I Z A Institute
of Labor Economics
Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11452

Maternal Stress during Pregnancy and Early Childhood Development

Matias Berthelon
Diana Kruger
Rafael Sanchez

APRIL 2018

I Z A Institute
of Labor Economics

Initiated by Deutsche Post Foundation

DISCUSSION PAPER SERIES

IZA DP No. 11452

Maternal Stress during Pregnancy and Early Childhood Development

Matias Berthelon
Universidad Adolfo Ibañez

Diana Kruger
Universidad Adolfo Ibañez and IZA

Rafael Sanchez
Universidad Adolfo Ibañez

APRIL 2018

IZA – Institute of Labor Economics

Schaumburg-Lippe-Straße 5–9
53113 Bonn, Germany

Phone: +49-228-3894-0
Email: publications@iza.org

www.iza.org

ABSTRACT

Maternal Stress during Pregnancy and Early Childhood Development[1]

There is a consensus in the literature on the relevance of the first 1,000 days since conception in the development of a child's cognitive and non-cognitive skills. However, little is known of the determinants of these skills at that age, as previous literature has focused on the effect of in utero and early childhood shocks on outcomes at birth or at age 7 and beyond. In this paper, we analyze the impact of prenatal stress on cognitive and non-cognitive development of the child by age 2. By exploiting a longitudinal dataset of children and their parents, we find that children who were exposed in-utero to maternal stress do not have different birth-weight relative to those who were not exposed, yet by age 2, exposed children had a lower level of development, cognition skills, and more attention problems relative to children not exposed to in utero stress. We also find that the negative impacts are observed if in-utero stress occurs during the first trimester of pregnancy. The negative impact on cognitive skills and development is concentrated on lower-income children and attention problems occur among high-income children, and boys suffer lower development and worse attention problems, while girls' cognition is negatively affected by in-utero stress.

JEL Classification: I10, I19, J13

Keywords: in-utero, stress, early childhood development, maternal stress, maternal mental health, earthquake, Chile

Corresponding author:
Diana Kruger
Adolfo Ibañez Business School
Universidad Adolfo Ibañez
Avenida Padre Hurtado 750
Viña del Mar
Chile

E-mail: diana.kruger@uai.cl

[1] We thank Camila Carrasco and Rocio Valdebenito for outstanding research assistance, and seminar participants at Adolfo Ibañez University and Oregon State University. We thank Prashant Bharadwaj, Juan Eberhard and Todd Pugatch for helpful comments; all errors and omissions are our own.

1. Introduction

There is now consensus that cognitive and non-cognitive skills developed in early childhood have a significant impact on future adult outcomes (see Almond and Currie 2017 for a recent survey). Heckman and coauthors have provided a theoretical framework to understand skill formation and its dynamics (Heckman 2006, Heckman 2007, Heckman and Masterov 2007, Heckman et al. 2010, among others). Two relevant characteristics of these models are dynamic complementarities and self-productivity. The former means that previously acquired capabilities may make current investments more productive, while the latter means that a given dimension of capacity may also affect the accumulation of another distinct dimension (i.e. cognitive capacity might promote health or vice versa). Since early childhood is a critical period in the formation of these skills, parents, educators and policy makers should be attentive to negative shocks during early ages in life, including the *in utero* period.[2]

Identification of causal effects of in utero conditions on future outcomes is challenging because children's family background may be correlated with in utero conditions as well with children's human capital investments and outcomes. Economists have complemented the traditional epidemiological literature by improving the causal identification strategies, often appealing to different types of exogenous shocks during pregnancy to identify causal effects of in-utero conditions on child's physical health at birth, as well as on later human capital outcomes. In general, these studies find that in-utero exposure to events that directly affect the mother's physical health—such as infections, disease, malnutrition, and negative income shocks—leads to lower birthweight, worse future health of the child, lower educational attainment, worse educational achievement (test scores and grades), and worse labor market outcomes in adulthood (e.g. Almond et al. 2015, Hoynes et al. 2016, Lavy et al. 2016, Banerjee et al 2010, Currie and Rossin-Slater 2013, Torche 2011, Field at al. 2009).

Economists have also studied whether mothers' mental health during pregnancy affects the child's physical health and educational outcomes. This is a relevant question because some mental conditions are prevalent in everyday life and affect a large proportion of the population. For example, 27% of the adult population in the European Union had experienced at least one mental disorder in the past year,[3] and in the United States, an estimated 44 million adults aged 18 or older suffer from a mental illness (representing 18.1% of all U.S. adults in 2013).[4] Research has found that exogenous variations in the mother's level of stress during pregnancy, brought about by events such as exposure to terrorism and military conflicts, or to natural phenomena such as hurricanes or

[2] These conclusions are in line with what the "fetal origin hypothesis" suggests. It was developed by Barker (1992) and suggests that the in-utero period of development is critical in shaping future cognitive and non-cognitive skills, health trajectories and economic outcomes.

[3] World Health Organization (WHO): http://www.euro.who.int/en/health-topics/noncommunicable-diseases/mental-health/data-and-statistics

[4] National Institute of Mental Health (IMH): https://www.nimh.nih.gov/health/statistics/prevalence/any-mental-illness-ami-among-us-adults.shtml

earthquakes, have negative consequences for child's birthweight, cognition, physical health and schooling outcomes.[5]

Partly due to data limitations, this large and growing literature has focused on the effect of pre-natal shocks on children's outcomes at birth, and then at ages seven or later (Breining et al. 2015, Akee et al. 2015, Bharadwaj et al. 2017, Baker and Milligan 2016 among many others). Much less is known about the impact on early childhood development outcomes between birth and age 6, known as middle years or intermediate outcomes in the literature (Almond and Currie 2017). In utero shocks may affect early development of cognitive and/or non-cognitive outcomes during the first two years of life, which may have a direct effect on future wages—a channel that it is different than affecting early health, which in turn affects wages. Identifying the effects on intermediate outcomes could help identify individuals in need of assistance more quickly and to target interventions more effectively.

In this paper, we contribute to this gap in the literature and analyze whether in-utero stress exposure affects a child's early development—by age 2—thereby contributing to our understanding of the impact of in-utero stress experiences on a child's early cognitive and non-cognitive abilities, and emotional well-being. As discussed above, early childhood skills are important determinants of future outcomes, and early interventions to remediate deficiencies are more cost-effective than policy interventions at later ages; furthermore, early interventions might also contribute to alleviate inequalities (Cunha and Heckman 2009).

Our setting is mothers' in-utero exposure to stress brought about by a strong earthquake in Chile, and we study whether it affected children's early cognitive and non-cognitive (socio-emotional) skills by about age 2. The stress-inducing event was the fifth strongest in recorded history, which shook most of Chile's population on February 27, 2010 (henceforth, 27-F). Our data comes from Chile's *Longitudinal Early Childhood Survey* (ELPI), which includes results from several child development tests (Batelle Developmental Inventory, Child Behavior Checklist, and TADI)[6] taken up to 30 months after the earthquake, as well as a rich set of family background variables, including family member's health, behaviors, and socioeconomic conditions before, during and after pregnancy.

It is worth mentioning that the identification strategies in most papers that analyze stressful events during the in-utero period implicitly assume that (i) all women exposed to a stressful event suffer from stress, (ii) that all women exposed to the event suffer the same level of stress, (iii) that women sufficiently removed from the event experience no stress, and (iv) in the case of natural phenomena or conflicts, that women do not migrate after a stressful event (Currie and Rossin-Slater 2013). Similar to previous studies, we can identify mothers' exposure to the earthquake through their municipality of residence (which can be matched to geophysical measures of earthquake intensity). However, as discussed above,

[5] Lipkind et al. 2010, Eccleston 2011, Eskenazy et al. 2007, Camacho 2008, Mansour and Rees 2011, Currie and Rossin-Slater 2013, Torche 2011 and Aizer et al. 2016, Rosin-Slater 2016.

[6] TADI is the Spanish acronym for Childhood Learning and Development Test, a childhood development test designed in Chile.

exposure doesn't account for the heterogeneous effects of the event on each individual mother.

Our data allows us to construct an individual, self-reported measure of earthquake-induced stress, so that we can estimate more precisely whether in-utero stress impacts child development approximately two years after birth. In our paper, therefore, we improve on previous estimates because we do not rely on the assumptions listed above. To the best of our knowledge, ours is the first study to measure shock-induced stress directly, and thereby account for individual heterogeneity in susceptibility to stress.

We find that stress suffered from the 27-F earthquake during pregnancy has a negative impact on a child's early childhood development. Specifically, we find that children whose mothers suffered in-utero stress from the 27-F earthquake had lower cognitive and socio-emotional outcomes relative to children who were conceived up to one year after the event. We explored heterogeneous effects by trimester of pregnancy on 27-F, sex of the child, and household income. We find that the negative impacts on cognitive outcomes mostly occur during the first trimester of pregnancy, whereas the effects on socio-emotional outcomes occur during the second and third trimesters. Girls' cognition is negatively affected by in-utero stress relative to boys; however, boys suffer negative impacts in overall development and some socio-emotional outcomes compared to girls. Finally, we find that the negative impacts of in-utero stress are concentrated among children of lower-income households.

We perform several verification exercises as to the plausibility that the self-reported stress was due to the 27-F earthquake and not to indirect impacts or behavioral responses to 27-F, with two approaches. First, we use a national, post-earthquake household survey to analyze whether the 27-F quake had economic impacts affecting individuals' income or employment, migration decisions, and/or housing or infrastructure, which could potentially also affect the child's future outcomes; we find that despite its magnitude, the earthquake did not significantly impact individual's employment, income or residence. Additionally, we analyze whether the impact of in-utero stress was correlated to mothers' behavioral responses to stress—such as drinking, smoking, and others—which could also impact early child development,[7] and find that these behaviors did not respond to the earthquake, and that the behavioral responses are not correlated with the effect of maternal stress on children's outcomes.

This paper has several contributions to the existing literature on in-utero transmissions of health shocks, as highlighted by Almond and Currie (2017). First, ours is among the first to analyze the impact of in-utero stress on the first 2 years of a child's life, a relevant period for the formation of cognitive and non-cognitive skills, and for which we know little regarding stress exposure effects. In this way, our paper provides evidence of whether—and which specific—cognitive and non-cognitive skills are sensitive to episodes of in-utero

[7] We analyze the impact of behavioral responses to the earthquake using ELPI data, and we analyze the economic impacts of the earthquake using a special, Post-Earthquake wave of Chile's CASEN Household Surveys (http://observatorio.ministeriodesarrollosocial.gob.cl/casen/casen_obj.php).

stress, which in turn has important implications for youth and adult health and economic outcomes.

Second, we directly measure the stress that results from a natural disaster, rather than exposure to the event, which allows us to account for the heterogeneous impact that natural disasters have on individuals. Third, we are able to analyze precise measures of cognitive and non-cognitive skills, as evidenced by several psychological test instruments. Fourth, we are able to discern whether the impact of earthquake-induced stress is due to the in-utero stress resulting from the event, and not to mothers' behavioral responses to the event. Fifth, our results suggest that birthweight is a limited proxy for a child's health, since in our study, in-utero shocks that affect maternal mental health do not affect birthweight, but they do affect child development at age 2.[8] Finally, since we find negative effects of stress suffered during the first two trimesters, our findings suggest that policy interventions focalized on pregnant women should pay special attention to early stages of pregnancy. Earthquakes are very common in the Pacific Rim, affecting millions of people, our findings are relevant to policy makers in such countries, because since we analyze the impact of a recurrent, frequent shock on children's cognitive and non-cognitive skills.

