Maternal Stress during Pregnancy and Early Childhood Development[1]

Matias Berthelon*
Universidad Adolfo Ibañez

Diana Kruger**
Universidad Adolfo Ibañez

Rafael Sanchez***
Universidad Adolfo Ibañez and Ministerio de Hacienda

August 2018

Abstract:

We estimate the causal impact of prenatal stress on early childhood cognitive and socio-emotional development, using exogenously-induced stress caused by a strong earthquake in Chile. We find that in-utero maternal stress affects childhood skills developed by age two. Prenatal stress reduces children's cognitive skills and increases attention problems, relative to children not exposed to in-utero stress, and the effects are heterogeneous. The negative impacts on cognition occur during the first trimester of pregnancy, are concentrated on lower-income children, and among girls; while the harmful effects on socio-emotional problems are found among high-income children and boys.

Keywords: In-utero; stress; early childhood; child development; maternal stress; maternal mental health; earthquake; Chile.

JEL Classification: J13; I10; I19

* Email: matias.berthelon@uai.cl. Address: Av. Padre Hurtado 750, Viña del Mar, Chile. Phone: (+56) 32 2503838.
** Email: diana.kruger@uai.cl. Address: Av. Padre Hurtado 750, Viña del Mar, Chile. Phone: (+56) 32 2503837.
*** Email: rsanchez@hacienda.cl. Address: Teatinos 120, Santiago, Chile. Phone: (+56) 2 28282162.

[1] We thank Camila Carrasco and Rocio Valdebenito for outstanding research assistance, as well as seminar participants at Adolfo Ibañez University, University of Chile, and Oregon State University. We thank Jere Behrman, 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 socio-emotional skills developed in early childhood have a significant impact on future adult outcomes (Almond et al., 2017). Heckman and co-authors have provided a theoretical framework to understand skill formation and its dynamics (Heckman, 2006; Cunha and Heckman, 2007; Heckman, 2007; Heckman and Masterov, 2007; Heckman et al., 2006; 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 as 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, and 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, 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).

Research has also 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 earthquakes, have negative consequences for child's

[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 socio-emotional skills, health trajectories and economic outcomes.

birthweight, cognition, physical health and schooling outcomes.[3] 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.[4] 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 socio-emotional outcomes during the first two years of life, which may have a direct effect on future wages—a channel that 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.

We contribute to this gap in the literature analyzing whether in-utero stress exposure affects 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 socio-emotional 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. The stress-inducing event was the fifth strongest earthquake in recorded history, which shook most of Chile's population on February 27, 2010 (henceforth, 27-F). Identification strategies in most papers that analyze stressful events during the in-utero period define exposure to stress using geographic proximity to the event. This approach implicitly assumes 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

[3] Lipkind et al. (2010), Eccleston (2011), Eskenazy et al. (2007), Camacho (2008), Mansour and Rees (2011), Currie and Rossin-Slater (2013), Torche (2011), Aizer et al. (2016), and Persson and Rossin-Slater (2016), Torche (2018).

[4] See among many others Breining et al. (2015), Akee et al. (2015), Bharadwaj et al. (2017), and Baker and Milligan (2016).

matched to geophysical measures of earthquake intensity). However, simply using exposure to the earthquake 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 early child development. 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.

Our identification relies on the plausibly random timing of pregnancy at the time of the stressful event. 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 whose mothers suffered stress but 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.

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 socio-emotional skills, and for which we know relatively little regarding stress exposure effects. In this way, our paper provides evidence of whether—and which specific—cognitive and socio-emotional skills are sensitive to episodes of in-utero 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

socio-emotional 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 stress do not affect birthweight, but they do affect child development at age 2.[7] Finally, since we find negative effects of stress suffered during the first trimester, our findings suggest that policy interventions focalized on pregnant women should pay special attention to early stages of pregnancy. Our findings are especially relevant to policy makers in many countries and areas of the world that have suffered or are prone to earthquakes of large magnitudes, such as most countries located in the Pacific Rim.

