

Prenatal Exposure to an Acute Stressor and Children's Cognitive Outcomes*

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Abstract. Exposure to environmental stressors is highly prevalent and unequally distributed along socioeconomic lines and may have enduring negative consequences, even when experienced before birth. Yet, estimating the consequences of prenatal stress on children's outcomes is complicated by the issue of confounding (i.e., unobserved factors correlated with stress exposure and with children's outcomes). I combine a natural experiment—a strong earthquake in Chile—with a panel survey to capture the effect of prenatal exposure to acute stress on children's cognitive ability. I find that stress exposure in early pregnancy has no effect on children's cognition among middle-class families, but it has a strong negative influence among disadvantaged families. I then examine possible pathways accounting for the socioeconomic stratification in the effect of stress, including differential exposure across socioeconomic status, differential sensitivity, and parental responses. Findings suggest that the interaction between prenatal exposures and socioeconomic advantage provides a powerful mechanism for the intergenerational transmission of disadvantage.

Keywords. Prenatal stress, cognitive ability, natural experiment, life course, child development, stratification.

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Introduction

A growing body of research has indicated that *in utero* exposures matter for individual outcomes later in life. The seminal fetal programming hypothesis suggests that developments that enable the fetus to adapt to an adverse uterine environment may result in permanent programming of developmental patterns, leading to illness and early death (Barker 1990; Barker et al. 1993). Research has shown that the prenatal period has critical developmental stages that affect later cognitive and emotional development (Nijland et al. 2008; Tomalski and Johnson 2010), which in turn could shape educational attainment and socioeconomic well-being (Knudsen et al. 2006; Palloni 2006). Although Barker's (1990:1111) conjecture that "the womb may be more important than the home" may be an overstatement, it demands an empirical investigation. This study addresses two main questions about the consequences of prenatal exposures. First, does *in utero* exposure to acute stressors shape children's cognitive ability? And second, does the effect of acute prenatal stress vary by socioeconomic status (SES)?

In this study, I focus on prenatal exposure to stress because prior research suggests, but does not prove, that stress is a key factor in explaining the negative effects of poverty and disadvantage, particularly among children (Aber et al. 1997). Poverty is associated with multiple stressors, including noise, crowding, poor housing, economic instability, higher levels of family turmoil, and violence. The continuous exposure to these stressors is claimed to put pressure on children's adaptive capacities and to be toxic for the developing brain at a stage during which neurological systems are highly plastic (McEwen and McEwen 2017; Shonkoff 2010). This hypothesis is plausible but impossible to verify using observational data. The main challenge is disentangling exposure to stress from other characteristics that are unobserved and that may affect the outcome of interest, leading to confounding. To address this challenge, I combine a natural experiment—a strong earthquake affecting a region of Chile—with an instrumental variable approach and an original longitudinal survey. By exploiting a stressor arguably allocated at random, I can isolate the effect of stress from its unfortunately common correlates.

Although most research to date has focused on noxious exposures during childhood, I extend this concern to the prenatal period based on the hypothesis that the nine months spent *in utero* are critical for later development as well as highly susceptible to the environment. Most research to date has focused on chronic stress. I shift the attention to acute stress, positing that even discrete and short-term exposure to stressors experienced prenatally can have long-term consequences. I focus on children's cognitive ability for two reasons. First, cognitive ability predicts

health, schooling, and earnings in adulthood (Heckman et al. 2006; Murnane et al. 1995), linking prenatal exposures with adult socioeconomic well-being. Second, because cognitive ability is stable since early in the life course and because it is correlated with socioeconomic advantage (Hackman and Farah 2009), it is an easy target for the misleading interpretation that it is determined only by genetic factors passed across generations.

Prenatal Exposure to Environmental Stressors: Why Does it Matter?

Because stress is a broad concept used by experts and laypeople alike, definitions are necessary at the outset. Following Kugelmass and Lynch (2014:1), stressors are defined as a “wide range of conditions, forces, and experiences with the potential to challenge the adaptive capacities of individuals.” The term *stress* describes an overarching process that begins with exposure to a stressor and ends with its manifestation, usually termed *distress*. As I discuss in detail later, this analysis examines a specific dimension of the stress process: the population-level effect of prenatal exposure to an acute environmental stressor.

The stress process is an important concern for social scientists because exposure to stressors is both highly prevalent and unequally distributed. Socioeconomic disadvantage is associated with a higher exposure to stressors and fewer resources to cope successfully (Aneshensel 1992; McLeod and Kessler 1990). Both long-term stressors (such as economic strain and discrimination) and acute stressors (such as adverse life events) have been shown to be more prevalent among the disadvantaged (Pearlin et al. 2005; Turner et al. 1995).

In the stress literature, the distinction between chronic and acute stress is relevant. Early post-war research was based on a biological stimulus response model (Dohrenwend and Dohrenwend 1970; Selye 1956). Stressors—viewed as life events and understood as discrete, directly measurable circumstances with a limited time frame—were termed *acute stressors*; examples are being laid off or being a crime victim. An alternative perspective suggested understanding stress as a long process of excessive load and fatigue, leading systems to collapse without the need of a triggering event (Wheaton and Montazer 2009). Applied to human populations, this perspective highlighted long-term exposures emerging, for example, from persistent economic disadvantage, living in dangerous neighborhoods, or racial discrimination (Pearlin 1999; Thoits 2010).

This type of persistent exposure came to be known as *chronic stressors* (Pearlin et al. 1981). Whereas acute stress came to be regarded as an adaptive and beneficial response, at least in the short term (Schneiderman et al. 2005), chronic stress came to be seen as particularly maladaptive

and toxic. Concepts such as cumulative biological risk factors (Evans et al. 2013; King et al. 2011), allostatic load (McEwen 1998; McEwen and Stellar 1993), and weathering (Geronimus 1992) highlight the wear and tear across the multiple systems of the body that result from continuous, repeated, or cumulative exposure to a number of stressors. Social sciences research has further focused attention on chronic stressors' harmfulness by showing that chronic stress has a stronger negative association with physical and mental health than acute stress and that it is more strongly stratified along socioeconomic lines (Pearlin 1989, 1999; Thoits 1983; Turner 2010; Turner and Avison 2003).

A New Understanding of Human Development and the Relevance of Acute Stress

Although a focus on chronic stress is warranted, acute stress may produce long-lasting consequences when experienced in the prenatal period for two reasons. First, as the first years of life, the prenatal period contains sensitive and critical developmental stages (Nijland et al. 2008; Tomalski and Johnson 2010). Second, because human skills develop in a hierarchical and complementary manner, later attainment builds on earlier stages (Cunha et al. 2006; Heckman 2006).

Sensitive periods are limited developmental stages in which the effect of the environment on a certain capability is stronger (Knudsen 2004). Critical stages are particularly brief and discrete sensitive periods in which the environment may have irreversible effects on a certain capability, regardless of subsequent experience (Brown 2005). The notion of a critical period suggests a window of developmental opportunity, as in the case of imprinting in animals, first and second language acquisition in humans, and critical developments of the central nervous system and the brain during early life (Rice and Barone 2000).

Although these findings suggest that prenatal exposure to acute stressors could have long-lasting consequences, they do not offer a mechanism for their persistent influence over the life course. A new hierarchical understanding of human development as characterized by self-productivity and dynamic complementarity offers such a mechanism (Cunha and Heckman 2007). *Self-productivity* refers to the facts that capabilities produced at one stage augment the skills attained at later stages and that capabilities are self-reinforcing and cross-fertilizing. For example, emotional security fosters better health, which in turn may promote learning. *Dynamic complementarity* means that capabilities acquired at one stage of the life course raise the productivity of investment at subsequent stages: for example, mastering basic math concepts makes learning more complex concepts easier. This recent understanding of human development

suggests that stress experienced before birth, even short-term, may produce enduring effects throughout the early life course. This understanding invites an empirical examination of the influence of acute stress experienced *in utero*.

The Effect of Prenatal Stressor Exposure on Childhood Outcomes.

To date, the literature on prenatal stress has focused on its effects on birth outcomes, such as low birth weight and prematurity. This focus is understandable. Birth outcomes have consequences for later health, development, and well-being (Alderman and Behrman 2006; Conley et al. 2003), and they identify the infants who are most at risk for mortality, morbidity, and developmental problems (Kline et al. 1989). Also, examining birth outcomes requires birth record data, which are easy to obtain and of high quality. In contrast, examining outcomes during childhood requires longitudinal data, a much taller order. However, birth outcomes provide only a rough indicator of a child's resources at the beginning of life. Recent studies have suggested that the influence of *in utero* stress may extend into childhood, affecting motor skills, cognitive ability, and early educational achievement and causing emotional problems (Beydoun and Saftlas 2008; Huizink et al. 2003; Van den Bergh et al. 2005; Weinstock 2008). Given the relevance of these developmental outcomes for socioeconomic well-being, these findings suggest that prenatal stress can have long-lasting consequences. To date, however, this evidence is mostly associational and invites the question about the effect of prenatal stress.

The literature highlights several mechanisms linking prenatal stress with children's cognitive development, including neuroendocrine, immune/inflammatory, vascular, behavioral, and epigenetic (Beijers et al. 2014; Beydoun and Saftlas 2008; Hobel et al. 2008). Maternal stress has been implicated in the production of so-called stress hormones, including corticotrophin-releasing hormone (CRH), adrenocorticotrophic hormone (ACTH), and cortisol in the mother, the placenta, and the fetus (Charil et al. 2010; Gutteling et al. 2006; Van den Bergh et al. 2005). Elevated levels of these stress hormones may delay nervous system maturation, diminish gray matter volume, and impair brain development (Davis and Sandman 2010; Sandman et al. 2011).

Although evidence in humans is still limited, research on nonhuman primates has suggested that stress depletes the placenta's ability to protect the fetus against noxious maternal cortisol, increasing the risk of neurological impairments (Avishai-Eliner et al. 2002; Uno et al. 1994). Stress has also been found to be correlated with decreased blood flow in the uterine artery that is crucial for fetal development (Sjostrom et al. 1997); a decline in immune function and inflammation in the mother (Beijers et al. 2014); and higher-risk health behaviors, such as cigarette smoking and

unhealthy eating (Dunkel Schetter and Glynn 2011; Lobel et al. 2008; Umberson et al. 2008). Recent research has highlighted the importance of epigenetic changes as a potential mechanism linking prenatal stress exposure to cognitive function in childhood. A growing literature suggests that epigenetic transformations—molecular transformations in gene expression that do not involve changes in underlying DNA sequence—may account for the influence of early-life environmental exposures on later health and development (Benyshek 2013; Kuzawa and Sweet 2009; Non et al. 2016; Thayer and Kuzawa 2011). Findings from animal models and, increasingly, human studies suggest that the epigenetic regulation of gene expression through processes such as methylation and histone modification could play a critical role in the programming effects of early-life stress on neural circuitry and brain development (Bock et al. 2015; Monk et al. 2012).

The timing of stressor exposure is important. Early- and mid-pregnancy stress appear to predict children's cognitive outcomes, such as cognitive ability and attention disorders. During early pregnancy, the developing brain is susceptible to alteration in its programming because neurons are still immature (Welberg and Seckl 2001), and many brain areas undergo a cascade of timed processes of neuron proliferation, migration, early differentiation, and sometimes death (Van den Bergh et al. 2005; Weinstock 2008). Subtle alterations in these processes may disturb brain development. In contrast, children's emotional problems—such as anxiety, fearfulness, aggression, and depression—appear to be more sensitive to late pregnancy exposures because the developing brain undergoes rapid growth and is particularly susceptible to a reduction in oxygen and nutrients (O'Connor et al. 2002).

