The Effects of the 2010 Haiti Earthquake on Children's Nutrition and Education

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Abstract

This paper assesses the effects of natural disasters on human capital accumulation. Using geo-coded shaking intensity data and four waves of the Haiti Demographic Health Survey we study the impact of the 2010 Haiti earthquake on children's nutrition and education. We find lasting negative impacts of the earthquake on children's stunting and wasting as well as on school enrolment and attendance. A one standard deviation increase in shaking intensity raises infant stunting by 0.08 standard deviations and wasting by 0.04 standard deviations. Our estimates account for the millions in aid funds allocated by the World Bank to overcome the earthquake's aftermath. This aid mitigated but could not fully prevent the adverse effects on children's health and education. The results are robust to alternative specifications, to different measures of exposure to the earthquake, and to controlling for selective mortality and migration patterns. Our results highlight the need for improved aid targeting to prevent infant malnutrition and poor educational outcomes after natural disasters in resource-poor settings.

Keywords: Natural disasters; earthquake; nutrition; education; school attendance; Haiti.

JEL: I15, I25, Q54, O10.

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Introduction

Global economic losses from natural disasters in 2020 were valued at USD 210 billion (Munich Re, 2021). Among these, earthquakes are by far one of the most destructive type of disasters. When earthquakes strike, thousands of people can die in a matter of seconds and many more can be severely injured. Moreover, public infrastructure, private residences and business capital can be damaged or fully destroyed over large areas. Beyond their immediate destruction and large death toll, the consequences of earthquakes can potentially last over many years. This paper focuses on such mid- and long-term detrimental effects of earthquakes by assessing the changes in children's nutrition and education following the 7.0-degree earthquake that occurred in January of 2010 in Haiti. This earthquake was the second largest one in terms of fatalities during the last 40 years.[1] The estimated death toll ranged between 222,000 (United Nations, 2011) and 300,000(Government of the Republic of Haiti, 2010a). The lower-bound estimate of monetary damages was USD 8.1 billion (Cavallo et al., 2010). The 2010 Haiti earthquake also illustrates an example of one of the biggest mobilizations of humanitarian assistance ever recorded.

The group most vulnerable to the consequences of natural disasters are children. Shocks experienced in early childhood can be carried on throughout the adult life, affecting cognitive development and skills, labour productivity, and lifetime income, which in turn produce grave repercussions for the economic well-being of a country's future population (Ho et al., 2017; Frankenberg and Thomas, 2019). Within the framework of the epidemiological theory, the fetal origins hypothesis (also known as the Barker hypothesis) states that chronic and degenerative conditions of adult health may be triggered by circumstances of the individual's early life, including in-utero nutrition (Barker, 1990).

In this paper we quantitatively assess the effects of the 2010 Haiti earthquake on human capital accumulation among children exposed to the earthquake. We add to the literature by identifying local exposure to the earthquake with both objective (shaking intensity) and subjective (reported damage) data and we also provide a novel contribution to this literature by accounting for the two billion USD World Bank aid that had been distributed after the earthquake. Moreover, we also explore the medium and longer-term effects of the earthquake by examining the persistence of the estimated negative effects on children's nutrition and education six to seven years after the shock.

To measure the disaster effects on children's nutrition, we focus on three anthropometric measures: height-for-age, height-for-weight and weight-for-age z-scores. The particular interest of this paper is stunting, which reflects short height-for-age and is a result of inadequate nutrition intake over a longer period of time. Therefore, stunting is expected to be increasing even in the mid- or long-term after the earthquake and it can be a good predictor of future adult health status. To capture the disaster effects on children's education, we focus on primary and secondary school enrolment, years of education, and current school attendance.

[1] Between 1970 and 2008 the largest earthquake registered occurred in 1976 in China with a death toll of 242,000 casualties (Spence et al. 2011).

We use data from four main sources: (i) geo-coded survey data on over 15,000 children from four different waves of the Haiti Demographic and Health Survey (DHS) for the period 2000 to 2017; (ii) the United States Geological Survey (USGS) for measures of ground motion produced by the earthquake known as Peak Ground Acceleration (PGA) ; (iii) DesInventar data on damages and destructions after the Haiti earthquake; and (iv) the World Bank (WB) database of geo-located aid projects implemented in 2011 to overcome the aftermath of the natural disaster. We assign every household and child an objective measure of shaking intensity based on the distance from each survey cluster to the stations providing ground motion measures. The World Bank data is used to gain a better understanding of how humanitarian assistance could have mitigated the negative effects of the earthquake on health and human capital accumulation.

We measure exposure to the earthquake using the geographical coordinates of the DHS clusters in several ways. First, we construct a continuous treatment intensity measure based on the weighted peak ground acceleration (PGA) indices reported by geological stations spread throughout the country. While computing the weighted averages, we account for the distances between the stations providing the PGA measures and the DHS clusters. Second, we use the USGS ShakeMaps to identify the treatment groups based on shaking intensity radiuses, which indicate the earthquake depth and ground motion. Then, we apply a Difference-in-Difference estimation to capture causal effects of the earthquake on children's nutrition and education. To account for potential shifts in the effects due to humanitarian assistance, we control for the amount of aid distributed to different areas of Haiti by the World Bank in 2011. The geo-locations of WB aid projects allow to calculate a weighted measure of humanitarian assistance for every DHS cluster. Finally, to demonstrate the robustness of our results, we alternatively measure the earthquake's impact through data on the physical damage at the district level.

Our findings provide substantial evidence of lasting effects of the 2010 Haiti earthquake on children's nutrition and education. Using different identification methods, we consistently show that two and six to seven years after the earthquake, children living in areas of highest shaking intensity still suffered from lower height-for-age z-scores and significantly higher stunting. We do not find any significant differences by gender, but younger children at the time of the earthquake suffered a higher degree of stunting than older children. The strong negative impacts of the earthquake are also evident for school attendance and attainment. Boys demonstrate even lower school attendance and attainment in comparison to girls. The adverse effects are more pronounced for children in primary school. We also confirm the "delay hypothesis" that young adults were enrolled in school even after the age of 19, the official age limit for school attendance.[2] Our estimates show, not accounting for World Bank aid would lead to an underestimation of the effects of the earthquake on children's nutrition and education. Our results remain also significant after controlling for selective child mortality and displacement patterns and several additional robustness checks.

[2] 19 years old is not a strict graduation rule and many children enter secondary school later. As a result, many children graduate at the age of 20-25 years old.

The negative effects of different natural hazards on human capital development in resource-poor settings have been previously investigated in the literature (Baez et al., 2010; Caruso, 2017; Nguyen and Minh Pham, 2018; Thamarapani, 2021 for many disasters; Tiwari et al., 2017 for monsoons; Gaire et al., 2006 for floods and epidemics; Datar et al., 2013 for droughts and floods; Frankenberg and Thomas, 2009 for tsunamis, Spencer et al., 2016 for hurricanes; Jensen, 2000 and Maccini and Yang, 2009 for weather shocks). However, these studies rarely provide evidence on the prevalence of these effects in the long-term which is critical in the context of children's nutrition and education. In addition, these studies typically do not employ high resolution data to measure exposure of households and children to disasters at the local level. We contribute to this strand of the literature by using the geo-coded data from four DHS waves covering the period from 2000 to 2017 and USGS data on shaking intensity to identify potential damages at the moment of the earthquake at the community level.

So far only a few studies have focused on the effects of *earthquakes* on children's nutrition and education, notable exceptions are Bustelo et al. (2012), Gignoux et al. (2017) and Andrabi et al. (2021).[3] In contrast to Bustelo et al. (2012), we measure earthquake exposure at the local community level, and use both objective (shaking intensity) and subjective (reported damage) measures. In addition to Gignoux et al. (2017), we estimate the earthquake effects after controlling for the development aid provided by the World Bank for infrastructure recovery. Further, Gignoux et al. (2017) present evidence from Indonesia, a very particular country which experiences multiple earthquakes per year. Such a context with a series of disasters does not allow to estimate long term effects of a single event. Finally, Andrabi et al. (2021) use one wave of survey data and measure exposure to the earthquake by the distance to the fault line where the earthquake was generated. In contrast to them, we employ repeated cross-sectional data for a period of 17 years and are able to compare closely located clusters before and after the earthquake throughout the country.

We also add to the literature on the impacts of the 2010 Haiti earthquake. Other scholars have previously presented evidence of its influence on child labour as a coping strategy (Novella and Zanuso, 2018) and on household economic well-being and labour market participation (Saint-Macary and Zanuso, 2016). However, the impact of the 2010 Haiti earthquake on children's nutrition and education has not yet been studied. Given that Haiti has been hit by another severe earthquake in August 2021 with at least 2,200 fatalities, the topic has not lost its relevance.

The remainder of the paper proceeds as follows. Section 2 describes the Haitian context and the earthquake. Section 3 presents the data. Section 4 outlines the empirical strategies to exploit the natural experiment setting provided by the earthquake. Section 5 discusses the main results, including a heterogeneity analysis. Section 6 presents robustness checks. The final section concludes.

[3] Other studies have explored the macro-economic impacts of earthquakes (see e.g. Noy, 2009, Felbermayr and Groschl, 2014; Felbermayr et al., 2018; Fabian et al., 2019), or the effects of earthquakes on household welfare (see e.g. Gignoux and Menéndez, 2016), or labour market outcomes and firm performance (see e.g. Kirchberger, 2017; Cole et al. 2019).

2 Haitian Context and the 2010 Earthquake

With a Gross Domestic Product (GDP) per capita of about USD 2,925 in 2020, Haiti remains one of the poorest countries in the world, and the poorest one in Latin America and the Caribbean. On January 12th of 2010, it was struck by the second largest earthquake in the past 50 years. It had a magnitude of 7.0 and its epicenter was located near the town of Léogâne, at an estimated depth of 13 kilometers (Eberhard et al., 2010). The quake struck 25 kilometers away from Haiti's largest city and political capital, Port-au-Prince. After the event, one in two Haitians were left living with less than USD 2.41 a day, and one in four lived below the national extreme poverty line of USD 1.23 a day (Novella and Zanuso, 2018).

Community infrastructure was largely affected by the earthquake. For example, 1,300 schools and more than 50 hospitals and health centers collapsed or were ruled unusable (Government of the Republic of Haiti, 2010b). The overall damage and losses were estimated at about USD 8 billion, the equivalent of more than 120% of Haiti's GDP (Cavallo et al., 2010; United Nations, 2011). More than 2.3 million people were homeless after the quake (United Nations, 2011). In the weeks following the shock, 1.2 million people were living in 460 camps (Government of the Republic of Haiti, 2010b). Approximately 130,000 houses were destroyed and over 915,000 were damaged (Herrera et al., 2014).

The earthquake severely affected the food security of the Haitian population via the loss of goods, employment, forced migration and an increase in food prices which eroded the livelihoods of households (United Nations, 2011). According to the World Food Programme, about 1.3 million people living in the affected areas did not have enough to eat. An additional 600,000 people who had lost their homes were also struggling to meet their basic food needs (WFP, 2015). The whole country, not only heavily affected areas, suffered from a food deficit because of the strong integration of imported rice markets in Haiti. The most vulnerable groups in terms of food insecurity included households who were among the poorest before the earthquake, households who lost their dwellings and those with handicapped members and with only one bread winner for many inhabitants (Coordination Nationale de la Sécurité Alimentaire, 2010).

After the earthquake, Haiti saw one of the biggest mobilizations of humanitarian assistance ever recorded. As of 2013, the international community had pledged USD 13.5 billion for humanitarian relief and recovery efforts (U.S. Congress, 2014). The World Bank partnered with the United Nations, the European Union, the Inter-American Development Bank and multiple non-profit organizations for the post-disaster assessment of needs and disbursement of funds (World Bank, 2019). The emergency disaster response included the creation of temporary learning spaces by UNICEF, additional support for previously establish School Feeding Programmes, general food distributions, food and cash-for-work programs, among others (United Nations, 2011; WFP, 2011).

3 Data Sources and Sample Composition

This study combines several data sets to empirically test the impact of the 2010 earthquake on children's nutrition and education. In the following sections, we describe the data sources and variables used in the analysis.

3.1 Children's Nutrition and Education

The data on children's nutrition and education was extracted from four waves of the Demographic Health Survey (DHS) conducted in Haiti in the period from 2000 to 2017. Specifically, the surveys were implemented in the years 2000, 2005/6, 2012, and 2016/17, thus providing two waves before and two waves after the 2010 earthquake as reflected in Figure 1. The DHS data includes information on a variety of topics such as child health, education, household and respondent characteristics, infant and child mortality, maternal health, wealth, child feeding practices, vitamin supplementation, anthropometry and anemia. The richness of the data permitted the introduction of a vast set of control variables to isolate the effects of the earthquake on nutrition and education. Geographical covariates and GPS coordinates are also available for all clusters covered by the survey.

Figure 1. Sample composition based on timing of the DHS roll-out.

Children's growth and nutritional status are assessed on the basis of height and weight measures via a standardised age- and sex- specific growth reference. We use a height-for-age z-score (HAZ), a weight-for-age z-score (WAZ) and a weight-for-height z-score (WHZ), all of which express values in units of standard deviations above or below the reference with an expected mean of 0 and a standard deviation (SD) of 1 for normalised indices (World Health Organization, 2007).

