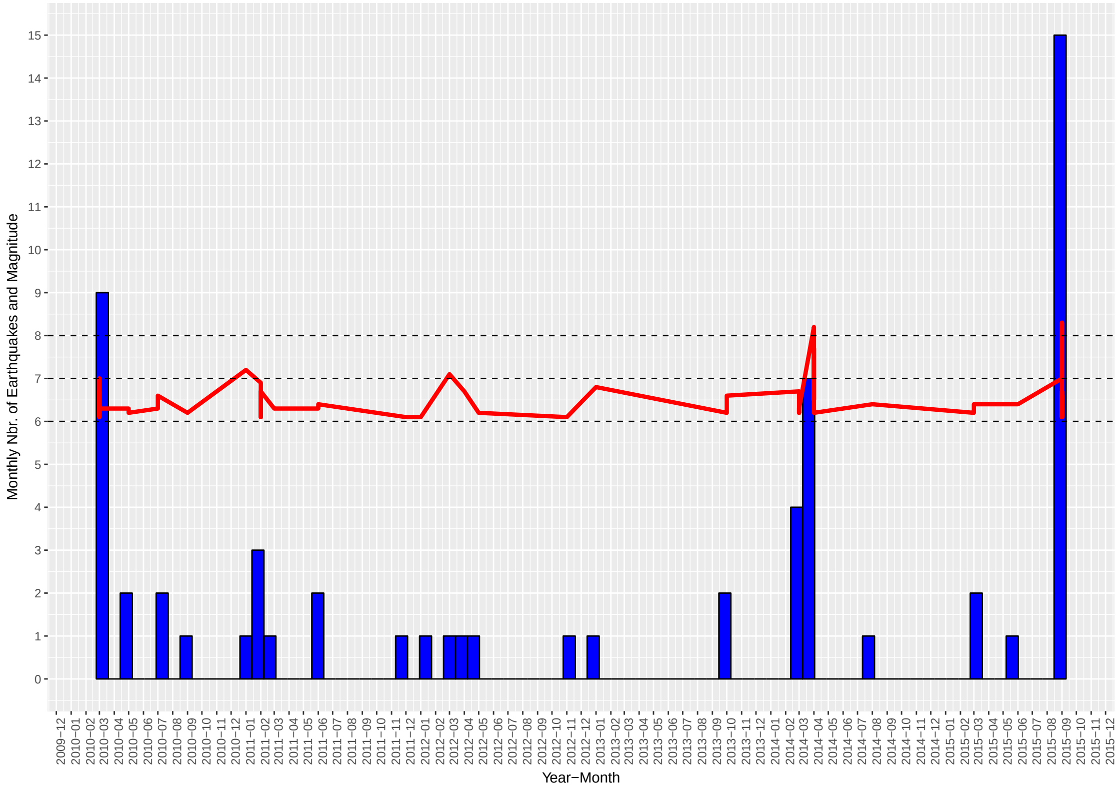


Figure 1: Earthquakes in Chile, temporal distribution of earth tremors of magnitude 6.0+ during March -2010 and December -2015.