Socioeconomic Stratification: Does the Effect of Prenatal Exposure to Acute Stressors Vary by Socioeconomic Advantage?

The sociological stress model situates personal experiences of stress in the broader social context, examining how position in the stratified social structure shapes exposures and responses to stressors (McLeod et al. 2014; Pearlin et al. 1981). A central implication from this model is that characteristics of the social context could moderate—that is, reduce or intensify—the influence of early exposure to stressors on later outcomes.

Although some scholars have warned us that “a child who falls behind may never catch up” (Heckman 2006:1900), individuals exposed to early insults show substantial variation. Strong evidence comes from studies of epigenetic transformations showing that postnatal experiences may have a critical moderating influence on prenatal effects (Monk et al. 2012) and from studies of orphanage-rearing showing that orphans exposed to severe adversity and deprivation experience

remarkable cognitive and emotional recovery once adopted into families (Duyme et al. 1999; Rutter 1998). These insights highlight the crucial role that the social context could play in shaping the effect of early exposures.

In this analysis, I consider whether family SES moderates the effect of prenatal exposure to an acute stressor. I hypothesize that the effect of exposure will be stronger among disadvantaged families than among their more advantaged counterparts. The literature suggests at least three mechanisms that could account for a stronger effect among poor families: differential exposure, differential sensitivity, and differential parental responses.

Differential Exposure

Socioeconomic advantage may shape the ability of families and communities to protect themselves from environmental stressors such as natural disasters, armed conflict, pollution, and violence. Many factors could result in poor families' greater exposure to environmental stressors. As examples, poor families are likely to reside in more vulnerable areas and in worse-quality dwellings, and to be unable to afford temporary relocation or supplies. This variation will result in differential dosages of stress across SES, even if the stressor is nominally the same for the entire population. This variation has been conceptualized as a methodological nuisance because it violates the assumption of a homogeneous treatment effect that is necessary for causal inference (Rubin 1990; VanderWeele and Hernan 2013). However, the variation is substantively relevant, and it invites the question about differential exposure depending on individual, family, or community resources.

Differential Sensitivity

Even if exposure does not vary along socioeconomic lines, disadvantage may heighten the sensitivity to environmental stressors (McLeod and Kessler 1990; Turner et al. 1995). The theoretical approaches of allostatic load, weathering, and cumulative risk factors suggest that chronic stress emerging from socioeconomic disadvantage may act as a predisposing factor for the influence of acute stressors: that is, a novel stressor will cause more damage to an individual already debilitated by chronic exposures (McEwan and Stellar 1993). However, the opposite hypothesis is also plausible. Exposure to socioeconomic disadvantage may result in reduced reactivity to novel stressors through a protective mechanism known as "habituation," "inoculation," and "adaptation" (Eysenc 1983; Feder et al. 2009; Gump and Matthews 1999; Kirshbaum et al. 1995).

Differential Parental Responses

An emergent literature suggests that parental responses may compensate for the consequences of early-life shocks and that compensatory responses among advantaged families provide a strong mechanism for transmitting advantage across generations (Almond and Mazumder 2013; Bernardi 2014). Ethnographic research has shown that parenting approaches and practices are rooted in differential access to economic, social, and cultural resources as well as in a class-based sense of entitlement and familiarity with institutional dynamics, resulting in stratified parenting styles (Lareau 2011). As a result, upper- and middle-class parents may be more able to mobilize resources to mitigate the effect of adverse exposures. In contrast, disadvantaged parents may be more likely to concentrate on providing basic material and emotional support but have limited resources to relate to relevant institutions (such as schools) and devote less time to the explicit development of cognitive ability. Empirical evidence has provided indirect support for this claim, showing that children's birth weight has a stronger effect on later cognitive and educational outcomes among poor families than among better-off families (Torche and Echevarria 2011), and suggesting that advantaged parents compensate for the negative consequences of an earlier adverse outcome (Bernardi 2014; Conley 2004; Hsin 2012).

Stratification of stress exposure, sensitivity, and parental responses provide alternative mechanisms that would result in a stronger effect of prenatal stress exposure on children's outcomes among disadvantaged families. These factors are not mutually exclusive or exhaustive, and to the best of my knowledge, no empirical study has tested their relative importance. Although I cannot fully verify these mechanisms with the data at hand, I offer these hypotheses as an initial attempt to examine the multiple ways in which the effect of early exposures could vary by socioeconomic advantage.

Capturing the Effect of Prenatal Exposure to Acute Stressors: The Challenge of Confounding

Many studies have documented the association between prenatal stress and children's cognitive outcomes (Beydoun and Saftlas 2008; Entringer et al. 2015; King and Laplante 2005; Tarabulsky et al. 2014; Weinstock 2008). However, these studies cannot rule out the role of unobserved factors that are correlated with both stress exposure and children's outcomes. As a review of the literature candidly states, "there could be other . . . effects that account for these associations, ranging from shared genetic variance to indirect behavioral mechanisms . . . a number of potential third variables (remain) that might explain the apparent association" (Talge et al. 2007:252).

A potential strategy for addressing the challenge of confounding is the use of natural experiments—events occurring in the physical or social world that are allocated as “at random” within a particular population and thus are not correlated with unobserved maternal or ecological characteristics; a sudden economic decline, a natural disaster, or a drastic change in social policy are examples (Dunning 2012). Natural experiments have been used to study the effect of prenatal stress on birth outcomes, using stressors such as economic contraction (Margerison-Zilko et al. 2011), a natural disaster (Torche 2011), a terrorist attack (Eskenazi et al. 2007), racial discrimination (Lauderdale 2006), and an immigration raid (Novak et al. 2017). A seminal attempt to examine the effect of prenatal stress over the early life course is the Project Ice Storm, which exploits a major winter storm affecting Quebec in 1998 to assess outcomes of children exposed *in utero*. The project recruited approximately 200 exposed pregnant women and has followed their children since birth up to early adolescence (King and Laplante 2005; Laplante et al. 2008). The ice storm study provides a blueprint for further research, but it has limitations that highlight the methodological challenges of this type of study, including a small sample size, the lack of a control group, and the nonrandom nature of the sample. By combining a natural experiment with a panel survey, this study addresses these limitations and offers a study of the effect of prenatal stress over the early life course.

Methods

I exploit a strong earthquake as a natural experiment. The Tarapacá earthquake hit the northernmost region of Chile on June 13, 2005, reaching a magnitude of 7.9 on the moment-magnitude (MM) scale (considered extremely high). The use of this natural disaster as an instrumental variable for stress requires satisfying several assumptions (Angrist et al. 1996). First, the earthquake needs to occur randomly. Although the entire Chilean territory is prone to earthquakes, current technology does not predict when and where a tremor will occur. As a result, the earthquake was essentially a random exposure within the Chilean population.

Second, the earthquake needs to be correlated with stress. It is well documented that earthquakes are a source of acute anxiety, signaled by such health indicators as acute cardiac events and stroke (Dimsdale 2008; Leor et al. 1996), changes in brain function (Lui et al. 2009), and population reports of distress and anxiety following the disaster (Siegel 2000).

Third, the exclusion restriction assumption requires that the earthquake’s effect on children’s cognitive outcomes occur entirely through stress, without alternative pathways of influence. The exclusion restriction is the main reason for selecting this event from the many

disasters that have occurred around the world in the recent past. The consequences of most natural disasters are devastating and wide. They include loss of life and property, displacement, destruction of infrastructure, pollution, and creating a public health emergency, among other corollaries: think Hurricane Katrina in the United States in 2005, the 2010 Haiti earthquake, or the 2011 Tōhoku earthquake and tsunami in Japan. In contrast, the Tarapacá earthquake had few spillover effects, despite its violence. In terms of lives and property damage, the earthquake's toll was small: 11 people died, 130 were injured, 180 residences were destroyed, and 0.035 % of the population had to temporarily relocate to shelters (ONEMI 2005). This limited damage was the result of seismic preparedness and low population density. Chile has enforced a stringent building code for decades, and much of its infrastructure uses earthquake-proof technology (Hidalgo and Arias 1990). Low population density minimized problems associated with human concentration in disaster-affected areas. The earthquake also had little impact on employment. The unemployment rate in the June–August quarter of 2005 increased to 12 % compared with 11 % for the same quarter a year earlier; this trend was not distinct from the rest of the country. Displacement was minimal because the earthquake damaged sparsely populated rural villages most heavily, which accounted for less than 8 % of the population and less than 3 % of the births in the affected region (Earthquake Engineering Research Institute 2005). The consequences for population health in terms of acute respiratory infections and other communicable diseases were also minor. These limited spillover effects suggest that the main corollary of earthquake exposure was heightened levels of stress and anxiety.

The fourth assumption for using the Tarapacá earthquake as an instrument for stress is monotonicity: that is, the earthquake should increase stress (or have no effect) among those exposed, but it cannot increase stress for some while reducing stress for others. Despite no formal test of this assumption, it would be extremely unlikely for a strong earthquake to have reduced the amount of stress among exposed individuals. Finally, the stable unit treatment value assumption (SUTVA) states that the effect of being exposed to the earthquake or experiencing stress on any particular individual should not depend on others being exposed or experiencing stress. This “no interference” requirement is most likely violated in this setting, as it is in most social settings in which individuals are embedded in social networks of influence and interaction that could ameliorate or exacerbate the individual-level effect of exposure. I return to this assumption in the conclusions.

The instrument is defined as the intensity of the earthquake in the county where mothers resided during their pregnancy. The moment-magnitude scale measures energy released, but the modified Mercalli intensity scale evaluates the effect of the earthquake on the earth's surface,

humans, objects of nature, and human-made structures; that is, the scale evaluates the earthquake as experienced by the population. It uses a 12-point ordinal scale with the following categories: instrumental (I), feeble (II), slight (III), moderate (IV), rather strong (V), strong (VI), very strong (VII), destructive (VIII), ruinous (IX), disastrous (X), very disastrous (XI), and catastrophic (XII). This last category, which has never been observed, denotes total destruction. The Tarapacá earthquake intensity ranged from I (instrumental) to IX (ruinous). Counties with an intensity of very strong to ruinous (VII–IX) are defined as the treated area because its lower bound defines a categorical boundary at which the earthquake is felt by the entire population and damage starts occurring (Ramirez and Peek-Asa 2005). The control group is defined as counties with similar demographic and socioeconomic characteristics as the treated counties but with an earthquake intensity that is moderate or less. The control counties selected were located in the center-north region of the country.

Data

I combine data from two sources. The first source is the file of Chilean birth certificates for 2004, 2005, and 2006 established by the Chilean Ministry of Health. Each record includes information on infant and mother's characteristics as well as the mother's county of regular residence when children were born. The second data source is the Children of the Earthquake panel survey, fielded in 2013/2014, when the children were approximately age 7. Using Chilean birth registry data as a sampling frame, the Ministry of Education supplied information from the schools that the children born in the treated and control counties attended, with children's individual identities masked. A multistage sampling design was used. In the first stage, schools were randomly selected with probability proportional to size. A varying number of students within schools was then randomly selected in order to achieve a self-weighted sample. The sample size is 1,149 with 591 cases in the treated area and 558 in the control area. Importantly, randomly selected children were located and included in the sample regardless of whether they had moved since birth, thus avoiding producing a selected sample. The data collection instruments consisted of a questionnaire given to the mothers or primary caregivers and an assessment of the children's cognitive and executive function. All instruments were used with the entire sample, including both the treatment and control groups.