Children with HAZ, WHZ, and WAZ scores of 2 SD or more below average are classified as displaying stunting, wasting and underweight respectively (World Health Organization, 1995). HAZ reflects achieved linear growth. Low HAZ scores in a pathological context, refer to stunting and indicate a process of failure to reach linear growth potential as a result of suboptimal health and/or nutritional conditions (World Health Organization, 1995). WHZ scores reflect body weight relative to height and indicate the deficit in tissue and fat mass. Wasting refers to significant weight loss because of acute starvation, severe disease or chronic dietary deficiencies. WAZ scores reflect body mass in relation to age. Their interpretation is more complex since they are influenced by both child height and weight. For robustness checks, we also create dummies for *severe* stunting, wasting and underweight, when the corresponding HAZ, WHZ and WAZ scores fall 3 SD or more below average.

Further, to study the effects of the earthquake on educational outcomes we focus on four outcomes: primary and secondary school enrolment, total years spent in school, and current school attendance. Primary and secondary school enrolment are computed for children of the corresponding age groups, 6-14 and 15-18. The other two outcomes are taken for the entire range of school age (6 to 18 years old).

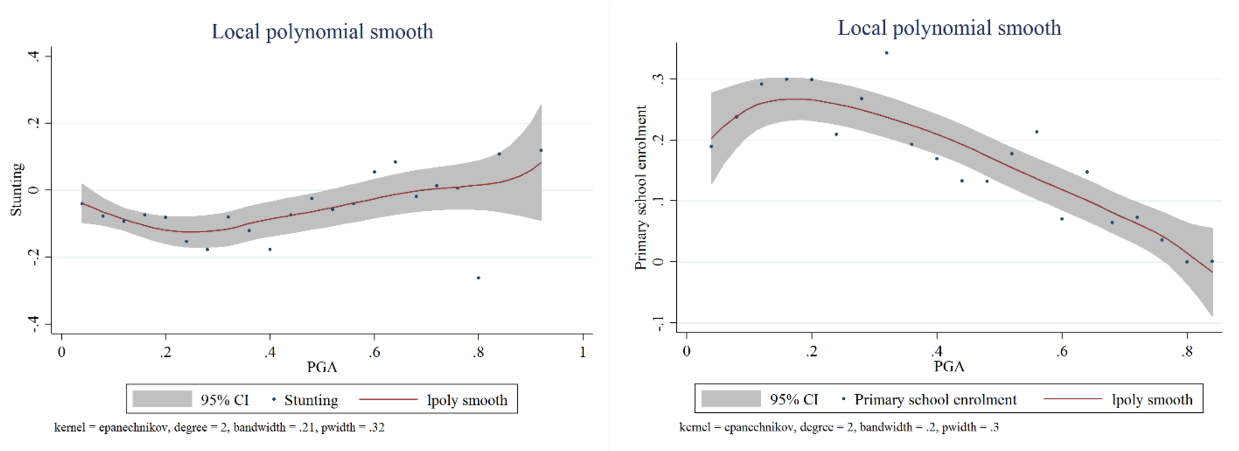

Figure 2. Difference in stunting (left) and in primary school enrolment (right) between the before- and after-earthquake periods by shaking intensity

Figure 2 shows the difference in stunting and in primary school enrolment between the before- and after-earthquake periods by ground shaking intensity. For the considered outcomes, we first calculate the means for the 2000 and 2005/6 DHS waves as well as for the 2012 and 2016/17 DHS waves. Then, we find the difference between the means of the before- and after-earthquake time periods on the DHS cluster level. We plot these differences against ground shaking intensity measured with PGA g% and present their local polynomial smooth with a 95% confidence interval. We observe a strong increase in stunting and a strong decrease in primary school enrolment as shaking intensity increases, which motivates us to explore the impact of the earthquake in more detail.[4]

Finally, we delve into the effects of the earthquake on child labour and focus on three main variables: a) whether the child has worked outside the household including paid and non-paid work; b) whether the child has performed domestic household work, and c) whether the child has performed work for a family member. These variables are available in two of the four waves, in one wave before and in another wave after the earthquake. Child labour is widespread in Haiti. In the period 2005/6, over 33% and 20% of the children taking part in the survey were working outside of the household and for a family member, respectively. By 2012 the

[4] The graphs for other outcomes are presented in Appendix Figures A3 and A4.

share of children working outside had been reduced to 23% and the share of children working for a family member had remained at 20%.[5]

3.2 *Shaking Intensity and Damage Measures*

The treatment variables are constructed on the basis of the 2010 seismic data from the U.S. Geological Survey (USGS). The treatment status is defined as shaking intensity based on the USGS ShakeMaps data. As observed in Figure A1, the impact of the earthquake across Haiti was measured in terms of several indicators such as peak ground acceleration (PGA), peak ground velocity (PGV), and instrumental intensity from the Modified Mercalli Intensity Scale (MI), from which categories of potential damage and perceived shaking were derived. Despite the availability of these different measures, both theory and evidence indicate that for the case of Haiti, PGA proves to be an optimal choice. PGA is a geological measure of the maximum acceleration experienced by a particle on the ground and is independent on building characteristics but considered a good index-to-hazard for low buildings up to seven stories, and most buildings in Haiti consist of only one story. PGV is a good index-to-hazard for taller buildings (USGS, 2018). Several recent studies (Santos and Baez, 2008; Saint-Macary and Zanuso, 2016; Gignoux et al., 2017), use PGA values as a proxy for earthquake intensity. Figure A1 also presents categorised earthquake impacts based on PGA values, where all values higher than 12%g imply strong perceived shaking and severe destructions.

The DHS data is merged at the cluster level with the USGS parameters of ground motion produced by the earthquake such as the Peak Ground Acceleration (PGA) to assign every cluster an objective measure of perceived shaking intensity. The map in Figure 3 shows the distribution of DHS clusters across every wave, against the background of the USGS ShakeMap. It can be seen that all clusters are dispersed over the entire country in all four periods of time.

We compute treatment intensity in two ways. First, we extract the information from a total of 175 stations, which report the earthquake intensity in terms of PGA.[6] We use these PGA values to construct a weighted index that identifies the level of ground motion and perceived shaking intensity for every DHS cluster on the map. More specifically, the weighted PGA index for DHS cluster c can be written as follows:

$WPGA_c = \frac{\sum_{\vartheta=1}^{\aleph} W_{c\vartheta} \cdot PGA_\vartheta}{\sum_{\vartheta=1}^{\aleph} W_{c\vartheta}}$, where PGA_ϑ is a PGA value reported by station ϑ, and $W_{c\vartheta} = \frac{1}{(distance_{c\vartheta}+\delta)^2}$ is a weight based on a specific function defined by the distance between DHS cluster c and station ϑ with buffer zone δ. For the main specification we assume that $\delta = 1$ implying that the PGA values from the stations within one kilometre radius are taken with a much higher weight than the PGA values from remote stations. This functional form of the weight outperforms the standard inverse distance function without any buffer zone as it takes the PGA values from very close stations into account as very large but not infinite. We also check the

[5] Supplementary Online Appendix 1 reports in detail the descriptive statistics of all outcomes (S1.1) and control variables (S1.2, S1.3).
[6] 34 stations which did not report PGAs are ignored in the analysis.

robustness of the results by considering $\delta = 5$ or 10. The computed $WPGA_c$ index represents a continuous treatment variable for DHS cluster c that we use in our empirical analysis.[7]

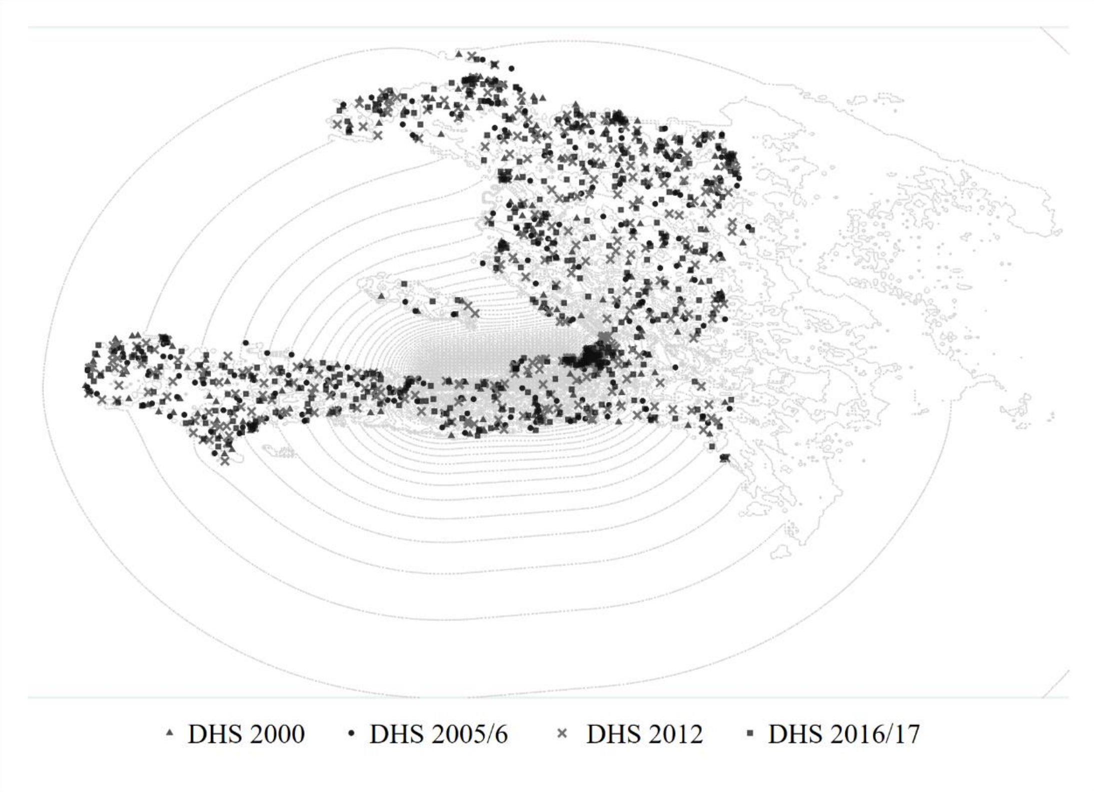

Figure 3. USGS ShakeMap Haiti together with DHS clusters

Second, we assign each DHS cluster a PGA value corresponding to a particular radius of perceived shaking intensity on the USGS ShakeMap (see Figure 3). Then, we create four treatment groups based on categories of the PGA values in Figure A1. We choose the following intervals based on the official PGA scale:

- <12%g – low treatment or no treatment
- [12%g, 20g%) – moderate treatment
- [20%g, 50g%) – strong treatment
- ≥50%g – severe treatment

For example, the severe treatment group comprises all DHS clusters that experience severe and extreme shaking and their PGA values are greater than 50%g.

3.3 Aid Allocation

The Haiti earthquake resulted in the destruction of more than 250,000 dwellings and in the loss of over 220,000 lives. In view of many interventions by the international donor community, it is important for our analysis to control for the humanitarian assistance that became available to affected households after 2010. The map in

[7] Figure A2 shows the distribution of the continuous WPGA index for all DHS clusters.

Figure 4 shows that the World Bank's relief aid was targeted to areas with a higher concentration of crisis reports after the earthquake.