Our paper is organized as follows: section 2 discusses in-utero health shocks and early child development; section 3 describes our data, including a description of the 27-F earthquake. In Section 4 we our empirical methodology, followed by a section describing our results. In Section 6 we include concluding comments, implications for policy and suggestions for future research.

2. In-utero Health and Childhood Development

2.1. In-utero physical health shocks and future outcomes

There have been many studies of the effect of in utero shocks on children's development in the epidemiological literature, but in general these studies report correlations, are estimated from small samples that lack important control variables, among other caveats (see for example Cosmi et al. 1990, Barker 1995, Wadhwa 1996, O'Connor et al. 2005, Abel et al 2014).

Recent studies in economics contribute to the causal identification of effects of in utero conditions on later life outcomes by exploiting exogenous and random shocks affecting pregnant mothers. There is a strand of the literature that focuses on the effect of infections; for example studies find that prenatal exposure to an influenza pandemic led to lower high school graduation and wages later in life in the U.S., while exposure to the Asian flu in Great Britain led to lower academic achievement measured by test scores (Almond, 2006; Kelly, 2009). Interestingly, while birth weight was reduced by prenatal flu exposure, the effect appears to be independent of later test score effects. Maternal malnutrition due to the 1959-1961 Chinese famine was associated with higher illiteracy, as well as worse labor market and marriage outcomes Almond et al. (2007), whilst a cohort of Swedish children

[8] This finding is consistent with the medical study in Palmeiro-Silva et al. (2018).

who were exposed in-utero to the 1986 Chernobyl accident radiation performed substantially worse in school, though there was no future health damage Almond et al (2009).

Others have focused on the effects of nutritional changes during pregnancy and later outcomes; for example Field at al. (2009) found that prenatal iodine supplementation raised educational attainment in Tanzania by half a year of schooling, with larger impacts for girls. Almond et al. (2015) use the month-long Ramadan fast as a natural experiment to examine whether Ramadan's overlap with pregnancy affects subsequent academic outcomes at age 7; they found that test scores are 0.05-0.08 standard deviations lower for students exposed to Ramadan in early pregnancy. Hoynes et al. (2016) innovate and examine the impact of the introduction of the Food Stamp Program in the U.S., which increased economic resources available in-utero and during childhood, finding that the Food Stamp program has beneficial effects on children decades after initial exposure through the reduction in the incidence of "metabolic syndrome" [obesity, high blood pressure, and diabetes], and higher economic self-sufficiency among women. In a related line of research, Lavy et al. (2016) use quasi-experimental variation created by the immigration of Ethiopian Jews to Israel in May 1991, exploiting the fact that children in-utero faced dramatic differences in medical care technologies, prenatal conditions, and prenatal care prior to immigration from Ethiopia to Israel. One of the major differences was adequacy of micronutrient supplements, particularly iodine, iron and folic acid. They found that children exposed to better environmental conditions in utero at earlier stages of pregnancy have higher educational attainment (lower repetition and dropout rates and higher Baccalaureate rate) and higher education quality (achieve a higher proficiency level in their Baccalaureate diploma) two decades later.

A third strand of the literature has focused on the effect of income shocks during pregnancy, for example, Banerjee et al (2010) study the XIX century blight to French vineyards from the phylloxera insect, which decreased wine production and income, and found a negative effect on affected children's height (0.5-0.9 centimeters shorter in adulthood).

Common to these studies is the use of exogenous environmental or policy driven in-utero shocks to study short term health outcomes (such as birthweight, mortality and gestational length) or long run outcomes such as educational attainment, graduation rates, wages, marriage outcomes, and height, among others.

2.2. Pre-natal Maternal Stress and future outcomes

A large medical literature has studied the inter-generational effect of pregnant mothers' PTSD on fetal health. Maternal stress can affect fetal development through various channels: first, through the exposure of the fetus to stress hormones that are transported through the placenta, which are in turn related to premature delivery and which can also compromise fetal development and function (Stott, 1973; Myers, 1975; Lockwood, 1999). Additionally, stress may suppress the developing immune system, which could account for the higher incidence of respiratory and other infections in the infants. And finally, mothers' behavior may change in response to stressful events, specifically,

stress may induce high-risk behaviors such as drinking alcohol, smoking, poor diet, etc., and these behaviors may affect fetal development and health (Dunkel-Schetter, 2009).

The economics literature has analyzed the impact of exogenous shocks to mother's in-utero mental health on children's future outcomes, typically focusing on in-utero stress episodes. Different methodologies have been applied to establish a causal effect of stress on future child's outcomes. One identification strategy is to infer causality by exploiting geographic exposure to stressful episodes. Examples include the September 11 terrorist attacks (Lipkind et al. 2010, Eccleston 2011, Eskenazy et al. 2007), landmine explosions in Colombia (Camacho 2008), political conflict in the West Bank and Gaza (Mansour and Reeds 2011) and Korea Lee (2014); terrorist attacks in Spain (Quintana-Domeneque and Rodenas-Serrano 2016); and an earthquake in Northern Chile (Torche 2011). These studies identify effects by exploiting exposure to stress—i.e., they compare women living or working in the area affected by a stressful event under the assumption that women further away experienced less stress. As Currie and Rossin-Slater (2013) point out, however, the population of women may change in an affected area following disasters; maternal characteristics and birth outcomes may differ significantly by month of birth (Buckles and Hungerman 2008); stressful events may also affect women living outside the affected area, if they fear that the event can occur were they live (as in terrorist attacks, hurricanes or earthquakes). Furthermore, these studies usually count exposure backwards from the date of birth rather than forwards from the date of conception and such a procedure could bias the estimated relationship between exposure to the stressful event, gestation and other outcomes that depend on gestational length.

Other methodologies include sibling fixed effects to identify impacts of in-utero stress exposure. For example, Aizer et al. (2016) finds that in-utero stress exposure has little effect on birth weight but has a significant, negative impact on school attainment and verbal IQ scores, and exposed children are more likely to have a chronic health condition at age 7. Currie and Rossin-Slater (2013) found that exposure to hurricanes during pregnancy increases the probability of abnormal conditions of the newborn, but they found no effects on the incidence of low birth weight or gestation length.

A final approach uses random dates of conception/pregnancy at the moment a stressful event occurs to identify effects. Recently, Persson and Rossin-Slater (2016) studies the effect of in-utero exposure to maternal stress from family ruptures (deaths) on children's birth weight and future outcomes, finding that pre-natal exposure to the death of a maternal relative increases take-up of Attention Deficit Hyperactivity Disorder (ADHD) medications during childhood and anti-anxiety and depression medications in adulthood; lowers birth weight; and raises the risk of perinatal complications that require hospitalization.

To the best of our knowledge, none of the studies discussed above has analyzed the impact of in-utero maternal mental health on early childhood development between ages 0-5 years. Our results contribute to fill this gap in what we currently know about maternal stress effects on children.

3. Data

Our main source of data is the Early Childhood Longitudinal Survey (ELPI, for its Spanish acronym) carried out in Chile in 2010 and 2012.[9] ELPI is a longitudinal survey designed to be representative of the population of children from 6 months to 7 years at the country level. The survey collects information on several socio-economic dimensions of the child, her parents, and the household. It also collects information on children´s development by applying several developmental tests to the child, as well as tests to measure cognitive and non-cognitive skills of the main caretaker (overwhelmingly mothers; henceforth we refer to them interchangeably).

ELPI's 2012 wave included a complementary sample that collected information from children born between September 1st 2009 and December 31st 2011, who were not part of the first wave.[10] Thus, the complementary sample includes children that were in-utero on the date of the earthquake, as well as children that were conceived after 27-F.

We construct our final sample from the second wave of the ELPI survey and include only children who were in-utero on 27-F and children who were conceived after the earthquake. When the test instruments were applied in 2012, children in our sample are aged between 7 to 36 months.

Figure 1. ELPI Timeline

3.1. Children's cognitive and non-cognitive outcomes

The tests that were applied to measure child development were the Battelle Developmental Inventory (BDI); the Childhood Learning and Development Test (TADI for its Spanish acronym);[11] and the Child Behavior Checklist (CBCL). The BDI screens and evaluates early childhood developmental milestones.[12] It assessed 100 items grouped in five areas: personal-social, adaptive, motor, communication, and cognitive; only the average score for the BDI is included in the data. TADI is an instrument designed in Chile to measure learning in four dimensions: cognition, motor, language, and socioemotional skills (similar to the BDI). Each of these dimensions generates a separate measurement that is reported, along

[9] The Spanish name of the survey is Encuesta Longitudinal de Primera Infancia (ELPI).
[10] ELPI's wave 1 collected information on children born before the earthquake. They were also followed up in wave 2.
[11] Test de Aprendizaje de Desarrollo Infantil.
[12] Screening Test, 2nd ed. (BDI-ST2) (Newborg, Stock y Wnek 1996).

with an aggregate measure that includes the average of all dimensions. Its administration combines observation, application and self-reporting from the main caretaker.

The CBCL assesses behavior and socio-emotional competencies of the child as reported by the parents, and can be used to identify problematic areas in child development (Achenbach and Rescorla 2000). The CBCL test asked the main caretaker to respond about 99 behaviors of the child, and then grouped them seven clinical syndromes included in the Diagnostic and Statistical Manual of the American Psychiatric Association, DSM IV (American Psychiatric Association 1994). The test also includes aggregate measures for the total test, as well as three categories: internalization, externalization and sleep problems. The *internalization* category includes syndromes that involve only the child, in: emotional reactivity, anxiety/depression, somatic complaints, and autism. The *externalization* category includes problems involving conflicts with other people and the expectations about the child; it includes attention problems and aggressive behavior. The *sleep problems* syndrome stands alone.

The data reports age-adjusted T-scores for the Battelle, TADI and CBCL total, internalization and externalization aggregates; to facilitate interpretation, we standardized the T-scores to have a mean of zero and standard deviation equal to 1.[13] The ELPI data did not report T-scores for each of the CBCL syndromes; it reported the percentile of each child in the distribution. In the case of the BDI and TADI scores, a larger value indicates higher developmental levels, whereas higher values in the CBCL test indicate greater socio-emotional difficulties. The Battelle and TADI test were applied to children aged 7 to 36 months old, and the CBCL test was applied to children aged between 18 and 36 months.

Table 1 reports descriptive statistics of the test for our final sample of children, for earthquake and non-earthquake regions (see discussion below regarding the definition of earthquake and non-earthquake regions); an asterisk indicates whether variables are statistically different across regions. We can observe that in general, children in areas that were affected by the 27-F earthquake had similar performance in the tests, relative to children in areas that were not.

3.2. Earthquakes and Maternal Stress

The earthquake in our setting occurred on February 27th, 2010. With a magnitude of 8.8 on the Richter scale, it shocked the valleys and coastal regions of central Chile (where about 80 percent of the country's population live) for more than three minutes, and it was the fifth largest earthquake ever recorded by a seismograph. Appendix 1 reports information regarding observed intensities by Astroza et al. (2010) and also reports estimated average intensities at municipal level for the six regions most affected by the earthquake, which we classify as earthquake regions.[14]

[13] ELPI reports T-scores distributed with mean equal to 50 and standard deviation equal to 10.