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

Physical health shocks

There have been many studies of the effect of in utero health shocks on children's development in the epidemiological literature, but in general these studies report correlations, are estimated from small samples with few 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. For instance, prenatal exposure to an influenza pandemic has been found to lower high school graduation and wages later in life in the U.S., while exposure to the Asian flu in Great Britain lowered academic achievement (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., 2010), whilst a cohort of Swedish children who were exposed in-utero to the 1986 Chernobyl accident

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

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) 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 it 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, particularly regarding to access to micronutrient supplements, such as iodine, iron and folic acid. They found that children exposed to better environmental conditions 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. 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 centimetres 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.

Pre-natal Maternal Stress and future outcomes

A large medical literature has studied the inter-generational effect of pregnant mothers' stress 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). 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, 2017); and an earthquake in Northern Chile (Torche, 2011; Torche, 2018). 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 new born, 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 study contributes to fill this gap in what we currently know about maternal stress effects on early childhood.

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.[8] 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 socio-emotional 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.[9] 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 this second wave of the ELPI survey and include only children who were in-utero on 27-F

[8] The Spanish name of the survey is *Encuesta Longitudinal de Primera Infancia* (ELPI).
[9] ELPI's wave 1 collected information on children born before the earthquake. They were also followed up in wave 2.

and children who were conceived after the earthquake. When the test instruments were applied in 2012, children in our sample were aged between 7 to 36 months.

3.1. Children's cognitive and socio-emotional outcomes

The tests applied to measure child development were: the Battelle Developmental Inventory (BDI); Childhood Learning and Development Test (TADI for its Spanish acronym);[10] and the Child Behavior Checklist (CBCL). The BDI screens and evaluates early childhood developmental milestones.[11] It assessed 100 items grouped in five areas: personal-social, adaptive, motor, communication, and cognitive; however only the average score for the BDI is reported in the survey. 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 along with an aggregate measure that includes the average of all four 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 to about 99 behaviors of the child, and then grouped them into seven clinical syndromes included in the Diagnostic and Statistical Manual of the American Psychiatric Association, DSM V (American Psychiatric Association, 2013). ELPI reports CBCL test results for the overall 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 BDI, 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.[12] The ELPI data did not report T-scores for each

[10] *Test de Aprendizaje de Desarrollo Infantil*.
[11] Screening Test, 2nd ed. (BDI-ST2) (Newborg, Stock and Wnek, 1996).
[12] ELPI reports normalized test scores, distributed with mean equal to 50 and standard deviation equal to 10 (denominated T-scores in the educational assessment literature).

of the CBCL syndromes; however, 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 BDI 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 tests for our final sample in 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 and shocked regions of central Chile (where about 80 percent of the country's population live). With a magnitude of 8.8 on the Richter scale it was the fifth largest earthquake ever recorded by a seismograph. 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 on 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. 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 fraction of the population, even in parts of the country that were not directly affected by it.

An important body of research has studied the consequences of natural disasters (including earthquakes) on individuals' health, including 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). 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 can 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 et al., 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.[14] With this information, we created a variable indicating maternal stress if a mother reported any of the five symptoms described above.[15]

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-affected regions:[16] 42 percent of mothers in earthquake regions experienced stress as a direct consequence of the 27-F earthquake, compared to 16 percent in non-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.[17]

[14] 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).

[15] We did not consider the response "Other symptoms" because it did not allow us to identify stress related symptoms in a precise way.

[16] Chile is divided into 15 administrative regions. Following Astroza et al. (2010), we classified regions V, VI, VII, VIII, IX and XIII (Metropolitan region) as earthquake regions because the intensity of the earthquake was at least 5.0 on the Mercalli scale; non-earthquake regions were I, II, III, IV, X, XI, XII, XIV, XV.

[17] 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.

4. Methodology

Our aim is to estimate the effect of maternal stress during pregnancy on children's cognitive and socio-emotional outcomes. Previous analyses approximate maternal stress with geographic exposure shocks and estimate relationships such as the following:

$$y_i = \alpha_0 + \alpha_1 IU_i + \alpha_2 S_i + \alpha_3 (S_i \times IU_i) + M_i\delta + C_i\beta + F_i\theta + u_i \qquad (1)$$

where y_i is the outcome of child i; IU_i is a binary variable that is equal to 1 if the child was in-utero during the shock;[18] and S_i is a binary variable indicating whether the mother lived in the area exposed to the stress-inducing shock. Identification of the effect of in-utero stress comes from the interaction term, and α_3 is the difference-in-difference estimator.