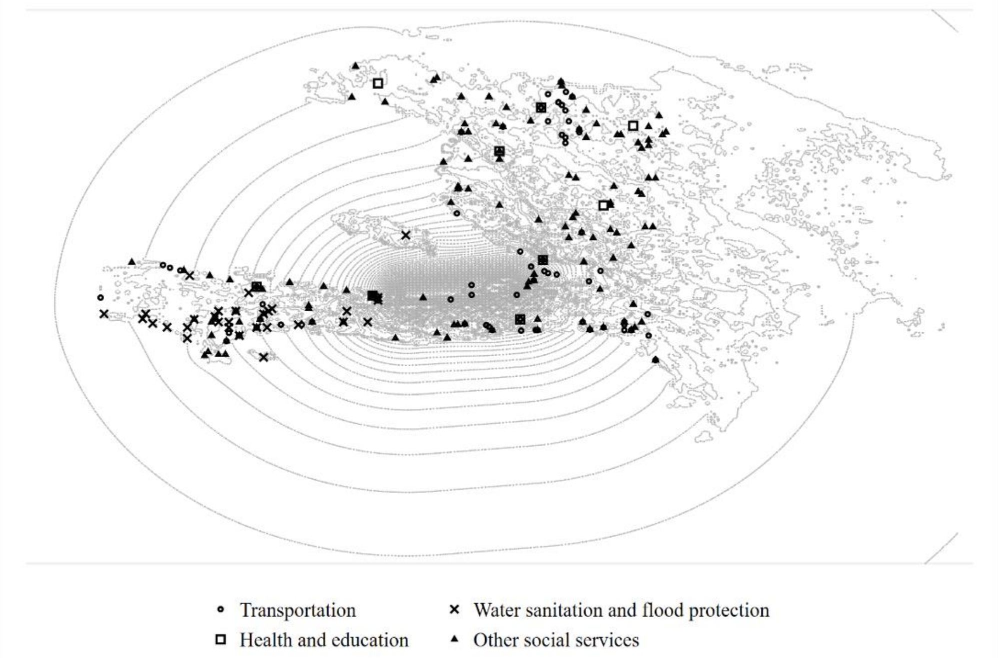

Figure 4. World Bank Aid Projects

To account for this targeted aid, we use geo-localised data on aid projects funded by the World Bank in 2011 (Strandow et al., 2011).[8] The data set covers 58 projects in 338 locations in sectors as agriculture, fishing, and forestry; education, energy and mining; finance; health and other social services; industry and trade; information and communications; public administration, law, and justice; transportation; water, sanitation and flood protection. The projects with highest budget were implemented in agriculture, water and transportation including infrastructure recovery. The emergency relief, as discussed above, was provided by NGOs and other international donors, while the World Bank focused on potentially long-term projects. Some of the World Bank projects had been already established before 2011 and post-disaster relief in this case implied a considerable increase of disbursements. We partially overcome a potential bias due to underreported aid by constructing a continuous weighted measure of aid similar to a continuous treatment variable of shaking intensity. We take all aid projects implemented in Haiti by the World Bank into account and build an Aid index as follows:

$WAid_c = \frac{\sum_{\theta=1}^{\gimel} W_{c\theta} \cdot BUDGET_\theta}{\sum_{\theta=1}^{\gimel} W_{c\theta}}$, where $BUDGET_\theta$ is total budget committed for project θ,[9] and $W_{c\theta} = \frac{1}{(distance_{c\theta}+\delta)^2}$ is a weight based on a specific function defined by the distance between DHS cluster c and project θ with buffer zone δ. In the main specification, we assume that aid projects within a buffer zone

[8] For more information see https://www.aiddata.org/data/all-world-bank-ibrdida.

[9] In the main specifications, we use the WB aid data on commitments because the disbursements are only available for a much smaller number of projects. Nevertheless, for robustness checks we estimate the benchmark specification with the WB aid index computed based on the disbursement data.

of one kilometre are most important ($\delta = 1$). The value of buffer zones is chosen consistently with the continuous treatment measure and for robustness checks we also provide the results for $\delta = 5$ and $\delta = 10$.

4 Empirical Strategy

In order to capture the effects of the earthquake on children's nutrition and education, we use a Difference-in-Difference (DID) estimation approach. The structure of the DHS data set represents a challenge for constructing control and treatment groups. However, the known geo-locations of the DHS clusters help to solve this problem. For every survey wave 2000, 2005/6, 2012 and 2016/17 we can compute either a continuous treatment or a discrete treatment measure. Households and children interviewed in less affected areas are assigned to a control group. In the main sample, we exclude children living in camps and then test further potential displacement patterns in the robustness checks section.

Our identification strategy relies on the exogenous nature of the earthquake, and therefore, on exogenous degrees of ground shaking. The benchmark econometric model used to estimate the effects of the earthquake on children's nutrition and education in case of a continuous treatment is as follows:

$$Y_{ijcrt} = \alpha + \theta WPGA_{cr} + \rho(P_t \cdot WPGA_{cr}) + \gamma WAid_{crt}$$
$$+\lambda_r + \delta_t + X'_{ijcrt}\kappa + Z'_{ijcrt}\eta + H'_{jcrt}\mu + \varepsilon_{ijcrt}\ , \qquad (2)$$

where Y_{ijcrt} denotes the outcome variable (nutritional status or education outcome) for child i in household j in cluster c in region r, in period t; $WPGA_{cr}$ is a continuous treatment variable that denotes a weighted PGA index based on a special weight function taking into account the inverse distance between DHS clusters and PGA stations. $WAid_{crt}$ is a weighted index of the WB aid for cluster c in region r and period t. It equals 0 in 2000 and 2005/6. We also include wave fixed effects δ_t to account for time trends. The third and fourth survey waves (2012 and 2016/17) are combined in a post-earthquake time dummy P_t. The parameter of interest ρ measures the impact of the 2010 earthquake on children's nutrition and schooling via the interaction between time dummy P_t and continuous treatment measure $WPGA_{cr}$. The geo-locations of DHS clusters allow to compare the affected households in 2012 and 2016/17 with closely located households from 2000 and 2005/6. Additionally, this specification separates the impact of the earthquake from any region-specific trend in outcomes by including regional fixed effects λ_r.

All regressions include a series of additional controls. In particular, vector X_{ijcrt} captures children's characteristics, vector Z_{ijcrt} denotes parental traits, and vector H_{jcrt} controls for household characteristics. ε_{ijcrt} is an idiosyncratic shock term. In all estimations we account for the sample design features of our data set, and hence use the provided sample weights, primary sampling units and strata (the interaction of survey wave, region, and type of region). This allows us to compensate for stratum-level over-sampling and under-sampling, to adjust for non-response, and to produce robust standard errors clustered on the primary sampling unit. The weight adjustments can alter the estimated coefficients, while the cluster and strata adjustments only alter the standard errors.

In the second strategy, we distinguish between different treatment groups based on shaking intensity radii provided by the ShakeMaps taking into account the earthquake depth and ground motion. In particular, we construct four treatment groups as described above: low, moderate, strong and severe shaking groups. In each wave of the DHS data set we assigned every DHS cluster to one of the four treatment groups based on its geo-location and a potential shaking level when the earthquake struck. Thus, the second empirical strategy is similar and based on four treatment groups:

$$Y_{ijcrt} = \alpha + \sum_{k=1}^{3} \theta_k D_{kcr} + \sum_{k=1}^{3} \rho_k (P_t * D_{kcr}) + \gamma WAid_{crt} +$$

$$\lambda_r + \delta_t + X'_{ijcrt}\kappa + Z'_{ijcrt}\eta + H'_{jcrt}\mu + \varepsilon_{ijcrt} \; . \tag{3}$$

The parameter of interest ρ_k measures the impact of the 2010 earthquake on children's nutrition and schooling via the interactions between the after-earthquake dummy P_t and treatment dummies D_{kcr}.

In equations (2) and (3), the household, parental and children's characteristics are different depending on which outcome we consider, nutrition status or educational level or attendance. The details on these control variables are presented in Tables S1.2 and S1.3. The main concerns regarding the validity of these strategies such as the potential existence of unobserved trends that may change differently in the treated and control groups are addressed in the robustness checks section.

5 Results

This section presents all benchmark results, first for nutrition, and second, for education outcomes. We also consider heterogeneous effects by gender and age cohort.

5.1 Children's Nutrition

Table 1 reports the effects of the earthquake on children's nutrition. We focus on six outcomes, including three z-scores and three dummies of malnutrition. Panel A summarizes the benchmark results for a continuous treatment using the weighted PGA index with a buffer zone of one kilometre ($\delta = 1$). Panel B summarizes the results for four treatment groups based on PGA radii extracted from the USGS ShakeMaps. The light shaking intensity group is the reference group. The odd columns present the specifications not controlling for the distributed WB aid and the even columns present the specifications including the WB aid index. All regressions include a full set of control variables, among which are socio-economic characteristics of children and their parents.

The results suggest that after the earthquake, children experiencing one standard deviation (SD) higher shaking intensity have a HAZ score which is lower by 0.06 SDs. The effect on the stunting dummy is comparable and shows an increase of 0.07 SDs. This corresponds to a deterioration of stunting of 3 percentage points which is equivalent to 12% of the stunting mean. After controlling for the WB aid, the negative impact of the earthquake on HAZ scores and stunting becomes even a bit larger (0.08 SDs or 14% of the mean), suggesting that aid – as expected – was allocated to those areas that were most severely affected.

These findings are confirmed by an analysis where we consider four treatment groups based on PGA values. The effects' sizes are very similar. More specifically, the fourth treatment group comprising areas with severe shaking intensity shows a 0.09 SD decrease in HAZ scores and a 0.08 SD increase in stunting. In other words, children living in areas struck with a PGA higher than 50g% suffer from a 33-percentage point decrease in HAZ scores that translates into a 10-percentage point increase in stunting in comparison to areas with a PGA lower than 12g% (light shaking).

Wasting has also been aggravated in struck areas after the earthquake, though the change in WHZ scores is not significant. A one SD increase in shaking intensity is associated with a 2.5 percentage point increase in wasting, which is equivalent to 20% of the wasting mean. In specifications with four treatment groups, the highly struck areas demonstrate an almost 7 percentage point increase in wasting. In terms of SD, these effects are very comparable. The inclusion of WB aid as a control only slightly changes this effect. Underweight has not significantly increased after the disaster but WAZ scores decrease by 0.04 SD even after accounting for WB aid.

In both panels A and B, the WB aid effect is significant and has the expected sign: it increases the z-scores and decreases stunting, wasting and underweight by about 0.09 SD on average. However, accounting for the WB aid effect does not offset the negative impact of the earthquake on children's nutrition. The effects on stunting and wasting persist in affected areas even 6 years after the earthquake.

We also study the changes in indicators of *severe* stunting, wasting and underweight (< -3 SD). Controlling for the disaster relief, the effects on severe stunting and wasting are sizeable in heavily affected areas (see Table S2.1). These effects remain robust in both specifications with continuous and group treatments. A one SD increase in shaking intensity leads to a 0.08 SD increase in severe stunting and to a 0.04 SD increase in severe wasting, which corresponds to 26% and 18% of the corresponding means. In areas struck with a PGA higher than 50g%, severe stunting on average rises by 7.5 percentage points and severe wasting rises by 2 percentage points.

We also study the heterogeneity of these effects by gender, age cohort, in utero status, and trimester of gestation. The analysis for gender does not show any statistically significant difference between boys and girls for any of the six nutritional outcomes. In terms of age cohort, some of the indicators we consider suggest that one year old children at the time of the earthquake were more severely hit by the earthquake than older children. Finally, our results do not confirm that children who were in utero in highly affected areas at the time of the earthquake subsequently suffered more from malnutrition than the already born children. See Appendix B1 for further details.

Table 1. Effects of the Earthquake on Nutrition – Benchmark

	(1) HAZ	(2) HAZ	(3) Stunting	(4) Stunting	(5) WHZ	(6) WHZ	(7) Wasting	(8) Wasting	(9) WAZ	(10) WAZ	(11) Underweight	(12) Underweight
PANEL A												
Intensity*post	-0.0042***	-0.0051***	0.0014***	0.0017***	0.0004	-0.0004	0.0012***	0.0014***	-0.0023*	-0.0034***	0.0002	0.0003
	(0.0014)	(0.0014)	(0.0004)	(0.0004)	(0.0013)	(0.0013)	(0.0003)	(0.0003)	(0.0012)	(0.0013)	(0.0003)	(0.0003)
WB aid		0.0122**		-0.0038***		0.0109***		-0.0027***		0.0158***		-0.0018**
		(0.0050)		(0.0012)		(0.0040)		(0.0009)		(0.0040)		(0.0007)
Observations	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952
R-squared	0.1981	0.1988	0.1360	0.1368	0.0793	0.0802	0.0757	0.0764	0.1663	0.1680	0.0371	0.0376
Mean outcome	-1.1066	-1.1066	0.2537	0.2537	-0.1057	-0.1057	0.1297	0.1297	-0.7067	-0.7067	0.0566	0.0566
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
PANEL B												
Moderate*post	-0.0778	-0.0676	-0.0036	-0.0065	0.1250	0.1357	-0.0384	-0.0407	0.0419	0.0561	-0.0368*	-0.0384**
	(0.1069)	(0.1080)	(0.0308)	(0.0308)	(0.0942)	(0.0931)	(0.0262)	(0.0260)	(0.0862)	(0.0860)	(0.0192)	(0.0192)
Strong*post	-0.1074	-0.1179	0.0109	0.0139	-0.0126	-0.0236	0.0238	0.0261	-0.0707	-0.0853	0.0071	0.0086
	(0.0789)	(0.0794)	(0.0234)	(0.0237)	(0.0751)	(0.0746)	(0.0206)	(0.0206)	(0.0681)	(0.0681)	(0.0164)	(0.0163)
Severe*post	-0.3338***	-0.3732***	0.0902***	0.1015***	0.0560	0.0148	0.0652***	0.0741***	-0.1594**	-0.2140***	0.0030	0.0088
	(0.0855)	(0.0855)	(0.0251)	(0.0255)	(0.0814)	(0.0807)	(0.0211)	(0.0211)	(0.0803)	(0.0802)	(0.0167)	(0.0166)
WB aid		0.0116**		-0.0033***		0.0121***		-0.0026***		0.0161***		-0.0017**
		(0.0049)		(0.0012)		(0.0041)		(0.0009)		(0.0040)		(0.0008)
Observations	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952	14,952
R-squared	0.1991	0.1998	0.1363	0.1369	0.0795	0.0806	0.0766	0.0773	0.1667	0.1686	0.0377	0.0383
Mean outcome	-1.1066	-1.1066	0.2537	0.2537	-0.1057	-0.1057	0.1297	0.1297	-0.7067	-0.7067	0.0566	0.0566
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Notes: Panel A shows the results of continuous treatment specifications with buffer zone $\delta = 1$ km. Panel B shows the results of specifications with four intensity groups. All models include regional and year fixed effects, shaking intensity specific variables, and a full set of control variables. Only the interaction terms between shaking intensity and the after-earthquake dummy are reported. Robust standard errors in parentheses are clustered at the regional level *p<0.1; **p<0.05; ***p<0.01.