Dependent Variable

The main dependent variable is the children's cognitive ability, measured by the Wechsler Intelligence Scale for Children-Third Edition (WISC-III), adjusted for the Chilean context (Ramirez

and Rosas 2007). The WISC-III contains 13 subtests. Given time constraints, I use eight subtests: similarities, arithmetic, vocabulary, digit span, coding, block design, symbol search, and mazes. This subset has good properties in terms of validity and reliability (Campbell 1998; Kaufman et al. 1996). These items are combined to obtain measures of overall IQ, verbal IQ (first four subtests), and performance IQ (latter four subtests). Verbal and performance ability measures capture different domains, which are potentially affected differentially by prenatal exposures. The verbal scale focuses on language, reasoning, and memory skills, and the performance scale measures spatial, sequencing, and problem-solving skills.

Analytical Approach

I use a difference-in-differences (DID) methodology to capture the causal effect of exposure to an acute stressor at the population level, using the differences in mean outcomes over time and across treatment groups.¹ I distinguish two groups based on treatment assignment status: t_1 is an indicator variable coded 1 for children who were born in the treatment area (as determined by the Mercalli scale) and 0 for children who were born in the control area and were *in utero* during the same period as the treatment group. Given the potential importance for brain development of the timing of prenatal exposure to an acute stressor, I distinguish exposure by trimester of gestation, where d_1 , d_2 , and d_3 are indicator variables that identify exposure to the earthquake in the first, second, and third trimester of gestation, respectively.

The outcome Y is modeled by Eq. (1):

$$Y = \beta_0 + \beta_1 t_1 + \beta_2 d_1 + \beta_3 d_2 + \beta_4 (t_1 \times d_1) + \beta_5 (t_1 \times d_2) + \varepsilon, \quad (1)$$

where Y is the child's cognitive ability; β_1 is the treatment group-specific main effect, which captures differences in the outcome between treatment and control groups; and β_2 and β_3 capture changes over time in the outcome that are common to control and treatment groups. The terms β_4 and β_5 capture the effect of earthquake exposure in the first and second trimester of exposure, respectively. These terms, β_4 and β_5 , measure the difference (between treatment and control groups) in a difference (across trimester of exposure), giving the DID estimator its name; and they capture the difference in children's cognitive ability between the treatment and control groups between trimesters of exposure. By including an effect for the treatment group, the model accounts

¹ For simplicity, I refer to treatment and control groups based on exposure to the earthquake, although it should be kept in mind that the earthquake is the instrument for prenatal stress.

for any systematic differences across treatment groups that emerge, for example, due to the socioeconomic characteristics of the population, altitude, or preschool and educational institutions, which are captured by the parameter β_1 . By including an effect for timing of exposure, the model controls for any trends that may affect both treatment groups, including season of birth, the economic cycle, or any historical event affecting the entire country, which are captured by the parameters β_2 and β_3 . All models use robust standard errors clustered at the school level to account for the potential correlation of the errors within schools. Seven observations (0.6 % of the sample) contained missing values for one or more variables and were excluded from the analysis, reducing the analytical sample to 1,142.

The DID formulation requires that one of the treatment status groups and one of the timing-of-exposure groups be excluded and used as a baseline for comparing the estimation. As Eq. (1) shows, the excluded group based on treatment status is the control group, and the excluded trimester of exposure is the third trimester. As a result, the effect of earthquake exposure in the first and second trimesters is compared with that of the third trimester; I assume that there is no effect—positive or negative—associated with exposure during this period. The rationale for this decision is the aforementioned research indicating that the effect of prenatal stress on cognitive development likely emerges from early-pregnancy (and perhaps also mid-pregnancy) exposure but not from late-pregnancy exposure. If there were a negative effect associated with late-pregnancy exposure to stress, this analysis would underestimate the effect of the stressor because the third trimester of gestation, used as the baseline for comparison, would also be negatively affected by the earthquake. However, if third trimester exposure to the earthquake had a positive effect on cognitive ability, the parameter estimates for first and second trimester exposure would provide an overestimation of the negative effect because it will be compared with a positive-effect baseline. The latter possibility is extremely unlikely. There is no theoretical rationale or empirical evidence in either animal or human studies suggesting a positive effect of late-pregnancy acute stress on cognitive outcomes.²

The unbiasedness of the DID approach rests on the parallel trends assumption, which requires that there be no treatment group-specific trends that could bias the estimates of treatment effects. This assumption is highly plausible in this setting because an earthquake is a random occurrence in a national context in which the entire territory is prone to earthquakes. To

² The influence of small increases in cortisol within a normal range late in the pregnancy is subject to debate, with some studies reporting small negative effects and others reporting small positive effects (Davis and Sandman 2010; Huinzig et al. 2003).

further account for differences between the treatment or control populations as well as compositional change over time, all models include controls for mothers' and children's characteristics. Mother's characteristics were all obtained from the birth certificate to ensure their exogeneity and include mother's age, education (less than a high school diploma, high school graduate, college or more), and marital status at the time of the child's birth (married, unmarried). Children's attributes include sex, age in months at the time of test-taking, and its square. Table 1 offers descriptive statistics for the treatment and control areas.

[place Table 1 about here]

In this setting, to bias the observed effect, a systematic difference between treatment and control groups should be (1) correlated with the precise timing of exposure, (2) correlated with the outcome, and (3) uncorrelated or weakly correlated with observed controls. These conditions are implausible. Still, two sources of selectivity could emerge as a result of earthquake exposure. The first one is migration: some women might have left the area in response to the earthquake such that they would not have been observed in the treatment group. The second one is fetal loss: if acute stress had resulted in miscarriages or spontaneous abortions, some pregnancies would not be observed as births. These responses could alter the population composition of births, thus introducing selectivity. For example, healthier women leaving the area, and leaving behind their more vulnerable peers, would induce negative selectivity. Ancillary analyses, included in the online appendix (section A1), indicate that neither source of selectivity is likely to be at play in this case.

Before moving to the analysis, it is important to take stock on the attributes of this design to capture causal effects. In an ideal design, the researcher would randomly allocate stress to some pregnant women but not others in the controlled setting of an experimental laboratory, will wait for several years, and would then evaluate their children's outcomes. This strategy is naturally impossible and undesirable. I rely on a setting that provides an as close as possible parallel to the random allocation of stress in real life. Even if this design departs from the laboratory context, this natural experiment provides a naturalistic setting that overcomes artificiality concerns associated with manipulation and control. Because the treatment is measured for the population of children exposed to the earthquake and the stress response cannot be measured at the individual level, this analysis offers a reduced-form effect at the aggregate level. In instrumental variable parlance, the effect captured is an *intent to treat*—that is, the effect of experiencing the earthquake (instrument) rather than of experiencing stress (treatment).

The effect captured is an average that may contain heterogeneity across the population.

The second step of this analysis examines one crucial dimension of heterogeneity, family SES. I measure SES by mother's education, with three categories: less than high school, high school graduate, and some college or more. The effect of the stressor is evaluated separately across the three socioeconomic groups. Finally, the third step of the empirical analysis examines the potential mechanisms, identified previously, for stratifying the effect of prenatal stressor exposure: differential exposure, differential sensitivity, and differential parental responses.

Findings

The Effect of Prenatal Exposure to a Stressor on Children's Cognitive Ability

Table 2 offers models examining the effect of prenatal stressor exposure on children's subsequent cognitive ability. Column 1 shows the model for verbal ability, and columns 2 and 3 show models for performance and overall cognitive ability, respectively. Measures of cognitive ability are standardized so that parameter estimates can be interpreted using the standard deviation metric. As Eq. (1) specifies, the indicator variable identifying the treated area captures the main effect of residing in this area; the indicators for trimester of gestation 1 and 2 capture, respectively, the main effect of being exposed to the stressor in the first or second trimester of gestation (using the third trimester as the reference category). The effects of interest are captured by the interaction of the treatment group with the timing of exposure; these are presented in Fig. 1, along with 95 % confidence intervals.

Table 2 and Fig. 1 address this study's first question: Does prenatal exposure to an acute stressor have a negative effect on the children's cognitive ability? Exposure to the earthquake in the first trimester of the pregnancy results in a decline in verbal ability by 0.132 standard deviations, a decline in performance ability of 0.053 standard deviations, and a decline of 0.117 standard deviations in overall ability (effects are much smaller for second trimester exposure).³ As expected, the effect of stress exposure early in the pregnancy is negative when compared with exposure in the third trimester, but it is substantively small and fails to reach significance at the conventional $p < .05$ level. The conclusion from this analysis, then, is that the evidence is not consistent with a substantial detrimental effect of prenatal exposure to an acute stressor on children's cognitive ability.

³ There is also a significant overall difference in cognitive performance between treatment and control areas, captured by the parameter estimate associated with the treatment area. Interviews with local experts suggested that regional differences in quality of preschool and early education institutions may play a role in this baseline difference.

[place Table 2 and Figure 1 about here]

However, this analysis has proceeded with the likely naïve assumption that the effect is homogenous across the population. The second analytical step relaxes this assumption and raises the question about socioeconomic stratification of the effect of prenatal exposure to stress. To address this question, I stratify the sample by family SES as defined by the three groups outlined earlier: mothers with less than a high school diploma (33 % of the sample), who are high school graduates (40 % of the sample), or who completed some college education or more (27 % of the sample). Table 3 offers parameter estimates, standard errors, and significance tests; Fig. 2 plots the parameter estimates of interest comparing the effect of prenatal stress exposure across family SES (interaction terms between first trimester and treated area across levels of schooling in Table 3).

[place Table 3 and Fig. 2 about here]

The results show marked socioeconomic heterogeneity in the effect of prenatal stress. Although second trimester exposure has no effect on children’s cognitive ability for any socioeconomic group, the effect of first trimester exposure varies considerably by family SES. Among disadvantaged families—those in which the mother has less than a high school diploma—exposure to the acute stressor in the first trimester of gestation results in a decline in verbal ability by 0.457 standard deviations. The decline in cognitive ability reaches 0.676 standard deviations for performance ability, and 0.622 standard deviations for overall ability when comparing the difference in ability among children in the treated and control region for those exposed in the first trimester of gestation with the same difference for those exposed in the third trimester. Among more advantaged families, by contrast, the effect is indistinguishable from 0 at the $p < .05$ level and is substantively small.⁴ Figure 2 plots the focal parameter estimates and shows that the differences in the effects of prenatal stress exposure between poor families and advantaged families is significantly different from 0 for performance and overall ability (and close to significance at the $p < .05$ level for verbal ability).

