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"How earthquakes impact child development: Evidence from Indonesia"

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ABSTRACT IN ENGLISH (100 words):

Natural disasters frequently happen in Indonesia. However, the May 27, 2006 Yogyakarta earthquake still stands out with a magnitude of 6.3 on the Richter Scale. The total financial cost caused by the earthquake was US$ 3.1 billion. An estimated 154,000 houses were destroyed, and at least 260,000 households suffered some damage. This paper analyses the medium-term impact of this earthquake on the development of children five and below. We estimate that, on average, affected children are between 1.6-2.8 centimetres smaller and lose between 0.5-2.5 kilograms. Boys and children who reside within urban areas are adversely affected the most.

ABSTRACT IN CATALAN/ SPANISH (100 words)

Els desastres naturals ocorren sovint a Indonèsia. No obstant això, el terratrèmol de Yogyakarta del 27 de maig de 2006 continua destacant amb una magnitud de 6,3 en l'escala de Richter. El cost financer total causat pel terratrèmol va ser de 3.100 milions de dòlars. S'estima que es van destruir 154.000 cases, i almenys 260.000 llars van patir alguns danys. Aquest document analitza l'impacte a mitjà termini d'aquest terratrèmol en el desenvolupament dels nens de menys de cinc anys. Es calcula que, de mitjana, els nens afectats són entre 1,6 i 2,8 centímetres més baixos i pesen entre 0,5 i 2,5 quilos menys. Els nois i nens que resideixen dins les zones urbanes són els més afectats.

Los desastres naturales ocurren a menudo en Indonesia. Sin embargo, el terremoto de Yogyakarta del 27 de mayo de 2006 continúa destacando con una magnitud de 6,3 en la escala de Richter. El coste financiero total causado por el terremoto fue de 3.100 millones de dólares. Se estima que se destruyeron 154.000 casas, y al menos 260.000 hogares sufrieron algunos daños. Este documento analiza el impacto a medio plazo de este terremoto en el desarrollo de los niños de menos de cinco años. Se calcula que, de media, los niños afectados son entre 1,6 y 2,8 centímetros más bajos y pesan entre 0,5 y 2,5 kilos menos. Los chicos y niños que residen dentro de las zonas urbanas son los más afectados.

KEYWORDS IN ENGLISH (3)**: CHILDHOOD DEVELOPMENT, INDONESIA, EARTHQUAKE**

KEYWORDS IN CATALAN/ SPANISH (3)**: DESENVOLUPAMENT INFANTIL, INDONÈSIA, TERRATRÈMOL / DESARROLLO INFANTIL, INDONESIA, TERREMOTO**

How earthquakes impact child development: Evidence from Indonesia

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Abstract

Natural disasters frequently happen in Indonesia. However, the May 27, 2006 Yogyakarta earthquake still stands out with a magnitude of 6.3 on the Richter Scale. A comprehensive damage assessment by the Indonesian Government and international experts estimated the total financial cost caused by the earthquake was Rp 29.1 trillion, or US$ 3.1 billion (Consultative Group on Indonesia. Meeting, 2006). An estimated 154,000 houses were destroyed, and at least 260,000 households suffered some damage. This paper analyses the medium-term impact of this earthquake on the height, weight and prevalence of anaemia in children five and below. We estimate that, on average, affected children are between 1.6-2.8 centimetres smaller and lose between 0.5-2.5 kilograms. Our analysis also indicates that for some results, the proportion of children with anaemia increases in affected areas. When assessing this by disaggregated individual characteristics, we find that boys are adversely affected compared to girls and children who reside within urban areas are harder hit than those who live in rural areas.

1 Introduction

Indonesia has repeatedly made global headlines over the past 30 years for devastating natural disasters. Due to its location on the Pacific Ring of Fire (a very active seismic zone), Indonesia has suffered more earthquakes than any other country, according to the United States Geological Survey (Hayes et al., 2020). On average, the Indonesian National Board for Disaster Management reports one natural disaster every month which threatens the livelihoods of families and communities (UN WFP, 2020). Earthquakes cause significant negative economic impacts through various channels such as destruction of property, loss of physical assets or of household members, and in terms of health status and educational attainment. Therefore, increased seismic activity poses a serious risk to Indonesia's continued rapid economic growth. The UN and other international organisations have long worked with the government to strengthen the country's preparedness to respond to natural disasters in a holistic manner that includes food-related support, social development, and financial flows. Indeed, in the aftermath of the Yogyakarta earthquake, the Indonesian House of Representatives set up the National Disaster Management Agency (BNPB) to promote research on natural disasters and develop evidence-based risk mitigation measures as well as post-disaster approaches (BNPB, 2021).

However, the wider literature primarily focussed on economic variables such as income (Kellenberg & Mobarak, 2008; Sawada & Shimizutani, 2008), international financial flows (Yang, 2008; David, 2011), and long-term growth (Cuaresma, Hlouskova and Obersteiner, 2008; Skidmore & Toya, 2002) while only making limited contributions to the health and education related areas of the BNPB research agenda. There is some evidence of mental health impacts (Frankenberg et al., 2008; de Mel, McKenzie & Woodruff, 2008) from the 2004 tsunami Indian Ocean. Research of the impact on health outcomes in marginalised groups such as low-income individuals and children is even more sparse, although these groups are the most vulnerable. Not only is the immediate impact of natural disasters large on the general population, but even more so on children, as anthropometric deficits in early childhood often persist into adulthood (Currie & Almond, 2011). Poor children are likely the hardest hit as their households are the most vulnerable and lack the capacity to respond. Some case studies (mostly outside the economic literature) suggest that differential impacts on those affected by an earthquake are due to pre-disaster lifestyle differences and indirect effects arising from how recovery assistance is used or accessed (Bates et al., 1963; Cochrane, 1975; Haas, Kates and Bowden, 1977). Many of these studies do not apply to the Indonesian context given they were conducted in different countries, have different population demographics or have a growing population. However, the government needs to understand the impact on children and the possible long-term effects.

Given the limited evidence within the literature regarding systematic studies on the differential impact of earthquakes on children's health, we analyse the 2006 Yogyakarta earthquake on Java Island. In particular, we examine the medium-term effects of earthquake exposure on anthropometric outcomes (height and weight) and haemoglobin levels (anaemia) in children five years and younger[1]. We use the Indonesia Family Life Survey (IFLS) to identify a sample of children aged zero (in-utero) to five years old in Yogyakarta who were exposed to the disaster in 2006. In doing so, we seek to answer three interrelated questions. First, are there persistent negative effects on children five years and younger after exposure to a negative exogenous shock? Second, can we observe differential effects between subgroups? Third, does the intensity of exposure to the earthquake have an effect on the outcomes of interest? We also provide some back-of-the-envelope calculations to give an estimation of the long-term economic costs of the earthquake.