Measuring stress as geographic exposure in equation (1) assumes that mother's stress (which we denote by h_i) is a reaction to the earthquake, and that this reaction is the same for all individuals exposed to the shock. This can be expressed as

$$h_i = f(S_i) \qquad (2)$$

In most of the literature, this relationship is binary and defined based on geographic proximity or residence in an affected area. This specification has several assumptions. First, it assumes that all women in the area of the shock are affected. Second, it assumes that the shock has the same intensity for all women in the affected area, and third, that women in areas not affected by the shock did not suffer stress. These three assumptions can be easily violated, as it is possible that women in the affected area do get not stressed; some shocks vary in their intensity—such as earthquakes—and women exposed to higher magnitudes are more likely to suffer stress; and finally, women living in non-affected regions may also suffer from stress induced by the shock, or they may have migrated.[19]

A more flexible specification that allows for heterogeneous responses to the same event, including being stressed in areas not affected by the shock, could take the following form:

$$h_i = f_i(S_i) \qquad (3)$$

[18] As was previously discussed, the earthquake was followed by a period of frequent and strong aftershocks, so instead of a single date, we define the earthquake episode beginning on the 27th of February and ending on March 31, which is the period with the greatest concentration of high-intensity earthquakes. We consider children to be in-utero if their mothers were pregnant during the earthquake episode. We estimate the date of conception from the date of birth and weeks of gestation at birth.

[19] For instance, from worrying about family members or friends that live in affected areas.

where individuals may respond differently to the same event. Our empirical strategy uses this specification, and estimates a reduced-form model in which maternal stress is measured directly at the individual level. In our setting, stress was exogenously induced by the 27-F earthquake, and each woman responded differently to the same event. We have information on individual, self-reported her stress symptoms for women throughout Chile (in all areas, affected and not affected by 27-F). Our identification strategy relies on the random timing of women's pregnancies around the date of the earthquake.[20] We estimate the in-utero effects of exogenously-induced stress by comparing outcomes of children who were exposed to maternal stress while in-utero, with outcomes of children whose mother suffered stress but who were conceived after the stressful event.

The reduced form model that we estimate in this paper that incorporates heterogeneous responses to the shock reflected in equation (3) is the following:

$$y_i = \alpha_0 + \alpha_1 IU_i + \alpha_2 h_i(S_i) + \alpha_3 (h_i(S_i) \times IU_i) + M_i\delta + C_i\beta + F_i\theta + u_i \qquad (4)$$

The interaction between maternal stress and being in-utero on 27-F allows us to estimate the differential effect of pre-natal maternal stress on child development. Our parameter of interest is α_3 which is interpreted as the in-utero effect on child development due to the maternal stress actually induced by the earthquake episode. To the best of our knowledge, this is the first study to measure shock-induced stress directly, and to thereby account for individual heterogeneity in mothers' susceptibility to stress.

Our estimations also control for mother (M_i), child (C_i), and family/household characteristics (F_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-specific 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

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

incorporate a series of regional dummy variables to control for systematic differences across the fifteen administrative regions of the country.

The source of mothers' stress in our model is, specifically, the 27-F earthquake. Thus, the identifying assumptions of our reduced-form model are that the date and location of the earthquake and the timing of pregnancies are uncorrelated with observed and unobserved characteristics of the child or her family. Although we cannot test our assumption directly, Table 1 (columns 4 through 9) reveals that maternal, child and household characteristics are not significantly different between earthquake and non-earthquake-affected regions, nor between children who were in-utero on 27-F or conceived afterwards. Furthermore, the 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 decisions based on the earthquake.

We believe our assumption of orthogonality to unobservables is reasonable because first, earthquakes are 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 fault off the coast and 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.

Is mothers' stress exogenous?