Moving from statistical to substantive significance, it is important to evaluate the magnitude of the negative effect in cognitive ability among poor families. I use two benchmarking strategies. First, I compare this effect with the association between mother’s education and child’s cognitive

⁴ Substantive results remain unaltered if models include a larger set of covariates (Table A2.1 in the online appendix).

ability reported in Table 2. Based on Table 2, children of mothers with a college degree have, on average, 0.671 standard deviation higher cognitive ability compared with the children of mothers with less than a high school diploma (the reference category). The effect of acute prenatal stress exposure on children's ability among poor families is comparable with this gap in mother's education, which arguably represents a vast distance in terms of socioeconomic and cultural resources. As a second strategy, I compare the effect of prenatal stress exposure with the effect of early childhood interventions intended to boost cognitive ability. The effect of prenatal stress exposure on children's cognitive ability is comparable with the largest measured effect of renowned program interventions, including the Carolina Abecedarian Project (effect size = .620), the Perry Preschool Project (effect size = .970), the Chicago Child-Parent Centers program (effect size = .350), and the Houston Parent-Child Development Center program (effect size = .520) (Karoly et al. 2005). The effect of prenatal stress exposure on children's ability is also larger than conditional cash transfers making sizable payments to poor families in Latin American countries, including Nicaragua (effect size = .100; Macours et al. 2012) and Mexico (effect size = .110; Fernald et al. 2009). Naturally, these studies vary in design, age of measurement, and contents of the interventions. Nevertheless, they provide a general yardstick suggesting that the negative effect of prenatal stress exposure is substantial.

What Accounts for the Stratification in the Effect of Prenatal Stress Exposure on Children's Cognition?

The finding of a stratified effect in prenatal exposure to an acute stressor raises the question about the factors that account for socioeconomic stratification. Based on the literature, I propose three hypotheses: socioeconomic differences in exposure, sensitivity, and parental responses. The first hypothesis suggests that exposure to the stressor was not homogenous, but rather was more acute among disadvantaged families given the vulnerability of their residences and lack of resources. If that were the case, then what we have called heterogeneity of the effect would be an artifact of heterogeneity of exposure. To examine this possibility, I create an exposure scale. Using principal component analysis, I combine 18 indicators of earthquake impact, including whether the dwelling suffered any damage; electric power was lost; self/family member/neighbor was wounded or injured; and whether the household suffered a drop in income, had to temporally relocate to a shelter, or had to take in other people who were displaced. I use the first component as the measure of exposure. The Cronbach's alpha of the measure reaches .763, signaling acceptable reliability.

[place Table 4 about here]

Table 4 displays the mean of the exposure scale across the levels of family socioeconomic advantage, showing a substantial difference between treatment and control areas as well as very little socioeconomic variation in the treatment area. Consistent with the high level of seismic preparedness in Chile and the limited spillover effects of this natural disaster, the differences in intensity of exposure by family SES are very minor and do not reach statistical significance. This finding is thus inconsistent with the first hypothesis suggesting that SES variation in the effect of prenatal stress results from stratified exposure.

The second hypothesis indicates that the poor may be more sensitive to an acute environmental stressor because the chronic stress associated with poverty heightens their sensitivity to the novel stressor and exhausts their coping resources. To address this hypothesis, I create a stress sensitivity scale using 10 indicators based on such survey items as, “Everything brought back memories of the earthquake,” “I had difficulty sleeping as a result of the earthquake,” “I felt irritable and edgy,” and “I felt the earth was shaking permanently.” As with the exposure scale, the indicators are combined using a principal component analysis, and the first component is extracted as a measure of sensitivity (Cronbach’s $\alpha = .899$, indicating good reliability). The rationale for using this scale is that individuals who carry a greater bodily burden because of disadvantage will display stronger sensitivity to a novel stressor. As in the case of earthquake exposure, vast differences between treatment and control areas exist in the sensitivity scale, but socioeconomic differences in sensitivity to the stressor in the treatment area are slight (Table 4). Therefore, the observed pattern of effects makes it unlikely that either heightened exposure or sensitivity accounts for the stronger effect among the poor.

To test the role that intensity of exposure and sensitivity to exposure play as pathways for the effect of prenatal stressor exposure on children’s cognition, I conduct a mediation analysis, with the caveat that this analysis cannot be given a causal interpretation because the putative mediators are not randomly allocated, violating the sequential ignorability assumption (Imai et al. 2011)). Table 5 shows the result of the mediation analysis by level of family SES. The first set of parameter estimates for each level of family SES does not include any mediators and simply replicates the results of Table 3 for overall cognitive ability. Model 2 controls for the intensity of exposure using the exposure scale, and Model 3 adds a control for sensitivity to Model 2 using the sensitivity scale. As is clear from Table 5, the parameter estimates capturing the effect of prenatal stress on children’s cognitive development across family SES remain virtually unchanged after controlling for these factors. This indicates that none of these factors plays a significant role the stratification of the effect of prenatal stress

exposure.⁵

[place Table 5 about here]

Having established that the stratified effect of stress exposure is not due to socioeconomic differences in exposure or sensitivity, I offer an alternative hypothesis. Sociological and economic research has suggested that parental responses may play a role in the unequal effect of prenatal exposures if parents compensate for or reinforce what they perceive as children's early handicaps or adversity, and if such responses are stratified by SES (Almond and Mazumder 2013; Bernardi 2014; Conley 2004; Hsin 2012). Because my quantitative data do not allow testing the role of parental responses, I conduct a qualitative investigation to assess the plausibility of this potential mechanism. Given the objective of capturing socioeconomic differences, I select samples of advantaged and disadvantaged mothers who were exposed to the environmental stressor during the first trimester of gestation. I and a trained interviewer conducted 38 interviews (18 with mothers/primary caregivers with less than a high school diploma, and 20 with mothers with a high school diploma or more) in the respondent's residence or place of employment between January and November of 2015, when the children were, on average, 9 years old and attending fourth grade.

Findings from the qualitative interviews are reported in the online appendix (section A3). They show that advantaged parents continuously assess their children's strengths and weaknesses, mobilizing resources to mitigate the effect of what they perceive as their children's weaknesses and limitations (regardless of their attribution of the cause of these weaknesses), including time, money, assistance from professionals and experts, enrollment in organized activities, and close interaction with teachers and schools. Although some disadvantaged families have also resorted to the assistance of experts and educators and have requested institutional support, they face substantial barriers in terms of time, economic resources and—equally important—access to social networks and mastery of cultural resources to effectively negotiate with institutions for advantages for their children.

These qualitative findings are consistent with prior literature (e.g., Lareau 2011). Their value is not their novelty, but the fact that they offer the hypothesis that class-based parental responses provide a mechanism for the stratified effect of prenatal stress exposure on children's later development and achievement. Although this hypothesis cannot be formally tested with the data at

⁵ I also examined birth weight as a potential mediator of the relationship between stress exposure and children's cognitive outcomes, finding that it plays no mediating role (online appendix, Table A2.2).

hand, its plausibility based on prior research and the qualitative evidence invites further investigation of this potentially critical channel of stratification during the early life course.

Conclusion and Discussion

Recent scholarship has shown that the prenatal period is both consequential for later attainment and well-being and vulnerable to the environment, and suggests that in terms of individual development and attainment, “the womb may be more important than the home” (Barker 1990:1111). Prompted by these new findings, this study examines the effect of prenatal exposure to an acute environmental stressor on children’s cognitive ability as well as the stratification of that effect. To address the challenge of unobserved selectivity among women more likely to be exposed to stress, I combine a natural experiment—a strong earthquake—with a panel survey of children prenatally exposed to the earthquake and observationally similar but unexposed children constituting a control group. Findings show that prenatal exposure to an acute environmental stressor has no effect on children’s subsequent cognitive ability among advantaged families, but it has a negative effect among poor families.

This finding speaks to two alternative approaches to the effect of early-life shocks on individual development and well-being. The first approach indicates that an early shock may have lasting cumulative consequences over the life cycle, such that “a child who falls behind may never catch up” (Heckman 2006:1900). An alternative approach suggests that the effect of an initial shock will fade and disappear over time (Grossman 1972). This study indicates that both hypotheses are correct, with their plausibility dependent on family SES. Among poor families, children prenatally exposed to an environmental stressor had much lower levels of cognitive ability than comparable control children. In contrast, no effect was observed among socioeconomically advantaged families. Although it is not necessarily true that a child who falls behind never catches up, the ability to catch up depends on the family’s socioeconomic resources.

This finding raises a subsequent question about the factors accounting for the stratification of the prenatal exposure effect. I examine several mechanisms potentially accounting for stratification and find that the effect’s stratification does not emerge from stronger exposure or from heightened sensitivity among poor families. Having ruled out these hypotheses, I offer the hypothesis that stratification emerges from socioeconomic differences in parental responses. Advantaged parents might mobilize diverse resources to compensate for their children’s early disadvantage, including parental time, professional experts (such as developmental psychologists and neurologists), and private tutors. In contrast, poor parents face severe constraints in terms of time, material, cultural,

and social resources, which make compensation difficult. Although I cannot test this hypothesis at this point, this is a verifiable premise. Specifically, I invite future research to test whether class-based parental resources and styles interact with early exposure to adversity, shaping life chances in early childhood.

This analysis highlights a potentially powerful mechanism for the transmission of disadvantage across generations: poor children are more likely to be exposed to environmental stressors, and such exposure has a stronger effect on their cognitive development compared with their advantaged peers. The combination of these factors may result in cognitive gaps between poor and advantaged children very early in life. Because prenatal exposures are hard to observe, it would be easy to interpret these socioeconomic gaps as emerging from genetic or other innate attributes rather than from structural factors rooted in different access to resources. The findings reported here are especially important because stressors such as natural disasters are only one of the many form of toxic exposures faced disproportionately by the poor. It is now well documented that disadvantaged populations are more exposed to multiple environmental risks, including violence (Harrell et al. 2014), lead toxicity (Tong et al. 2000), and pollution (Bell and Ebisu 2012), all of which may induce largely invisible but cumulative damage very early in life. Whereas the literature has focused on the noxious effect of chronic stress resulting from persistent, continuous, or repeated exposure to stressors, this analysis highlights the potentially toxic effect of acute stress. The findings show empirically that exposure to acute stress, even if short-term, can have persistent consequences when experienced before birth.

Even if the combination of a quasi-experiment with a DID approach provides a safeguard against confounding, this study has a number of limitations, including the retrospective nature of the survey information, the lack of biomarkers or other direct measures of the stress response immediately after exposure to the earthquake, and the lack of additional control groups including (for example) children born before the earthquake. This study also raises additional questions. The focus is explicitly on an acute stressor rather than a chronic one. This decision was guided by the hypothesis that discrete exposures may have persistent effects when experienced during critical developmental periods. This raises the important question about interactions between acute and chronic sources of stress. Socioeconomic disadvantage, experiences of discrimination, work-related demands, or persistent family conflict are chronic stressors that can modify the effects of exposure to a novel acute stressor, either exacerbating or reducing its impact. This study offers an initial foray into this question by examining the stratification of the effect of a prenatal acute stressor by family disadvantage, representing a source of chronic stress. However, there are multiple factors that can

potentially shape responses to acute stressors and their consequences over the life course.

A further question refers to the relevant unit of analysis for the effect observed. I estimate a reduced-form effect among all women exposed to a natural disaster. This effect is likely shaped by social networks of interaction and influence connecting individuals. For example, interactions between friends or neighbors in the wake of the disaster could exacerbate fear and anxiety, magnifying the effect of stressor exposure. Alternatively, they could be the source of social support and relief, ameliorating the consequences of exposure. In methodological terms, the inability to isolate the individual-level from the community-level components of the effects is a limitation described as the violation of the stable unit treatment value assumption (SUTVA), and this assumption is required for causal inference. SUTVA requires that there should be no interference between subjects; that is, the potential outcomes of any exposed individual should not depend on other individuals being exposed to the stressor or experiencing stress (Rubin 1980, 1986). However, each individual's potential outcome due to experiencing the acute stressor is likely affected by other members of their social networks being exposed to or experiencing stress. This assumption is, therefore, virtually guaranteed to be violated in this case and in all social settings in which individuals are connected to each other through networks of interaction and influence.