[1] The first five years of life are particularly important because vital developments occur during that phase (National Research Council, 2000)

Our results show that children who were exposed to the earthquake exhibit lower height-for-age Z-scores (HAZ). Depending on the area they reside in we observe a decline between 0.241 and 0.388 standard deviations. In the two most affected areas, our difference-in-differences analysis demonstrates a weight decline between 0.5 and 2.5 kilograms. The results for anaemia are largely insignificant, except in intensity treatment 1 where the proportion of children with anaemia increases. We also provide an analysis of differential effects by looking at individual-level characteristics that may drive these results. We find that boys are adversely affected compared to girls, and children who reside in urban areas are more affected than those who live in rural areas. Based on our findings we do some back-of-the-envelope calculations that show foregone individual lifetime earnings, as a result of the lower HAZ, are between $640-$1,040.

Our work contributes to the literature in four ways. To the best of our knowledge, we are the first to provide a complete account of the effects of anthropometric measures and haemoglobin on children five years and under after an earthquake. More specifically, we measure the prevalence of low height relative to age, changes in weight, and changes in proportion of children with anaemia. The three measures are of particular economic importance as they can have long-term effects on cognitive development, school performance, economic productivity in adulthood, and maternal reproductive outcomes (Dewey & Begum, 2011; Allali et al., 2017; Basta et al., 1979). Secondly, as an innovative addition, we introduce a measure of intensity that allows us to assess whether children in harder-hit areas are more affected. Our approach is similar to a spatial difference-in-differences approach, a method that takes into account the distance to an intervention (Heckert, 2015). However, instead of distance, we use the severity of the earthquake as determined by the number of fatalities in different sub-districts. By showing that more severely affected sub-districts, rather than areas as a whole, have worse medium outcomes, we provide important evidence for the future distribution of aid after earthquakes. Thirdly, we analyse differential effects in Yogyakarta that support the determination of why certain children are more affected than others. This part of the analysis is based on both the intensity measure we introduce and different household characteristics before the earthquake. While policy needs to consider more than just earthquakes (Kusumastuti et al., 2014), we present the hypothesis that targeted interventions can support those people most affected by natural disasters. A detailed account of the differential effects is essential for the National Disaster Management Agency to determine better aid allocations and investments in preparedness. Finally, to show the robustness of our results, we implement a novel matching procedure. This is an important contribution due to Indonesia's great diversity in terms of urban and rural areas, religion, and other characteristics.

The paper is organised as follows: Section 2 offers a brief background on the magnitude and damages of the Yogyakarta earthquake. Section 3 provides a literature review of previous studies examining individual impacts of natural disasters in developing countries. Section 4 introduces the IFLS and data from the National Development Planning Agency used for intensity assessment. This section also outlines relevant summary statistics as well as introducing each treatment specification. Section 5 presents the empirical strategy, followed by an overview of the results in Section 6, including possible mechanisms and heterogenous effects of the earthquake. We also review data limitations and provide robustness checks in that section. Section 7 provides a discussion and finally, a conclusion is drawn in Section 8.

2 Setting

On May 27, 2006, at 5:54 a.m. local time, Yogyakarta was struck by a major earthquake with a magnitude of 6.3 on the Richter Scale. The USGS (2021) located the epicentre in the district (kabupaten) of Bantul in the Special Region of Yogyakarta. Due to its shallow nature at only 12.5 kilometres below the earth's surface, the on-ground effects were more intense than deeper earthquakes of the same magnitude. A comprehensive damage assessment by the Indonesian Government and international experts estimated the total financial cost caused by the earthquake to be Rp 29.1 trillion, or US$ 3.1 billion[2] (Consultative Group on Indonesia. Meeting, 2006). Approximately 154,000 houses were destroyed, and at least 260,000 households suffered some damage. The average per capita damage and losses were unevenly distributed. The Bantul district was by far the hardest hit, with per capita losses of Rp 12.3 million. The impact on Klaten district was also significant at Rp 6.5 million. The death toll is estimated to be above 5,700. More than 1.5 million people were left homeless, equivalent to one-third of the local population. While the government and international community responded quickly, the simultaneous eruption of the nearby Mount Merapi, which occurred as a result of the earthquake, further complicated humanitarian relief and recovery efforts after the earthquake. The Indonesian government responded within hours and allocated Rp 5 trillion for relief efforts. District authorities distributed the compensation and in-kind donations that were provided by the central government. The international community responded quickly, helped by the fact that many organisations were still operating in Aceh after the 2004 tsunami.

3 Literature

As described above, the available literature mainly examines the economic impact of natural disasters on economic variables such as economic growth, employment, and income (Kellenberg & Mobarak, 2008; Skidmore & Toya, 2002; Sawada & Shimizutani, 2008; Cuaresma, Hlouskova and Obersteiner, 2008; Yang, 2008; David, 2011). However, we seek to analyse the impact of natural disasters on children. In the following paragraphs, we will provide a brief introduction to the existing literature that focuses on individual impacts which can be divided into three categories: Health, Human Capital, and Differential Impacts.

Health. Previous research on natural disasters outside Indonesia shows heterogeneous results on child development in both the short and the long term. Using the Indian National Family and Health Survey with an international database of natural disasters, Datar et al. (2011) find that children exposed to a natural disaster in the past year had Z-scores for height and body weight that were 0.12-0.15 standard deviations lower and were also more likely to be stunted and underweight. Similarly, Bahru et. al. (2019) examined the effects of drought exposure on children under five years of age in Ethiopia and found that current and long-term drought exposure was negatively associated with the height Z-score. Bustelo et. al. (2012) found a strong negative impact of the 1999 earthquake in Colombia on child health outcomes such as height and weight. Z-scores for height-for-age decreased by 0.296 standard deviations for children living in Quindío one year after the earthquake. Assessing Z-scores allows important inferences about future educational attainment and wages. For example, Alderman, Hoddinott, and Kinsey (2006) report that a one standard deviation decrease in height leads to 0.85 lower years of schooling for children in Zimbabwe.

Human capital. Dong & Yang (2020) examine the impact of the 2006 Yogyakarta earthquake on school enrollment and child labour among Indonesian children. They find that after a natural disaster, children under the age of 15 have lower educational attainment and higher levels of child labour. Similarly, Paudel & Ruy (2018) assess the long-term impact of the 1988 earthquake in the border region of Nepal-India on the educational outcomes of children in affected regions in rural Nepal. They find that children born in severely affected areas in rural Nepal are 13.8% less likely to complete middle school, 10% less likely to

[2] 2006 prices

complete high school, and on average complete 0.8 grade levels less than children who were not affected by the earthquake. Literature has shown that educational attainment is an important measure and allows the possibility to make assertions about wages.