A threat to identification would occur if reported earthquake-induced stress is correlated to mothers' unobserved characteristics. We cannot examine this directly, but we can assess whether the self-reported measure of stress is induced by the earthquake, and whether it is sensitive to the inclusion of other characteristics. In Table 3 (column 1) we report the estimated effect of the 27-F earthquake on the probability that a mother suffers from earthquake-induced stress. We find that living in an earthquake region had a positive and highly significant effect on reported maternal stress (column 1 of Table 3).

Another potential threat to identification is that the earthquake occurred in areas where women were more likely to experience stress, or areas with higher (lower) socio-economic conditions that can affect stress. If earthquake intensity is unrelated to these variables, its measured effect will be robust to the inclusion of such variables in the regression. In Columns 2

and 3 of Table 3, we incorporate antecedents of mother and family members' mental health (as a proxy for stress susceptibility) and socio-demographic conditions, respectively; we find that the impact of the earthquake is robust to inclusion of these variables.

As with every natural disaster, there may be several mechanisms though which the disaster causes stress or mental health problems, such as decline in income, loss of employment, physical health problems, 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 also included questions regarding individuals' mental health—specifically, on their stress level.[22]

Table 4 reports statistics on key variables before and after the earthquake, in affected and non-affected regions. Although no mental health questions were included in the 2009 CASEN, we find that post-earthquake, mental health was worse 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 similar changes 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 points lower in earthquake regions (compared to no change in unaffected regions); the magnitude of the change is relatively small.[23] In terms of health, a self-

[22] The EPT (Post Earthquake Survey for its Spanish acronym) is a household survey that was a follow up to the 2009 national CASEN survey. The EPT was implemented in April 2010 (about one month after the earthquake) on a sub-sample of the CASEN households surveyed in 2009. The EPT included questions regarding the frequency and intensity of 17 stress symptoms as a direct consequence of the 27-F earthquake.

[23] Given the relevance of the labor market for mental health (Powdthavee and Vernoit, 2013; Layard, 2013; Kronenberg et al., 2015) we analyzed the impact of the earthquake on labor market outcomes in the CASEN-EPT dataset, and found no significant changes in occupations by region; 1.8% of the individuals lost their job and 1.3% of the individuals did not search for a job because of the earthquake; 88% of individuals reported working in the same job, 11% changed job for other reasons, and 0.9% changed jobs because of the earthquake. Although 17% of workplaces were affected by the earthquake, two thirds report minor damages.

reported index of general health shows no major changes after the earthquake, and only 2.7% of the individuals reported health problems due to the earthquake.

Another, source of stress, housing quality, shows a minor deterioration in regions not affected by the earthquake, and no changes in earthquake regions.[24] Finally, income is higher in non-affected regions, although both regions experienced similar decreases in income (with a smaller decline in earthquake regions).[25] These relatively minor changes in socio-economic, health, and infrastructure variables cannot explain the large differences in mental health indicators observed, suggesting that the differences in stress where most likely due to the direct exposure to a forceful, stress-inducing shock, and not to indirect effects of the earthquakes 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, 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 (earthquake-induced) stress during pregnancy harms early childhood development as measured by the BDI test score, with a reduction of 0.17 standard deviations (column 1 of Table 5). The point estimate for the TADI test indicates a negative effect (column 2), whilst the effect on the CBCL test is positive (column 3), which means that in-utero stress caused more behavior problems. Neither of these results are statistically significant.

[24] 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.
[25] Wages are higher in regions not affected by the earthquake due to concentration of mining activity in these areas.

Results for children in earthquake-affected areas in columns (4) through (6) are similar to the general results; henceforth, we will present and discuss results for all children only.[26]

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. Children in-utero on 27-F episode have higher scores on the TADI test, perhaps because those children are older. Most other control variables have the expected relationship with early childhood development. It is interesting to note that children whose mother has 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 socio-emotional 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.

Potential Alternative explanations

The earthquake likely affected mothers in many ways, so that our measure of maternal stress may indirectly capture other effects of the earthquake that may have impacted early childhood development. We explore whether alternative (indirect) channels might explain our results. The 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 incorporated 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 directly affected by in-utero stress from 27-F.

[26] All tables include all children; results for earthquake areas are similar, available upon request.