[14] We follow Astroza et al. (2010) and classified as earthquake regions those reported in Figure A1.1. At the time of the earthquake Chile was divided in 15 administrative regions. Earthquake regions include the V (Valparaíso), VI (O'higgins), VII (Maule), VIII (Bío-Bío), IX (Araucanía) and XIII (Metropolitana) regions. We

Aftershocks continued for several weeks after the main event; during the 27th and 28th of February, there were 214 aftershocks of magnitude 5.0 or more in the Richter scale (including one aftershock of 7.4 magnitude); during the month of March, 187 aftershocks above 5.0 were registered, including a 7.0 earthquake. By April and May, the number of large aftershocks had significantly decreased to 25 and 15, respectively (see Table A1.2 in Appendix 1). The earthquake and its immediate, strong aftershocks, therefore, had the potential of generating high levels of stress, anxiety, panic or other mental health problems of varying degrees in a large part of the population, even in parts of the country that were not directly affected by it.[15]

An important body of research has studied the consequences of natural disasters (including earthquakes) on individuals' health, and in particular, on mental health (Carr et al. 1997; Galea et al. 2005; Najarian et al. 2001, among others). The evidence concludes that the main effects of large earthquakes on mental health are related to post traumatic stress disorders (PTSD).[16] Typically, individuals with PTSD may re-experience the event via intrusive memories, flashbacks and nightmares, avoid anything that reminds them of the trauma, and have anxious feelings they did not have before that are so intense their lives are disrupted. The symptoms last more than six months and cause significant impairment in social, occupational, or other important areas of functioning (Bhalotra et al 2012). Regarding the persistence of the effects, previous psychological and psychiatric evidence finds that general distress levels following an earthquake return to normal after about 12 months, but post-traumatic stress reactions do not fade until 18 months after the earthquake (Karanci and Rustemli 1995; Shinfuku 1999). The prevalence of PTSD varies widely in earthquake survivors due to different exposures and proximity to the epicenter of the earthquake (Luo et al. 2012; Fukuda 2000; Glynn et al. 2001).

Due to its magnitude, several surveys in Chile—including ELPI's second wave—included questions related to the earthquake and its effects. The question most relevant to this study asked the main caretaker (i.e., mothers) whether they suffered a series of symptoms that she could attribute to the earthquake. The symptoms were: insomnia (difficulty in falling sleep or early waking up); stress, anguish or anxiety; crying or emotional instability; fear or panic; traumatic memories of the earthquake; and other effects.[17] With this information,

report intensities using a modified Mercalli scale as it is most relevant to our analysis because this scale measures the degree of housing damage in an area. The Richter scale measures the energy liberated by the earthquake at the epicenter. See the details of the Mercalli scale in Table A1.1 in the appendix. Average intensities at municipal level were estimated by computing the mean of all available observations in each municipality. For municipalities without direct observations we assigned the mean of all neighboring municipalities with available data.

[15] For instance, people in non-earthquake regions could increase their stress levels if they had relatives in areas affected by the earthquake, or by watching news or getting information about its consequences in other areas of the country.

[16] According to the American Psychological Association, PTSD is an anxiety problem that develops in some people after extremely traumatic events, such as natural disasters, accidents, wars, among others.

[17] Although it was not designed to screen for PTSD, the ELPI survey question contains some of the symptoms of post-traumatic stress disorder as defined by the American Psychiatric Association's Diagnostic and Statistical Manual of Mental Disorders (DSM-V).

we created a variable indicating maternal stress if a mother reported any of the five symptoms described above.[18]

Approximately 36 percent of mothers experienced at least one of the symptoms of stress as a result of 27-F (Table 1), with significant differences across earthquake regions: 16 percent of mothers in non-earthquake regions experienced stress, compared to 42 in earthquake regions. In Table 2 we report the incidence of the specific stress-related symptoms across regions, and we observe (statistically) significant differences across groups for each of the five symptoms. Stress symptoms are more than 4 times more likely in earthquake regions, and traumatic memories are at least 12 times more likely. Interestingly, a significant fraction of women report suffering symptoms in regions that were not directly affected by the 27-F earthquake. Therefore, in our estimations we will not restrict our sample to mothers in earthquake regions, but will instead include mothers from the whole country.[19]

4. Methodology

Our aim is to estimate the effect of maternal stress during pregnancy on children's cognitive and socio-emotional outcomes. We propose a reduced-form model in which maternal stress can affect child development. We take advantage of the exogenous shock on mothers' stress induced by the 27-F earthquake, and the plausibly random timing of women's pregnancies around the earthquake period.[20] This allows us to estimate the in-utero effects of stress by comparing children that were exposed to the stress in-utero, with children whose mother suffered stress but who were conceived after the earthquake, so that they were only affected by potential changes in mothers' behavior.

The reduced form model that we estimate for early developmental outcomes is the following:

$$y_i = \alpha_1(Stress_i = 1) + \alpha_2(IU_i = 1) + \alpha_3(Stress_i = 1) \times (IU_i = 1) + M_i\delta + C_i\beta + H_i\theta + u_i \quad (1)$$

where y_i is the outcome of child i (measured in 2012), $Stress_i$ is a binary variable indicating whether the mother reports any stress symptoms due to the earthquake, as previously described. IU_i is a binary variable that is equal to 1 if the child was in-utero during the earthquake. As it was previously discussed, the earthquake was followed by a period of frequent and strong aftershocks, so instead of a single date, we define an earthquake

[18] We did not consider the response "Other symptoms" because it did not allow us to identify stress precisely.

[19] Estimates that include children living exclusively in earthquake regions are similar to the ones reported in this paper. Results are available from the authors upon request.

[20] Additionally, the incidence of pregnancy on 27-F was the same in regions affected and not affected by the earthquake (Table 1).

episode beginning on the 27th of February and ending the last week of March, which is the period with the greatest concentration of high-intensity earthquakes.[21]

The interaction between maternal stress and being in-utero during the earthquake allows us to estimate the differential effect of maternal stress on child development due to in-utero stress exposure. Our parameter of interest is α_3 which is interpreted as the in utero effect on child development due to maternal stress (induced by the earthquake episode). In turn, α_1 is the effect of maternal stress on children that were conceived after the last week of March, 2010.

We also control for mother $(\mathrm{M_i})$, child $(\mathrm{C_i})$, and household characteristics $(\mathrm{H_i})$. Mothers' characteristics include age and age squared, years of schooling, and cognitive and socio-emotional development of the mother measured by results for the Wechsler Adults Intelligence Scale (WAIS) test (numeracy and vocabulary), and the Big Five Inventory (BFI) test in its five categories: extraversion, agreeableness, responsibility, neuroticism, and openness to experiences. Child control variables include the child's sex, child's birth order, age (in months), and number of siblings. Household characteristics include household income per capita, whether the father lives in household, and binary variables indicating prior mental health issues of the mother, father, or other relatives. Finally, we also incorporate a series of regional dummy variables to control for systematic differences across the fifteen administrative regions of the country.

The identifying assumptions of our reduced-form model are that the date and location of the earthquake are uncorrelated with child development, and uncorrelated with the timing of pregnancies. First, earthquakes are still not predictable events, thus it is unlikely that pregnancy timings would have been affected by the likelihood of the earthquake. Second, Chile is among the countries with greatest seismic activity in the world, and the whole country is located on an active subduction fault off the coast and therefore potentially subject to large earthquakes. Therefore, it is not possible for people to self-select into non-earthquake areas. Thus, the timing and location of the earthquake can be reasonably considered as an exogenous shock. As shown in Table 1 (columns 4 through 9), maternal, child and household characteristics are not significantly different between earthquake and non-earthquake regions.[22] Furthermore, fact that the fraction of in-utero children it is the same across earthquake and non-earthquake regions, also supports the idea that women did not adjust their pregnancy decision based on the earthquake.

To assess whether the earthquake caused stress, we estimated a regression of maternal stress on the earthquake intensity in a mother's location of residence (measured in the Mercalli scale).[23] We find that a larger earthquake magnitude had a positive and highly significant effect on maternal stress (column 1 of Table 3).

[21] Using the date of birth and weeks of gestation at birth we are able to generate the date conception to determine if the child was in utero during the earthquake episode. We consider children to be in-utero if their mothers were pregnant between February 27 and March 31, 2010.

[22] The only exception is maternal age, with mothers living in earthquake region being 0.8 years, or approximately 10 months older.

[23] See the details of the Mercalli scale in Table A1.1 in the appendix.

A potential threat to identification is that the earthquake affected areas where women were more likely to experience stress, or areas with higher (lower) socio-economic conditions that in turn affect stress. If the earthquake intensity is unrelated to these variables, its measured effect will be robust their inclusion of such variables in the regression. We find that the estimated relationship between earthquake intensity and maternal stress is robust to inclusion of variables that may affect mothers' likelihood of suffering stress (columns 2 and 3 of Table 3).

As with every natural disaster, there may be several mechanisms though which the disaster causes stress or mental health problems, such as changes in income, employment, physical health, death of a relative, house damage or loss, among others. Using an alternative data set, we explored whether the earthquake might have operated through some of these alternative mechanisms. We use data from the CASEN-EPT panel survey, which contains household's socio-economic information before and after the earthquake. In its post-earthquake wave, the CASEN-EPT included questions regarding individuals' mental health.[24]

Table 4 reports statistics on key variables before and after the earthquake, in affected and non-affected regions. It suggests that mental health was worse (about 1 month after the earthquake) in regions that were directly affected by the earthquake relative to non-affected areas in the rest of the country, which is similar to our findings with ELPI data. The variables that capture mental health disorders (frequency and intensity) are almost three times higher in regions affected by 27-F relative to the rest of the country.

Other health and socio-economic variables did not experience relevant changes that could explain such large differences in mental health. For example, fetal mortality rates present a similar trends in affected and not affected regions, as well as the percentage of people living in rural areas, married, or average years of education. In terms of employment, the fraction of adults working was two percentage point lower in earthquake regions (compared to no change in unaffected regions); the magnitude of the change is relatively small.[25] In terms of health, a self-reported index of general health shows no major changes after the earthquake and only a 2.7% of the individuals reported health problems due to the earthquake.

[24] The CASEN-EPT survey is a follow up survey of the 2009 CASEN survey (CASEN is the main household survey carried in Chile). The EPT (Post Earthquake Survey or Encuesta Post Terremoto in Spanish) household survey was a follow up was carried out in April 2010 (around one month after the earthquake) on a sub-sample of the CASEN households surveyed in 2009.

[25] Given the relevance of the labor market for mental health (Powdthavee and Vernoit 2013, Layard 2013, Kronenberg et al. 2015) we also investigated specific questions regarding the impact of the earthquake on labor market outcomes in the CASEN-EPT dataset. We found that there are no significant changes in occupations by region; furthermore, we observe that only a 1.3% of the individuals pointed out that they did not search for a job because of the earthquake and 1.8% of the individuals lost their job because of the earthquake. Approximately 88% of individuals who were working before the earthquake reported that they remain in the same job, 0.9% changed jobs because of the earthquake, and 11% changed job for other reasons. We also observed from the data that 17% of workplaces were affected by the earthquake, and two thirds of those suffered minor damages.

Another, source of stress, housing quality, shows a minor deterioration in regions not affected by the earthquake.[26] Finally, income is higher in non-affected regions,[27] both regions experienced similar decreases in income (with a smaller decline in earthquake regions). The minor changes in these socio-economic, health, and infrastructure variables cannot explain the large differences in mental health indicators, suggesting that the differences in stress where most likely due to the direct exposure to a large stress-inducing shock, and not to indirect effects that may also cause stress.

5. Results

We present our estimates of the impact of in-utero stress on childhood development outcomes in Table 5. In columns (1) through (3), we include the estimated effects for all children, as measured in the BDI test, TADI test, and the CBCL average, internalization, and externalization problems, respectively. In columns (4) through (6) we present results for a sub-group of children whose mothers reside in municipalities that were affected by the 27-F earthquake. It is plausible that mothers living in the most affected regions suffered higher stress so that point estimates are of a larger magnitude; however, the smaller sample size may affect statistical significance. Table 5 also presents estimated coefficients for the relationship between childhood development and the other control variables (mothers' characteristics, the child's characteristics, and household socio-economic variables).