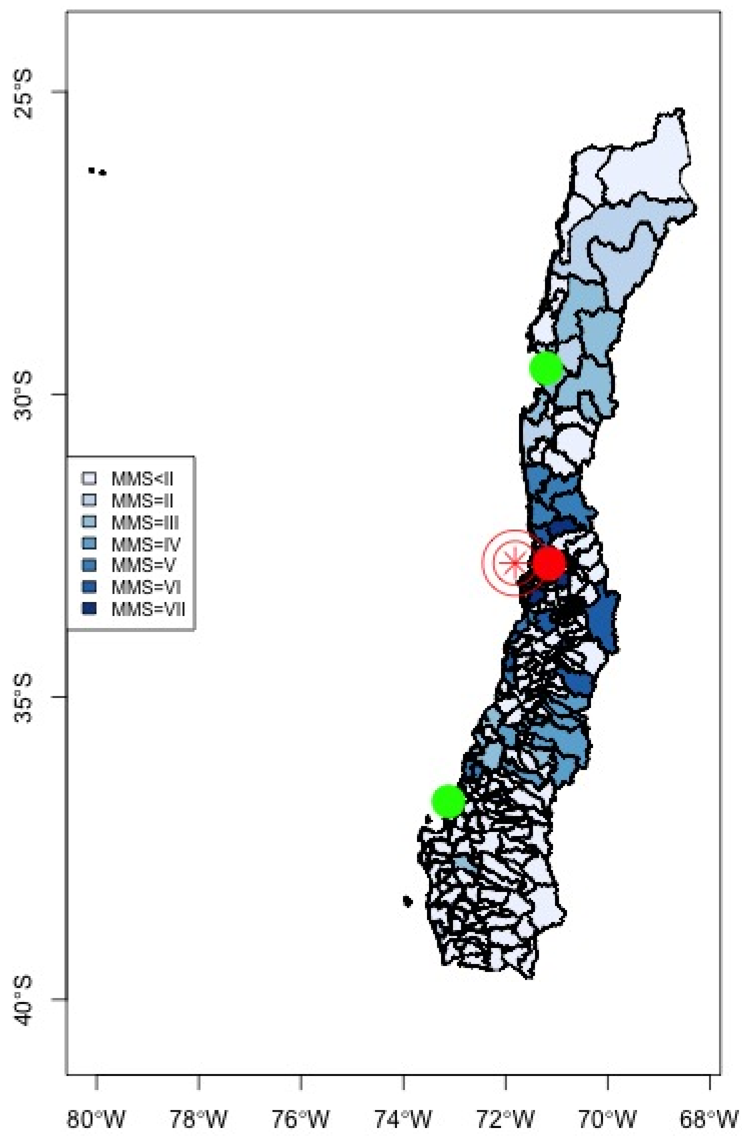
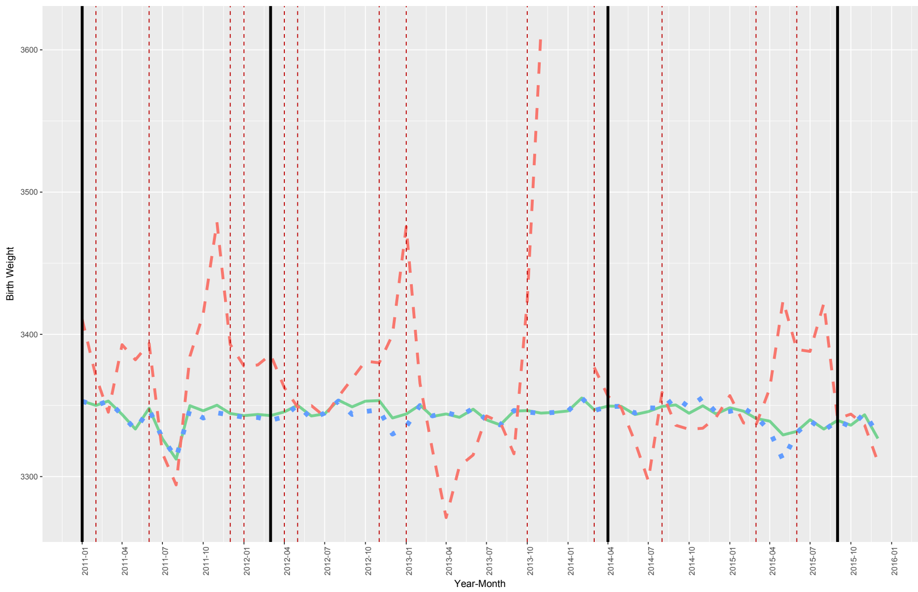
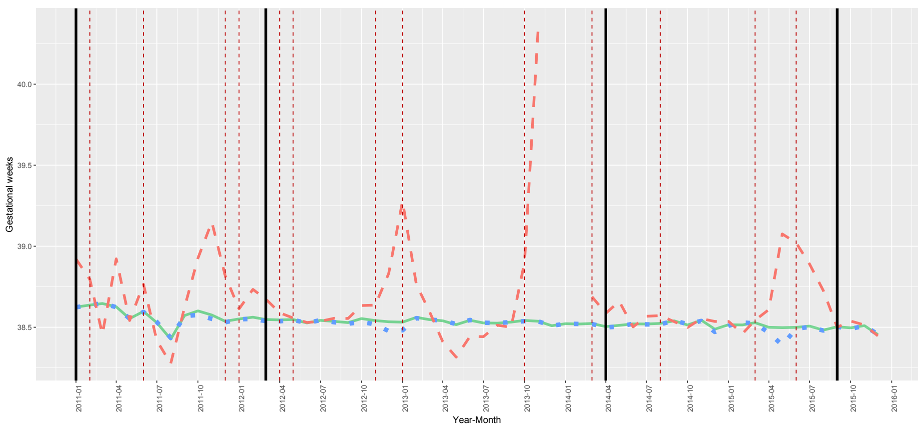


Figure 2: Geographical distribution of the intensities of the $Mw6.7$ earthquake, in 2012. The star shows the epicenter, near Valparaíso. Las Hijuelas, the red circle, was among the most affected *comunas*, with a reported intensity of VII. The green circles correspond to *comunas* with a reported intensity of III, Coquimbo (to the north) and Talcahuano (to the south).