Differential effects. Exposure to natural disasters does not affect children uniformly. Datar et al. (2013) find that the impact of disasters varies significantly by gender, age, and socioeconomic characteristics. They find that girls are significantly more likely to be underdeveloped and underweight compared to boys . The paper also concludes that children living in regions with better socioeconomic conditions, such as those with better pre-disaster health infrastructure, are less affected than children living in regions with worse socioeconomic conditions. Understanding how the impact of exposure varies between different socioeconomic characteristics and how the intensity of exposure can influence the magnitude of the effect is important for policy and aid allocation.

Our work contributes to these three streams of literature. We analyse post-earthquake health outcomes by determining the impact of exposure by different subgroups. This allows us to make some back-of-the-envelope calculations to infer the loss of educational attainment and subsequently income. We have seen that Indonesia is highly vulnerable to natural disasters and that previous research has shown evidence of negative impacts on children in the short, medium, and long term. It is therefore important to advance this area of economic research.

4 Data

4.1 IFLS

Our data sample comes from the IFLS, a nationally representative panel data set originally implemented by the RAND Corporation and the Demographic Institute at the University of Indonesia. There are five waves of this household-level survey, ranging from 1993 to 2014. As with any panel data set, there is attrition (the extent to which a household is not included in the follow-up survey) in our sample, but this is extremely low compared to other similar national household surveys. For instance, 87.8% of dynasties that were interviewed in IFLS1 (1993) are still in the sample or died. In our analysis, we use information from IFLS waves 3, 4, and 5, collected in 2000, 2007, and 2014, respectively, to capture the variables of interest before and after the 2006 Yogyakarta earthquake. The survey sample is representative of approximately 83% of the Indonesian population and includes approximately 30,000 individuals from 13 of the country's 27 provinces, including those within our analysis as shown in Figure 1 below. Our sample of children is fully covered by the IFLS.

The IFLS contains extensive household information covering a range of topics including wealth (both agricultural and non-agricultural), consumption, migration, income, goods prices, household expenditure, education, employment, fertility, and health. We use both IFLS4 which took place approximately 600 days after the Yogyakarta earthquake and IFLS5 to determine medium-term impacts.

4.2 Treatment Areas

Determining the area of people affected by an earthquake is no easy task. Earthquakes can often be felt thousands of miles away, but that does not mean that someone who felt the earthquake was affected by it. For example, on average, a magnitude five earthquake has a radius of 100 kilometres (Acaps, 2021). However, the amount of destruction caused by the earthquake depends not only on the magnitude and radius of the earthquake, but also on other factors such as topography, quality of dwellings, and depth

Figure 1: IFLS Map

of an earthquake. Given the large number of variables involved in measuring the effect of an earthquake, we decided to form three treatment groups based on different measures. The first group is identified in the IFLS, the second group is determined by the broader literature, and the third group is established by the number of fatalities in the sub-districts around the epicentre.

Survey treatment. In the IFLS, participants indicate whether they were affected by the earthquake, and if so, whether they were severely affected. This question allows us to directly identify the group of self-reported people who were exposed to the earthquake within our survey sample. For measurements of height, weight and proportion of children with anaemia, the treated sample sizes are 106, 111 and 150 respectively. However, this method is prone to measurement error and endogeneity problems. Given the time lag between the shock and the survey, it is likely that participants may not recall whether or how severely they were affected by the earthquake. Other concerns about self-reported measurements, such as different interpretations of the severity question or general response biases also apply.

Geographic treatment. To address these concerns, we use the broader literature to identify affected locations. We use multiple papers to determine which areas were affected (see, for example, Kaplan, 2010). This approach addresses the problem of endogeneity and is more objective. The sample size of treated individuals for height, weight and proportion of children with anaemia are 195, 200 and 285 respectively.

Intensity treatment. A standard measure for the intensity of earthquakes are peak ground acceleration (PGA) maps (Pawirodikromo, 2018). They provide detailed information about the intensity of the earthquake in any given location. While we were not able to construct a PGA map ourselves due to data access limitations, we constructed a map based on reported fatalities that exhibits a high correlation with the PGA maps for the Yogyakarta earthquake (ibid). The map was generated with data from the Preliminary Damage and Loss Assessment (Consultative Group on Indonesia. Meeting, 2006). Our map shows three levels of intensity with the worst hit being the darkest. The worst affected sub-districts (treatment 3) were assigned a value of three (over 200 fatalities). Areas with a fatality rate between 10 and 200 were assigned a value of two (treatment 2). Areas with less than 10 fatalities were assigned a value of one (treatment 1). We use the severity indicator in our empirical analysis to assess the impact on those treated, but also to analyse if more affected areas have different outcomes. In Figure 2, the sub-districts are colour coded (worst hit areas are darker) to indicate the different areas of impact. As a result of this approach, the number of treated individuals for height across the three intensity categories

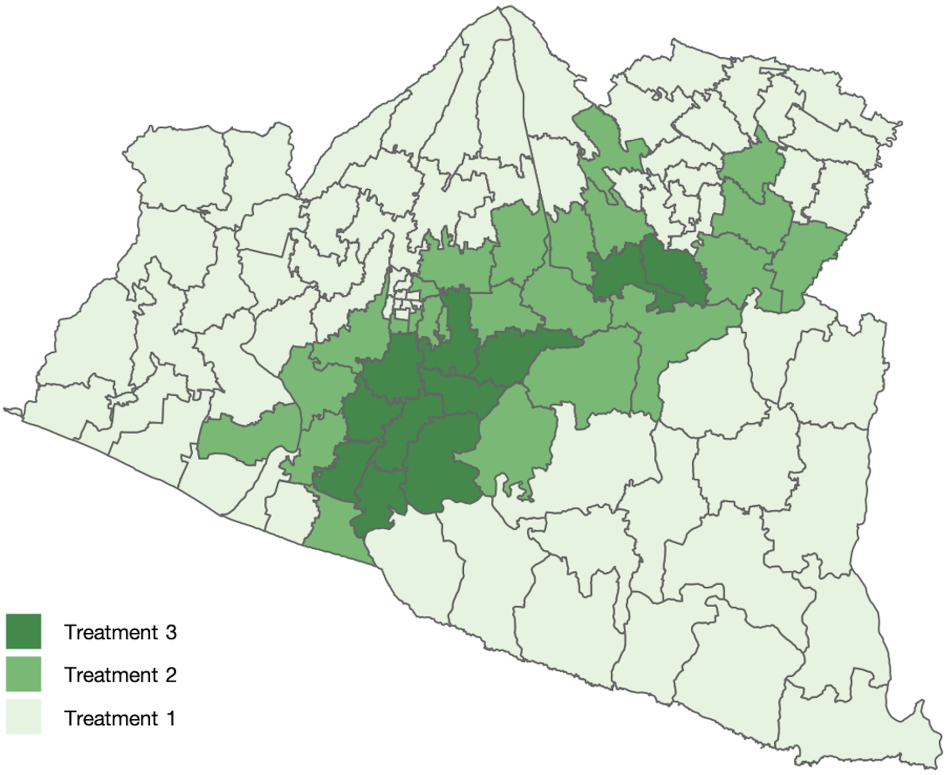

Figure 2: Intensity Map

Table 1: Treatment Sample Sizes

	Survey	Geographic	Intensity		
			Treatment 1	Treatment 2	Treatment3
Height	106	195	84	52	80
Weight	111	200	86	53	83
Anemia	150	285	133	80	111

are 84, 52 and 80, with 86, 53 and 83 for weight, and 133, 80 and 111 for proportion of children with anaemia (Table 1).