Our results reveal that suffering from (earthquake-induced) stress during pregnancy harms early childhood development: the Battelle test score is reduced by 0.17 standard deviations and is statistically significant at the 10% level (column 1 of Table 5), the TADI test score is reduced by 0.09 standard deviations (column 2), and the CBCL average score increases by 0.09 standard deviations (column 3). Since the CBCL measures problem behaviors, a higher score implies lower socio-emotional development. Results for children in earthquake-affected areas in columns (4) through (6) are similar to the general results; henceforth, we discuss results for all children only.[28]

The estimated coefficients for the variable "maternal stress" reveal the effect of earthquake-induced stress on children who were conceived after March 2010; our results suggest that suffering maternal stress prior to conception did not affect future early childhood development outcomes.

Being in-utero on 27-F is not systematically correlated to the different measures of childhood development, although we find that they have higher scores on the TADI test,

[26] Regarding housing, a 98% of the people live in the same place than in 2009 and among the 2% who change residence, 1.3% was due to the earthquake. Approximately 71% of houses did not suffer any damage, 21% suffered minor damages, 5.7% suffered major damages and only 1.4% were destroyed by the earthquake

[27] Wages are higher in regions not affected by the earthquake due to concentration of mining activity in these areas.

[28] All other tables of results include all children in the sample; results for children in earthquake areas yield similar results and are available upon request from the authors.

perhaps because those children are older.[29] Most other control variables have the expected relationship with early childhood development. It is interesting to note that children whose parents have prior diagnosed mental health problems have greater socio-emotional difficulties (CBCL measures are higher), and that relative to boys, girls have higher development outcomes as reflected in both BDI and TADI test scores. Mothers' cognitive and non-cognitive skills have important impacts on their child's development: children with mothers with higher cognitive skills (years of education and numeracy skills) had better performance on the BDI or TADI tests, while mothers' low BFI scores in extraversion, agreeableness, and responsibility, as well as high neuroticism test scores, had negative impacts on their child's development, with all measures.

Alternative explanations?

The earthquake likely affected the mothers in our sample in many ways, so that our measure of maternal stress may also indirectly capture other effects of the earthquake that may have impacted early childhood development. The alternative (indirect) channels include: potential health effects during the pregnancy (which have been widely studied in the literature), changes in mothers' behavior as a response to stress, and decisions regarding child care and employment after the child was born. For example, if the earthquake induced premature births—which then affected children's outcomes—then our identification strategy would be challenged.

To assess this possibility, we followed two approaches. First, we re-estimated regressions in Table 5, and included several variables that measure possible alternative channels as control variables; if these are correlated with the effect of in-utero stress, then the coefficient of stress will change once these channels are included. As a second approach, we estimated whether the alternative channels were affected by in-utero stress from 27-F.

The results of the first approach are summarized in Table 6, which presents the estimated coefficients of the effect of in-utero stress without controlling for an alternative channel (column 1 of Table 6), followed by the result of adding each additional channel to the baseline regression (columns 2 through 9). The alternative channels available in our data are: number of complications during labor, whether the birth was premature (<37 weeks gestation), child's weight-for-height at birth (z-score); whether the mother smoked, drank alcohol, or consumed recreational drugs during pregnancy; child care take-up after birth; and mothers' months of employment during the 6 months after the earthquake.

The dependent variables of Table 6 are the Battelle test in Panel A, the TADI test in Panel B, and the average result of the CBCL in Panel C. Column (1) of Table 6 reports the same regression result as Table 5 as a baseline (we do not present other control variables),

[29] Even though the regressions control for child's age in months, the average age of children who were in-utero on 27F is 25 months, compared to an average age of 14 months among the not in-utero sample; this coefficient could reflect differences due to thresholds of development that are crossed during that period that may not be captured by the continuous measure of the child's age.

and columns (2) through (9) of Table also 6 report the estimated effect of each individual channel described above.

If our estimated effect of stress is due to alternative channels, we would observe changes in the estimated coefficient of maternal stress when we include these channels in the regressions. However, we observe in all Panels of Table 6 that the estimated effects of in-utero stress are robust to the inclusion of these measures, suggesting that our estimated effect is not driven by other explanations. Furthermore, we find that complications during labor, premature births, and lower birth weight are correlated with lower childhood development (columns 2, 3 and 4 of Panels A and B); alcohol consumption during pregnancy reduces scores on the TADI test (column 6 of Panel B), and formal child care improves childhood development (column 8 of Panel B). Childhood behaviors as measured by the CBCL are not affected by the alternative explanations.

The second approach is summarized in Table 7. Each column reports the effect of in-utero stress on each of the eight alternative channels discussed above (other control variables are not shown). We can observe that the stress experienced by mothers from 27-F did not significantly affect most of the channels (the exception is use of child care after the child was born, which lower for mothers who experienced stress). Results in Tables 6 and 7 suggest that alternative channels are not systematically correlated to the negative effects that in-utero stress has on early childhood development.

Dimensions of Child Development

The psychological tests applied to children measure different dimensions of their development. We also analyzed whether in-utero stress had an impact on specific areas of development, and report results of the dimensions evaluated with the TADI test (Table 8), and the different behaviors measured in the CBCL (Table 9). We find that in-utero stress reduces cognitive skills by 0.17 standard deviations (column 2 of Table 8), and that it increases attention problems (column 8 of Table 9).

Heterogeneous effects by Trimester

Although biological evidence of the link between stress and cortisol-producing hormones is conclusive, the question about when during pregnancy stress is more detrimental is still unresolved (Torche 2011). One approach indicates that maternal stress later in the pregnancy—particularly in the third trimester—is more influential because stress-induced CRH alters the physiology of parturition, producing uterine contractions that result in early delivery (Wadhwa et al., 2004). On the other hand, De Weerth and Buitelaar (2005) suggest that stress early in the pregnancy has greater consequences and as pregnancy advances, physiological changes lead to dampened maternal responses to stress. These changes protect women from the consequences of stress later in the pregnancy but leave them vulnerable early on. Furthermore, early maternal stress initiates a chain of events leading to preterm labor by triggering CRH gene expression in the placenta, which sets a biological clock for early delivery months later (Sandman et al. 2006).

We explored whether the stress of the earthquake had different impacts on development outcomes, depending on the trimester of pregnancy on the day of the

earthquake; we present our results in Table 10. Our findings suggest that suffering in-utero stress during the first trimester of pregnancy negatively affects socio-emotional development as measured by the BDI and the socio-emotional dimension of the TADI test (columns 1 and 6 of Table 10, respectively); both outcomes are reduced by approximately 0.2 standard deviations as a result of pre-natal stress.

The results are less clear regarding children's behaviors, however, they suggest that the exposure to stress during the third trimester increases behaviors associated to anxiety and depression (column 11), and attention (column 14). Attention problems are also worse if the child's mother suffered stress in the first trimester, and in-utero stress in the second trimester leads to children's sleep problems (column 16). Although our results cannot be considered conclusive with regards to the timing of stress exposure, they suggest that timing of exposure during pregnancy may affect different dimensions of childhood development, which could reconcile the apparent disagreement in the medical field. To draw conclusions, more research is needed in this field.

Heterogeneous effects by household income

We also analyzed whether the effect of in-utero stress is different across socioeconomic level. We defined households as either high- or low-income according to whether they were above or below the median of total family income per capita, respectively. Then we interacted our variable of interest—maternal stress in-utero—with the income level of the family; we present results in Table 11.

Our findings suggest that in-utero stress harms childhood development of children from low-income families: suffering stress while in-utero reduces their BDI and total TADI test scores by approximately 0.2 standard deviations (columns 1 and 2, respectively). The dimension that is most affected is cognition, as it is reduced by 0.3 standard deviations due to in-utero stress.

Most behaviors do not suffer differential effects by income level of the household; one exception is attention problems, which are worse among children of high-income households (column 12 of Table 11).

Heterogeneous effects by child's sex

We explored whether in-utero stress affects boys and girls differently, and report those results in Table 12. Our estimates yield mixed results; we find that pre-natal stress reduced boys' development outcomes as measured by the BDI test, which was reduced by 0.24 standard deviations as a result of in-utero stress (column 1). Boys also experienced greater attention problems relative to girls (column 12). However, girls had lower results on the cognition dimension of the TADI test as a result of in-utero stress.

6. Conclusions

The transmission of in-utero health shocks from mothers to children has been widely studied in several disciplines. In the early 1990s, epidemiologist Robert Barker was an early proponent of the "fetal origins" hypothesis, which posited that physical health conditions a fetus is exposed to will condition his future health trajectories; many have tested this hypothesis since.[30] The contribution by economics is to assess the impact of in-utero conditions with several methodologies that aim to establish a causal relation.

As early as the mid-2000s, economists began to test whether pre-natal health conditions had short and long-run impacts on a child's birth-weight and adult health and education outcomes. A more recent line of research has analyzed the effects of mental health shocks during pregnancy—specifically, high levels of in-utero stress—on immediate health (birth-weight) and later outcomes (education, employment, morbidity, among others).

In this paper, we contribute to the existing literature by analyzing the impact of pre-natal stress exposure on a child's early development outcomes, which are crucial determinants of future success in school and the labor market. Our unique data allows us to exploit randomly-induced stress brought about by a large earthquake in Chile, as well as the random timing of pregnancies during and shortly after the earthquake. Furthermore, we are able to improve on previous measures of stress that rely on exposure to an event, which were not able to identify possible heterogeneous responses to the same phenomena. Our data includes actual (self-reported) maternal stress due to the earthquake, rather than exposure to stress.

Using a survey that contains results from several childhood development tests, as well as an extensive set of variables that describe the mother's pregnancy, her mental health background, mothers' cognitive and non-cognitive skills, and household socio-demographic information, we estimate a reduced-form model that estimates a difference-in-difference estimator of the effect of in-utero stress on several child development outcomes.

We find that in-utero stress is detrimental to childhood development. Our baseline estimates reveal that it reduces the Battelle Developmental Inventory test scores by 0.2 standard deviations. We also find that it reduces the cognitive dimension of the Childhood Learning and Development Test (TADI) by a similar magnitude, and that it increases attention problems measured in the Child Behavior Checklist. Our data allows us to explore whether the measured effect is due to alternative explanations, such as indirect physical health effects of the earthquake, changes in mothers' behaviors in response to stress, or to post-birth decisions of child care and mothers' employment. We find that these alternative explanations do not change our measured effect.

We also find suggestive evidence that the harmful effects on the two developmental tests (BDI and TADI) occur during the first trimester of pregnancy, while the effects on behavioral problems are less clear in relation to the timing of the shock during the pregnancy. Additionally, our results suggest that the harmful effects of the shocks are suffered by children in relatively low-income households, with the exception of attention problems, which are found among higher-income children. For the most part, the effects of stress affect boys and girls similarly; however, stress reduces boys' outcomes in the Battelle

[30] See Almond and Currie (2011) for a review.

test and increases their attention problems relative to girls. Meanwhile, girls' outcomes in the cognitive dimension of the TADI test are negatively affected.

To the best of our knowledge, this is the first paper to estimate the causal impact of in-utero stress brought about by an exogenous event, on early childhood development. We contribute to our understanding of the impact of stress suffered during pregnancy on the early years of a child's life. Our findings have relevant policy implications, because they suggest that children who suffer stress in the pre-natal period are a vulnerable group that should be monitored post-birth to provide remedial interventions, if necessary.

Our results suggest that cognitive and non-cognitive skills by age 2 are already affected by in utero events. Furthermore, we show that these effects start early during pregnancy (first trimester), which suggest that public policies should be focalized on early stages of pregnancy, and continue throughout the pregnancy. An additional policy implication is that birthweight as a proxy for fetal health has limitations—it is able to reveal some relevant health problems but misses others (as highlighted in Almond and Currie, 2017), so that better measures are needed. A third contribution is to highlight the relevance of generating public policies to remediate cognitive and non-cognitive effects of in utero shocks as early as possible during a child's life, and not wait until children enter school.