5.2 *Education*

Table 2 shows the impact of the Haiti earthquake on educational outcomes. We focus on current school attendance and years in school. Panels A and B show the results for continuous and group treatments, respectively. We also present all results with and without WB aid, but always include a full set of control variables as well as region and wave fixed effects. The results are robust among all educational outcomes illustrating the decrease of both school enrolment and school attendance.

Table 2. Effects of the Earthquake on Education – Benchmark

	(1) Primary	(2) Primary	(3) Secondary	(4) Secondary	(5) Years	(6) Years	(7) Attendance	(8) Attendance
PANEL A								
Intensity*post	-0.0025***	-0.0028***	-0.0008*	-0.0010**	-0.0034**	-0.0039**	-0.0016***	-0.0018***
	(0.0003)	(0.0003)	(0.0004)	(0.0004)	(0.0016)	(0.0016)	(0.0002)	(0.0002)
WB aid		0.0039***		0.0039*		0.0080		0.0027***
		(0.0010)		(0.0023)		(0.0056)		(0.0006)
Observations	47,673	47,673	19,225	19,225	66,898	66,898	66,898	66,898
R-squared	0.1493	0.1500	0.2585	0.2592	0.6036	0.6037	0.1395	0.1401
Mean outcome	0.6814	0.6814	0.4067	0.4067	2.7483	2.7483	0.8283	0.8283
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES
Age	6-14	6-14	15-18	15-18	6-18	6-18	6-18	6-18
PANEL B								
Moderate*post	0.0404	0.0412	0.0150	0.0182	0.2566**	0.2597**	0.0530*	0.0538*
	(0.0330)	(0.0330)	(0.0380)	(0.0378)	(0.1199)	(0.1195)	(0.0292)	(0.0293)
Strong*post	-0.0097	-0.0150	0.0188	0.0127	0.0740	0.0606	-0.0033	-0.0066
	(0.0199)	(0.0200)	(0.0249)	(0.0250)	(0.0785)	(0.0788)	(0.0176)	(0.0176)
Severe*post	-0.1526***	-0.1616***	-0.0496*	-0.0577**	-0.1537	-0.1747*	-0.0947***	-0.0999***
	(0.0195)	(0.0195)	(0.0288)	(0.0287)	(0.1016)	(0.1037)	(0.0157)	(0.0157)
WB aid		0.0031***		0.0038*		0.0079		0.0020***
		(0.0009)		(0.0022)		(0.0052)		(0.0006)
Observations	47,673	47,673	19,225	19,225	66,898	66,898	66,898	66,898
R-squared	0.1507	0.1512	0.2593	0.2600	0.6039	0.6040	0.1405	0.1408
Mean outcome	0.6814	0.6814	0.4067	0.4067	2.7483	2.7483	0.8283	0.8283
Controls	YES	YES	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES	YES	YES
Age	6-14	6-14	15-18	15-18	6-18	6-18	6-18	6-18

Notes: Panel A shows the results of continuous treatment specifications with buffer zone $\delta = 1$ km. Panel B shows the results of four intensity groups specifications. All models include regional and year fixed effects, shaking intensity specific variables, and a full set of control variables. Only the interaction terms between shaking intensity and the after-earthquake dummy are reported. Robust standard errors in parentheses are clustered at the regional level *p<0.1; **p<0.05; ***p<0.01.

Panel A of Table 2 suggests that a one SD increase in shaking intensity decreases primary school enrolment by almost 0.12 SD or 5 percentage points which corresponds to 8% of the mean. Secondary school enrolment is much less affected and decreases by only 0.04 SD, which translates into a change equal to 4.5% of the mean. When looking at the non-parametric treatment groups (Panel B), the effects for primary and secondary school enrolment come to a 15-percentage point decrease and a 5-percentage point decrease, respectively, for the most severely struck areas in comparison to areas with light shaking. Controlling for WB aid makes the effects larger by only 0.01 SD. The years of education decrease by only 0.03 SD in areas with a one SD higher shaking intensity. The negative effect on school attendance is much higher and comes to 0.09 SD when the shaking intensity increases by one SD. This translates into a decrease in current attendance equivalent to 4% of the mean.

The effect associated with WB aid is positive, sizeable and significant in all regressions. The estimated effects suggest that WB aid increased primary and secondary school enrolment by 0.08 SD and school attendance by 0.07 SD. These improvements correspond to changes equal to 6% and 10% of the corresponding means for school enrolment and equal to 3% of the mean for school attendance. These effects might be explained by the investments in school infrastructure and transport recovery in the aftermath of the earthquake. Despite the fact that aid mitigates the negative effects of the earthquake on school outcomes, it does not fully overcome them. Accounting for WB aid increases the effects associated with shaking intensity. The resulting effect sizes correspond to 9%, 6% and 5% of the corresponding means, respectively.

Panel B shows comparable effects for the specification with four treatment groups. In the most struck areas, all four educational outcomes decreased after the earthquake. Controlling for WB aid, primary school enrolment and secondary school enrolment are lower by 16 percentage points and 6 percentage points, respectively, in severely affected areas with a PGA above 50g% (group 4) compared to areas with a PGA below 12g%. Interestingly, years of education and attendance increased for the moderately affected areas (group 2 comprises areas with PGA between 12g% and 20g%). We do not have any well-founded explanation for these effects, but they might be due to very effective reconstruction efforts and humanitarian assistance, which is not captured by WB aid. The improvements in education for group 2 come up to 26 percentage points in years of education and 5 percentage points in attendance.

We also explored the heterogeneity of the education effects by gender, birth time and education cohort. We find that the negative effects of the earthquake on secondary school enrolment and years of education are not significantly different for boys and girls. However, gender matters in differentiating the impact of the earthquake on primary school enrolment and attendance. Further, our findings show that being in utero during the earthquake only affects total years of education but no other educational outcome. Finally, the results by education cohort suggest that in severely struck areas more children tried to catch up with education levels that correspond to their age. See Appendix B2 for further details.

Next, we explore whether the lower enrolment and attendance rates described before might be the consequence of increased child labour. We distinguish between child labour outside the household (paid and non-paid), child labour for a family member, and child housework. Table S2.2 shows that the earthquake had a positive and significant impact on the probability that children between 6- and 18-years old worked either outside their household for pay, or unpaid for a family member. A one SD increase in shaking intensity leads to a 0.08 SD increase in paid work outside. This is a sizeable effect which is equivalent to 55% of the corresponding mean. In contrast, hours spent on work outside the household did not significantly increase in the affected areas after the earthquake. We also find that the effect of the earthquake on non-paid work outside the household is negative and insignificant. A one SD increase in shaking intensity causes a 0.07 SD increase in child work for a family member which is equal to 13% of the respective mean. In terms of hours, a one SD increase in shaking intensity leads to a 33-percentage point increase in hours of child work for the family. This is equivalent to 22% of the mean and corresponds to an increase of child work for a family member by about 20 minutes per week.

Our second specification using four treatment groups leads to very similar results. Panel B of Table S2.2 confirms the increase in paid child labour outside the household and in work for a family member in highly struck areas. Paid child labour outside the household increases by only 3 percentage points in areas with a PGA higher than 50g% in comparison with areas with only light shaking intensity. Child labour for a family member in these areas increases by 5 percentage points. This might be explained by a higher involvement of children in the recovery and reconstruction of their family's houses. Increased child work is also confirmed when looking at hours spent by a child on work for a family member. This increase in severely struck areas in comparison to lightly struck areas corresponds to 68 percentage points or to about 40 minutes per week. The increased child labour, especially work for a family member and paid work outside the household, might explain the decrease in school enrolment and attendance in highly affected areas after the earthquake.

6 Robustness Checks

To further check the robustness of our results we test whether these hold for alternative specifications of the weight functions. In our benchmark results we construct ground shaking intensity and aid allocation using weighted indices based on a buffer zone $\delta = 1$ implying that all data within 1 kilometre is of higher importance. Alternative buffer zones $\delta = 5$ and $\delta = 10$ do not change the main results (Tables S4.1 and S4.2). We also perform placebo tests for both nutritional and educational outcomes where we reduce the sample to only the years 2000 and 2005, hypothetically assuming that the earthquake had already happened in the year 2004. Our results remain consistent for both nutritional (Table S4.3) and educational outcomes (Table S4.4). A second placebo test for education using a sample of people older than 35 in the year of earthquake also confirms the robustness of our findings (Table S4.5).

One potential threat to identification is selective migration across clusters and regions. To address this, we re-estimate our benchmark results with a sample of children who were living in the same house after the earthquake. Tables S4.6 and S4.7 show that our results do not change if we re-estimate our regressions with this sub-sample. Next, re-estimate our benchmark specifications now capturing displacement patterns and internal migration using data on all post-earthquake camps in Haiti from the Displacement Tracking Matrix (DTM) provided by the IOM. Tables S4.8 and S4.9 report the results that consider the location and the capacity of the camps, assuming that this could be a potentially omitted variable that is correlated with both the intensity of the earthquake and the outcomes of interest. The coefficients associated with the weighted index of camps are negative which implies that, despite receiving higher aid, the closeness to highly populated camps led to further and stronger deteriorations in children's nutrition and education, yet the coefficient associated with the earthquake intensity does not change in most cases or if it changes, decreases only slightly.

Another potential threat to identification is infant mortality caused by the earthquake. If the most severely affected children died our results would constitute lower bounds of the true effects. To address the issue, we first estimate the probability of a child having died in highly struck areas, and then control for the mortality patterns in the main estimation models. In Table S4.10, we find support for our intuition that highly struck areas are characterised by higher infant mortality in later years after the earthquake. We then use these results to predict the empirical probability of a child having perished after the earthquake and re-estimate the benchmark regressions on nutrition using mortality weights. The results in Table S4.11 confirm our main findings, selective mortality does not seem to bias our results, if anything we slightly underestimate the true effects.

Finally, we test the robustness of our findings to alternative measures of exposure. We explore how actual earthquake damages relate to children's nutrition and education using data on the destruction of infrastructure and on human casualties from the United Nations Disaster Information Management System (DesInventar). We consider measures of damage such as death toll, number of victims, houses destroyed and houses affected at the district level. However, damages are potentially endogenous to earthquake exposure because they are correlated with unobserved determinants of children's nutrition and education. Therefore, we apply an instrumental variable approach, in which we instrument observed damage with ground shaking intensity based on the PGA measure. The exclusion restriction requires that the earthquake affects children's nutrition and education exclusively through the damages reported in DesInventar. However, psychological shocks that come with an earthquake may also have a direct influence on children's nutrition and education. In this case, the exclusions restriction would not hold. As such, we prefer to use the main Difference-in-Difference specification as the benchmark and consider this instrumental variable approach although previously applied in the literature (see, e.g., Kirchberger, 2019) as a robustness check.

Appendix Tables C1 and C2 summarize the IV second stage results for children's nutrition and education, respectively. The results confirm that the earthquake causes stunting and wasting as well as a lower WAZ score. The estimated coefficients are now much larger. A one SD increase in the log of deaths, which corresponds to about 54 deaths, leads to a 0.2 SD increase in stunting and wasting. Likewise, a one SD increase in the log of homes destroyed, which corresponds to about 7 houses destroyed, causes a 0.1 SD increase in both stunting and wasting. The effects on education also become significantly larger in areas with more reported deaths and destruction. About 54 deaths (one SD) lead to a 0.3 SD decrease in primary school enrolment and a 0.1 SD decrease in secondary school enrolment. These changes correspond to 20% and 12% of the enrolment means, respectively. The same effects are caused by a 2 SD increase in homes destroyed that corresponds to about 14 homes destroyed. The decrease in attendance is equal to 0.24 SD as a result of the earthquake damages of 54 deaths or 14 homes destroyed. See Appendix C for more details on all robustness checks described above.

7 Conclusion

Using data from four waves of the Haiti Demographic Health Survey (DHS) and shaking intensity measures from the United States Geological Survey (USGS), this study analyses the effects of the second deadliest recorded earthquake in history, which occurred in Haiti on January 12th, 2010 on children's nutrition and educational outcomes. We assess the mid-term consequences on two important indicators of children's human capital to get a better understanding of the earthquake's impact on the Haitian population.

This study provides strong evidence that children living in households heavily affected by the earthquake, experienced severe malnutrition and showed lower school enrolment and attendance compared to children from less or unaffected areas. These effects persist even after controlling for individual, household, and regional characteristics. We also show that the effects were mitigated by World Bank aid, but this was not enough to undo the adverse effects on health and education. In particular, we find higher probabilities of moderate and severe stunting as well as moderate wasting. We also find strong and robust evidence of lower primary and secondary school enrolment, of an overall reduction in number of years spent in the education system and lower school attendance. These results are also robust to the inclusion of internal migration, selective mortality and to alternative measure of exposure to the earthquake.