The results of the first approach are summarized in Table 6. As a baseline, in Column 1 we present the estimated effect of in-utero stress without including any of the alternative channels (i.e., the same coefficient as column 1 of Table 5); we omit the coefficients of all the other control variables. Next, we display the coefficients of the effects of in-utero stress and each alternative channel we analyze (columns 2 through 9). The alternative channels we explored (due to data availability) 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; childcare take-up after birth; and mothers' months of employment during the 6 months after the earthquake. The dependent variables in Table 6 are: the BDI test (Panel A), the TADI test (Panel B), and the average CBCL (Panel C).

If the 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. We find that this is not the case: in all Panels of Table 6, we find that the estimated effects of in-utero stress are robust to the inclusion of these measures, suggesting that the estimated effect is not correlated to other explanations. Additionally, we find that complications during labor and premature births are correlated with lower childhood development measured by the BDI and TADI test (columns 2, 3 of Panels A and B). Also, we find that lower birth weight and alcohol consumption during pregnancy reduce scores on the TADI test (columns 4 and 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 channels.

The second approach to analyze the role of alternative explanations is summarized in Table 7. The dependent variable in each column is each alternative channel discussed above, and columns report the effect of in-utero stress on each of the eight alternative channels (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 is 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

Some of the tests that were applied to children in the ELPI survey are designed to measure different dimensions of their development. We analyze whether in-utero stress had an impact on specific areas of development for the two tests for which such data is available: TADI and CBCL. TADI studies four dimension of learning: cognition, motor skills, language and socio-emotional competencies. The CBCL test has three aggregate categories: internalization, externalization and sleep problems, with internalization including problems of emotional reactivity, anxiety/depression, somatic complaints, and autism. Externalization includes attention problems and aggressive behavior. Sleep problems are a stand-alone category. Table 8 report results of the dimensions evaluated with TADI and Table 9 the different problems measured in the CBCL.

Interestingly, although in-utero stress exposure did not affect the average TADI test performance, we find that it does have a deleterious effect in some specific areas of child development. As Table 8 shows it reduces cognitive skills by 0.17 standard deviations (column 2 of Table 8). At the same time, in-utero stress exposure 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 which period of pregnancy is more susceptible to shocks 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).

Among women who were pregnant on 27-F, we explored whether experiencing stress as a result of the earthquake had different impacts on their child's development outcomes depending on the trimester of pregnancy at the time of the earthquake episode, relative to mothers that did

not suffer stress. We present our results in Table 10, including estimates for the test averages as well as each of their dimensions (when available). 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 behavioral problems, however, they suggest that the exposure to stress during the third trimester increases behaviors associated to anxiety and depression (column 9), and attention (column 12). 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 14). 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 dimensions of childhood development differently, which could reconcile the apparent disagreement in the medical field. To draw more definite conclusions more research is needed.

Heterogeneous effects by household income

We also analyzed whether the effect of in-utero stress is different across socioeconomic levels. 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). When separating TADI estimations by dimension we find that is results are driven by the negative effect on cognition, as it is reduced by 0.3 standard deviations due to in-utero stress (column 3). In terms of behavioral problems, we find that attention problems are worsened by in-utero stress among children of high-income households (column 12 of Table 11).

Heterogeneous effects by child's sex

As a final exercise, we explored whether in-utero stress affects boys and girls differently, and report those results in Table 12. We find that pre-natal stress decreases girls' development on the cognition dimension of the TADI test by 0.2 standard deviation (column 3). For boys, we find a reduction of 0.24 standard deviations as a result of in-utero stress in their development outcomes as measured by the BDI test (column 1). The harmful effect of stress on attention problems occurred among boys only (column 12).

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.[27] The contribution by the field of economics has been 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 future adult health and education outcomes. A more recent line of research has included analyses of 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).

Less is known about the short-term effects of in-utero stress on early childhood outcomes. In this paper, we contribute to the existing literature by analyzing the impact of pre-natal stress exposure on a child's early cognitive and socio-emotional 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 heterogeneous individual responses to the same phenomena. Our data includes mothers' actual (self-reported) 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,

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

mothers' cognitive and socio-emotional 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 by the Child Behavior Checklist. Our data allows us to rule out that 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 BDI test and increases their attention problems. 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 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 socio-emotional skills by age 2 are already affected by in-utero events. Furthermore, we show that these effects might 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 socio-emotional 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.