Our results also suggest that public policies could provide support to adults diagnosed with mental health problems if they become parents, as some of our results suggest the existence of strong negative effects of mother's mental health on child development. Finally, our study reveals the relevance of longitudinal datasets of early childhood development (such as ELPI) in the design of public policies. Furthermore, and given the heterogeneous effects found in this study, it is important that these new datasets consider the multiple dimensions of child development, which should consider not only cognitive skills but also socioemotional, mental health, and attention problems, among others.

REFERENCES

Abel, K., H. Heuvelman, L Jörgensen, C Magnusson, S Wicks, E Susser, J Hallkvist, and C Dalman (2014) "Severe bereavement stress during the prenatal and childhood periods and risk of psychosis in later life: population based cohort study," British Medical Journal, 348, f7679

Aizer, A., L. Stroud and S. Buka (2016) "Maternal Stress and Child Well-Being: Evidence from Siblings". Journal of Human Resources, 51(3): 523-555.

Almond, D. and J. Currie (2011). "Killing Me Softly: The Fetal Origins Hypothesis", Journal of Economic Perspectives, Volume 25, Number 3, Pages 153--172.

Almond, D., B. Mazumder and R. van Ewijk (2015) "In Utero Ramadan Exposure and Children's Academic Performance" The Economic Journal, 125 (December), Pages 1501--1533

Astroza, M., Cabezas, F., Moroni, M. O., Massone L., Ruiz S., Parra, E., Cordero F. and Mottadelli, A. (2010) "Intensidades sísmicas en el área de daños del terremoto del 27 de febrero de 2010", http://www.eqclearinghouse.org/20100227-chile/wp-content/uploads/2010/04/Informe de Intensidades

Banerjee, A., E. Duflo, G. Postel-Vinay and T Watts (2010). "Long-Run Health Impacts of Income Shocks: Wine and Phylloxera in Nineteenth-Century France." Review of Economics and Statistics 92 (4): 714--28.

Barker, D. J. P. (1992). "Fetal and Infant Origins of Adult Disease" British Medical Journal 301 (6761): 1111.

Barreca, A. (2010) "The Long-Term Economic Impact of In Utero and Postnatal Exposure to Malaria" Journal of Human Resources 45 (4): 865--92

Bhalotra, S., C. Sanhueza and Y. Wu (2012) "Long-term economic consequences of the 1960 Chile earthquake". Draft.

Buckles, K. and D. Hungerman (2008) "Season of birth and later outcomes: Old questions new answers". NBER Working Paper Nº 14573.

Camacho, A. (2008) "Stress and birth weight: Evidence from terrorist attacks". American Economic Review: Papers and Proceedings 98 (2), 511-515.

Carneiro, P., J. Heckman and D. Masterov "Labor Market Discrimination and Racial Differences in Pre-Market Factors." Journal of Law and Economics, 48(1), 1–39.

Carr V.,Lewin T., Webster R. and J. Kenardy (1997). "A synthesis of the findings from the Quake Impact Study: A two-year investigation of the psychosocial sequelae of the 1989 Newcastle earthquake". Social Psychiatry, 32, 123-136.

Cosmi, E.G. Luzi, F. Gori and A. Chiodi (1990) "Response of utero-placental fetal blood flow to stress situation and drugs". European Journal of Obstetrics, Gynecology and Reproductive Biology, 36, 239.

Cunha, F. and J. Heckman (2009) "The Economics and Psychology of Inequality and Human Development". Journal of the European Economic Association, Volume 7, Issue 2-3, 1.

Cunha, F (2017) "Gaps in Early Investments in Children". Draft.

Currie, J. and M. Rossin-Slater (2013) "Weathering the Storm: Hurricanes and Birth Outcomes", Journal of Health Economics, 32, 487-503.

Dahlen, H. (2016) "The impact of maternal depression on child academic and socioemotional outcomes", Economics of Education Review 52, Pages 77--90.

De Weerth, C., and J. Buitelaar (2005). "Physiological stress reactivity in human pregnancy". A review Neurosciences Biobehavioral Review, 29, 295--312.

Dunkel-Schetter, C. (2009) "Stress Processes in Pregnancy and Preterm Birth". Current Directions in Psychological Science, 205-209.

Eccleston, M. (2011) "In utero exposure to maternal stress: Effect of 9/11 on Birth and early schooling in New York City". Working Paper, Harvard University.

Eskenazy, B., A. Marks, R. Catalano, T. Bruckner and P. Toniolo (2007) "Llow birth weight in New York City and upstate New York following the events of September 11th". Human Reproduction 22(11), 3013-3020.

Fukuda, S., Morimoto, K., Mure, K., and Maruyama, S. (2000) “Effect of the Hanshin-Awaji earthquake on posttraumatic stress, lifestyle changes, and cortisol levels of victims,” Archives of Environmental Health, vol. 55, no. 2, pp. 121–125.

Galea S., A. Nandi and D. Vlahov (2005). "The epidemiology of post-traumatic stress disorder after disasters". Epidemiologic Reviews, 27(1), 78-91.

Glynn, L.M., Wadhwa, P.D., Dunkel-Schetter, C., Chicz-DeMet, A., & Sandman, C.A. (2001). When stress happens matters: Effects of earthquake timing on stress responsivity in pregnancy. American Journal of Obstetrics and Gynecology, 185, 779–780.

Heckman, J. and D. Masterov (2007) "The productivity argument for investing in young children". NBER Working Paper Nº13106.

Heckman, J. J., Stixrud, J., & Urzua, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. Journal of Labor Economics, 24(3), 411-482.

Hoynes, H., D. Whitmore and D. Almond (2016) "Long-Run Impacts of Childhood Access to the Safety Net". American Economic Review, 106(4): 903--934

Karanci, N. and A.Rustemli (1995). "Psychological consequences of the 1992 Erzincan (Turkey) Earthquake". Disasters, 19(1), 8-18.

Kronenberg, C., R. Jacobs and E Zucchelli (2015) "The impact of a wage increase on mental health: Evidence from the UK minimum wage". Health, Econometrics and Data Group Working Paper 15/08, University of York.

Lavy, V., A. Schlosser and A. Shany (2016) "Out of Africa: Human Capital Consequences of In Utero Conditions". NBER Working Paper No. 21894

Layard, R. (2013) "Mental Health: The New Frontier for Labour Economics". CEP Discussion Paper No 1213

Lipkind, H., A. Curry, M. Huynh, I. Thorpe and T. Matte (2010) "Birth outcomes among offspring of women exposed to the september 11, 2001 terrorist attacks". Obstetrics and Gynecology 116(4), 917-925.

Luo, H., Hu, X., Liu, X., Ma, X., Guo, W., Qiu, C., … Li, T. (2012). Hair cortisol level as a biomarker for altered hypothalamic-pituitary-adrenal activity in female adolescents with posttraumatic stress disorder after the 2008 Wenchuan earthquake. Biological Psychiatry, 72, 65–69. doi:10.1016/j.biopsych.2011.12.020

Mansour, H. and D. Rees (2011) "Prenatal Stress on birth weight: Evidence from the Al-Aqsa intifada". Discussion Paper Series Nº5535, IZA

Myers, R.E. (1975). "Maternal psychological stress and fetal asphyxia: a study in the monkey". American Journal of.Obstetrics & Gynecology 122, 47--59.

Najarian L., A. Goenjian, D. Pelcovitz, F. Mandel, B. Najarian (2001). "The effect of relocation after a natural disaster". Journal of Traumatic Stress, 14, 511-526.

Newbor J., J. Stock, L. Wnek (1996). “Inventario de desarrollo Battelle”. Madrid: TEA.

O'Connor, T., Y. Ben-Shlomo, J. Heron, J. Golding, D. Adams and V. Glover (2005) "Prenatal anxiety predicts individual differences in cortisol in pre-adolescent children". Biological Psychiatric, 58, 211-217.

Palmeiro-Silva YK, Orellana P, Venegas P, Monteiro L, Varas-Godoy M, Norwitz E, et al. (2018) Effects of earthquake on perinatal outcomes: A Chilean register-based study. PLoS ONE 13(2): e0191340. https://doi.org/10.1371/journal.pone.0191340.

Persson, P. and M. Rossin-Slater (2016) "Family Ruptures, Stress, and the Mental Health of the Next Generation" American Economic Review, Forthcoming.

Powdthavee, N. and J. Vernoit (2013) "Parental unemployment and children's happiness: A longitudinal study of young people's well-being in unemployed households". Volume 24, Pages 253--263

Sandman, C., L. Glynn, C. Dunkel-Schetter, P. Wadhwa, T. Garite, A. Chicz-DeMet and C. Hobel (2006). "Elevated maternal cortisol early in pregnancy predicts third trimester levels of placental corticotropin releasing hormone (CRH): Priming the placental clock". Peptides, 27, 1457--1463.

Shinfuku, N. (1999). "To be a victim and a survivor of the great Hanshin-Awaji earthquake". Journal of Psychosomatic Research, 46, 541-548.

Stott, D.H. (1973)." Follow-up study from birth of the effects of prenatal stresses". Development Medicine &.Child Neurology. 15, 770--787.

Torche, F. (2011) "The Effect of Maternal Stress on Birth Outcomes: Exploiting a Natural Experiment". Demography 48, 1473-1491.

Wadhwa, P., C. Dunkel-Schetter A. Chicz-DeMet, M. Porto, C. Sandman (1996) "Prenatal psychosocial factors and the neuroendocrine axis in human pregnancy". Psychosomatic Medicine, 58, 432-446

Wadhwa, P., T. Garite, M. Porto, L. Glynn, A. Chicz-DeMet, C. Dunkel-Schetter & C. Sandman (2004). "Placental corticotropin-releasing hormone (CRH), spontaneous preterm birth, and fetal growth restriction: A prospective investigation". American Journal of Obstetrics and Gynecology, 191, 1063--1069.

Weinstock, M. (2008) "The long-Term Behavioural Consequences of Prenatal Stress", Neuroscience and Biobehavioral Reviews, 32, 1073-1086.