From one perspective, the impossibility of separating individual- from collective-level mechanisms for the effect is irrelevant. I am not interested in the effect that an acute stressor would have on individuals in the fictitious isolation that an experimental laboratory could provide. However, this feature raises the question about the generalizability of the results. The treatment effect captured in any particular social setting might differ from that in other settings depending on the type of social networks prevalent in each case. This invites more research on the role that social networks and other macro-level process play in accounting for the consequences of stress exposure at the population level. Researchers have traditionally considered SUTVA a nuisance: the notion of interference explicitly suggests something that needs to be eradicated to capture a true causal effect. However, interference through social networks is an important substantive phenomenon in its own right, and social scientists are particularly qualified to examine the scope and dynamics of social influence contributing to observed causal effects.

The final, and perhaps the most important, question this study raises returns to a life course perspective. In an attempt to provide a dynamic account of the influence of prenatal exposures, this analysis examines children's cognitive outcomes at age 7, still early in their life course. Although this expands a literature that is largely focused on effects of prenatal exposures either at the very beginning of life (that is, birth outcomes) or very late in life (that is, later-life health and mortality),

this is just a starting point. Given that cognitive ability in childhood predicts schooling, health, and economic well-being later in life, the findings offered here call for additional research following up individual trajectories into adulthood, as the children affected engage institutions and settings beyond their families of origin, such as schools and neighborhoods. Such research is essential to further illuminate the dynamics underlying persistence and change of early disadvantage over the life course.

Acknowledgments The author thanks the Departamento de Estudios Sociológicos at Universidad Católica de Chile for implementing the fieldwork. Viviana Salinas provided outstanding assistance managing the project, and Alejandra Abufhele and Daniela Aranís provided exceptional research assistantship. The author also thanks Nicole Marwell, Carolina Milesi, Ricardo Rosas, Matt Salganik, Rachel Sherman, and Donald Treiman for their helpful comments and suggestions. This study was partially funded by the National Science Foundation (Grant SES 1023841) and the United Nations Development Program UNDP.

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Table 1 Descriptive statistics: Means (with standard deviations in parentheses) and percentage distribution of analytical variables in the treatment and control areas

	Control Area		Treatment Area	
Mother's Age	27.05	(6.77)	27.04	(6.71)
Mother Is Married	0.34	(0.47)	0.36	(0.48)
Urban Residence	0.97	(0.16)	0.97	(0.17)
Mother's Education (%)				
Less than high school	33.51		32.88	
High school graduate	41.40		39.49	
College	25.09		27.63	
Child Is Male	46.67		50.93	
Child's Age (months)	90.99	(3.55)	91.10	(3.63)
Number of Observations ^a	555		587	

^a Excludes seven observations with missing data in one or more variables used in the analysis.

Table 2 Difference-in-differences model of the effect of prenatal earthquake exposure on children's cognitive ability at age 7: Verbal ability, performance ability and overall ability

	Verbal Cognitive Ability	Performance Cognitive Ability	Overall Cognitive Ability
Trimester 1	0.203 (0.193)	0.276 (0.182)	0.264 (0.188)
Trimester 2	0.055 (0.141)	0.201 (0.139)	0.130 (0.139)
Trimester 3 (ref.)			
Treated Area	-0.281** (0.120)	-0.184 (0.124)	-0.276** (0.129)
Trimester 1 × Treated	-0.132 (0.116)	-0.053 (0.122)	-0.117 (0.117)
Trimester 2 × Treated	0.083 (0.165)	-0.031 (0.133)	0.044 (0.155)
Trimester 3 × Treated (ref.)			
Mother's Age	-0.005 (0.005)	0.001 (0.006)	-0.003 (0.005)
Mother Is Married	-0.003 (0.055)	0.067 (0.078)	0.031 (0.068)
Mother's Education Is Less Than HS (ref.)			
Mother's Education Is HS Graduate	0.337*** (0.072)	0.299*** (0.083)	0.364*** (0.078)
Mother's Education Is College	0.659*** (0.089)	0.479*** (0.097)	0.671*** (0.098)
Male	0.093* (0.056)	0.147*** (0.051)	0.136*** (0.050)
Age in Months	-0.507 (5.740)	2.471 (6.099)	0.797 (5.928)
Age in Months Squared	0.000 (0.005)	-0.002 (0.006)	-0.001 (0.005)
Constant	152.3 (1,575.0)	-656.4 (1,674.7)	-200.0 (1,626.5)
Number of Observations	1,142	1,142	1,142

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 3 Difference-in-differences model of the effect of prenatal earthquake exposure on cognitive ability at age 7 by family socioeconomic status (measured by mother's education)

	Verbal Cognitive Ability			Performance Cognitive Ability			Overall Cognitive Ability		
	Less Than High School	High School Graduate	College	Less Than High School	High School Graduate	College	Less Than High School	High School Graduate	College
Mother's Education:									
Trimester 1	-0.302 (0.325)	0.514** (0.255)	0.233 (0.359)	0.142 (0.367)	0.314 (0.307)	0.324 (0.308)	-0.147 (0.349)	0.499* (0.258)	0.308 (0.343)
Trimester 2	-0.179 (0.255)	0.023 (0.198)	0.273 (0.198)	0.141 (0.249)	0.193 (0.227)	0.191 (0.226)	-0.057 (0.262)	0.107 (0.192)	0.268 (0.191)
Trimester 3 (ref.)									
Treated area	0.002 (0.176)	-0.401** (0.167)	-0.472** (0.187)	0.273 (0.198)	-0.320* (0.162)	-0.514** (0.207)	0.123 (0.195)	-0.418** (0.174)	-0.558*** (0.206)
Trimester 1 × Treated	-0.457** (0.212)	0.044 (0.234)	0.021 (0.249)	-0.676*** (0.234)	0.187 (0.198)	0.249 (0.284)	-0.622*** (0.217)	0.117 (0.236)	0.116 (0.271)
Trimester 2 × Treated	-0.369 (0.282)	0.246 (0.211)	0.372 (0.265)	-0.335 (0.231)	0.188 (0.218)	0.032 (0.231)	-0.389 (0.275)	0.253 (0.213)	0.260 (0.258)
Trimester 3 × Treated (ref.)									
Mother's Age	0.004 (0.007)	-0.009 (0.008)	-0.008 (0.010)	-0.005 (0.008)	-0.000 (0.009)	0.015* (0.008)	0.000 (0.008)	-0.006 (0.009)	0.001 (0.008)
Mother Is Married	-0.092 (0.108)	0.151 (0.099)	-0.132 (0.093)	0.134 (0.134)	0.155 (0.134)	-0.101 (0.102)	-0.000 (0.118)	0.177 (0.117)	-0.135 (0.098)
Male	0.183 (0.111)	0.077 (0.086)	0.070 (0.104)	0.128 (0.094)	0.246*** (0.082)	0.054 (0.101)	0.190* (0.100)	0.170** (0.083)	0.076 (0.100)
Age in Months	2.234 (10.920)	12.273 (8.986)	-21.101 (13.049)	5.897 (12.364)	-1.125 (8.171)	8.159 (12.884)	3.968 (12.405)	7.776 (9.067)	-9.960 (12.127)
Age in Months Squared	-0.002 (0.010)	-0.011 (0.008)	0.019 (0.012)	-0.005 (0.011)	0.001 (0.007)	-0.008 (0.012)	-0.004 (0.011)	-0.007 (0.008)	0.009 (0.011)
Constant	-628.7 (2998.1)	-3,345.0 (2468.7)	5,821.1 (3,584.0)	-1,622.0 (3,397.1)	344.0 (2,240.8)	-2,212.4 (3,540.1)	-1,101.4 (3,406.9)	-2,101.9 (2,488.5)	2,766.0 (3,331.0)
Number of Observations	378	461	303	378	461	303	378	461	303

* $p < .05$, ** $p < .01$; *** $p < .001$

Table 4 Mean exposure and sensitivity to stressor scales by family socioeconomic status (measured by mother's education) in treated and control areas^a

	Treated Area		Control Area	
	Mean	SD	Mean	SD
Exposure Scale				
Mother's education				
Less than high school diploma	0.762	(1.013)	-0.684	(0.396)
High school graduate	0.757	(0.865)	-0.665	(0.414)
Some college or more	0.568	(0.949)	-0.699	(0.375)
Sensitivity Scale				
Mother's education				
Less than high school diploma	0.897	(0.612)	-0.856	(0.418)
High school graduate	0.848	(0.579)	-0.850	(0.450)
Some college or more	0.645	(0.696)	-0.915	(0.323)

^a Exposure and sensitivity scales based on principal component analysis of several indicators, with the first component extracted. Scales have a mean of 0 and variance of 1 by construction.

Table 5 Difference-in-differences model of the effect of prenatal earthquake exposure on children's overall cognitive ability by family socioeconomic status: No potential mediators (Model 1), controlling for earthquake exposure (Model 2), and exposure and sensitivity (Model 3)

	Model 1: No Controls			Model 2: Model 1 + Control for Earthquake Exposure			Model 3: Model 2 + Control for Earthquake Sensitivity		
	Less Than High School	High School Graduate	College	Less Than High School	High School Graduate	College	Less Than High School	High School Graduate	College
Mother's Education:									
Trimester 1	-0.147 (0.349)	0.499* (0.258)	0.308 (0.343)	-0.013 (0.358)	0.564** (0.269)	0.289 (0.341)	-0.009 (0.353)	0.551** (0.269)	0.324 (0.334)
Trimester 2	-0.057 (0.262)	0.107 (0.192)	0.268 (0.191)	0.023 (0.280)	0.152 (0.201)	0.229 (0.195)	0.028 (0.279)	0.143 (0.201)	0.252 (0.188)
Trimester 3 (ref.)									
Treated Area	0.123 (0.195)	-0.418** (0.174)	-0.558*** (0.206)	0.231 (0.283)	-0.338 (0.208)	-0.479** (0.223)	0.330 (0.377)	-0.257 (0.213)	-0.310 (0.232)
Trimester 1 × Treated	-0.622*** (0.217)	0.117 (0.236)	0.116 (0.271)	-0.557** (0.211)	0.062 (0.236)	0.170 (0.278)	-0.554** (0.218)	0.081 (0.238)	0.207 (0.286)
Trimester 2 × Treated	-0.389 (0.275)	0.253 (0.213)	0.260 (0.258)	-0.449 (0.274)	0.330 (0.232)	0.324 (0.268)	-0.463* (0.275)	0.309 (0.230)	0.315 (0.269)
Trimester 3 × Treated (ref.)									
Mother's Age	0.000 (0.008)	-0.006 (0.009)	0.001 (0.008)	0.002 (0.009)	-0.008 (0.010)	0.003 (0.009)	0.003 (0.009)	-0.008 (0.010)	0.003 (0.009)
Mother Is Married	-0.000 (0.118)	0.177 (0.117)	-0.135 (0.098)	-0.030 (0.120)	0.173 (0.129)	-0.138 (0.101)	-0.034 (0.113)	0.175 (0.128)	-0.144 (0.102)
Male	0.190* (0.100)	0.170** (0.083)	0.076 (0.100)	0.165* (0.097)	0.182** (0.089)	0.104 (0.096)	0.168* (0.097)	0.185** (0.091)	0.091 (0.095)
Age in Months	3.968 (12.405)	7.776 (9.067)	-9.960 (12.127)	0.013 (14.061)	7.392 (10.222)	-7.883 (11.827)	0.116 (13.961)	7.576 (10.234)	-6.645 (11.693)
Age in Months Squared	-0.004 (0.011)	-0.007 (0.008)	0.009 (0.011)	0.000 (0.013)	-0.007 (0.009)	0.007 (0.011)	-0.000 (0.013)	-0.007 (0.009)	0.006 (0.011)
Exposure				-0.074 (0.081)	-0.050 (0.071)	-0.089 (0.067)	-0.052 (0.068)	-0.003 (0.091)	0.013 (0.077)
Sensitivity							-0.049 (0.108)	-0.065 (0.069)	-0.136* (0.080)
Constant	-1,101.4 (3,406.9)	-2,101.9 (2,488.5)	2,766.0 (3,331.1)	-8.467 (3,863.3)	-1,993.2 (2,805.4)	2,194.5 (3,249.5)	-36.604 (3,835.9)	-2,043.9 (2,808.8)	1,855.7 (3,211.8)