Treatment overlap. While the intensity measure is the most insightful, having three different measures of treatment allows us to conduct robustness checks to corroborate our findings. The survey treatment has the smallest sample size, then the geographic and the largest - with the three individual intensity treatments summed - the overall intensity treatment. The survey treatment sample has a large overlap - roughly 65% - with the highest casualty intensity area (intensity treatment 3), as seen in Table 2 and Table 3. Furthermore, 90% fall within the geographic treatment sample, essentially making the survey treatment a subgroup of the geographic treatment which is nearly twice as large. The geographic treatment includes everyone in intensity treatment 3 but excludes roughly 20% of those in both intensity treatment 1 and treatment 2.

Table 2: Treatment comparison - Survey vs Intensity

Survey	Intensity				
	0	1	2	3	Total
0	2,929	119	41	15	3,104
1	1	14	39	96	150
Total	2,930	133	80	111	3,254

Table 3: Treatment comparison - Geographic vs Intensity

Geog	Intensity				
	0	1	2	3	Total
0	2,925	30	14	0	2969
1	5	103	66	111	285
Total	2,930	133	80	111	3,254

Control group. Indonesia is made up of numerous islands. We restrict the control group of our analysis to be the main island of Java where Yogyakarta is located. The island consists of five provinces, of which two districts are affected by the earthquake. The unaffected districts in these two affected provinces, and the other three unaffected Java island provinces form the control group. As part of our robustness checks, we also implement a matching procedure to ensure that our results are not driven by differences in the covariates between the treatment and control groups.

4.3 Variables

We analyse height, HAZs, weight and anaemia for children between seven and thirteen years of age in 2014 (henceforth outcomes of interest). Since we have three different treatment classification strategies, the average results of the treatment groups vary depending on the specification. The averages of the outcomes of interest across treatment and control groups in 2014 are shown in Table 4. For our main specification, all data is collected from household survey responses. To account for household characteristics, we consider variables such as the number of occupants in the household, the household size in square metres and the income of the household. We also use individual-level data to measure changes in the outcome measures of interest.

Height. The average height eight years after the earthquake (2014) in the treatment groups is between 129.2-132 centimetres whereas in the control group the mean is 131.3 centimetres.

Z-score. Our calculations for the HAZs are based on World Health Organization (WHO) standards. The WHO does not have data on weight-for-age or weight-for-height for children above five years old,

Table 4: Means of outcome variables in 2014

	Height (cm)		Weight (kg)		Anaemia		Z-score	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Survey								
Treatment	131.2	12.6	30.2	7.9	0.20	0.40	-1.35	0.91
Geographic								
Treatment	130.3	12.0	30.0	8.6	0.19	0.40	-1.37	0.86
Intensity								
Treatment 1	130.0	11.8	28.8	8.8	0.19	0.39	-1.30	0.82
Treatment 2	129.2	12.1	28.7	8.4	0.11	0.32	-1.21	0.91
Treatment 3	132.0	12.5	30.7	8.2	0.22	0.41	-1.36	0.95
Control	131.3	11.9	29.4	8.6	0.16	0.37	-1.31	0.85

Table 5: Means of covariates in 2007

	Survey	Geographic	Intensity			Control
			T1	T2	T3	
Age	10.41	10.31	10.32	10.34	10.32	10.35
Education	7.15	7.44	6.82	6.13	7.47	11.25
Number of rooms	6.00	6.31	6.78	6.13	5.74	6.08
Household size	4.49	4.63	4.83	4.23	4.51	4.62
Sqm of house	86.0	94.64	110.97	74.0	90.37	90.70
Urban	0.82	0.70	0.65	0.84	0.84	0.57
Electricity	1.00	0.98	0.98	0.97	1.00	0.99
TV	0.90	0.84	0.78	0.84	0.95	0.83
Grade	2.27	2.29	2.51	2.00	2.45	2.52

Note: Age represents the age of child, Education represents the child´s highest level of education, Number of rooms in a given household, Household size represents the number of individuals living in one household, Urban represents the proportion of children living in urban areas, Electricity is the proportion of households who use electricity, TV represents the proportion of households that have a television, Grade represents the highest grade completed by child.

and thus we do not calculate Z-scores for weight. The Z-score represents the distance from the median when measured in units of standard deviation. It is calculated by standardising a child's height at a given age and sex against an international standard of well-nourished children. The HAZ has the advantage over height in centimetres that it is more widely used in the literature, allowing for a comparison of our results to existing studies. A Z-score of minus one corresponds to a standard deviation of one below the median height of children in its age and sex group (Alderman et. al. 2006). For 2014, the mean Z-score of treated children ranges from -1.21 to -1.37 standard deviations below the median, compared with -1.31 standard deviations below the median of children living in control areas.

Weight. For 2014, the mean weight in the treatment groups is between 28.7-30.7 kilograms. In the control group, the average weight is 29.4 kilograms.

Anaemia. Anaemia is a condition in which an individual's red blood cell count - their haemoglobin levels - are insufficient to meet their body's physiological needs. It is primarily driven by a restricted or nutrient limited diet, and is often associated with low iron levels (Lozoff, 2007). By definition, children under five are classified as anaemic if they have a haemoglobin level less than 11 grams per deciliter. For children between five and eleven years of age the threshold rises to 11.5 grams per deciliter and children above 11 years are classified as anaemic if their haemoglobin levels are below 12 grams per deciliter

(WHO, 2011). In 2014, the proportion of anaemic children in the treatment groups varies from 11-22% compared to 16% in the control group.

5 Empirical Strategy

Our outcomes of interest - height, weight and anaemia - are recorded in the latest IFLS wave (IFLS 5)[3]. All three measures are determined by a certified nurse. We analyse changes for weight, height and HAZs, and the proportion of children with anaemia.

We explore three alternative model specifications. First, we utilise a simple regression model on both the treated and control groups in 2014. However, this approach assumes that there are no differences between the treated and control regions before the earthquake. Our subsequent analysis of the means in both groups shows that such differences do exist. As a result, if we were to identify significant differences in 2014 using a simple regression, we would not be able to confirm that the differences were not already present when comparing treated and control areas before the earthquake which could bias our analysis. Second, we explore a simple difference approach between cohorts in the treatment area: before and after the earthquake. This approach did yield results, however, it does not account for any temporal trends (e.g. Indonesia's strong economic growth improves the average health of children). Therefore, we decide to employ a difference-in-differences approach which allows us to take time trends into account.