(a) Average monthly evolution of birth weight by group.



(b) Average monthly evolution of gestational age by group.

Figure 3: Evolution of birth weight and gestational length over the period 2011-2015. The solid curve corresponds to monthly -average values of all births, the square-dotted curve corresponds to un-exposed newborns, and the dashed curve corresponds to exposed newborns.

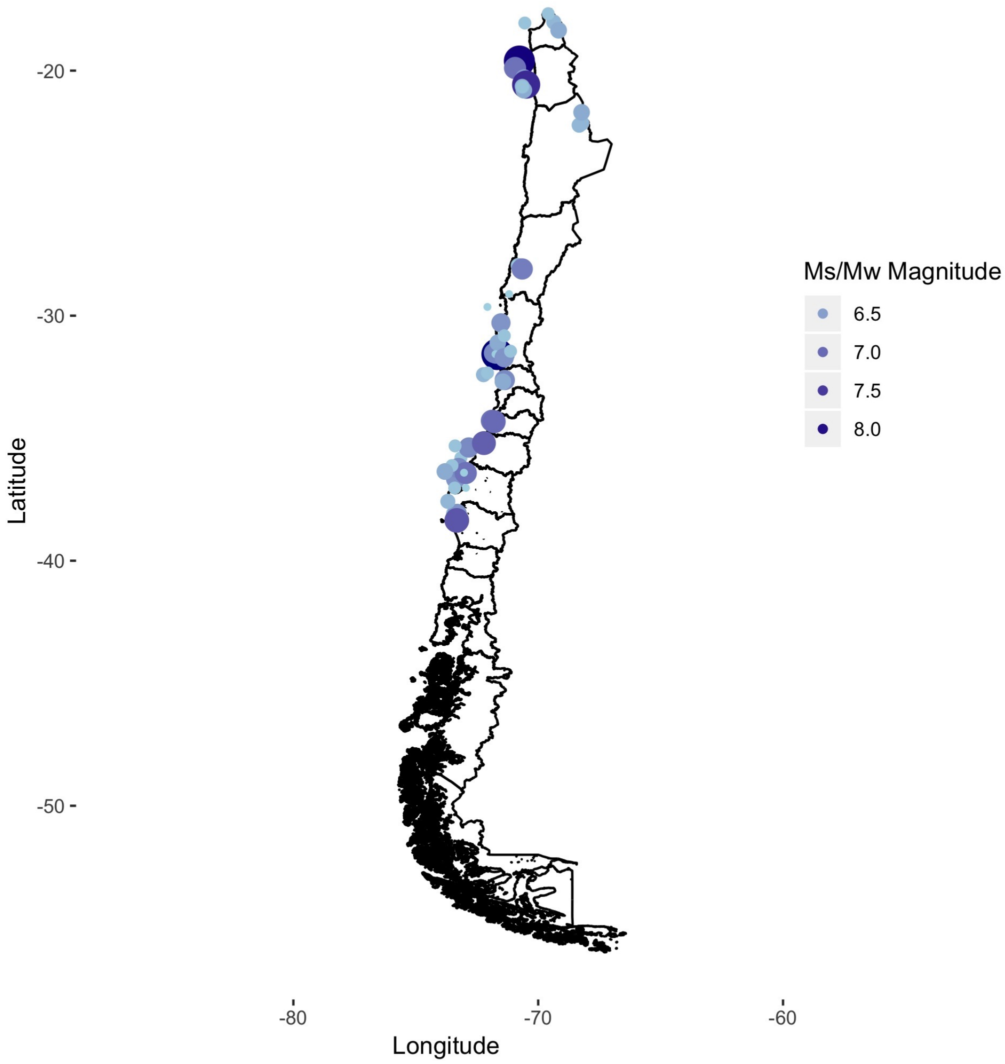


Figure 4: Earthquakes in Chile, regional distribution of earth tremors of magnitude 6.0+ during the earthquake-time-window.