While the earthquake's impact was sizeable for both girls and boys, we do not find any evidence for substantial gender differences in the nutritional status. However, boys were significantly more discouraged from school enrolment than girls. We also show that younger children in heavily affected areas suffered more than older children and we find interesting patterns with respect to child labour. Paid child work outside the home and child work for the family increased for children living in highly affected areas. This may also, at least partly, explain the deteriorated educational outcomes in highly affected areas. Higher attendance and fewer years of education of students at older ages suggest that children seem to have postponed their education to later ages.

Interestingly, we find slightly positive changes in the years of education and school attendance in moderately affected areas. Our results suggest that this might be due to the impact of massive humanitarian aid allocated to these areas. Indeed, the findings of this study and those of the studies by Herrera et al., (2014), Novella and Zanuso (2018), Gignoux et al., (2017) and Saint-Macary and Zanuso (2016) all show the importance of the presence of international donors and other government institutions as well as targeted nutritional and educational interventions in the aftermath of a natural disaster.

Yet, our study suggests that overall the effects on human capital accumulation are enormous, the longer-term costs of the implied loss in human capital may have tremendous private and social costs, maybe much higher than the immediate loss implied by the destruction of physical capital and infrastructure.

Future research could try to uncover the ways in which children from affected households could recover from such shocks and to shed light on the potential mechanisms behind such a recovery. Numerous studies (Martorell et al., 1994; Prentice et al., 2013; Crookston et al., 2010) show that catch-up growth can be triggered in interventions outside the 9 to 24-month period of a child's life, and that adolescence is an additional window during which nutritional interventions and reliable food consumption patterns might still yield effects. The children studied in this paper are soon to reach their adolescence, and in their case, it might not be too late to revert the negative effects of the earthquake on children's human capital.

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References

Almond, D., Mazumder, B., & Van Ewijk, R. (2015). In utero Ramadan exposure and children's academic performance. *Economic Journal, 125*(589), 1501-1533.

Andrabi, T., Daniels, B., & Das, J. (2021). Human capital accumulation and disasters: evidence from the Pakistan earthquake of 2005. *Journal of Human Resources*, 0520-10887R1.

Baez, J. E., & Santos, I. V. (2008). On shaky ground: The effects of earthquakes on household income and poverty. New York: RPP LAC – MDGs and Poverty – 02/2008, RBLAC-UNDP.

Baez, E. J., de la Fuente, A., & Santos, I. (2010). Do natural disasters affect human capital? An assessment based on existing empirical evidence. IZA DP No. 5164, IZA Bonn.

Barker, D. P. (1990). The fetal and infant origins of adult disease: The womb may be more important than the home. *British Medical Journal, 301*(6761), 1111.

Bustelo, M., Arends-Kuenning, M., & Lucchetti, L. (2012). Persistent impact of natural disasters on children's nutrition and schooling: Evidence from the 1999 Colombian earthquake. IZA DP No. 6354, IZA Bonn.

Caruso, G. D. (2017). The legacy of natural disasters: The intergenerational impact of 100 years of disasters in Latin America. *Journal of Development Economics, 127*, 209–233.

Cavallo, E., Powell, A., & Becerra, O. (2010). Estimating the direct economic damages of the earthquake in Haiti. *Economic Journal, 120*(546), F298-F312.

Cole, M.A., Elliott, R.J.R., Okubo, T. & Strobl, E. (2019). Natural disasters and spatial heterogeneity in damages: the birth, life and death of manufacturing plants. *Journal of Economic Geography, 19*, 373-408.

Coordination Nationale de la Sécurité Alimentaire. (2010). Rapid post-earthquake emergency food security assessment. CNSA, FAO, WFP, ACF, FEW NET, OXFAM. (81).

Crookston, B. T., Penny, M. E., Alder, S. C., Dickerson, T. T., Merrill, R. M., Stanford, J. B. & Dearden, K. A. (2010). Children who recover from early stunting and children who are not stunted demonstrate similar levels of cognition. *Journal of Nutrition, 140*(11), 1996-2001.

Datar, A., Liu, J., Linnemayr, S., & Stecher, C. (2013). The impact of natural disasters on child health and investments in rural India. *Social Science & Medicine, 76*(1), 83-91.

Desai, R. J., & Franklin, J. M. (2019). Alternative approaches for confounding adjustment in observational studies using weighting based on the propensity score: a primer for practitioners. *British Medical Journal, 367*(l5657)

Eberhard, M. O., Baldridge, S., Marshall, J., Mooney, W. & Rix, G. J. (2010). The Mw 7.0 earthquake of January 12, 2012: USGS/EERI Advance Reconnaissance Team report. USGS open-file report 2010-1048. Retrieved from US Geological Survey; US Department of the Interior: https://pubs.usgs.gov/of/2010/1048/of2010-1048.pdf.

Fabian, M., Lessmann, C., & Sofke, T. (2019). Natural disasters and regional development – the case of earthquakes. *Environment and Development Economics, 24*(5), 479-505.

Frankenberg, E. & Thomas, D. (2019). Human capital and shocks: Evidence on education, health and nutrition. In *The Economics of Poverty Traps* (23-56). University of Chicago Press.

Felbermayr, G. and Groschl, J. K. (2014). Naturally negative: The growth effects of natural disasters. *Journal of Development Economics, 111*, 92–106.

Felbermayr, G., Groschl, J. K., Sanders M., Schippers, V. & Steinwachs T. (2018). Shedding light on the spatial diffusion of disasters, *CESifo Working Paper Series 7146*, CESifo Group Munich.

Gaire, S., Delbiso, T. D., Pandey, S., & Guha-Sapir, D. (2016). Impact of disasters on child stunting in Nepal. *Risk Management and Healthcare Policy, 9*, 113-127.

Gignoux, J., & Menéndez, M. (2016). Benefit in the wake of disaster: Long-run effects of earthquakes on welfare in rural Indonesia. *Journal of Development Economics, 118*, 26-44.

Gignoux, J., Menéndez, M., & Music, A. (2017). In the wrong place, at the wrong time: Long-run effects of income shocks on children's education and health outcomes. *mimeo*.

Government of the Republic of Haiti. (2010a). Haiti Earthquake PDNA: Assessment of damage, losses, general and sectoral needs. Retrieved from Government of the Republic of Haiti: https://www.gfdrr.org/sites/default/files/GFDRR_Haiti_PDNA_2010_EN.pdf

Government of the Republic of Haiti. (2010b). Action plan for national recovery and development of Haiti. Immediate key initiatives for the future. Retrieved from Government of the Republic of Haiti: https://unesdoc.unesco.org/ark:/48223/pf0000211363

Herrera, J., Lamaute-Brisson, N., Milbin, D., Roubaud, F., Saint-Macary, C., Torelli, C., & Zanuso, C. (2014). *L'évolution des conditions de vie en Haiti entre 2007 et 2012. La réplique sociale du séisme.* Paris, Port-au-Prince: IHSI, DIAL.

Ho, J. Y., Frankenberg, E., Sumantri, C., & Thomas, D. (2017). Adult mortality five years after a natural disaster. *Population and Development Review*, *43*(3), 467-490.

Jensen, R. (2000). Agricultural volatility and investments in children. *American Economic Review, 90*(2), 399-404.

Kirchberger, M. (2019) Natural disasters and labor markets. *Journal of Development Economics*, 125 (C), 40-58.

Maccini, S., & Yang, D. (2009). Under the weather: Health, schooling, and economic consequences of early-life rainfall. *American Economic Review, 99*(3), 1006-1026.

Martorell, R., Khan, L. K., & Schroeder, D. G. (1994). Reversibility of stunting: Epidemiological findings in children from developing countries. *European Journal of Clinical Nutrition, 4*(1), S45-57.

Munich RE. (2021, 01 07). Record hurricane season and major wildfires – The natural disaster figures for 2020. Retrieved from Munich RE: https://www.munichre.com/en/company/media-relations/media-information-and-corporate-news/media-information/2021/2020-natural-disasters-balance.html

Nguyen, C. V. & Minh Pham, N. (2018). The impact of natural disasters on children's education: Comparative evidence from Ethiopia, India, Peru, and Vietnam. *Review of Development Economics, 22*(4), 1561-1589.

Novella, R., & Zanuso, C. (2018). Reallocating children's time: Coping strategies after the 2010 Haiti earthquake. *IZA Journal of Development and Migration, 8*(1), 1-32.

Noy, I. (2009). The macroeconomic consequences of disasters. *Journal of Development Economics, 88*(2), 221-231.

Prentice, A. M., Ward, K. A., Goldberg, G. R., Jarjou, L. M., Moore, S. E., Fulford, A. J., & Prentice, A. (2013). Critical windows for nutritional interventions against stunting. *American Journal of Clinical Nutrition, 97*(5), 911-918.

Ravallion, M., & Wodon, Q. (2000). Does child labour displace schooling? Evidence on behavioural responses to an enrollment subsidy. *Economic Journal, 110*(462), 158-175.

Saint-Macary, C., & Zanuso, C. (2016). Build back better? Long-lasting impact of the 2010 earthquake in Haiti. DIAL Working Paper DT/2015-15, DIAL Paris.

Spence, R., So, E., & Scawthorn, C. (2011). *Human casualties in earthquakes* (1st ed. 2011 ed., Vols. Advances in Natural and Technological Hazards Research, 29). Dordrecht: Springer Netherlands.

Spencer, N., Polachek, S., & Strobl, E. (2016). How do hurricanes impact scholastic achievement? A Caribbean perspective. *Natural Hazards, 84*(2), 1437-1462.

Strandow, D., Findley, M., Nielson, D., & Powell, J. (2011). *The UCDP and AidData Codebook on Georeferencing Aid, Version 1.1*. Uppsala, Sweden: Uppsala University.

Thamarapani, D. (2021). Natural disasters and child health. *Environment and Development Economics, 26*(1), 26-44.

Tiwari, S., Jacoby, H., & Skoufias, E. (2017). Monsoon babies: Rainfall shocks and child nutrition in Nepal. *Economic Development and Cultural Change, 65*(2), 167-188.

United Nations. (2011). Rapport des Nations Unies en Haïti 2010 - Situation, défis et perspectives. Retrieved from United Nations: http://www.un.org/en/peacekeeping/missions/minustah/documents/un_report_haiti_2010.pdf.

OCHA. (2021). Global humanitarian overview 2022. Retrieved from United Nations Office for the Coordination of Humanitarian Affairs: https://gho.unocha.org/U.S. Congress. (2014, July 28). *S. 1104 (113th):* Assessing progress in Haiti Act of 2014. Retrieved from: https://www.govtrack.us/congress/bills/113/s1104/text

USGS. (2010, January 12). M 7.0 - Haiti region. Retrieved from United States Geological Survey: https://earthquake.usgs.gov/earthquakes/eventpage/usp000h60h#executive

WFP (2011). Standard Project Report 2010: Food assistance to earthquake affected population in Haiti. Retrieved from World Food Programme: https://reliefweb.int/report/haiti/wfp-emergency-operation-200110-haiti-food-assistance-earthquake-affected-populations.

WFP (2015). Remembering our response to the Haitian earthquake - A food crisis averted. Retrieved from World Food Programme: https://www.wfp.org/stories/remembering-our-response-haitian-earthquake-food-crisis-avoided.

World Bank. (2019, May 3). Rebuilding Haitian infrastructure and institutions. Retrieved from The World Bank - Projects and Operations: https://www.worldbank.org/en/results/2019/05/03/rebuilding-haitian-infrastructure-and-institutions

World Health Organization. (1995). WHO Expert Committee on Physical Status. The use and interpretation of anthropometry: Report of a WHO Expert Committee. Geneva: World Health Organization (WHO Technical Report Series, 854).

World Health Organization. (2007). WHO | Standard deviation of anthropometric z-scores as a data quality assessment tool using the 2006 WHO growth standards: a cross country analysis. *Bulletin of the World Health Organization, 85* (6), 421-500. Retrieved from: http://www.who.int/bulletin/volumes/85/6/06-034421/en/.