World Health Organization (2004) "Promoting Mental Health: Concepts, emerging evidence and practice" Summary Report.
(http://www.who.int/mental_health/evidence/en/promoting_mhh.pdf)

Table 1. Summary Statistics by Earthquake Regions, Maternal Stress and In-Utero exposure (2012)

	All			Regions: Non-Earthquake			Earthquake			
	Obs	Mean	S.D.	Obs	Mean	S.D.	Obs	Mean	S.D.	
Variables:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	
Child Development Outcomes:										
Battelle test (T-scores)	1975	0.00	1.00	419	-0.07	1.01	1556	0.02	1.00	
TADI - Total (T-scores)	1960	0.01	0.99	416	0.05	1.02	1544	0.00	0.98	
TADI - Cognition (T-scores)	1960	0.01	0.99	416	0.00	1.01	1544	0.01	0.99	
TADI - Motor skills (T-scores)	1969	0.01	0.99	417	0.05	1.02	1552	0.00	0.98	
TADI - Language (T-scores)	1969	0.01	1.00	417	-0.05	1.00	1552	0.03	1.00	
TADI - Socioemotional (T-scores)	1969	0.01	0.99	417	0.16	1.02	1552	-0.03	0.98	*
CBCL - Total (T-scores)	1124	0.00	1.00	231	-0.05	1.00	893	0.01	1.00	
CBCL - Internalization (T-scores)	1124	0.00	0.99	231	-0.07	1.00	893	0.02	0.99	
CBCL - Externalization (T-scores)	1124	0.00	1.00	231	-0.03	0.98	893	0.01	1.01	
CBCL - Reactivity (percentile)	1124	64.4	17.0	231	64.4	16.9	893	64.4	17.0	
CBCL - Anxiety/Depression (percentile)	1124	68.0	17.4	231	66.4	17.1	893	68.4	17.5	
CBCL - Somatic complaint (percentile)	1124	68.8	16.9	231	66.6	16.0	893	69.3	17.1	*
CBCL - Withdrawn (percentile)	1124	72.9	15.4	231	71.8	15.4	893	73.2	15.4	
CBCL - Attention problems (percentile)	1124	72.5	15.4	231	72.4	15.7	893	72.6	15.3	
CBCL - Aggressive behavior (percentile)	1124	72.2	17.1	231	71.6	16.8	893	72.4	17.2	
CBCL - Sleep problems (percentile)	1124	65.6	14.3	231	65.9	14.4	893	65.5	14.3	
Maternal Controls										
Maternal Stress (fraction)	1975	0.36	0.48	419	0.16	0.36	1556	0.42	0.49	*
In-utero at earthquake (fraction)	1975	0.44	0.50	419	0.44	0.50	1556	0.44	0.50	
Age (years)	1975	28.3	6.9	419	27.7	6.6	1556	28.5	6.9	*
Education (years)	1975	11.7	2.7	419	11.8	2.9	1556	11.6	2.7	
Low Numeracy Skills in WAIS (fraction)	1975	0.69	0.46	419	0.67	0.47	1556	0.70	0.46	
Low Vocabulary Skills in WAIS (fraction)	1975	0.50	0.50	419	0.53	0.50	1556	0.49	0.50	
Low Extraversion in BFI (fraction)	1975	0.19	0.39	419	0.16	0.36	1556	0.20	0.40	
Low Agreeableness in BFI (fraction)	1975	0.08	0.27	419	0.08	0.27	1556	0.08	0.27	
Low Responsibility in BFI (fraction)	1975	0.06	0.23	419	0.06	0.24	1556	0.06	0.23	
Low Neuroticism in BFI (fraction)	1975	0.50	0.50	419	0.51	0.50	1556	0.49	0.50	
Low Openness Exper. in BFI (fraction)	1975	0.08	0.28	419	0.07	0.26	1556	0.09	0.28	

Source: Author's calculations using ELPI 2012 data. Chile is divided into 15 administrative regions. Earthquake regions: V, VI, VII, VIII, IX and XIII (Metropolitan region). Non-earthquake regions: I, II, III, IV, X, XI, XII, XIV, XV. * : Difference between areas affected and not affected by earthquake is statistically significant at the 5% level.

Table 1 (continued). Summary Statistics by Earthquake Regions, Maternal Stress and In-Utero exposure (2012)

	All			Regions: Non-Earthquake			Earthquake		
	Obs	Mean	S.D.	Obs	Mean	S.D.	Obs	Mean	S.D.
Variables:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Child Controls									
Girl	1975	0.49	0.5	419	0.49	0.5	1556	0.49	0.5
Child's birth order	1975	1.0	0.2	419	1.0	0.2	1556	1.0	0.2
Age (months)	1975	19.3	6.6	419	19.0	6.6	1556	19.4	6.6
Number of siblings	1975	0.9	1.0	419	0.9	1.0	1556	0.9	1.0
Household/Family Controls									
Total household income per capita ($'000)	1975	125.8	149.6	419	130.1	137.0	1556	124.6	152.8
Father lives in household (fraction)	1975	0.68	0.47	419	0.70	0.46	1556	0.67	0.47
Prior mental health issues: mother (fraction)	1975	0.13	0.34	419	0.13	0.34	1556	0.13	0.33
Prior mental health issues: father (fraction)	1975	0.02	0.14	419	0.02	0.13	1556	0.02	0.14
Prior mental health issues: relatives (fraction)	1975	0.16	0.37	419	0.15	0.36	1556	0.17	0.37
Channels									
Smoked during pregnancy (fraction)	1971	0.08	0.27	417	0.09	0.29	1554	0.07	0.26
Alcohol during pregnancy (fraction)	1974	0.08	0.27	419	0.08	0.27	1555	0.08	0.26
Recreational drugs during pregnancy (fraction)	1971	0.02	0.12	418	0.01	0.10	1553	0.02	0.13
Labor complications (number)	1975	0.25	0.50	419	0.26	0.52	1556	0.24	0.49
Premature birth (<37 weeks) (fraction)	1975	0.11	0.31	419	0.10	0.30	1556	0.11	0.31
Weight-for-height (z-score)	1881	0.01	1.00	397	0.01	0.98	1484	0.01	1.00
Formal (external) childcare (fraction)	1975	0.05	0.17	419	0.04	0.15	1556	0.05	0.17
Months employed after earthquake	1975	3.0	3.4	419	3.0	3.4	1556	3.0	3.4

Source: Author's calculations using ELPI 2012 data. Chile is divided into 15 administrative regions. Earthquake regions: V, VI, VII, VIII, IX and XIII (Metropolitan region). Non-earthquake regions: I, II, III, IV, X, XI, XII, XIV, XV. * : Difference between areas affected and not affected by earthquake is statistically significant at the 5% level.

Table 2. Mothers reporting stress symptoms after the earthquake, ELPI 2012 (percentage)

Stress Symptoms:	Non-Earthquake Region	Earthquake Region
Insomnia	1.7	12.1
Stress, anguish or anxiety	3.0	12.3
Crying or emotional instability	2.2	10.7
Fear or panic	11.4	30.2
Traumatic memories	0.6	7.9
Others	0.6	1.3
Any symptom[a]	15.1	40.8
Number of obs.	537	1,892

Source: Author's calculations using ELPI 2012 data. Mother's asked whether they suffered a series of symptoms that she could attribute to the earthquake. Chile is divided into 15 administrative regions. Earthquake regions: V, VI, VII, VIII, IX and XIII (Metropolitan region). Non-earthquake regions: I, II, III, IV, X, XI, XII, XIV, XV. [a]: Excludes the Others category.

Table 3. Earthquake Intensity and Maternal Stress (2012)

	Dependent variable: Maternal stress		
VARIABLES	(1)	(2)	(3)
Earthquake intensity	0.0370***	0.0369***	0.0366***
	(0.00648)	(0.00634)	(0.00632)
Prior mental health issues (mother)		0.123***	0.0974***
		(0.0324)	(0.0327)
Prior mental health issues (father)		0.0104	0.0214
		(0.0787)	(0.0728)
Prior mental health issues (relative)		0.0215	0.0276
		(0.0299)	(0.0299)
Total hhold income per capita ($)			-2.49e-07***
			(7.48e-08)
Number of siblings			0.000529
			(0.0132)
Father lives in hhold			0.0402
			(0.0262)
Mother's age (years)			0.000830
			(0.00160)
Mother's educ (years)			-0.00784*
			(0.00428)
Mother-Low Numeracy Skills (WAIS)			0.00324
			(0.0238)
Mother-Low Vocabulary Skills (WAIS)			0.0550**
			(0.0229)
Mother-Low Extraversion (BFI)			-0.0368
			(0.0253)
Mother-Low Agreeableness (BFI)			-0.00213
			(0.0351)
Mother-Low Responsibility (BFI)			-0.0176
			(0.0440)
Mother-Low Neuroticism (BFI)			-0.0886***
			(0.0192)
Mother-Low Openness Exper. (BFI)			-0.0311
			(0.0460)
Observations	2,124	2,124	2,124
R-squared	0.048	0.056	0.083

Source: Author's calculations using ELPI 2012 data. Earthquake intensity is measured at the municipal level with a Modified Mercalli scale (see Appendix 1) theoretically ranging from 1 to 12. In our data the maximum value is 9. Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10.

Table 4. Descriptive Statistics Before and After 2010 Earthquake (CASEN-EPT)

	Region:			
	Non-Earthquake		Earthquake	
Variables:	**2009**	**2010**	**2009**	**2010**
Mental Health problems (Frequency)	n.a.	2.3	n.a.	6.0
Mental Health problems (Intensity)	n.a.	2.2	n.a.	5.6
Fetal Mortality (Rate/1,000 born)	8.6	8.8	9.2	9.4
Rural area (Fraction)	0.31	0.31	0.29	0.29
Married (Fraction)	0.32	0.32	0.37	0.37
Education (Years)	10.1	10.2	10.3	10.3
Working (Fraction)	0.72	0.72	0.69	0.67
Working at least 1 hour last week (Fraction)	0.69	0.7	0.67	0.66
General Health, self-reported index (1-7)	5.6	5.7	5.6	5.6
Housing Global Quality (1-3)	1.31	1.26	1.30	1.30
Outward Appearance Index (1-3)	1.33	1.46	1.30	1.55
Household Income (CL $'000)	653	590	551	503

Source: Author's calculations using CASEN 2009 and CASEN-EPT 2010 data. Chile is divided into 15 administrative regions. Earthquake regions: V, VI, VII, VIII, IX and XIII (Metropolitan region). Non-earthquake regions: I, II, III, IV, X, XI, XII, XIV, XV. Mental Health is measured in a 0-68 point scale, where mental health worsens with higher scores and it is not available for 2010. All the statistics are for females between 15-59 years old. General Health varies from 1 equal to very bad, to 7 equal to very good. Housing Global Quality and Outward Appearance Index are measured by the following scale: Acceptable=1, Recoverable=2 and Not Recoverable=3.

Table 5. Effect of Maternal Stress on Early Childhood Development Tests

	All Children			Earthquake Regions		
	Battelle	**TADI**	**CBCL**	**Battelle**	**TADI**	**CBCL**
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Maternal Stress x In utero at quake	-0.167*	-0.0910	0.0937	-0.186*	-0.0855	0.0502
	(0.0888)	(0.0844)	(0.126)	(0.0987)	(0.0918)	(0.131)
Maternal stress	0.0889	0.0411	0.0602	0.0730	0.0321	0.0976
	(0.0655)	(0.0644)	(0.104)	(0.0708)	(0.0704)	(0.105)
In-utero at earthquake	-0.0679	0.227***	-0.0750	-0.0588	0.181*	-0.119
	(0.0960)	(0.0850)	(0.104)	(0.110)	(0.101)	(0.130)
Prior mental health issues (mother)	0.0328	-0.0292	0.195**	0.0685	0.00312	0.145
	(0.0673)	(0.0610)	(0.0860)	(0.0788)	(0.0702)	(0.0891)
Prior mental health issues (father)	0.112	0.0364	0.162	-0.0925	-0.133	0.251
	(0.157)	(0.174)	(0.148)	(0.165)	(0.173)	(0.153)
Prior mental health issues (relative)	0.0348	0.135***	0.0574	0.0245	0.118**	0.0662
	(0.0627)	(0.0506)	(0.0705)	(0.0715)	(0.0555)	(0.0756)
Girl	0.174***	0.108**	-0.0434	0.154***	0.101**	-0.0387
	(0.0486)	(0.0425)	(0.0543)	(0.0580)	(0.0469)	(0.0622)
Child's birth order	-0.134	-0.159	0.148	-0.190*	-0.208*	0.0998
	(0.114)	(0.134)	(0.131)	(0.109)	(0.122)	(0.141)
Age (months)	0.0154**	-0.0164***	0.000175	0.0146*	-0.0137*	0.00903
	(0.00686)	(0.00626)	(0.0110)	(0.00769)	(0.00738)	(0.0128)
Total household income per capita ($)	1.23e-07	8.50e-08	-3.64e-07**	1.81e-07	2.65e-08	-4.02e-07**
	(1.62e-07)	(1.44e-07)	(1.46e-07)	(1.81e-07)	(1.54e-07)	(1.57e-07)
Number of siblings	-0.0207	-0.0244	-0.0300	-0.0109	-0.0452	-0.0313
	(0.0297)	(0.0311)	(0.0322)	(0.0356)	(0.0352)	(0.0357)
Father lives in household	0.0679	0.0552	-0.0354	0.0616	0.0961	-0.0315
	(0.0504)	(0.0542)	(0.0734)	(0.0593)	(0.0640)	(0.0857)
Mother's age (years)	0.00183	0.00268	-0.0130***	-0.000779	0.00469	-0.00929*
	(0.00444)	(0.00421)	(0.00477)	(0.00512)	(0.00463)	(0.00530)