The main identifying assumption in the difference-in-differences approach is that of parallel trends. This proposes that in the absence of the earthquake, the difference between the treatment and control groups is constant and therefore allows for the implicit calculation of a counterfactual for the treatment in the post period. To judge whether such an assumption is valid we investigate the pre-trends in the outcomes of interest by making use of the earlier waves of the IFLS and conduct the same difference-in-differences estimation but on earlier cohorts in treatment and control areas. By looking at difference-in-differences for outcomes of seven to 13 year-olds in 1997 and 2000 (IFLS2 and IFLS3 respectively) we conclude that there are largely no significant differences[4] in children's outcomes of interest between 1997 and 2000, and therefore the parallel trends assumption is supported. These results can be found in the Appendix. In the absence of this parallel trend assumption, we would not be able to assume that treated children post earthquake would have followed a similar trajectory to control children, and so, it would not have been possible to conduct a difference-in-differences approach. An additional assumption to ensure the presence of parallel trends is that no other external factor solely affects the treatment group.

To implement a difference-in-differences approach, we also need to construct a baseline for the pre-earthquake period. This is because it is not possible to consider the same children prior to the earthquake due to the data limitations of the IFLS and the age of the children (there are seven years between IFLS3 and IFLS4). Therefore, we use an earlier cohort of children in what will be the treatment and control areas as pre-groups; zero to six-year-olds in 2000 (IFLS3) using their outcomes of interest in 2007 (IFLS4). This approach is similar to Duflo's (2001) strategy in studying the effect of school building construction in Indonesia. One point to be considered is that IFLS4 was conducted 20 months after the Yogyakarta earthquake, so in this survey we use zero to six-year-old children[5] to reflect those who were five years and under during the earthquake and were also in-utero, as these years are considered the key years for anthropometric development in the existing literature.

[3]We drop those observations which have an anthropometric outcome that is below the 3rd or above the 97th percentile according to Acta Science growth charts in accordance with WHO recommendations and other literature (WHO, 2006).

[4]For height we find that the intensity treatment 2 group is significantly taller in 2000 by 1.77 centimetres

[5]Given the data, we cannot pinpoint age at the monthly level and hence the use of 0-6

Thus, the difference-in-differences approach we use is as follows: the post-treated and post-control groups are children aged zero to six years in 2007 (IFLS4) and the pre-treated and control groups are children aged zero to six years in 2000 in the future treated and control areas.

Our main specification is:

$$AM_i = \alpha + \beta_1 Treatment_i + \beta_2 Post_i + \underbrace{\beta_3 \left(Treatment_i \times Post_i\right)}_{\text{Coef. of interest}} + \gamma X_i + \epsilon_i$$

where AM denotes the three outcomes of interest: height, weight, and anaemia. Treatment is a dummy variable equal to one if an individual is in a treatment area as defined by one of our three treatments, or zero if in the control group. Post is a time dummy variable equal to one for the later cohort (children aged zero to six years in 2007) and equal to zero for children in the earlier cohort (children aged zero to six years in 2000). Finally, X is a vector of control variables, which can be divided into three categories: Individual, Household, and Location. Individual-level variables include gender, age, religion, and education. Household-level variables consist of household income per capita[6], number of rooms in the dwelling, household size (both in terms of persons and square metres), highest level of education in the household, a dummy for access to electricity, a dummy for ownership of TV, and a dummy for land to farm. The location variables (province, district and sub-district) allow for the estimation of region fixed effects in addition to an "urban" dummy. Finally, is the idiosyncratic error term and the standard errors have been clustered at the district level.

6 Results

The coefficient of interest in our main specification is β_3 for the post-earthquake interaction, which indicates the effect of the earthquake on children in the later cohort compared to those in the control group and the earlier cohort. Table 6 and Table 7 show the difference-in-differences results for HAZ and weight, respectively, for each of our treatments. Detailed results for height (in centimetres) and anaemia are in the Appendix.

For children who were seven to thirteen years old in 2014 and resided within an earthquake affected area, the results are largely statistically significant at the 1% level and consistent across the three treatments. Affected children as determined by the survey (column one) have 0.314 standard deviations lower HAZs. The second column exhibits similar results with a decline of 0.254 in the HAZ for children identified in the literature. Our intensity measure in column three demonstrates that children experienced lower HAZs (-0.241 to - 0.388 standard deviations for treatment treatment 3 and 2 respectively). This corresponds to lower heights of 1.59 for treatment 3 and 2.80 centimetres for treatment 2. When comparing the results from the intensity treatment, we see that treatment 2 is more affected than treatment 3, which aligns with our descriptive statistic in Section 4. To understand the mechanism behind these differences, a thorough analysis of aid allocation needs to be done in the future. Generally, our results align with those of Bustelo et. al. (2012) who found a decrease of 0.296 standard deviations for children following an earthquake in Colombia in 1999. We also find that our results support more comprehensive studies that analyse detrimental conditions in early childhood (see, for example, Currie & Almond, 2011). To put these results into an economic context, we perform back-of-the-envelope calculations in Section 7.

[6] A proxy calculated using reported income of each household member in the previous year which is aggregated across the household and divided by the number of household members

Table 7 presents our results for weight as an outcome variable. In the geographical treatment (column two) and intensity measure (column three), more specifically intensity treatments 2 and 3, children have lower weights; 1.3 kilograms, 2.5 kilograms and 0.5 kilograms respectively. This provides further evidence that the conditions that result from an earthquake can be detrimental to a child's health. The results for anaemia are largely insignificant, except in intensity treatment 1 where the proportion of children with anaemia increases (see Appendix).

Table 6: Height for age Z scores

Height-for-age Z scores	(1)	(2)	(3)
VARIABLES	Survey	Geographic	Intensity
Treatment1	0.179*	0.239	0.506***
	(0.0957)	(0.154)	(0.174)
Treatment2			0.665***
			(0.132)
Treatment3			0.339**
			(0.142)
Post	0.151***	0.160***	0.163***
	(0.0360)	(0.0347)	(0.0355)
Treatment1#Post	-0.314***	-0.254**	-0.195
	(0.0438)	(0.109)	(0.224)
Treatment2#Post			-0.388***
			(0.134)
Treatment3#Post			-0.241***
			(0.0395)
Observations	3,773	3,773	3,784
R-squared	0.163	0.164	0.168

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 7: Weight

Weight VARIABLES	(1) Survey	(2) Geographic	(3) Intensity
Treatment1	-0.107	2.850***	3.351***
	(0.626)	(0.472)	(0.588)
Treatment2			4.307***
			(0.763)
Treatment3			2.896***
			(0.848)
Post	0.556**	0.674**	0.752**
	(0.270)	(0.278)	(0.288)
Treatment1#Post	-0.323	-1.291***	-1.039
	(0.374)	(0.470)	(0.998)
Treatment2#Post			-2.469***
			(0.515)
Treatment3#Post			-0.538**
			(0.233)
Observations	3,767	3,767	3,784
R-squared	0.646	0.647	0.641