Appendix A. Maps and graphs

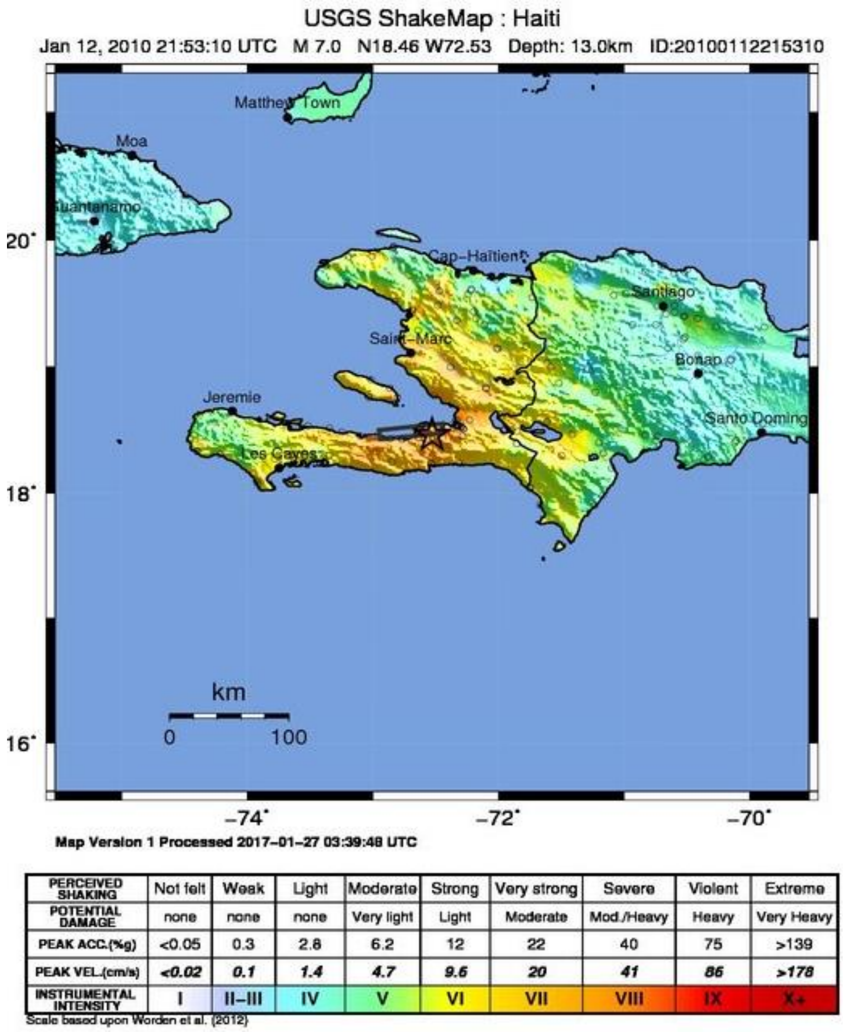

Figure A1. USGS ShakeMap of the 2010 Haiti Earthquake

Source: U.S. Geological Survey, Department of the Interior/USGS.

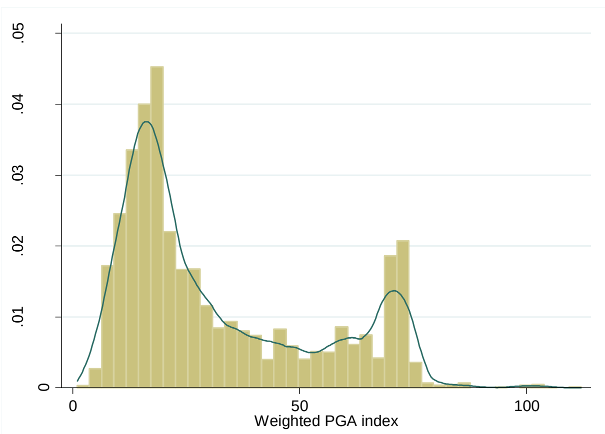

Figure A2. The Weighted PGA index distribution, $\delta = 1$.

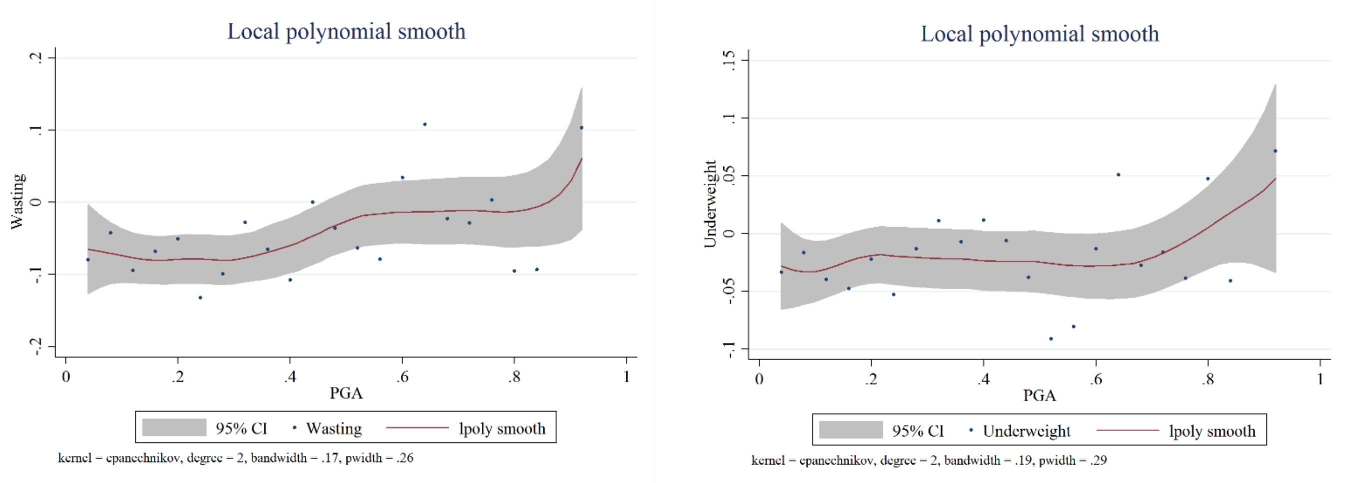

Figure A3. Difference in wasting (left) and underweight (right) between the before- and after-earthquake periods by shaking intensity

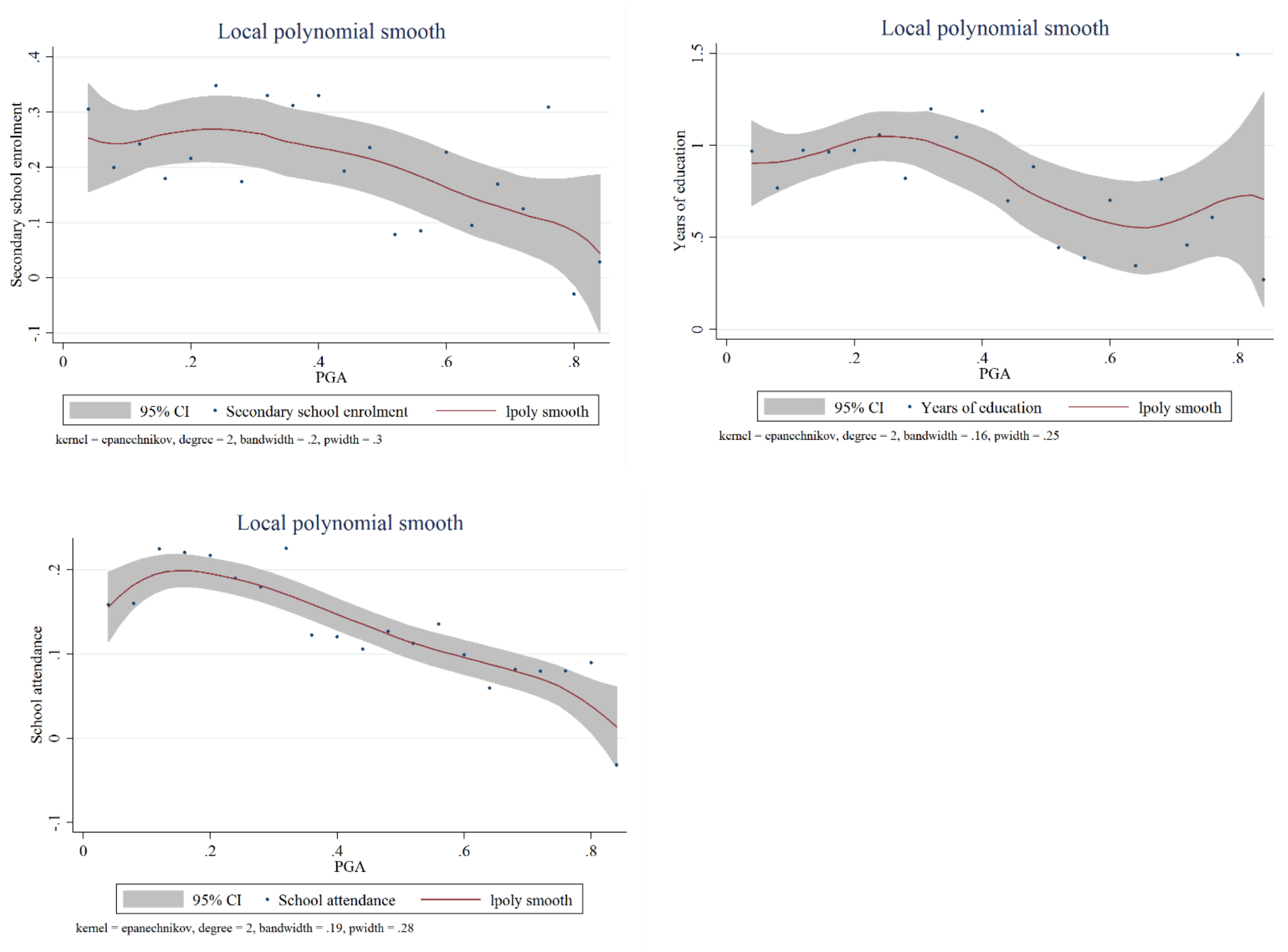

Figure A4. Difference in secondary school enrolment (top left), years of education (top right), and school attendance (bottom left) between the before- and after-earthquake periods by shaking intensity

Appendix B. Effect Heterogeneity

B1. Heterogeneous Effects in Children's Nutrition

In this section, we discuss the heterogeneity of the earthquake's effects on children's nutrition with respect to gender, age cohort and birth time. All specifications include a full set of control variables, time dummies, the interaction of the post-earthquake dummy and shaking intensity and the WB aid distributed to affected areas. Figures B1-B2 summarise these heterogenous effects on children's nutrition.[10]

After the introduction of gender indicators, as in the benchmark results, the interaction between the post-earthquake dummy and shaking intensity is statistically significant for HAZ scores, WAZ scores, stunting and wasting showing the persistence of children's malnutrition after the earthquake. The inclusion of WB aid is also significant and the results show that it helped to attenuate the detrimental effects of the earthquake, although not completely. However, the triple difference analysis for gender does not show any statistically significant difference between boys and girls for any of the six nutritional outcomes.

With regard to age cohorts, we study five different cohorts based on children's age measured in years.[11] One-year old children constitute the reference group (cohort 1). The main effects, irrespective of cohorts, remain unchanged. In addition, it becomes evident that older children of cohort 3 (25-36 months old at the time of the survey) and cohort 4 (37-48 months old at the time of the survey) demonstrate a faster recovery in their nutritional status measured by WHZ and WAZ scores than younger children of cohort 1 (0-12 months old at the time of the survey). A one SD increase in shaking intensity causes, on average, a 0.08 SD better WHZ score and a 0.07 SD better WAZ score for cohorts 3 and 4 in comparison to cohort 1. Underweight is also significantly lower for 4-year-old children and for one-year old children. Interestingly, there are no significant differences in stunting and wasting among various cohorts of children before and after the earthquake. Hence, only some of the indicators we consider suggest that children of cohort 1 are more vulnerable to natural disasters than older children.

Next, we test whether children who were in utero in January 2010 experienced subsequently more health problems because of their mother's food deficits during their pregnancy. For this purpose, we code a dummy that shows whether a child was in utero in the year of the earthquake. We thus drop children from the DHS 2016/17 survey as they are too old to have been in utero in January 2010 and compare only children from the DHS 2000, 2005/6 and 2012 surveys. As shown in Figures B1 and B2, children who have been in utero and exposed to a higher shaking intensity have, in contrast to our expectations, a higher WHZ score

[10] The coefficient plots are based on the regression results presented in the Tables S3.1 – S3.3. The results from the heterogeneity analysis in case of four treatment groups are available upon request.

[11] Cohort 1 was born in the years 1999, 2000, 2004, 2005, 2006, 2011, 2012, 2016 and 2017 and was under 0-12 months at the time of the survey. Cohort 2 was born in the years 1998, 1999, 2003, 2004, 2005, 2010, 2011, 2014, 2015, 2016 and was 13-24 months old at the time of the survey. Cohort 3 was born in the years 1997, 1998, 2002, 2003, 2004, 2009, 2010, 2014 and was 25-36 months old at the time of the survey. Cohort 4 was born in the years 1996, 1997, 2001, 2002, 2003, 2008, 2009, 2013 and was 37-48 months old at the time of the survey. Cohort 5 was born in the years 1995, 1996, 2001, 2007, 2008, 2012 and was 49-60 months old at the time of the survey.

than children who have not been in utero. However, the difference in wasting or stunting is not statistically significant. Interestingly, these children also demonstrate a slight improvement in the likelihood of being underweight. These findings might be explained by massive food distributions in highly struck areas after the earthquake. Looking at the results by trimesters, we find that these improvements are driven by women who, at the time of the earthquake, were in the first trimester of their pregnancy (see the results in Table S3.4). Pregnant women might have benefitted more from food distributions than other sections of the population. And probably the returns from additional food are the highest for women who are in the first trimester of their pregnancy. Generally, our results do not confirm that children who were in utero in highly affected areas at the time of the earthquake suffer more from malnutrition than the already born children.