* $p < .05$; ** $p < .01$; *** $p < .001$

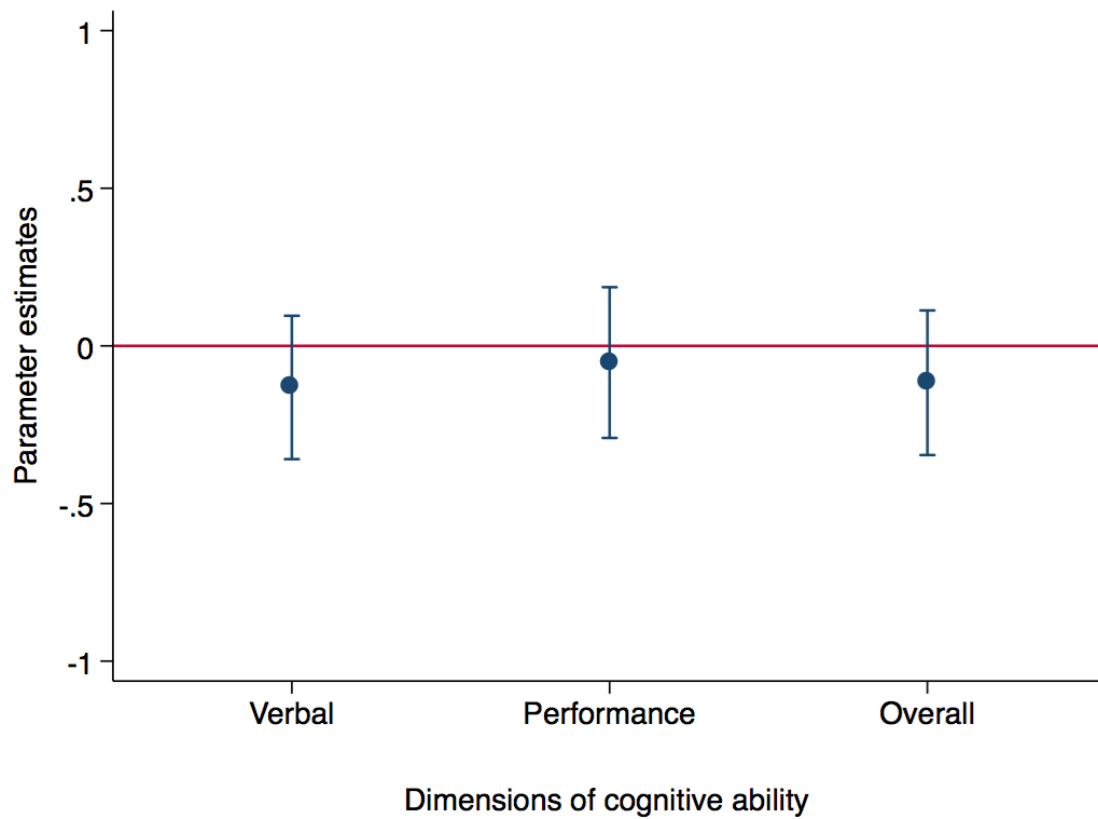


Fig. 1 Effect of prenatal exposure to earthquake in first trimester of gestation on children's cognitive ability at age 7: Verbal ability, performance ability, and total ability (WISC-III). Solid dots are parameter estimates; vertical bars are 95 % confidence intervals. *Source:* Table 2

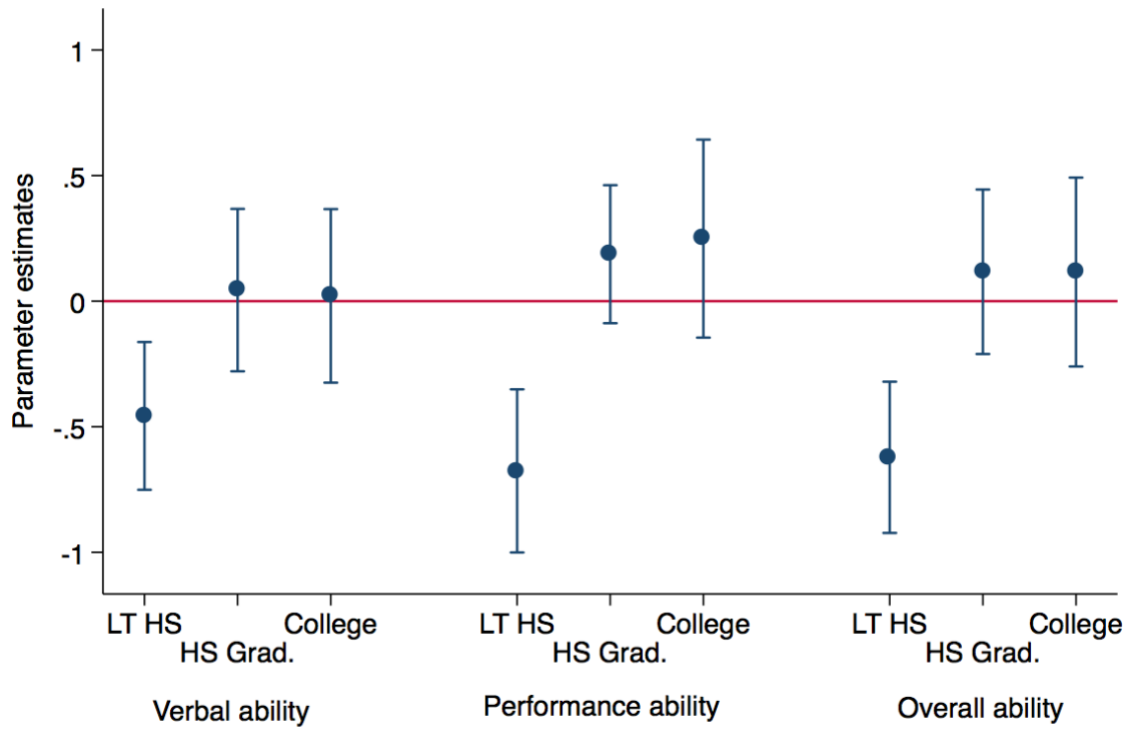


Fig. 2 Effect of prenatal exposure to earthquake in first trimester of gestation on children's cognitive ability at age 7 by family SES. LT HS: Less than high school, HS Grad.=High school graduate.

Solid dots are parameter estimates; vertical bars are 95 % confidence intervals based on tests for the null hypothesis that the difference in parameter estimates across SEs is different from 0 at the .05 level (Knol et al. 2011).

Chi-square tests for the difference in parameter estimates across family SES are as follows: (1) Performance ability_{LTHS} versus Performance ability_{HSGrad} = 7.53 ($p = .006$); (2) Performance ability_{LTHS} versus Performance ability_{College} = 5.55 ($p = .019$); (3) Overall ability_{LTHS} versus Overall ability_{HSGrad} = 4.75 ($p = .029$); (4) Overall ability_{LTHS} versus Overall ability_{College} = 4.11 ($p = .043$); (5) Verbal ability_{LTHS} versus Verbal ability_{HSGrad} = 2.30 ($p = .130$); (6) Verbal ability_{LTHS} versus Verbal ability_{College} = 2.20 ($p = .138$). *Source:* Table 3

Prenatal Exposure to an Acute Stressor and Children's Cognitive Outcomes.

Online Appendix

A1. Ancillary Analysis of Potential Sources of Selectivity in Population Exposed to the Earthquake.

The difference-in-differences approach relies on the parallel trend assumption, which requires that there be no treatment group-specific trends collinear with exposure to the earthquake that could bias the estimates of treatment effects. In this setting, two potential sources of violation of the parallel trend assumption are migration and fetal loss. Some women may have out-migrated from (or avoided immigration to) the area affected by the earthquake as a response to the natural disaster. If migratory responses were patterned by unobserved characteristics correlated with children's cognitive ability they may have altered the composition of the population exposed, inducing unobserved selectivity. For example, if women with higher cultural resources, cognitive ability, or network support were more likely to out-migrate, then the population that remained in the exposed area could be negatively selected. If, in contrast, disadvantaged women were more likely to out-migrate, then the remaining population could be positively selected. The *Children of the Earthquake* survey design accounts for out-migration after birth by locating and interviewing children randomly selected into the sample from the Chilean birth registry regardless of whether they still lived in that area or had moved away. However, if out-migration occurred between earthquake exposure and birth, the out-migrants would not be included in the sample frame.

Another potential source of selectivity is fetal loss. Research suggests that environmental stressors may induce unintended miscarriages and abortions and that the frailest pregnancies are more likely to be lost (Nakamura, Sheps, and Arck 2008). Fetal loss resulting from environmental stressors has been found to be more pronounced among male gestations (Bruckner et al. 2010, Catalano et al. 2005) and may result in an altered sex ratio at birth (Fukuda et al. 1998, Torche and Kleinhaus 2012). Prior research suggests that if the most vulnerable (and more likely to be male)

gestations had been lost, the population of surviving births could have been positively selected in terms of cognitive ability (Bruckner and Nobles 2013). In this scenario, the induced selectivity would likely result in a higher level of cognitive ability among the observed births in the treated area than it would be the case in the absence of selective fetal loss, leading us to underestimate of the negative effect of the stressor on children's cognitive ability at age 7.

While it is not possible to directly assess the impact of migratory flows or fetal loss, indirect tests can be implemented. The first strategy to do so relies on the reasoning that an increase in out-migration or fetal loss should result in a lower birth rate in the area exposed to the earthquake. To test for such decline in the birth rate, I examine the time series of the number of birth in the exposed area and evaluate whether there was a decline associated with earthquake exposure. I create a quarterly time series of the number of births from January-March of 2002 to October-December 2008. I first capture the series trend by means of a cubic basis spline function, and remove the trend component by using the residualized version of number of births net of trend. Then, I account for the seasonal fluctuation by means of a regression model. The de-trended number of births was predicted by four quarter-of-birth indicator terms, and the influence of such seasonal variation was eliminated by taking the regression residuals.

After accounting for trend and seasonality, the effect of earthquake exposure on the number of births was evaluated by means of a regression model with a set of indicator variables for each quarter of earthquake exposure (births occurring between July and September 2005, exposed in the third trimester of gestation; births occurring between October and December 2005, exposed in the second trimester of gestation; and births occurring between January and March 2006, exposed in the third trimester of gestation). If migratory responses or fetal loss resulted in a decline in the number of births, then these indicators will capture such decline. The analysis, reported in Table A1.1, shows no significant decline in number of births associated with exposure.