Table 5 (continued). Effect of Maternal Stress on Early Childhood Development Tests

	All Children			Earthquake Regions		
	Battelle	**TADI**	**CBCL**	**Battelle**	**TADI**	**CBCL**
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
Mother's education (years)	0.0227**	0.0248**	-0.0142	0.0188	0.0249**	-0.0111
	(0.0105)	(0.0103)	(0.0126)	(0.0128)	(0.0125)	(0.0151)
Mother-Low Numeracy Skills	0.0112	-0.143***	0.0350	-0.00221	-0.155***	0.0671
	(0.0514)	(0.0495)	(0.0666)	(0.0610)	(0.0577)	(0.0782)
Mother-Low Vocabulary Skills	0.0259	0.0262	0.0590	0.0254	0.0327	0.0880
	(0.0493)	(0.0507)	(0.0695)	(0.0601)	(0.0570)	(0.0812)
Mother-Low Extraversion (BFI)	-0.150**	-0.101*	0.197***	-0.107	-0.0426	0.207***
	(0.0677)	(0.0598)	(0.0719)	(0.0737)	(0.0662)	(0.0769)
Mother-Low Agreeableness (BFI)	-0.0840	-0.218***	0.252**	-0.154	-0.280***	0.173
	(0.0818)	(0.0724)	(0.103)	(0.0930)	(0.0775)	(0.111)
Mother-Low Responsibility (BFI)	-0.284**	-0.0524	-0.285*	-0.403**	-0.0762	-0.438**
	(0.131)	(0.116)	(0.166)	(0.159)	(0.143)	(0.201)
Mother-High Neuroticism (BFI)	-0.131***	-0.0332	0.319***	-0.109**	-0.0263	0.307***
	(0.0456)	(0.0510)	(0.0557)	(0.0525)	(0.0560)	(0.0609)
Mother-Low Openness Exper. (BFI)	-0.181**	-0.0751	0.0827	-0.186*	-0.0825	0.0748
	(0.0858)	(0.0859)	(0.0998)	(0.0954)	(0.0900)	(0.114)
Observations	1,975	2,062	1,217	1,556	1,615	958
R-squared	0.078	0.065	0.104	0.062	0.047	0.089

Constant not shown. Dependent variable is the standardized T-score obtained in each test. Additional controls: region dummy variables. Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10.

Table 6. Maternal Stress and Early Childhood Development: Alternative channels

	Channels:								
	None	Labor Complic.	Premature	Weight at birth	Smoked	Alcohol	Drugs	Child care	Worked after 27F
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
A. Dependent Variable: Battelle									
Stress x In utero at quake	-0.167*	-0.162*	-0.164*	-0.174*	-0.171*	-0.166*	-0.170*	-0.162*	-0.168*
	(0.0888)	(0.0892)	(0.0889)	(0.0913)	(0.0895)	(0.0891)	(0.0888)	(0.0884)	(0.0886)
Channel		-0.115***	-0.160**	0.0323	-0.0586	-0.117	-0.238	0.164	0.00564
		(0.0428)	(0.0724)	(0.0211)	(0.0957)	(0.0843)	(0.204)	(0.115)	(0.00742)
Observations	1,975	1,975	1,975	1,881	1,971	1,974	1,971	1,975	1,975
R-squared	0.078	0.081	0.080	0.073	0.078	0.079	0.079	0.079	0.078
B. Dependent Variable: TADI									
Stress x In utero at quake	-0.0910	-0.0888	-0.0875	-0.0891	-0.0947	-0.0889	-0.0901	-0.0812	-0.0925
	(0.0844)	(0.0855)	(0.0841)	(0.0878)	(0.0850)	(0.0832)	(0.0839)	(0.0848)	(0.0838)
Channel		-0.0840*	-0.228***	0.0507**	-0.0539	-0.197**	-0.0863	0.321**	0.00659
		(0.0473)	(0.0735)	(0.0226)	(0.0808)	(0.0774)	(0.198)	(0.125)	(0.00667)
Observations	2,062	2,062	2,062	1,963	2,058	2,060	2,057	2,062	2,062
R-squared	0.065	0.067	0.070	0.064	0.064	0.068	0.065	0.068	0.066
C. Dependent Variable: Child Behavior Checklist - Total Score									
Stress x In utero at quake	0.0937	0.0913	0.0970	0.0701	0.0939	0.0939	0.0964	0.0979	0.0962
	(0.126)	(0.126)	(0.126)	(0.130)	(0.125)	(0.125)	(0.126)	(0.127)	(0.125)
Channel		0.103	0.0775	-0.0430	0.0958	0.121	-0.255	0.0965	-0.00866
		(0.0695)	(0.0873)	(0.0292)	(0.111)	(0.0896)	(0.185)	(0.154)	(0.00887)
Observations	1,217	1,217	1,217	1,154	1,217	1,216	1,214	1,217	1,217
R-squared	0.104	0.107	0.105	0.106	0.105	0.105	0.105	0.105	0.105

Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10. Constant not shown. Dependent variable is the standardized T-score obtained in each test. Channels are: number of complications during labor; whether the child was premature (<37 weeks), child's weight-for-height at birth (z-score); whether the mother smoked, drank alcohol, or consumed recreational drugs during pregnancy; whether the child attended formal child care (% months since birth); and the number of months the mother worked in the 6 months after the earthquake. Additional controls (not shown): Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (Chilean pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 7. Maternal Stress and Early Childhood Development: Alternative channels

	Dependent Variable:							
	Labor Complic.	**Premature**	**Weight at birth**	**Smoked**	**Alcohol**	**Drugs**	**Childcare**	**Worked after 27F**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Stress x In utero at quake	0.0257	0.00706	0.00911	-0.0180	-0.0105	0.00820	-0.0296*	0.217
	(0.0470)	(0.0259)	(0.0919)	(0.0244)	(0.0272)	(0.00985)	(0.0155)	(0.271)
Observations	2,081	2,081	1,982	2,077	2,079	2,076	2,081	2,081
R-squared	0.026	0.034	0.042	0.056	0.031	0.022	0.045	0.218

Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10. Constant not shown. Channels are: number of complications during labor; whether the child was premature (<37 weeks), child's weight-for-height at birth (z-score); whether the mother smoked, drank alcohol, or consumed recreational drugs during pregnancy; whether the child attended formal child care (% months since birth); and the number of months the mother worked in the 6 months after the earthquake. Additional controls (not shown): Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (Chilean pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 8. Effect of Maternal Stress on Early Childhood Development Tests: TADI

	TADI Tests				
	Total	**Cognition**	**Motor skills**	**Language**	**Socio-emotional**
VARIABLES	(1)	(2)	(3)	(4)	(5)
Stress x In utero at quake	-0.0910	-0.168*	-0.0720	-0.0186	-0.0112
	(0.0844)	(0.0891)	(0.0887)	(0.0870)	(0.0808)
Observations	2,062	2,062	2,072	2,072	2,072
R-squared	0.065	0.054	0.044	0.055	0.070

Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10. Constant not shown. Dependent variable is the standardized T-score obtained in each test. Additional controls: Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and low score on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 9. Effect of Maternal Stress on Child Behavior Checklist (specific areas)

	Total	Internal.	External.	Reactivity	Anxiety/ Depression	Somatic complaints	Withdrawn	Attention problems	Aggressive behavior	Sleep problems
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Stress x In utero at quake	0.0937	0.0473	0.0905	1.325	2.086	-1.530	1.765	3.885*	-0.289	2.596
	(0.126)	(0.137)	(0.126)	(2.443)	(2.523)	(2.383)	(1.835)	(2.076)	(2.250)	(1.882)
Observations	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217
R-squared	0.104	0.091	0.090	0.072	0.118	0.075	0.048	0.067	0.096	0.092

Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10. Constant not shown. Dependent variable: Child behavior problem (standard deviation of percentile in distribution of problem area). Additional controls: Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 10. Effect of Maternal Stress on Early Childhood Development - by Trimester of Pregnancy at time of shock

In-utero Maternal stress during:	Battelle Test	TADI Tests					Child Behavior Check List Test[1]							
		Total	Cognition	Motor skills	Language	Socio-emotional	Total	Reactivity	Anxiety/ Depression	Somatic complaints	Withdrawn	Attention problems	Aggressive behavior	Sleep problems
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
1st Trimester	-0.227*	-0.106	0.0569	-0.0273	-0.138	-0.199*	0.143	0.621	1.901	1.871	-0.259	4.351**	2.650	2.506
	(0.117)	(0.115)	(0.128)	(0.126)	(0.121)	(0.110)	(0.102)	(2.054)	(1.943)	(2.083)	(1.838)	(1.786)	(2.016)	(1.718)
2nd Trimester	-0.0590	-0.0292	-0.138	-0.00363	-0.00371	0.0617	0.117	1.252	1.695	0.314	1.991	-1.166	0.904	4.738**
	(0.0983)	(0.137)	(0.136)	(0.117)	(0.140)	(0.116)	(0.144)	(1.850)	(2.192)	(2.157)	(1.751)	(2.091)	(2.445)	(1.925)
3rd Trimester	-0.0158	-0.0199	-0.0868	0.0402	0.0814	-0.117	0.222*	2.408	3.663*	-0.738	0.0354	3.481**	2.655	2.205
	(0.0810)	(0.104)	(0.0999)	(0.106)	(0.103)	(0.0973)	(0.114)	(1.910)	(2.160)	(1.999)	(1.854)	(1.632)	(1.769)	(1.565)
Observations	865	917	917	919	919	919	917	917	917	917	917	917	917	917
R-squared	0.226	0.105	0.087	0.075	0.117	0.100	0.108	0.075	0.124	0.078	0.058	0.081	0.110	0.093

[1]: Battelle, TADI and Child behavior aggregate tests measured as standardized T-scores. Specific child behavior problems measured as percentile of problem distribution.