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

6.1 Heterogeneity Analysis

On the basis of our previous results, we estimate a difference-in-difference-in-differences (DDD) model. The motivation for this approach is that within the analysis above, the underlying assumption is that household characteristics act linearly across the entirety of the sample which is unlikely to hold in reality. To overcome this, a number of heterogeneous effects are accounted for, including whether the participant lives in an urban or rural area, the individual was male or female, or the participant had ever participated in a rice subsidy or Conditional Cash Transfer (CCT) programme[7]. The triple difference estimator is the difference between two difference-in-differences estimators (Olden & Moen, 2020). We estimate the following model:

$$AM_i = \alpha + \beta_1 Treatment_i + \beta_2 Post_i + \beta_3 \left(Treatment_i \times Post_i\right) + \beta_4 Male_i + \beta_5 \left(Treatment_i \times Male_i\right)$$

$$+ \beta_6 \left(Post_i \times Male_i\right) + \underbrace{\beta_7 \left(Treatment_i \times Post_i \times Male_i\right)}_{\text{Coef. of interest}} + \gamma X_i + \epsilon_i$$

where we have used here "Male" as an example of the subgroup dummy. The coefficient of interest

[7]Given data limitations, some variables of interest such as farm income, non-farm related income and household expenditure on education have been excluded from the analysis

here is β_7 which signifies the difference-in-differences estimate for that subgroup relative to the other subgroup. We use the same vector of control variables, X, as in the difference-in-differences.

Conditional Cash Transfer Programme.[8] In October 2005, Indonesia's government launched an unconditional cash transfer to target households that were living below the national poverty line. To be eligible for an unconditional cash transfer, households had to be identified by local authorities on the basis of 14 criteria[9] developed by the Indonesian Central Agency on Statistics (Badan Pusat Statistik). In July 2007, the government revised the eligibility criteria of the unconditional cash transfer programme and turned it into a conditional cash transfer programme (Program Keluarga Harapan). The new target group for this programme are poor households with pregnant women and children under 15 years of age. Households can receive a conditional cash transfer for a maximum period of six years. Additional eligibility requirements for the conditional cash transfer include certain conditions on health and education[10] (ILO, 2008).

Rice Subsidies. Along with the cash transfer programme, Indonesia also offers rice subsidies to households living in poverty or near poverty. After the Asian financial crisis in 1997-1999 the Indonesian government launched a subsidised rice programme called RASKIN to subsidise the rapid increase in food prices and sharp reduction in employment of poor households. The objective of the programme is to provide food security to households living under the national poverty line (Gupta & Huang, 2018).

[8] Given that no detailed programme information is provided as part of the study, we can not determine the start date of when each recipient started the programme. Therefore, we cannot fully assess the impact of the programme.

[9] Criteria considered for receiving cash transfers were size of house (square meters), flooring material of house, material used for walls of house, sanitary facilities in house, source of drinking water, source of main lighting, kind of fuel used for daily cooking, source of main lighting, how many times a week the family buy meat/chicken/milk, how many times per day the family eat, how many new clothes the family buy for majority of members per year, financial ability to go to clinic if sick, main job of head of family, possession of specified assets worth over 500,00 rupiah (savings, gold, colour TV, livestock).

[10] 12 indicators that need to be met: Health indicators: 1. Four prenatal care visits for pregnant women, 2. Taking iron tablets during pregnancy, 3. Delivery assisted by a trained professional, 4. Two postnatal care visits, 5. Complete childhood immunizations, 6. Ensuring monthly weight increases for infants, 7. Monthly weighing for children under three and biannually for under-fives. 8. Vitamin A twice a year for under-fives. 9. Primary school enrollment of all children 6 to 12 years old, 10. Minimum attendance rate of 85% for all primary school-aged children, 11. Junior secondary school enrollment of all 13 to 15 years old, 12. Minimum attendance rate of 85% for all junior secondary school-aged children.

Table 8: Heterogeneity - Gender

Gender VARIABLES	(1) Height	(2) Weight	(3) Anaemia
Treatment1	3.363**	4.002***	-0.0679*
	(1.518)	(0.981)	(0.0346)
Treatment2	3.796***	4.378***	-0.0572
	(0.937)	(0.969)	(0.0518)
Treatment3	1.187	1.675**	-0.0343
	(0.790)	(0.787)	(0.0484)
Post	1.205***	0.872***	0.0788***
	(0.289)	(0.214)	(0.0187)
Treatment1#Post	-0.556	-1.690	0.0378
	(1.971)	(1.113)	(0.0636)
Treatment2#Post	-4.019***	-2.692**	0.0271
	(1.043)	(1.009)	(0.0576)
Treatment3#Post	-1.066***	0.392	0.0818***
	(0.336)	(0.358)	(0.0222)
Male	-0.435	-0.688***	-0.0114
	(0.281)	(0.250)	(0.0129)
Treatment1#Male	-0.965	-1.371	0.0123
	(1.195)	(1.500)	(0.0342)
Treatment2#Male	-0.0340	-0.913	0.0385
	(0.853)	(0.728)	(0.0242)
Treatment3#Male	0.746**	1.191***	0.117***
	(0.282)	(0.336)	(0.0142)
Post#Male	-0.139	-0.0680	-0.0237
	(0.377)	(0.373)	(0.0245)
Treatment1#Post#Male	-1.099	0.775	0.0366
	(1.400)	(1.765)	(0.0628)
Treatment2#Post#Male	2.830	1.375	-0.142*
	(1.991)	(1.218)	(0.0796)
Treatment3#Post#Male	-1.167**	-1.935***	-0.139***
	(0.455)	(0.513)	(0.0311)
Observations	4,094	4,084	6,056
R-squared	0.784	0.638	0.035

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 8 displays our estimates for all outcomes of interest for boys versus girls, whilst tables for urban versus rural children and finally, the effect of participating in either a subsidised rice programme or CCT scheme can be found in the Appendix. When assessing the effects by gender, boys are adversely affected (-1.2 centimetres)[11] compared to girls. In support of this finding, boys are also adversely affected in comparison to girls in terms of weight. Our analysis suggests that boys in treatment 3 lost, on average, 1.9 kilograms more than girls. Finally, in treatment areas 2 and 3, the change in the proportion of affected boys who have anaemia is 13.2% and 13.9% less respectively than the change in proportion of affected girls who have anaemia. Overall, it becomes evident that boys are more adversely affected than girls. In the future, it would be interesting to explore the pathways of why boys are more impacted than girls.