10 Appendix A

In this appendix, we provide detailed information about the variables used in section (7). The CASEN survey provides sociodemographic information of Chilean individuals: age, marital status, relative position in the income distribution, educational attainment, *comuna* of residence, and whether they have health insurance coverage (public, private, or do not have). We use this information as controls in our regressions.

The health module is of particular interest to us. Each wave of the survey has a question about pregnancy: "Are you pregnant or breast-feeding your baby?" (s9 in 2011, s7 in 2013, and s6 in 2015). The possible answers are: (1) Yes, pregnant, (2) Yes, breast-feeding, and (3) No. We build a dummy variable called $Preg$ that equals 1 when the answer is (1). The mean of $Preg$ is 0.0298 (standard deviation is 0.169).[18] Unfortunately, we have no information about the stage of the pregnancy, and we will not be able to measure the timing of the stressor.

Questions s7 in 2011, s5 in 2013 and s4 in 2015 asks, "How many live births has the mother had?" The possible answer ranges from 0 to 20. We build measures of parity: $Birth0$ is a dummy that equals 1 if the answer is 0, and zero otherwise; $Birth1$, $Birth2$, and $Birth3$ are dummies that equal 1 if the answer is 1 or 2 or 3, respectively, and 0 otherwise. In our regression, the omitted category is $parity \geq 4$.

The survey contains several questions about individuals' health conditions. In particular, individuals are asked about their health status, about whether they have been under medical treatment, and about their nutritional status. The exact wording of the question about health status is the following: "In the last three months, have you had a health problem or an accident?" (question s20 in 2011, s17 in 2013, and s15 in 2015). The possible answers are (1) Yes, a job-related illness, (2) Yes, a non-job-related illness, (3) Yes, a job or scholar accident, (4) No, and (5) Do not Know/No Answer. We construct a dummy variable $Health\_Ok$ that equals 1 when the answer is equal to (4), and zero otherwise. The mean and standard deviation are, respectively, 0.834 and 0.372. Individuals are also asked about the number of times they required mental health assistance (questions s27a in 2011, s24a in 2013, and s2a in 2015). The possible answer ranges between 0 to 20 and individuals are allowed to choose "Do not know/No answer" option. The dummy variable $Mental\_Health\_Ok$ equals 1 if the answer is 0. The mean and standard deviation of this variable are equal to 0.972 and 0.165, respectively.

We also have information about whether individuals have diabetes or hypertension. A question asks individuals whether they have been under medical treatment within the last 12 months (question s34 in 2011, s31 in 2013, and s28 in 2015). The possible answers include diabetes and hypertension (among other afflictions). We construct two dummies variables, $Diabetes$ and $Hypertension$, which, respectively, equal 1 if the answers are "yes, diabetes" or "yes, high blood pressure." The variable $Diabetes$ has a mean equal to 0.021 and a standard deviation equal to 0.143; the mean (standard deviation) for $Hypertension$

[18] For every variable we construct from this survey, our criterion is to consider missing values those cases in which the respondent choose the option "Do not know/No answer."

is 0.033 (0.179). The 2011 and 2013 waves include a question about the nutritional state of the individual (s10 in 2011 and s8 in 2013). They are asked to assess their nutritional condition and the possible answers are (1) Underweight, (2) Normal, (3) Overweight, (4) Obese, and (9) Do not know. We build two dummy variables, one for answer (1), which we call $Underweight$, and the other for answer (2), called $Normalweight$. Overweight and Obese are our omitted categories in the regressions.

Questions s17 in 2011, s14 in 2013, and s12 in 2015 ask about whether the individual has health insurance coverage. Possible answers include any variant of the public health insurance system (called FONASA), the system of the Chilean Force Army, the private health insurance system (called ISAPRE), and another system or do not have health insurance coverage (Do not know/No Answer is also a possible answer). $Public\_Insurance$ is a dummy variable that equals 1 if the individual has public health insurance coverage or the system corresponding to the Chilean Force Army, and $Private\_Insurance$ is a dummy variable that equals 1 when the individual chooses the private option.