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, doi: 10.1136/bmj.f7679

Achenbach, T., and Rescorla, L. (2000) "Manual for the ASEBA Preschool Forms & Profiles". Burlington: University of Vermont, Research Center for Children, Youth & Families.

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.

Akee, R., Simeonova, E., Costello, E. J., & Copeland, W. (2015). How does household income affect child personality traits and behaviors? (No. w21562). National Bureau of Economic Research.

Almond, D. (2006) "Is the 1918 Influenza Pandemic Over? Long-term Effects of In Utero Influenza Exposure in the post-1940 US Population". Journal of Political Economy, 114(4): 672–712.

Almond, D., and B. Mazumder (2011) "Health Capital and the Prenatal Environment: The Effect of Ramadan Observance during Pregnancy." American Economic Journal: Applied Economics, 3 (4): 56-85.

Almond, D., J. Currie, and V. Duque (2017) "Childhood Circumstances and Adult Outcomes: Act II", NBER Working Paper No. 23017, January. DOI: 10.3386/w23017

Almond, D., L. Edlund, H. Li, and J. Zhang (2010) "Long-Term Effects of the 1959–61 China Famine: Mainland China and Hong Kong." In The Economic Consequences of Demographic change in East Asia, NBER-EASE Vol. 19, ed. T. Ito and A. Rose, 321–50. Chicago: University of Chicago Press.

Almond, D., L. Edlund, and M. Palme (2009) "Chernobyl's Subclinical Legacy: Prenatal Exposure to Radioactive Fallout and School Outcomes in Sweden." Quarterly Journal of Economics, 124(4): 1729–72.

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

Baker, M., & Milligan, K. (2015). Maternity leave and children's cognitive and behavioral development. Journal of Population Economics, 28(2), 373-391.

Barker, D. J. (1998). In utero programming of chronic disease. Clinical science, 95(2), 115-128.

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.

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

Bharadwaj, P., Lundborg, P., & Rooth, D. O. (2017). Birth weight in the long run. Journal of Human Resources, 0715-7235R.

Breining, N., Daysal, M., Simonsen, M., and Trandar, M. (2015) Spillover Effects of Early-Life Medical Interventions. IZA Working paper, 9086.

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.

Carr V., T. Lewin, R. Webster, 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 (2007) "The Technology of Skill Formation." American Economic Review, 97 (2): 31-47. DOI: 10.1257/aer.97.2.31

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.

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

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.

Field, E., Robles, O., & Torero, M. (2009). Iodine deficiency and schooling attainment in Tanzania. American Economic Journal: Applied Economics, 1(4), 140-69.

Fukuda, S., K. Morimoto, K. Mure, and S. Maruyama (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. J. (2006). Skill formation and the economics of investing in disadvantaged children. Science, 312(5782), 1900-1902.

Heckman, J. J., Stixrud, J., and 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.

Heckman, J. J. (2007). The economics, technology, and neuroscience of human capability formation. Proceedings of the national Academy of Sciences, 104(33), 13250-13255.

Heckman, J., and Masterov, D. (2007) “The Productivity Argument for Investing in Young Children”. Review of Agricultural Economics, 29(3), 446-493.
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.
Kelly, Elaine (2011) “The Scourge of Asian Flu: in utero Exposure to Pandemic Influenza and the Development of a Cohort of British Children.” Journal of Human Resources, 46(4): 669-694.
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". IZA Journal of Labor Policy, 2(2): 1—16.
Lee, C. (2014) “Intergenerational Health Consequences of In Utero Exposure to Maternal Stress: Evidence from the 1980 Kwangju Uprising.” Social Science & Medicine, 119(C): 284-291.
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.
Newborg J., J. Stock, and 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”. Labour Economics, Volume 24, Pages 253—263.
Quintana-Domeque C, Ródenas-Serrano P. (2017) “The hidden costs of terrorism: The effects on health at birth.” Journal of Health Economics, 56:47-60. doi: 10.1016/j.jhealeco.2017.08.006.

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.