Our results also indicate that children in treatment 3 urban areas are adversely affected by 1.5 centimetres compared to those in rural areas. In line with this analysis, our results show that children in treatment 3 urban areas are also adversely affected relative to those in rural areas. On average, urban children are 3.2 kilograms lighter than those in rural areas. Furthermore, within this same treated 3 area, the change in the proportion of affected children living in urban areas who have anaemia is 18.7% more than the change in the proportion of affected children who live in rural areas that have anaemia. We can thus conclude that urban children are more adversely affected compared to those children who live in rural areas. One reason for this finding could be that the destruction of buildings was more severe in urban areas and therefore reconstruction took longer (Consultative Group on Indonesia. Meeting, 2006).

Further, our analysis shows a positive change for children in the treatment 3 area who had participated in a CCT or rice subsidy programme of 3.3 centimeters and 2.4 centimetres respectively compared to the change in height for those who did not. Similarly, CCT recipient children in treated area 3 reported a positive change of 3.7 kilograms compared to those children who had never participated in the CCT programme. Finally, across both treatment 1 and 3 areas for CCT recipient children, and in the treatment 3 area for rice subsidy recipients, the change in the proportion of programme recipient children who have anaemia is 26.3%, 7.8% and 5.3% less respectively compared to non-programme participant children. This analysis therefore provides evidence in favour that these programmes positively affect the outcomes of children affected by the earthquake.

Our results imply that the most affected marginalised group are boys, and those who live in urban areas. It also suggests that targeting programmes at the poorest households has a positive effect on all outcomes of interest. How these findings will be used to support future government policy will be summarised in Section 7.2 below.

6.2 Limitations

It must be acknowledged that there is a potential sample selection problem with our approach as the least healthy fetuses may not have survived the pregnancy or may have died prematurely. However, studies that also focus on child health outcomes (Lokshin & Radyakin, 2012; Maccini & Yang, 2009) do not find selection bias. Moreover, this would most likely occur in earthquake-affected areas and would therefore mean that the results we present here would represent an underestimation of the true effects.

Moreover, since our baseline cohort is affected by the earthquake 20 months prior to the measurement

[11] Given the lower sample sizes and that our HAZ are standardised using only the year reference groups, rather than year and month (due to our lack of a month variable in the IFLS data) as is standard, we use height in centimetres here as it is more precise.

of the outcomes of interest, it is likely that individuals in the baseline treated areas are also negatively affected. Therefore, their outcomes will be worse than they would have been in an ideal, "uncontaminated" baseline, and thus our results again underestimate the true effect. However, given the literature, the magnitude of the underestimation will have been less harmful because it occurred outside the important time window of the first five years of a child's life.

6.3 Robustness Checks

One consideration to keep in mind is that the treated and control areas, across our treatment groups, are unbalanced with respect to several covariates. As a robustness check, we therefore apply nearest neighbour matching using Mahalonobis distances to our difference-in-differences approach. We perform the matching using the same household characteristics that we use in our main difference-in-differences approach.

Ideally, we would like to match the covariates in the pre-period and then compare the averages of the outcomes of interest in the post-period for these matched individuals. However, due to the data limitations discussed previously, we do not have the same individuals pre- and post-treatment; the individuals in the pre-period belong to the earlier cohort (age zero to six-years in 2000) and the individuals in the post-period belong to the later cohort (age zero to six-years in 2007). Therefore, it is necessary that we first create the pre-period groups by matching the post-treated with the pre-treated and do the same for the control group. This creates proxy pre-groups for both the treated and control individuals. The pre-individuals matched to our post-individuals become the post-individuals in the pre-period for the purposes of the analysis by adopting their identifiers. We then perform conventional matching as previously described - matching on covariates in the pre-period between the constructed pre-treatment and pre-control individuals. Because these individuals have been assigned the identifiers of the actual individuals in the post-period, we can compare the average outcomes of these matched individuals in the post-period.

The matching results[12] support our main results from the standard difference-in-differences framework. Although the differences are not significant, the mean scores of the treatment group compared with the control group suggest poorer overall outcomes in the treated areas. It should also be noted that due to the lack of individual-level covariates and the restriction to using the most general household characteristics, matching does not eliminate all problems between the comparability of the treatment and control groups. The matching results for height in centimetres are shown in Table 9, those for weight and anaemia can be found in the Appendix.

Table 9: Matching - Height

Height (cm) VARIABLES	(1) Survey	(2) Geographic	(4) Intensity1	(5) Intensity2	(6) Intensity3
Untreated	132.2	132.2	131.8	130.5	133.4
	(1.200)	(0.925)	(1.523)	(1.641)	(1.314)
Treated	131.4	130.7	130.1	129.8	132.9
	(1.264)	(0.907)	(1.380)	(1.790)	(1.479)
Observations	194	354	152	94	142

Note: Standard errors in parentheses

[12]Similarly to the heterogeneity regressions, we use height in centimetres given the greater precision this measure should give us compared to HAZ due to the latter's calculation.

7 Discussion

Our analysis shows that natural disasters negatively affect the health outcomes of young children. We find evidence that children exposed to the 2006 Yogyakarta earthquake are on average significantly smaller and lighter. As described throughout this paper, the early childhood period is particularly important for healthy development because children's immune systems are less resilient to fight off disease at this time. Children also have less fluid in their bodies and therefore fluid loss from dehydration or blood loss after a natural disaster can have a greater effect on children than adults (CDC, 2020). We have also shown that the negative effects last over a long period of time. Because the risk of future disasters in Indonesia is high, it is important to consider the policy implications of our findings and quantify their impact in economic terms.

7.1 Policy Implications

Therefore, to limit the negative impacts of natural disasters on the health outcomes of children five years and below, both ex ante, and ex post targeted policies are needed. This could take the form of improved infrastructure to build more stable homes to withstand earthquakes and limit loss of life, or targeted post aid programmes to ensure childrens' needs are met. To support relevant interventions, two important questions arise regarding aid following a natural disaster. Firstly, how much aid is needed to adequately reconstruct and assist households to offset the damage generated by a natural disaster? And secondly, how should this aid be allocated?[13] To maximize the use of aid, it is important to target the most marginalized groups with both financial, and medical assistance. Our analysis indicates the most affected groups as a result of the earthquake are boys, and those children that live in urban areas. Based on our analysis, we therefore propose that appropriate and targeted programmes are implemented quickly in response to any future earthquakes. For instance, both nutritional schemes and fortified rice programmes could support the development of all children, but in particular, boys and children who live in urban areas. Currently, there are two such programmes in operation in Indonesia. Therefore, we propose to expand their capacity and staff so they can quickly react in case of natural disasters. This is a cost effective measure that utilises pre-existing knowledge.

7.2 Economic Implications

There is a large literature analysing the effects of exogenous shocks on later life outcomes (see Dewey & Begum, 2011; McGovern et al., 2017). In Yogyakarta, we have shown that children experience adverse medium-term effects - we show a negative persistent effect on height and weight. From a policy perspective, exogenous shocks require special consideration when such shocks induce path dependence. Shocks to children five years old and below are important to policymakers because they have long-lasting effects that impose large costs in the future. We show that the earthquake caused lower anthropometric outcomes in the affected children in the medium term, which is a risk factor for reduced survival, health in adulthood, learning capacity and productivity (Dewey & Begum, 2011). Here we aim to provide an economic intuition for what kind of consequences this may have in the long run.