We focus on two aspects of the use antenatal care: healthcare facilities and supplementary nutritional assistance. Questions s11 in 2011, s9 in 2013, and s7 in 2015 ask, "In the past three months, did you have access to supplementary assistance at the health care center?" The possible answers are (1) yes, milk for babies younger than 18 months, (2) yes, milk for pregnant women, (3) yes, both type of milk, (4) No, and (9) Do not know/No answer. The dummy variable SNA equals 1 when the answers are less than or equal to (3). Individuals are also asked about the number of health care visits and the number of X-rays or sonograms (in questions s32a and s31a in 2011, s29a and s28a in 2013, and s26a and s25a in 2015). For the number of health-care visits, the possible answer ranges between 0 and 46, and for sonograms, between 0 and 40. In both cases, the option "Do not know/No answer" is allowed. We construct two dummy variables: one for health-care visits, called $HC - visit$, that equals 1 if the number of visits is greater than 0; and the other, called $Sonogram$, that equals 1 if the number of sonograms is ≥ 1.

Appendix B

Exposure to earthquakes and fetal deaths		
	Fetal Deaths	Log (Fetal Deaths + 1)
	(1)	(2)
EQ_I	0.080	0.048**
(s.e.)	(0.053)	(0.020)
EQ_II	0.007	-0.007
(s.e.)	(0.047)	(0.018)
EQ_III	0.022	-0.001
(s.e.)	(0.058)	(0.026)
Num. of obs. (month-year-*comuna* cells)	19217	19217
Num. of clusters	346	346

Table 10: Each column is a regression that corresponds to the number of fetal growth (column 1) or to log of (fetal growth +1), in Column 2. All regressions include *comuna* (interacted with) year and month fixed effects. Standard errors (reported in parentheses) are clustered at the level of *comuna*. Significance level at (***) 1%, (**) 5%, and (*) 10%.

	Panel of Mothers - IV-Mother-Fixed-Effect Model for Cutoff MMS=V						
	Birth Weight	Gestational Age	LBW	Pre-term birth	SGA	AGA	LGA
EQ^{1}	8.086	-0.010	-0.001	0.003	-0.002*	0.002	0.000
(s.e.)	(7.022)	(0.025)	(0.003)	(0.004)	(0.001)	(0.004)	(0.004)
EQ^{2}	7.979	-0.048*	0.001	0.011***	0.000	-0.012***	0.012***
(s.e.)	(7.488)	(0.027)	(0.004)	(0.004)	(0.001)	(0.004)	(0.004)
EQ^{3}	-0.796	-0.035	-0.003	0.006	-0.001	-0.001	0.002
(s.e.)	(7.199)	(0.025)	(0.004)	(0.004)	(0.001)	(0.004)	(0.004)
$EQ^{1\&2}$	-20.923	-0.041	0.014	0.010	0.001	-0.018	0.017
(s.e.)	(18.106)	(0.062)	(0.009)	(0.010)	(0.004)	(0.012)	(0.011)
$EQ^{2\&3}$	-17.100	0.011	0.003	0.008	0.001	-0.012	0.011
(s.e.)	(18.448)	(0.061)	(0.009)	(0.010)	(0.004)	(0.012)	(0.011)
$EQ^{1\&3}$	-20.006	0.058	-0.004	-0.009	0.002	0.009	-0.011
(s.e.)	(22.855)	(0.072)	(0.010)	(0.011)	(0.004)	(0.015)	(0.014)
$EQ^{1\&2\&3}$	40.200	0.200	-0.006	-0.012	-0.003	-0.022	0.025
(s.e.)	(54.076)	(0.172)	(0.018)	(0.030)	(0.006)	(0.028)	(0.027)
Number of observations	205205	205205	205205	205205	205193	205193	205193
Number of clusters	101010	101010	101010	101010	101004	101004	101004

Table 11: Relationship between prenatal stress and birth outcomes under cutoff V of MMS. Each column is a regression that corresponds to a birth outcome. All regressions control for mothers' and fathers' sociodemographic characteristics. Standard errors (reported in parentheses) are clustered at the level of mothers. All regressions include *comuna* (interacted with) birth-year and birth-month fixed effects. Significance level at (***) 1%, (**) 5%, and (*) 10%.
In all cases, we cannot reject the null hypothesis that the instruments are valid instruments (Sargan-Hansen test) and we reject the null hypothesis of both underidentification (with p-value = 0.000, LM version of Kleibergen-Paap's *rk*-statistic) and weak-identification (Kleibergen-Paap Wald *rk* F-statistic$> 12.2e+04$)