The second analysis examines the change in socioeconomic composition of women giving birth in the exposed area, including mother's age, the proportion of mothers who are married, and

the proportion of mothers with less than a high school diploma and with college education or more (all of them included as controls in all models). A change in the characteristics of women giving birth as a result of earthquake exposure would also signal a potential selectivity induced by out-migration and fetal loss. For example, a decline in the proportion of women with college education giving birth will indicate that highly-educated women were more likely than others to out-migrate or experience fetal loss. Table A1.2 offers a difference-in-difference analysis similar to Model 1, using each socioeconomic characteristic of the mothers as dependent variables and shows that there are no significant changes in any of the socioeconomic attributes of mothers exposed to the earthquake. In sum, analyses in tables A1.1 and A1.2 provide no evidence supporting the hypothesis that a decline in size or a compositional change induce selectivity in the population exposed to the environmental stressor.

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Table A1.1. Regression analysis of the effect of prenatal earthquake exposure on number of births in the area exposed to the earthquake. Quarterly time-series of number of births 2002-2008.

	Number of births
Birth occurring July-September 2005	-112.7 (72.64)
October-December 2005	-102.7 (72.64)
January-March 2006	-43.7 (72.64)
Constant	1,189.70*** (15.85)
Observations	28

* $p < .05$, ** $p < .01$, *** $p < .001$

Note: Time series purged from trend and seasonality (see text for details).

Table A1.2. Difference-in-differences model of the effect of prenatal earthquake exposure on mother's socioeconomic characteristics.

	Mother's age	Mother is married	Less than high school diploma	College education or more
Trimester 1	1.054 (0.661)	0.056 (0.045)	0.005 (0.055)	-0.059 (0.043)
Trimester 2	-0.447 (0.744)	0.036 (0.058)	0.002 (0.055)	0.016 (0.049)
Trimester 3 (Reference category)				
Treated area	-0.407 (0.735)	0.085 (0.048)	0.030 (0.081)	-0.012 (0.070)
Trim1*Treated	0.088 (0.999)	-0.094 (0.068)	-0.055 (0.075)	0.101 (0.068)
Trim2*Treated	1.490 (1.043)	-0.074 (0.072)	-0.068 (0.070)	0.029 (0.063)
Trim3*Treated (reference category)				
Constant	26.680*** (0.588)	0.300*** (0.036)	0.335*** (0.058)	0.261*** (0.058)
Observations	1,142	1,142	1,142	1,142

* p<.05, ** p<.01, *** p<.001

Note: Analysis is based on a linear regression model for mother's age and a linear probability model for mother's marital status, mother with less than a high school diploma, and mother with a college education or more.

A2. Additional analyses

Table A2.1. Difference-in-difference model of the effect of prenatal earthquake exposure on cognitive ability at age 7 by family socioeconomic status (measured by mother's education) and supplementary covariates.

	Less than HS	HS Graduate	College
Trimester 1	-0.287 (0.413)	0.435* (0.258)	0.174 (0.381)
Trimester 2	-0.138 (0.329)	0.089 (0.190)	0.166 (0.198)
Trimester 3 (ref. category)			
Treated area	0.025 (0.233)	-0.443** (0.174)	-0.654*** (0.196)
Trim1*Treated	-0.491** (0.217)	0.183 (0.241)	0.080 (0.276)
Trim2*Treated	-0.426 (0.316)	0.247 (0.225)	0.332 (0.269)
Trim3*Treated (ref. category)			
Mother's age	0.009 (0.014)	-0.003 (0.014)	0.009 (0.016)
Mother married	-0.038 (0.136)	0.180 (0.119)	-0.097 (0.097)
Male	0.196 (0.121)	0.195** (0.076)	0.055 (0.096)
Age in months	3.542 (15.267)	5.505 (9.646)	-8.385 (12.730)
Age in month sq.	-0.003 (0.014)	-0.005 (0.009)	0.008 (0.012)
Father's age	-0.008 (0.008)	0.000 (0.006)	0.011 (0.012)
Father less than HS (ref. category)			
Father HS graduate	0.160 (0.120)	0.414*** (0.118)	0.201 (0.299)
Father college	0.364** (0.174)	0.305** (0.125)	0.559* (0.285)
Number siblings	0.002 (0.067)	-0.085 (0.064)	-0.180** (0.068)
Urban residence	0.006 (0.210)	-0.300 (0.282)	0.132 (0.227)
Constant	984.5 (4,194.90)	1,478.00 (2,648.50)	2,329.50 (3,499.70)

* p<.05, ** p<.01, *** p<.001

Table A2.2 Difference-in-difference model of the effect of prenatal earthquake exposure on children's cognitive ability by family socioeconomic status, with controls for earthquake exposure, sensitivity, and birth weight.

	Less than HS	HS Graduate	College
Trimester 1	0.101 (0.380)	0.501 (0.302)	0.428 (0.320)
Trimester 2	-0.032 (0.280)	0.072 (0.211)	0.253 (0.188)
Trimester 3 (ref. category)			
Treated area	0.203 (0.391)	-0.195 (0.256)	-0.393 (0.259)
Trim 1 * Treated	-0.469** (0.205)	-0.101 (0.262)	0.192 (0.303)
Trim 2 * Treated	-0.307 (0.272)	0.218 (0.277)	0.316 (0.315)
Trim 3 * Treated (ref. category)			
Mother's age	0.005 (0.009)	-0.008 (0.010)	-0.000 (0.010)
Mother married	0.018 (0.108)	0.186 (0.133)	-0.127 (0.105)
Male	0.175* (0.091)	0.202* (0.104)	0.106 (0.097)
Age in months	5.559 (14.436)	15.765 (12.799)	-3.719 (11.547)
Age in months squared	-0.005 (0.013)	-0.014 (0.012)	0.003 (0.011)
Exposure	-0.052 (0.069)	0.015 (0.094)	0.018 (0.076)
Sensitivity	-0.029 (0.113)	-0.063 (0.070)	-0.116 (0.086)
Birth weight <2500 grams (ref. category)			
Birth weight 2501-3000 grams	0.862 (0.521)	-0.035 (0.246)	0.318 (0.261)
Birth weight 3001-3500 grams	0.790 (0.503)	-0.024 (0.231)	0.118 (0.296)
Birth weight 3501-4000 grams	0.694 (0.525)	-0.031 (0.225)	0.404 (0.329)
Birthweight >4000 grams	0.556 (0.531)	-0.336 (0.410)	-0.027 (0.364)
Constant	-1,530.5 (3,964.9)	-4,302.3 (3,516.9)	1,056.0 (3,173.3)

* p<.05, ** p<.01, *** p<.001

A3. In-depth Interviews with Mothers and Primary Caregivers.

Having ruled out the stratification of exposure and sensitivity to the stressor, we turn to family responses. In order to examine parental responses as a potential mechanism driving the stratification of the effect of prenatal stress, a qualitative examination based on interviews with mothers or primary caregivers was conducted. Given the objective of capturing socioeconomic differences, samples of advantaged and disadvantaged mothers exposed to the environmental stressor during the first trimester of gestation were selected. 38 interviews were conducted by me and a trainer interviewer (18 with mothers/primary caregivers with less than a high school diploma, 20 with mothers with a high school diploma or more) in the respondent's residence or place of employment between January and November of 2015, when children were on average 9 years old and attending fourth grade. Interviews lasted between 27 and 131 minutes, with an average length of 67 minutes. Interviews were recorded upon the respondent's consent, transcribed, and analyzed. The transcripts were read looking for key themes, searching for disconfirming evidence, and producing data matrices. Before offering the findings it should be stressed that the purpose of this analysis is not to provide a conclusive test of parental responses as a source of stratification. Rather, the analysis provides necessary initial assessment of the plausibility of this pathway of influence.

To preview the findings, the analysis of the qualitative data is consistent with the hypothesis of stratification of parental responses to children's attributes since birth. Advantaged parents actively assess their children's strengths and weaknesses and mobilize diverse resources including time, money, and assistance from professionals and experts to compensate for what they perceive as their children's limitations. At the same time, no evidence was found that parents allocate scarce resources among children based on their perceived ability, even when this theme was explicitly considered in the iterative interview analysis process. While most parents do perceive differences

between siblings, their responses do not appear to emerge from zero-sum calculations about how to allocate scarce resources. In general, advantaged parents mobilize diverse resources to support and nurture all their children, and disadvantaged families face substantial constraints and difficulties to compensate for potential disadvantages experienced by any of them. These findings are consistent with ethnographic approaches documenting a strong class-based patterning of parenting styles that applies to all children rather than a comparative evaluation of allocation of resources across siblings postulated by some economics theories.

The case of Karen⁶ is illustrative of advantaged families. Karen has some college education but did not finish her degree in administration because she became pregnant with Andres when she was attending university. Andres was extremely active as a child “like a little bouncing ball, every day, all day long until 1am” so much so that she attempted to enroll him in childcare when he was 11 months but had to remove him because the teacher could not keep up and he hurt himself when trying to climb some steps. As a result Karen decided to quit her part-time job as a real estate agent to take care of Andres full-time. At age 3 he “quieted down but he had difficulty paying attention in school.” Karen has marshalled different resources to support her son’s development; including switching schools to one that “fits him better.” She explains:

“until last year Andres attended The Academy (a very academically demanding school) and they told me he had concentration issues. I took him to the neurologist but did not want to give him the pills that the neurologist prescribed... then he started having problems with five boys who teased and bullied him... in the end I made the decision to switch schools... I took him to a school that has small class sizes, about 20 kids in each classroom, which is better for him.”

Karen reports that Andres is doing much better in a more “personalized environment.” Still, Andres does not like reading, so she takes a proactive approach:

Karen: “I have to sit down and study with him. I force him, I tell him: ‘Sit down and read,’ sometimes he reads well, sometimes he reads as if nobody had ever taught him how to read. *Interviewer: Have you sought out help about this issue?* Karen: I took him to an educational psychologist, he had a few sessions with her, and she told me ‘you know, your son does not have any condition; I’d say he does not have ADHD, perhaps

⁶ All names are pseudonyms.

it's just the school system that they do not teach him the way that fits him'. So I hired private tutors so that he could study with them. He paid attention to the teacher when she came, but we're not yet at a point in which he studies on his own, in which he feels that's his duty and just does it... I have to be on top of him, like 'here, Andres, your book, take it,' otherwise he does not pick it up..."

Karen spends a substantial amount of time supporting and supervising Andres, and made a conscious decision to quit her job to be available for him, which the family is able to afford because Karen's husband has a well-paid, stable job as an Armed Forces employee. She is attuned to what she perceives as Andres's specific needs and switched schools in an attempt to provide a more personalized learning environment that would fit her son's needs for additional attention.

Marcela, a teacher with a college degree, has helped her son Sebastian develop study habits since early in his school career. Currently, according to his mother, Sebastian is one of the best students in a very academically demanding school. When asked about her expectations for Sebastian, she explains

"I believe, well, I'm certain that he (and his siblings,) the 4 of them will have a college degree. For Sebastian, I think it's going to be in engineering, I don't know which kind, but I think some kind of engineering...I notice that he is able to understand, to reason, and analyze. *Interviewer: What is the dynamic like when he needs to study or do homework?* Marcela: When I'm tutoring [my clients], I have him with me so he can study, otherwise we sit on the bed and we review the material, I reinforce whatever he's learned that day. I usually download study guides from the internet or I write questions myself, because I know the type of questions he may get, but what matters to me is not just that he gets the answer right but rather that he's able to do the reasoning. We do this for every test. He has quizzes or tests every week, so we reinforce all the time."