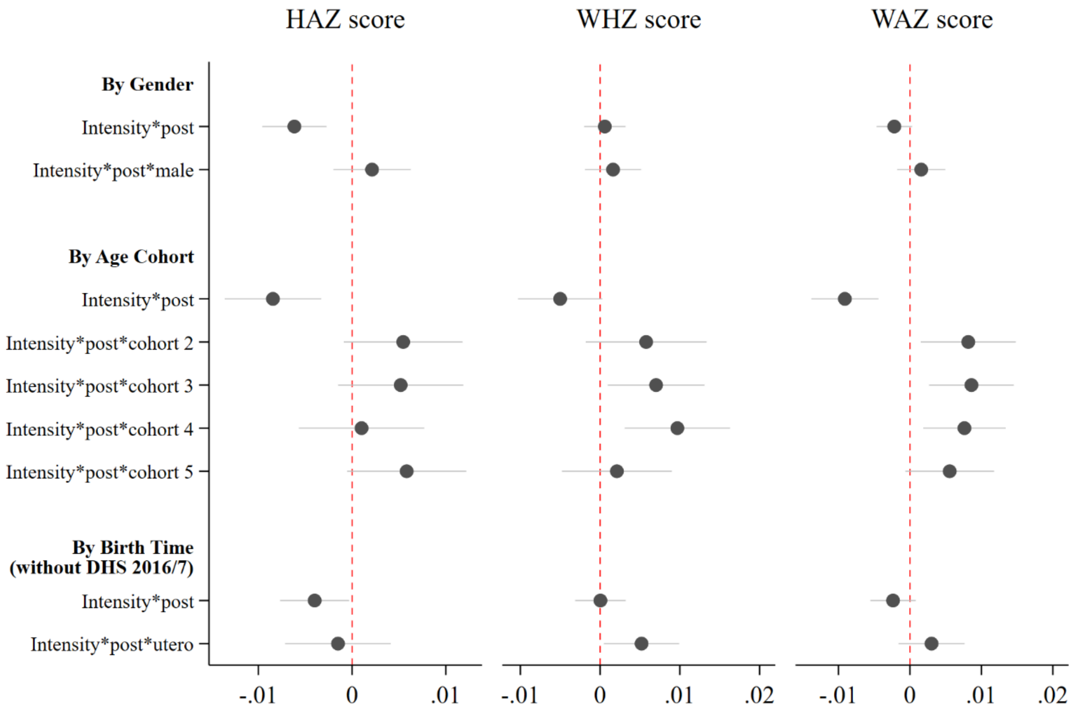

Figure B1. Effects of the Earthquake on Nutrition (z-scores) by Gender, Age Cohort and Birth Time

Notes: This figure visualizes the results of the regressions presented in Tables S3.1-S3.3. All models include regional and year fixed effects, shaking intensity specific variables, and a full set of control variables including the WB aid index. The regressions by age cohort use cohort 1 as the reference level. Cohort 1 was under 0-12 months at the time of the survey. Cohort 2 was 13-24 months old at the time of the survey. Cohort 3 was 25-36 months old at the time of the survey. Cohort 4 was 37-48 months old at the time of the survey. Cohort 5 was 49-60 months old at the time of the survey.

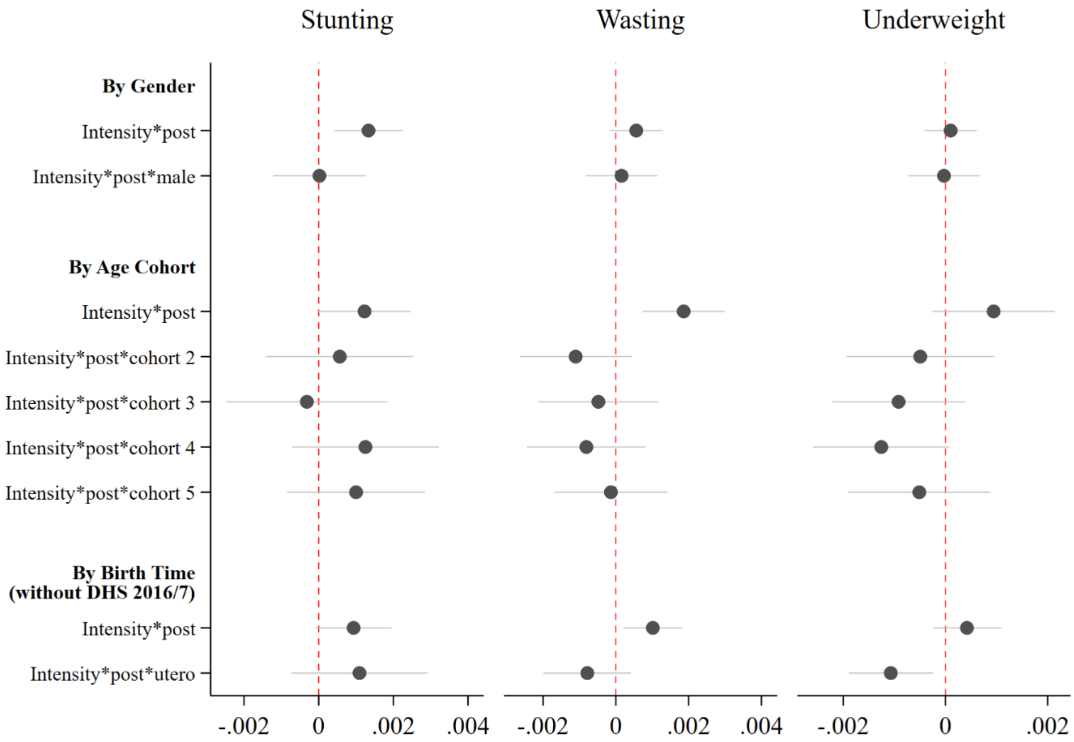

Figure B2. Effects of the Earthquake on Nutrition (Dummies) by Gender, Age Cohort and Birth Time

Notes: This figure visualizes the results of the regressions presented in Table S3.1-S3.3. All models include regional and year fixed effects, shaking intensity specific variables, and a full set of control variables including the WB aid index. The regressions by age cohort use cohort 1 as the reference level. Cohort 1 was under 0-12 months at the time of the survey. Cohort 2 was 13-24 months old at the time of the survey. Cohort 3 was 25-36 months old at the time of the survey. Cohort 4 was 37-48 months old at the time of the survey. Cohort 5 was 49-60 months old at the time of the survey.

B2. Heterogeneous Effects in Education

Figure B3 provides additional insights into how the impact of the earthquake differs with regard to gender and birth cohort.[12] The negative effects of the earthquake on secondary school enrolment and years of education are not significantly different for boys and girls. However, gender matters in differentiating the impact of the earthquake on primary school enrolment and attendance. A one SD increase in shaking intensity decreases both primary school enrolment and current attendance for boys by 0.025 SD or 1 percentage point more than for girls. These effects are not large in magnitude but statistically significant. Boys are more discouraged from attending school after the earthquake and from enrolling into primary school, although there is no change in secondary school enrolment or in years of education. This might be explained by a higher probability that families use their labour for reconstruction, i.e. recovering house ruins and repairs at home. We test this hypothesis in the next subsection when we focus on child labour.

We also explore the impact of the earthquake on children's education by birth cohort and also for those in-utero when the earthquake occurred. For example, it has been shown that children who were in utero during Ramadan have worse school performance than children who were not (Almond et al., 2015). However, as shown in Figure B3, primary school enrolment and attendance do not differ significantly for affected

[12] The coefficient plots are based on the regression results presented in Tables S3.5-S3.6. The heterogeneity of the results in case of four treatment groups will be available upon request.

children who were in utero compared to affected children not in utero at the moment of the earthquake. Only years of education decrease significantly for such children. This effect might be explained by the fact that many children only started attending first grade at the age of 6 years in 2016/17, so for the majority of that group of children, years of education are equal to 0.[13] Hence, we do not find any robust evidence that children exposed to the shock while in utero suffered more in terms of their education.

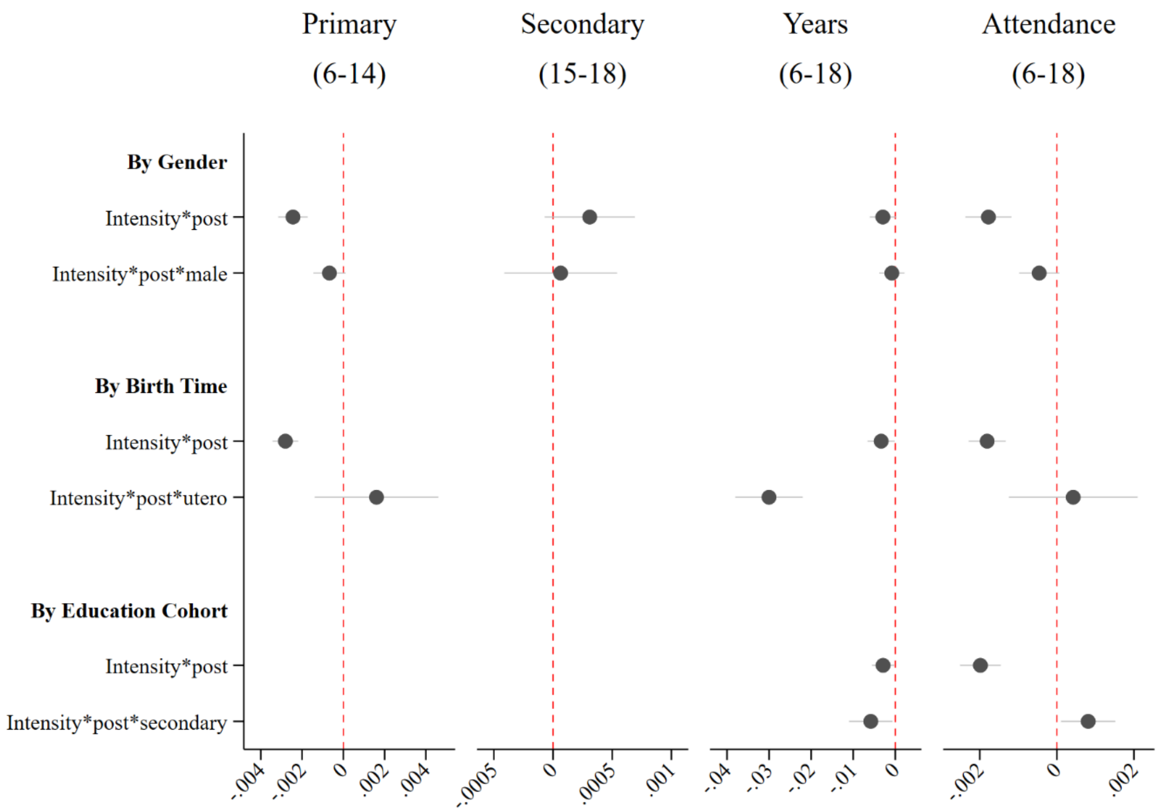

Figure B3. Effects of the Earthquake on Education by Gender, Birth Time, and Education Cohort

Notes: This figure visualizes the results of the regressions presented in Tables S3.5-S3.6. All models include regional and year fixed effects, shaking intensity specific variables, and a full set of control variables including the WB aid index. The heterogeneity by birth time reduces our sample as we focus on children who were in utero at the moment of the earthquake and thus secondary school enrolment is omitted. In the heterogeneity by education cohort, only school years and attendance are considered as only in these cases the sample comprises children of both age categories.

Next, we compare children of different cohorts, in particular, children aged 6 to 14 and 15 to 18. Only school years and attendance are considered in this heterogeneity check as the sample comprises children of both age categories. Interestingly, in highly struck areas, attendance in secondary school is higher than in primary school by 0.03 SD which corresponds to an increase equivalent to 9% of the attendance mean. However, the overall number of years of schooling drops by 0.03 SD in secondary school implying that more children dropped out in primary school and/or postponed their education. Hence, the two effects together may suggest that in severely struck areas more children tried to catch up with education levels that correspond to their age.

[13] We do not consider secondary school enrolment as there are no children who were simultaneously in utero in January 2010 and turned 15 years old in later waves.

Appendix C. Robustness Checks

To further check the robustness of our results we test whether these hold for alternative specifications of the weight functions. We also perform placebo tests for both nutritional and educational outcomes and use an alternative measure of damage based on the data from DesInventar. Finally, we run regressions where we also control for post-disaster displacement patterns and selective child mortality.

C.1. Alternative Specifications and Placebo Tests

First, we vary the specifications with regard to ground shaking intensity and aid allocation calculations. In order to construct the weighted indices, our benchmark results are based on the buffer zone $\delta = 1$ implying that all data within 1 kilometre is of higher importance. Now, we consider alternative weight functions with buffer zones $\delta = 5$ and $\delta = 10$. These modifications do not change the main results, although the effect sizes become lower because of the smoother distributions of the weighted indices. Tables S4.1 and S4.2 report these results for nutritional and educational outcomes, respectively.