	Panel of Mothers - IV-Mother-Fixed-Effect Full Term Gestation and Maternal Mobility Model						
	Birth Weight	Gestational Age	LBW	Pre-term birth	SGA	AGA	LGA
EQ^1	-5.260	-0.023	0.007	0.008	-0.001	-0.004	0.005
(s.e.)	(9.864)	(0.034)	(0.005)	(0.005)	(0.002)	(0.006)	(0.006)
EQ^2	5.882	-0.048	0.007	0.011*	0.001	-0.021***	0.020***
(s.e.)	(10.245)	(0.036)	(0.005)	(0.006)	(0.002)	(0.006)	(0.006)
EQ^3	-6.973	-0.050	0.003	0.006	-0.000	-0.007	0.007
(s.e.)	(10.432)	(0.037)	(0.005)	(0.006)	(0.002)	(0.006)	(0.006)
$EQ^{1\&2}$	-5.295	0.108	-0.009	-0.004	0.003	-0.039**	0.036*
(s.e.)	(32.796)	(0.114)	(0.016)	(0.020)	(0.005)	(0.020)	(0.019)
$EQ^{2\&3}$	-69.480**	-0.053	0.016	0.005	0.003	-0.023	0.019
(s.e.)	(32.529)	(0.115)	(0.016)	(0.019)	(0.006)	(0.020)	(0.019)
Number of observations	205203	205203	205203	205203	205191	205191	205191
Number of clusters	101009	101009	101009	101009	101003	101003	101003

Table 12: Relationship between prenatal stress and birth outcomes under full-term gestation exposure and first *comuna* of residence instrument. Each column is a regression that corresponds to a birth outcome. All regressions control for mothers' and fathers' sociodemographic characteristics. Standard errors (reported in parentheses) are clustered at the level of mothers. All regressions include *comuna* (interacted with) birth-year and birth-month fixed effects. Significance level at (***) 1%, (**) 5%, and (*) 10%.
In all cases, we cannot reject the null hypothesis that the instruments are valid (Sargan-Hansen test) and we reject the null hypothesis of both underidentification (with p-value = 0.000, LM version of Kleibergen-Paap's *rk*-statistic) and weak-identification (Kleibergen-Paap Wald *rk* F-statistic$>$ 7033)

	Placebo Test						
	Birth Weight	Gestational Age	LBW	Pre-term birth	SGA	AGA	LGA
$\bar{\hat{\beta}}_{EQ^1}$	-0.197	0.001	0.000	0.000	0.000	0.000	0.000
(s.d.)	(7.785)	(0.028)	(0.004)	(0.004)	(0.001)	(0.005)	(0.004)
$\bar{\hat{\beta}}_{EQ^2}$	0.212	0.000	0.000	0.000	0.000	0.000	0.000
(s.d.)	(8.193)	(0.029)	(0.004)	(0.004)	(0.001)	(0.005)	(0.005)
$\bar{\hat{\beta}}_{EQ^3}$	0.388	0.002	0.000	0.000	0.000	0.000	0.000
(s.d.)	(7.137)	(0.025)	(0.004)	(0.004)	(0.001)	(0.004)	(0.004)
$\bar{\hat{\beta}}_{EQ^{1\&2}}$	-0.465	0.000	0.000	0.000	0.000	0.001	-0.001
(s.d.)	(35.054)	(0.12)	(0.017)	(0.020)	(0.006)	(0.020)	(0.019)
$\bar{\hat{\beta}}_{EQ^{2\&3}}$	-0.919	0.003	0.001	0.000	0.000	0.000	0.000
(s.d.)	(32.142)	(0.108)	(0.015)	(0.018)	(0.005)	(0.019)	(0.018)

Table 13: Placebo test: random assignment of $EQ^g = 1$, with $g = \{1, 2, 3, 1\&2, 2\&3\}$, on Chilean mothers. For each measure of birth outcome, we estimate (600 times) an OLS-mother-fixed-effect model, where we include the "fake" measures of exposure to an earthquake. All regressions include mothers' and fathers' sociodemographic characteristics as well as *comuna*, birth-year, and birth-month fixed effects. *Comuna* and birth-year fixed effects are interacted with each other. Each column corresponds to a birth outcome, and each row reports the average value of the estimated coefficients along the exercise; standard deviations are in parentheses. Significance level at (***) 1%, (**) 5%, and (*) 10%.

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