Since early in his life Sebastian has been exposed to high expectations and has been coached to develop strong study habits. Marcela's approach was probably more systematic than other advantaged parents given that she was a teacher, but it reflects a common concerted effort by advantaged parents to develop regular study habits in their children and to be extremely involved in their study practices.

While Marcela did not report a particular difficulty or limitation that needed to be addressed with Sebastian, Jose, a basketball coach with college education, used a similar approach to address

areas that he perceived as weak in his son Gabriel (the focal child) and his daughter Catalina, who is 15 years old. The household is formed by Jose, Catalina, Gabriel, and Jose's uncle and aunt. Gabriel's parents separated when he was two years old, and his mother now lives in a nearby town. The separation was difficult for him and especially for Catalina, who was 7 years old at the time. After her parents separated, Catalina had difficulties at school, and Jose felt the teacher did not provide the necessary support. He indicates that: "regretfully, her teacher was not very good, but we switched classrooms immediately, and she got another teacher who supported her needs well." Jose felt it was his right and duty as a father to request a change because, he reports: "if [the teacher] does not give her the tools, I need to switch her so that my daughter gets the support she needs and can flourish." As to Gabriel, Jose reports a lot of collaboration among the adults in the household to support him:

"Gabriel got a [very good] GPA last semester, with some weaker points, sometimes he forgets things, but we're all helping them here at home – because if we leave them [Gabriel and Catalina] alone with the computer, the tablet, the TV, they may get lost... so we divide the work, my uncle is more in charge of my daughter, we also have a private tutor to help her, and I am more in charge of Gabriel. *Interviewer: What would you say are Gabriel's weaker points?* Language is weaker, but he reads a lot, he likes to read, so we all read here at home. Gabriel has to read a book a month, so we all read the book every month here at home to be able to help him. It's like the adults at home going back to school in a way, but we are happy to do it because we cannot leave him alone... we're firm about having a schedule and we teach him how to use his free time, for example Playstation and Xbox he cannot play on weekdays, only weekends... but he has learned good habits, he knows that there is a time to study, time to play sports, time to read, because when he does not have a test, or homework, he's reading for the test 2-3 weeks ahead, that is, we have inculcated discipline to be able to organize himself... because if he does not learn now, it is harder later, it is harder to have a study system and to be organized."

Like Marcela, Jose has taught study habits to his children from an early age, and the entire household is involved in helping the children do well in school. Jose has provided substantial support to both his children when they have needed it the most. Jose was also able to successfully interact with the school system in order to switch his daughter to another classroom when he thought it would benefit her.

A similar set of parental orientations and skills emerge in our conversation with Iris, who has some college education and works as a secretary. Iris reports that her son Max does well in school, and she jokes that when he gets a good grade “I tell Max ‘I got the good grade too,’ ... because I know all about the Greeks, the Romans, because I study with him, I have to learn too, I read his notebooks... for instance English, he has to learn a song, and I write it down phonetically for him so that he learns how to pronounce it, because I know some English, not so much spoken but rather written, so I write it down, and we both sing it until we get it.” Iris reports an incident between Max and a classmate last year. They had a big fight and after that Max became very fearful, so she enrolled him in basketball and self-defense martial arts. According to Iris, these activities have helped Max regain self-confidence. In addition to these activities, Iris had Max see a child psychologist about a month before the fighting incident

“because I am always observing Max and I noticed he was nervous, he slept well but he was nervous, like he needed to release tension, so I took him [to a child psychologist]... and right after I had taken him, this fight happened, so I brought it up with the psychologist and he helped [Max] deal with it.”

Iris was able to search for and afford professional assistance and to enroll Max in organized activities, which seems to have helped him overcome a difficult situation with potentially negative consequences. Furthermore, the interview reveals that Iris was acutely attuned to Max’s mood and demeanor, and decided to be proactive and consult an expert when she witnessed a change that elicited concern.

While some disadvantaged families have also resorted to the assistance of experts and educators, have enrolled them in organized activities to foster their development, and have taken pains to address their children’s difficulties, they face substantial barriers in terms of time, economic resources and, equally important, access to social networks and mastery of cultural resources to effectively negotiate with institutions for advantages for their children.

Esther offers an example. Esther is a 79-year-old widow who has been the primary caregiver of her grandson Jorge since 2013, when Jorge’s mother was incarcerated. Jorge lives with

Esther, who attained a 3rd grade education, two of her daughters and their partners, and four other grandchildren. Jorge's GPA has been barely above the minimum required to pass a grade every year since the first grade. Esther has become the main caregiver for five of her grandchildren given that their parents have unstable jobs and family circumstances. When asked about Jorge's grades, Esther indicates that they are "so so," and when asked if there was one subject that was more difficult for Jorge, she explained "Hum, I'm not sure, I think so, I think Math is the hardest... but he's bad at spelling, he does not get a single word." A few months ago, Jorge misbehaved at school and Esther was called to the school. When the interviewers asked what the issue was, Esther did not know the details, and said "I don't quite know, I think the physical education teacher, I don't know, [Jorge] did something wrong in physical education class, and the principal called me..." When the interviewers probed about Jorge's specific weaknesses or strengths, Esther indicated "There are so many of them [Jorge and his cousins]...nothing really... they cannot sit still, all of them, the middle one [Jorge's younger cousin] is even more restless, but none of them can sit still."

Esther made an enormous effort to collect social assistance to be able to feed, clothe, and keep her grandchildren safe. She did not, however, have the energy or educational resources to support their educational attainment or to reach out to sources of institutional support that could help them.

A particular limitation that disadvantaged families face is the limited cultural capital to interact with school personnel on behalf of their children (Lareau 2011[2003]). Rosa, who dropped out of high school in 10th grade and lives with her husband and their three children, had to remove her son Javier from the school he was attending when he was in third grade. She reports a confusing incident that made her feel tricked by the school into removing her son because he did not have good grades:

"Mid-way through the school year I realized that with the grades he had he might have to repeat the grade, so I went to the school and asked about Javier's situation, and the lady said that with these grades he was going to have to repeat the grade, so she suggested I take him out of the school so that he would not repeat, because if he

repeated they would have to expel him. But then I learned that they would have been forced by law to keep my son in school even if he had repeated the grade, so they tricked me. They had me sign a document in which I committed myself to help my child, to improve his grades, and I did not read it, I just signed it, and then they said that Javier needed to leave the school if he repeated because I had signed the document. But they didn't follow a protocol with me, they did not call me, they did not let me know about the grades, nothing. So I took him to another school. It was for the best after all because in the new school there are children who are more disorderly than Javier is, so he's not among the most unruly. Besides, Javier ended up not wanting to go to the old school because other kids bullied him, and they did nothing at the school to stop the bullying."

Even if Rosa sees advantages in the school change, she had few resources to successfully interact with school personnel at Javier's old school, and felt they had tricked her to get rid of her son. Furthermore, when her son experienced bullying she decided not to intervene directly, feeling "they were going to be more biased against my kid if I complained and made trouble," and she felt the school did not address the problem. The new school Javier is attending has a reputation for low academic standards and it may be detrimental for his educational attainment in the long term.

Selena is also constrained in her ability to help her son. She is a single mother who lives with her five children, aged 3 to 18 and works sewing and selling baby clothes. Selena reports that her son Pablo's grades dropped the prior semester. When asked why she thought this happened, she explained

"I think ... in part it's because I work and I don't have too much time for him, to study with him, and sometimes he does not take notes in class so there is nothing to study from. I know if I studied with him every day it'd be better, but I can't because he's in fourth grade now and I attended school until fourth grade so I don't know the multiplication tables, I don't remember... sometimes my daughter helps him, but she's in 12th grade and has a lot of tests ... so she does not have much time, and my other son who's 15, he has learning difficulties, he had a language disorder so he really cannot help Pablo, so I think the main issue with Pablo is the lack of support here at home."

Selena is severely constrained by her need to work long hours and her limited formal schooling, which makes it difficult for her to help Pablo, even though she knows this is an important parental role.

The case of Maria also highlights how limited resources, the need to work outside of the home and the limited understanding of the requirements for scholarly success may affect her ability to provide support for her daughter Jennifer. Maria attended school until the 8th grade. She separated from Jennifer's father two years ago and now has a new partner who lives at home but is not involved in raising Jennifer. Maria works as a security guard. Jennifer has low grades and severe behavioral issues. She has been suspended several times for talking back to the teacher, hitting a classmate, and disrupting the classroom; Maria has been called to the school at least three times in the last two months to discuss Jennifer's behavior.

Maria attempts to juggle a demanding job and a long commute of about one and a half hours each way with raising her daughter. She explains that the prior week she was called to school because Jennifer had misbehaved and they told her Jennifer was going to be suspended. Maria begged them not to suspend her because

"they wanted to suspend her for 4 days, but if she gets suspended she is on the street the whole day, because I work in the morning and I get back home in the evening. I even had to switch my shift at work to be able to be with her in the evenings. I used to work from 3pm to 11pm and got back home around 12, 12:30 at night, so I changed my shift so that she wasn't on the street all afternoon. Even the neighbors told me that she was in the street all day, and they gossiped, once I overheard them saying 'if we keep seeing this girl in the street all day, we're going to call the SENAME (Child Protective Service) so that they take her,' so I got worried and changed my shift... they are right because she's a minor so I cannot leave her home alone, but I have to work." *Interviewer: Is Jennifer part of any organized activity of workshop so that she does not have to be alone?* Maria explains that she is not, that she wanted to enroll Jennifer in the scout movement, but when the organization did not return her calls, she got tired of calling and so Jennifer just stays at home. *How do you do it when Jennifer has to study?* "Jennifer never studies for tests, I don't know how she does it, I sometimes scold her because I never see her grab a notebook to study, nothing. She tells me "I have a test tomorrow" and I tell her "Well, go study" and she says "no, what for, I already know the subject."

Maria attempts to provide the best for her daughter but lacking educational experience and overwhelmed by work and a difficult separation she does not have the resources to inculcate study habits, teach content, or successfully reach out to institutions –such as the scout movement—to find an alternative to Jennifer staying at home alone.

These vignettes are not meant to provide a conclusive answer. Rather, they test, and support, the hypothesis that parental responses are a plausible pathway for the stratification of the effect of prenatal stressor exposure on children's cognition. Two findings emerge consistently from the interviews. First, while all parents care about their children, disadvantaged parents face a myriad of obstacles –material, time, cultural, social— in their efforts to support their children when they have difficulties. Second, the interviews suggest that advantaged parents mobilize diverse resources to support their children, address their limitations, and foster their talents. However, no evidence emerged about differential allocation of resources among siblings under a zero-sum framework, either compensatory or reinforcing, in spite of systematic probing about children's differential needs and demands, allocation of time and resources among children, and tradeoffs in decision making about investments. While most parents are aware of differences between their children, they do not appear to engage in purposeful allocation of investments among them, and seem to respond to needs or issues as they emerge, to the extent that they can. More than allocation of scarce resources across siblings, parental responses appear to be substantially shaped by the time, economic, cultural and social resources they are able to mobilize on behalf of their children.