Robust standard errors in parentheses. Errors clustered at the municipality level. *** p<0.01, ** p<0.05, * p<0.10. Includes children whose mothers were pregnant at time of earthquake. Constant not shown. Additional controls: Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 11. Effect of Maternal Stress on Early Childhood Development - By Household's Income Level

	Battelle Test	TADI Tests					Child Behavior Check List Test[1]							
In-utero Maternal stress during:		Total	Cognition	Motor skills	Language	Socio-emotional	Total	Reactivity	Anxiety/ Depression	Somatic complaints	Withdrawn	Attention problems	Aggressive behavior	Sleep problems
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Stress In Utero x Low Income	-0.209*	-0.214*	-0.320**	-0.0889	-0.0931	-0.114	0.101	2.457	0.428	-0.445	3.349	2.948	-1.429	2.626
	(0.122)	(0.121)	(0.128)	(0.132)	(0.112)	(0.101)	(0.151)	(2.675)	(2.943)	(2.810)	(2.074)	(2.478)	(2.748)	(2.230)
Stress In Utero x High Income	-0.169	0.0274	0.0161	-0.166	0.0824	0.146	0.132	3.254	1.280	0.766	-0.434	6.301**	-0.00632	3.285
	(0.120)	(0.126)	(0.135)	(0.107)	(0.124)	(0.129)	(0.183)	(3.242)	(3.503)	(3.030)	(2.657)	(2.830)	(3.256)	(2.654)
Observations	1,578	1,666	1,666	1,673	1,673	1,673	986	986	986	986	986	986	986	986
R-squared	0.083	0.079	0.067	0.054	0.065	0.075	0.107	0.085	0.118	0.088	0.060	0.071	0.100	0.100

[1]: Battelle, TADI and Child behavior aggregate tests measured as standardized T-scores. Specific child behavior problems measured as percentile of problem distribution.
Includes children in all areas. Low (High)-income: household income per capita below (above) median. Constant not shown. Additional controls: Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

Table 12. Effect of Maternal Stress on Early Childhood Development - By child's sex

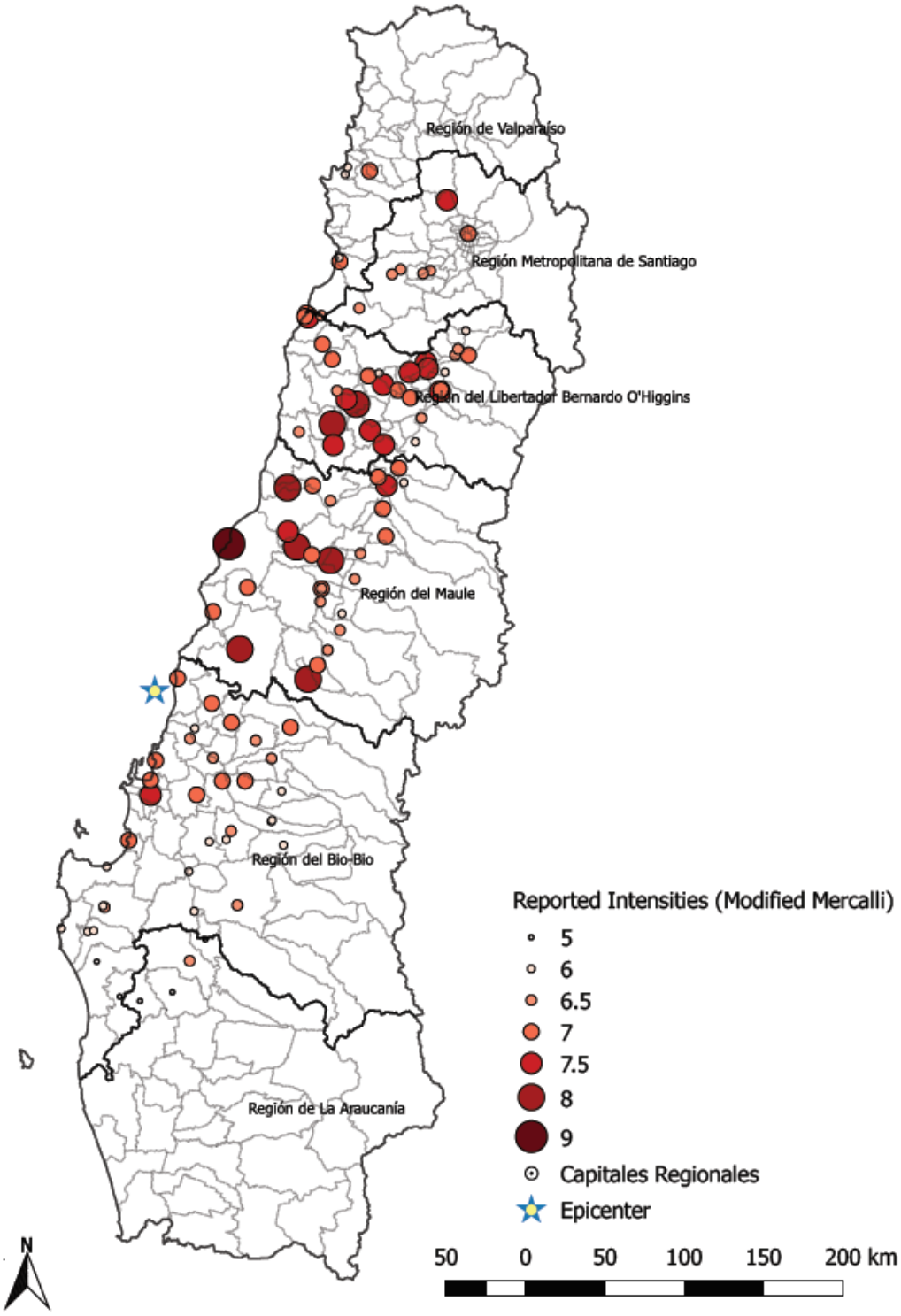
In-utero Maternal stress during:	Battelle Test	TADI Tests					Child Behavior Check List Test[1]						
		Total	Cognition	Motor skills	Language	Socio-emotional	Total	Reactivity	Anxiety/ Depression	Somatic complaints	Withdrawn	Attention problems	Aggressive behavior	Sleep problems
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Stress In Utero x Girl	-0.0992	-0.0468	-0.202**	0.00869	0.0147	0.0354	0.0638	-0.0239	2.254	-0.638	0.852	3.442	-1.752	1.842
	(0.0883)	(0.0914)	(0.100)	(0.0984)	(0.0899)	(0.0923)	(0.130)	(2.659)	(2.759)	(2.545)	(1.795)	(2.363)	(2.301)	(1.978)
Stress In Utero x Boy	-0.244**	-0.140	-0.129	-0.161	-0.0555	-0.0630	0.126	2.758	1.908	-2.479	2.735	4.355**	1.266	3.399
	(0.116)	(0.112)	(0.109)	(0.115)	(0.117)	(0.107)	(0.147)	(2.769)	(2.614)	(2.746)	(2.352)	(2.111)	(2.672)	(2.104)
Observations	1,975	2,062	2,062	2,072	2,072	2,072	1,217	1,217	1,217	1,217	1,217	1,217	1,217	1,217
R-squared	0.079	0.066	0.054	0.045	0.055	0.071	0.104	0.074	0.118	0.075	0.049	0.093	0.067	0.097

[1]: Batelle, TADI and Child behavior aggregate tests measured as standardized T-scores. Specific child behavior problems measured as percentile of problem distribution.

Includes children in all areas. Constant not shown. Additional controls: Child's: sex, birth order, and age (months); mother's: age, education, numeracy and vocabulary skills (WAIS test), and problem scores on Big Five Inventory characteristics (extraversion, agreeableness, responsibility, neuroticism, and openness to new experiences); prior mental health issues reported by: mother, father, or other close relative; total household income per capita (pesos), number of siblings; indicator for whether the child's father lives in the household; and region dummy variables.

APPENDIX 1

Figure A1.1. Reported Intensities: Earthquake of 27 February 2010, Chile.



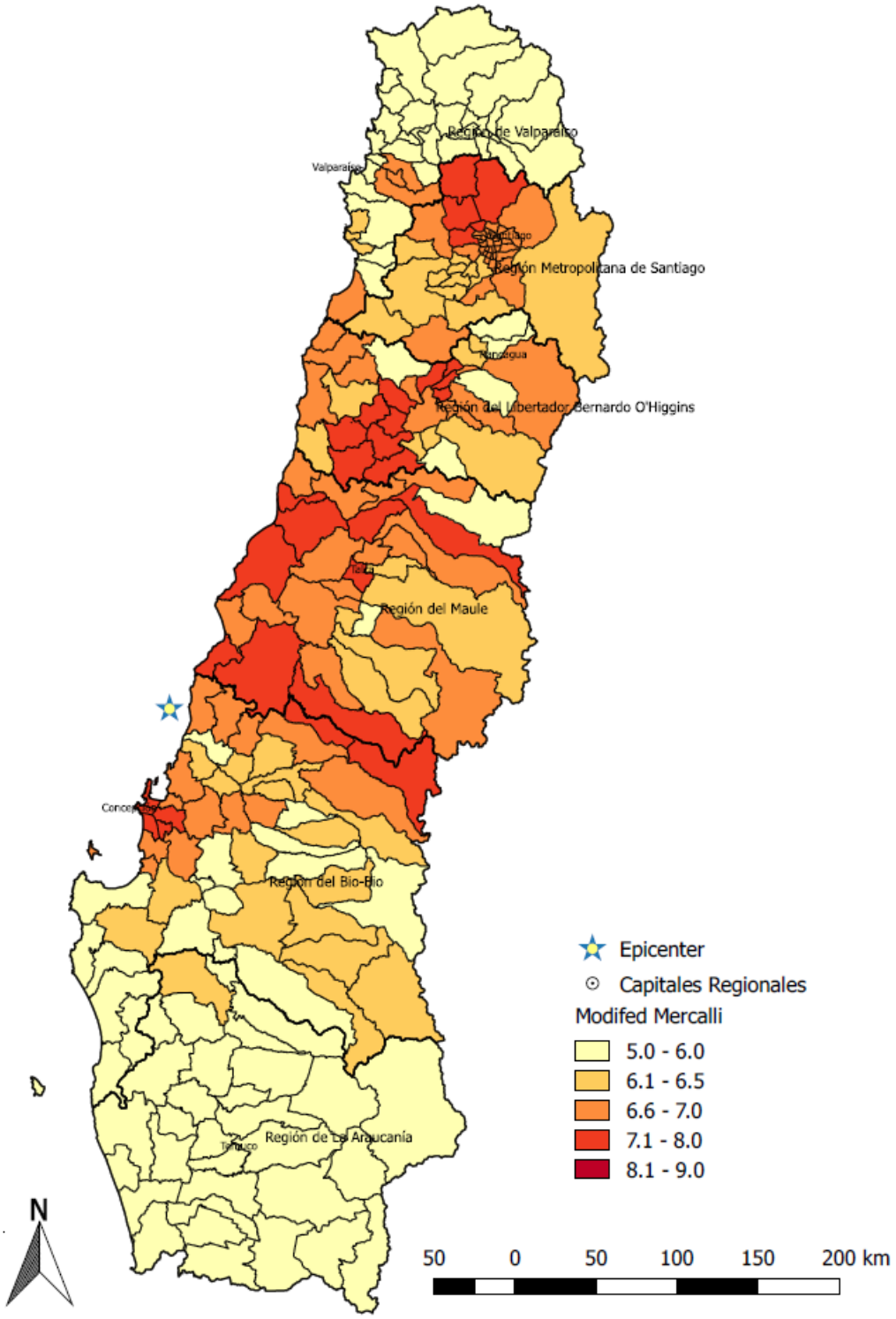
Source: Own elaboration based on Astroza et al. (2010).

Table A1.1. Description of the Modified Mercalli Intensity categories.

Intensity	Description of Shaking/Damage
I	Not felt except by a very few under especially favorable conditions.
II	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly.
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air.

Source: American Red Cross Multi-Disciplinary Team (2011). Categories are based on observation, and not measurements made by instruments.

Figure A1.2. Estimated Municipal Intensities: Earthquake of 27 February 2010, Chile.



Source: Own elaboration based on Astroza et al. (2010).

Table A1.2. Chile: Number of large magnitude earthquakes between February and August 2010 (Richter scale)

Month	5.0+	5.5+	6.0+	6.5+	7+	Total
February	162	37	12	2	2	215
March	144	27	11	4	1	187
April	17	6	2	0	0	25
May	12	2	1	0	0	15
June	7	3	0	0	0	10
July	14	3	1	1	0	19
August	6	1	0	0	0	7

Source: USGS, own calculations. Eathquakes are counted starting of the 27 February.

Figure A1.3. Number of large magnitude earthquakes between February and August 2010 (Richter scale)