In our placebo tests, we consider the same specifications as before but reduce the sample to only the years 2000 and 2005, and hypothetically assume that the earthquake had already happened in the year 2004, i.e. before the second DHS wave was conducted. Table S4.3 shows that in this case there is no significant change in HAZ scores or in stunting. WHZ and WAZ scores even show a slight increase, i.e. wasting and underweight declined in areas that later experienced a higher shaking intensity. These effects further support our main findings. The placebo test for educational outcomes is presented in Table S4.4. It shows that there are no changes in education, except for primary school enrolment, but this effect is much smaller than what we find for the period after the earthquake. Hence, this test also supports our main findings for education.

In the next test, we consider people older than 35 in the year of earthquake. At the time of the first DHS wave, they would have already finished school since that is when they turned 25 years old. For this reason, we do not expect any significant effects on education as all people considered have already finished their education by the time of the earthquake. Table S4.5 confirms our intuition except for secondary school attainment but the coefficient implies a decrease by 0.02 SD in highly struck areas after the earthquake. Although this effect is statistically significant, economically it is very small.

C.2. Displacement

Based on tracking data provided by the International Organization for Migration (IOM) and survey data reported in Herrera et al., (2014), Novella and Zanuso (2018) and Saint-Macary and Zanuso (2016), we know that most Haitians were residing in their original place of residence in 2011-2012. Yet, in order to address any potential concern regarding selective migration across clusters and regions we perform two additional checks. First, we re-estimate our benchmark estimations and keep only children that after the earthquake were living in the same house as before the earthquake. This information is provided in the DHS 2012 but not the DHS 2016. Hence, for this test we cannot use this later wave. Tables S4.6 and S4.7 show that our results do not change if we re-estimate our regressions with this sub-sample.

Second, we capture potential displacement patterns through the information on camp locations and their shelter capacity in 2010. We extract data on geographical coordinates and registered residents of all camps in Haiti for the period from September to December 2010 from the Displacement Tracking Matrix (DTM) provided by the IOM.[14] We re-estimate our benchmark specifications, but include the weighted indices of camp locations to capture displacement patterns and internal migration. The weights are defined as $WCamp_c = \frac{\sum_{\theta=1}^{\beth} W_{c\theta} \cdot POPULATION_\theta}{\sum_{\theta=1}^{\beth} W_{c\theta}}$, where $POPULATION_\theta$ is the number of people living in camp θ in the time after the earthquake until the end of 2010, and $W_{c\theta} = \frac{1}{(distance_{c\theta}+\delta)^2}$ is a weight based on a specific function defined by the distance between DHS cluster c and camp θ with buffer zone δ. In the main specification, a buffer zone is 1 kilometre. We expect that camps with larger capacities were located in the most affected areas so they could reveal stronger negative effects of the earthquake. On the other hand, according to the OCHA (2021), the bulk of humanitarian aid was allocated through the camps, so negative effects of the earthquake could have been attenuated by more intensive assistance in these areas.

Tables S4.8 and S4.9 report the results that take into account the location and the capacity of the camps assuming that their omission could lead to a bias. The coefficients associated with the weighted index of camps are negative which suggest that indeed areas that are close to camps are those areas that were hit the most severely and hence where the negative effects are largest. This seems to be the case despite the humanitarian support that was channelled to these camps and the surroundings. If the camps are taken into account, the effect on stunting is lower by 0.01 SD than in the benchmark results and comes to an effect equivalent to 11% of the stunting mean. The effect on wasting remains at the same level of 0.08 SD which equals 21% of the wasting mean. Further, as in the benchmark results, while WHZ scores show a significant reduction, the effect of the earthquake on being underweight remains insignificant. The effects of the earthquake on education, controlling for the closeness of camps, remain robust for primary school enrolment and current attendance. The sizes of these effects are lower by only 0.02 SD; they amount to 0.11 SD and 0.09 SD, respectively. The effects on secondary school enrolment and years of education are not significant after controlling for the closeness of camps. This might be a signal that the results in these outcomes are driven by those areas which are close to the camps, where the infrastructure was heavily destroyed.

C.3. Selective Mortality

Another potential threat to identification is infant mortality caused by the earthquake. It could well be that the most severe effects of the shock on children's malnutrition are hidden behind the deceased infants and

[14] For more information visit https://dtm.iom.int/

children. In this case, our results presented above would constitute lower bounds of the true effects. In order to take selective mortality into account, we first estimate the probability of a child having died in highly struck areas, and then control for the mortality patterns in the main estimation models.

We extract the information on child mortality from the corresponding DHS question in all four waves. Following the same empirical strategy as in the benchmark estimations, we estimate the probability of a child having died conditional on shaking intensity. Table S4.10 shows the results, again for both the shaking intensity specifications and with and without the control for WB aid. We find support for our intuition that highly struck areas are characterised by higher infant mortality in later years after the earthquake. In areas where the reported PGA was higher than 50g%, the number of perished children increased by about 3%.

We then use these results to predict the empirical probability of a child having perished after the earthquake and re-estimate the benchmark regressions on nutrition using mortality weights. These were constructed as the product of two weights: a DHS design sampling weight and a post-stratification weight computed as 1/predicted probability if a child is dead and 1/(1-predicted probability) if a child is alive (Desai & Franklin, 2019). Table S4.11 reports the results, again for both specifications (panel A and B). These results confirm the main findings above. A one SD increase in ground shaking intensity results in a 0.09 SD increase in stunting and in a 0.095 SD increase in wasting, which correspond to effects equal to 15% and 25% of the stunting and wasting means, respectively. These effects are higher by about 0.01 SD than the effects in the benchmark specification implying that the latter's coefficients represent lower bounds of the true effects. Alternatively, in severely affected areas with a PGA higher than 50g%, stunting and wasting are significantly higher by 11 percentage points and 9 percentage points than in less affected areas with a PGA lower than 12g%. These effects are larger by one and two percentage points in comparison to the benchmark results. In addition, severe stunting and wasting are also confirmed after considering selective mortality (see Table S4.12). Hence, our benchmark results including the effects of WB aid remain robust to controlling for selective mortality, but accounting for selective mortality implies even somewhat higher negative effects on children's health.

C.4. Alternative Measure of Exposure

We argue that ground shaking intensity is an objective and exogenous measure of exposure to the earthquake. However, we alternatively explore how actual damages induced by the earthquake relate to children's nutrition and education. We extract data on the destruction of infrastructure and on human casualties from the United Nations Disaster Information Management System (DesInventar). In particular, we consider measures of damage such as death tolls, number of victims, houses destroyed and houses affected at the district level. Following the procedure in the previous sub-sections, we calculate the weighted index of damages for each DHS cluster based on the information on the distance between clusters' and districts' centroids. However, actual damages are potentially endogenous to exposure to the earthquake because they are correlated with unobserved determinants of children's nutrition and education, for example through the quality of the infrastructure and people's residences or household preferences. We therefore apply an instrumental variable approach, in which we instrument observed damage of a specific type with ground shaking intensity based on the PGA measure. All types of damage are highly correlated with shaking intensity. A F statistic higher than 700 further confirms the relevance of the instrument in the first stage (see Tables S4.13 and S4.14 in the Online Appendix). The exclusion restriction requires that the earthquake affects children's nutrition and education exclusively through the damages reported in DesInventar. However, psychological shocks that come with an earthquake may also have a direct influence on children's nutrition and education. In this case, the exclusions restriction would not hold. As such, we prefer to use the main Difference-in-Difference specification as the benchmark and consider this instrumental variable approach although previously applied in the literature (see, e.g., Kirchberger, 2019) as a robustness check.

Table C1. Effects of the Earthquake on Nutrition, IV estimation (Second stage)

Instrumented variables	(1) HAZ	(2) Stunting	(3) WHZ	(4) Wasting	(5) WAZ	(6) Underweight
Log deaths	-0.0116	0.0049	0.0211	-0.0089	0.0109	-0.0012
	(0.0220)	(0.0071)	(0.0197)	(0.0058)	(0.0172)	(0.0041)
Log deaths*post	-0.0657***	0.0218***	-0.0040	0.0172***	-0.0433***	0.0044
	(0.0181)	(0.0053)	(0.0164)	(0.0042)	(0.0162)	(0.0033)
Log victims	-0.0095	0.0041	0.0207	-0.0092*	0.0118	-0.0013
	(0.0217)	(0.0070)	(0.0193)	(0.0057)	(0.0169)	(0.0040)
Log victims*post	-0.0706***	0.0234***	-0.0048	0.0187***	-0.0469***	0.0047
	(0.0195)	(0.0058)	(0.0178)	(0.0046)	(0.0175)	(0.0036)
Log homes destroyed	-0.0118	0.0049	0.0210	-0.0088	0.0106	-0.0012
	(0.0219)	(0.0071)	(0.0196)	(0.0058)	(0.0171)	(0.0041)
Log homes destroyed*post	-0.0656***	0.0218***	-0.0046	0.0175***	-0.0437***	0.0044
	(0.0182)	(0.0054)	(0.0166)	(0.0043)	(0.0163)	(0.0034)
Log homes affected	-0.0096	0.0042	0.0212	-0.0094*	0.0121	-0.0013
	(0.0221)	(0.0072)	(0.0197)	(0.0058)	(0.0173)	(0.0041)
Log homes affected*post	-0.0731***	0.0242***	-0.0051	0.0195***	-0.0487***	0.0049
	(0.0203)	(0.0060)	(0.0185)	(0.0048)	(0.0182)	(0.0037)
Observations	14,952	14,952	14,952	14,952	14,952	14,952
Controls	YES	YES	YES	YES	YES	YES
Region FE	YES	YES	YES	YES	YES	YES

Notes: The second stages of the IV specifications are presented where the instruments are the weighted index of the PGA measure of ground shaking intensity and its interaction with the after-earthquake dummy. Every two lines represent the results of different regressions depending on the type of damage including death tolls, number of victims, homes destroyed, homes affected. All damages are taken under logarithm. All models include regional and year fixed effects and a full set of control variables including the WB aid. Only the damages and their interactions with the after-earthquake dummy are reported. Robust standard errors in parentheses are clustered at the regional level *p<0.1; **p<0.05; ***p<0.01.

Tables C1 and C2 summarize the IV second stage results for children's nutrition and education, respectively. Regarding nutritional outcomes, the results confirm that the earthquake causes stunting and wasting as well as a lower WAZ score. In terms of size, the effects are much larger. A one SD increase in the log of deaths, which corresponds to about 54 deaths, leads to a 0.2 SD increase in stunting and wasting. Likewise, a one SD increase in the log of homes destroyed, which corresponds to about 7 houses destroyed, causes a 0.1 SD increase in both stunting and wasting. The effects on education also become significantly larger in areas with more reported deaths and destruction. About 54 deaths (one SD) lead to a 0.3 SD decrease in primary school enrolment and a 0.1 SD decrease in secondary school enrolment. These changes correspond to 20% and 12% of the enrolment means, respectively. The same effects are caused by a 2 SD increase in homes destroyed that corresponds to about 14 homes destroyed. The decrease in attendance is equal to 0.24 SD as a result of the earthquake damages of 54 deaths or 14 homes destroyed.

Table C2. Effects of the Earthquake on Education, IV estimation (Second stage)

Instrumented variables	(1) Primary	(2) Secondary	(3) Years	(4) Attendance
Log deaths	0.0139*	0.0086	0.0599*	-0.0033
	(0.0085)	(0.0099)	(0.0338)	(0.0075)
Log deaths*post	-0.0350***	-0.0125**	-0.0496**	-0.0218***
	(0.0039)	(0.0055)	(0.0206)	(0.0031)
Log victims	0.0154*	0.0093	0.0634*	-0.0028
	(0.0089)	(0.0105)	(0.0352)	(0.0079)
Log victims*post	-0.0373***	-0.0134**	-0.0519**	-0.0236***
	(0.0042)	(0.0059)	(0.0219)	(0.0033)
Log homes destroyed	0.0146*	0.0091	0.0634*	-0.0039
	(0.0091)	(0.0108)	(0.0365)	(0.0082)
Log homes destroyed*post	-0.0351***	-0.0126**	-0.0499**	-0.0218***
	(0.0040)	(0.0056)	(0.0208)	(0.0032)
Log homes affected	0.0158*	0.0096	0.0654*	-0.0031
	(0.0092)	(0.0109)	(0.0364)	(0.0082)
Log homes affected*post	-0.0385***	-0.0139**	-0.0536**	-0.0244***
	(0.0044)	(0.0061)	(0.0226)	(0.0034)
Observations	47,673	19,225	66,898	66,898
Controls	YES	YES	YES	YES
Region FE	YES	YES	YES	YES
Age	6-14	15-18	6-18	6-18

Notes: The second stages of the IV specifications are presented where the instruments are the weighted index of the PGA measure of ground shaking intensity and its interaction with the after-earthquake dummy. Every two lines represent the results of different regressions depending on the type of damage including death tolls, number of victims, homes destroyed, homes affected. All damages are taken under logarithm. All models include regional and year fixed effects and a full set of control variables including the WB aid. Only the damages and their interactions with the after-earthquake dummy are reported. Robust standard errors in parentheses are clustered at the regional level *p<0.1; **p<0.05; ***p<0.01.