Torche, F. (2018) "Prenatal Exposure to an Acute Stressor and Children's Cognitive Outcomes". Demography. https://doi.org/10.1007/s13524-018-0700-9

Wadhwa, P., C. Dunkel-Schetter A. Chicz-DeMet, M. Porto, and 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, and 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.

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

				Regions:						
	All			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:										
BDI 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 Experience in BFI (fraction)	1975	0.08	0.28	419	0.07	0.26	1556	0.09	0.28	

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

				Regions:					
	All			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 exposure and Maternal Stress (2012)

	Dependent variable: Maternal stress		
Variables	(1)	(2)	(3)
Earthquake region	0.255	0.255	0.258
	(0.0444)	(0.0434)	(0.0437)
Prior mental health issues (mother)		0.120	0.0927
		(0.0324)	(0.0326)
Prior mental health issues (father)		-0.00420	0.00255
		(0.0783)	(0.0728)
Prior mental health issues (relative)		0.0259	0.0314
		(0.0305)	(0.0303)
Total household income per capita ($)			-1.84e-07
			(6.45e-08)
Number of siblings			0.000898
			(0.0132)
Father lives in household			0.0341
			(0.0262)
Mother's age (years)			0.000747
			(0.00162)
Mother's education (years)			-0.00741
			(0.00404)
Mother-Low Numeracy Skills			0.000148
			(0.0243)
Mother-Low Vocabulary Skills			0.0555
			(0.0237)
Mother-Low Extraversion (BFI)			-0.0397
			(0.0257)
Mother-Low Agreeableness (BFI)			-0.00999
			(0.0354)
Mother-Low Responsibility (BFI)			-0.0167
			(0.0445)
Mother-Low Neuroticism (BFI)			– 0.0971
			(0.0196)
Mother-Low Openness to Experience (BFI)			-0.0347
			(0.0464)
Observations	2,081	2,081	2,081
R-squared	0.048	0.056	0.082

Source: Author's calculations using ELPI 2012 data. Constant not shown. Robust standard errors in parentheses. Errors clustered at the municipality level. Earthquake region is a binary variable that equals one if mother lives in region affected by earthquake and 0 otherwise. Earthquake regions: V, VI, VII, VIII, IX and XIII (Metropolitan region). Non-earthquake regions: I, II, III, IV, X, XI, XII, XIV, XV.

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

	Region:			
	Non-Earthquake		Earthquake	
Variables:	**2009**	**2010**	**2009**	**2010**
Mental health/stress symptoms (Frequency)	n.a.	2.3	n.a.	6.0
Mental health/stress symptoms (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 on a 0-68 point scale, based on the frequency and intensity of the following symptoms of the 27-F earthquake/tsunami: painful memories, nightmares, reliving event, memory-induced physical symptoms, avoidance of feelings or memories of the event, avoidance of activities that elicit memories of the event, cannot remember important parts of the event; and more general symptoms such as inability to enjoy every day activities, feel distant from other people, incapable of feeling sadness or affection, difficulty projecting a long and productive life, trouble sleeping, irritability, inability to concentrate, easily distracted, and/or easily frightened. All the statistics reported are for females aged 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		
	Batelle	**TADI**	**CBCL**	**Batelle**	**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 hhold 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 hhold	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)
Mother's educ (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.

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

	Channels:								
	None (Baseline)	**Labor Complic.**	**Pre-mature birth**	**Weight at birth**	**Smoked**	**Alcohol**	**Drugs**	**Child-care**	**Worked after 27F**
Variables:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				A. Dependent Variable: BDI					
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. 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.	**Pre-mature**	**Weight at birth**	**Smoked**	**Alcohol**	**Drugs**	**Child-care**	**Worked after 27F**
Variable:	(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. 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**
Variable:	(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. 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	**Interna-lization**	**Externa-lization**	**Reac-tivity**	**Anxiety/ Depression**	**Somatic complaints**	**With-drawn**	**Attention problems**	**Aggressive behavior**	**Sleep problems**
Variable:	(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. 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

		TADI Tests					Child Behavior Check List Test[1]							
In-utero Maternal stress during:	**Batelle Test**	**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]: Batelle, 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. 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 27F - 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 27F - 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]: 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. 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

	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 27F - 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 27F - 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.