Of course, since our study is medium-term, we cannot yet fully assess the economic impact - through human capital formation and income - of the earthquake on the affected children. However, there are a number of studies (see Alderman, Hodinott, and Kinsey, 2006; Hodinott et al., 2011; LaFave & Thomas, 2017; Hodinott et al., 2013) that analyse the impact of lower anthropometric scores on

[13] In order to analyse the efficiency of the aid allocated following the earthquake, data on sub-district allocation is needed or data on the household level. Unfortunately, due to data and time limitation, this analysis was not conducted in this paper but we suggest it for future research.

educational attainment and wages later in life that we can use to estimate the future impact of these lower anthropometric scores on children's lives. Alderman, Hodinott, and Kinsey (2006) are well known for their work in Zimbabwe. They found that greater height relative to age was associated with a higher number of schooling attainment. We acknowledge that there are some differences between Indonesian and Zimbabwean children, so we use a paper by Galasso and Wagstaff (2019). The authors provide a literature review of studies analysing the impact of below-average height on human capital and earnings later in life. They find that a one standard deviation increase in HAZ is associated with 0.87 years fewer years of schooling[14]. They also suggest that this is equivalent to a 3.3% decrease in wages in adulthood.

On the basis of these estimates, we make some back-of-the-envelope calculations. We find that using our lower result for HAZ (-0.241 in intensity treatment 3), affected children have 0.21 fewer years of schooling and earn 0.80% less than unaffected children. At the high end (-0.388 for intensity treatment 2), we calculate a 0.34 year decrease in schooling and a 1.28% decrease in earnings. In monetary terms, per year, affected children forego earnings between $16 (Rp 230.000) and $26 (Rp 370.000)[15]. To provide some context, the average earnings are $2,040 in Indonesia, therefore our estimate is roughly equivalent to four working days' wages (Central Bureau of Statistics of Indonesia, 2021). Using these figures (ceteris paribus), we calculate a range of lifetime earnings lost for these children between $640-$1,040[16]. To determine the total earnings lost for the generation of affected children, we multiply these lifetime numbers by the total number of children in the relevant intensity treatment area, the latter by multiplying the sample size in the two affected provinces (Yogyakarta and Central Java) by the survey weight corresponding to the population of the respective province (Statistics Indonesia, 2015). As a result, we find that the Yogyakarta earthquake leads to a loss of approximately $144 million[17] in foregone lifetime earnings for the affected generation of children (zero to six years in 2007).

8 Conclusion

The purpose of the paper is to assess the impact on health outcomes of children five years and below as a result of the 2006 Yogyakarta earthquake. We conclude that not only does the earthquake negatively affect the height, weight and in some instances the proportion of children with anaemia, these effects are not uniform across different sub groups. On average, children experienced lower HAZs by between 0.241 and 0.388 standard deviations. Children also recorded lower weights between 0.5-2.5 kilograms.

When disaggregating these results by sub groups, we find that boys are adversely affected in two out of the three outcomes of interest compared to girls. Boys report both a greater change in height and weight. Similarly, children within urban areas are also adversely affected compared to those in rural areas. Analysis indicates urban children experience a larger change in height and weight and an positive change in the proportion of children with anaemia. We do find evidence of a positive effect of both the rice subsidy and CCT programme on the outcomes of interest. Programme participating children experienced a positive change in height. Similarly, CCT recipient children reported a positive change in weight compared to those children who had never participated in the CCT programme. Finally, programme participating children saw a greater reduction in the proportion of children affected by anaemia.

[14] The authors calculate that moving from HAZ two standard deviations below the reference population to non-stunting increases schooling by 1.74 years. Assuming linearity we define one standard deviation to be equal to 0.87 years of schooling.

[15] If we were to use Bustelo et al (2012) findings - for a similar HAZ (-0.296) they find a 2% fall in adult wages - these estimates would be larger.

[16] We assume a working life length of 40 years.

[17] Note, this is not discounted.

Our analysis indicates the most affected groups as a result of the earthquake are boys, and those children that live in urban areas. Based on our analysis, we therefore propose that appropriate and targeted programmes are implemented quickly in response to any future earthquakes. For instance, both nutritional schemes and fortified rice programmes could support the development of all children, but in particular, boys and children who live in urban areas.

In economic terms our results indicate that affected children see a decrease in school attainment by 0.21 to 0.34 years. We then convert this into a standard economic measure - foregone earnings - using comparable results in the literature which shows that on average these children lose out on $640-$1,040 in their lifetime which is equivalent to approximately half a year of income. For all affected children we estimate lost earnings of roughly $144 million.

In terms of future research, it would be interesting to see the program effectiveness of the CCT and rice subsidies. As mentioned in Section 6.1, a household can be on the CCT programme for a maximum of six years. Due to data limitations, we do not know how long a household has been on the program or the total subsidy they received. It is reasonable to assume that the benefits of the program are not immediately visible, and thus a child who has been on the program for five years will have more favourable outcomes of interest compared to a child who has just started the programme. Therefore, a more thorough analysis of these programs is needed to fully understand their impact. Similarly, looking into why boys are adversely affected would be an interesting avenue for future research.

9 References

Acaps, 2021. Impact Analysis of Earthquakes [online] Available at: https://reliefweb.int/sites/reliefweb.int/files/resources/earthquakes-quick-impact-analysis-earthquakes.pdf [Accessed 10 June 2021].

Alderman, H., Hoddinott, J. and Kinsey, B., 2006. Long term consequences of early childhood malnutrition. *Oxford economic papers*, 58(3), pp.450-474.

Allali, S., Brousse, V., Sacri, A.S., Chalumeau, M. and de Montalembert, M., 2017. Anemia in children: prevalence, causes, diagnostic work-up, and long-term consequences. *Expert review of hematology*, *10*(11), pp.1023-1028.

Bahru, B.A., Bosch, C., Birner, R. and Zeller, M., 2019. Drought and child undernutrition in Ethiopia: A longitudinal path analysis. *PloS one*, *14*(6), p.e0217821.

Basta, S.S., Karyadi, D. and Scrimshaw, N.S., 1979. Iron deficiency anemia and the productivity of adult males in Indonesia. *The American Journal of Clinical Nutrition*, *32*(4), pp.916-925.

Bates, F.L., Fogleman, C.W., Parenton, V.J., Pittman, R.H. and Tracy, G.S., 1963. The social and psychological consequences of a natural disaster: A longitudinal study of Hurricane Audrey.

BNPB, 2021. *History of BNPB*. [online] Available at: https://www.bnpb.go.id/sejarah-bnpb [Accessed 3 June 2021].

Bustelo, M., Arends-Kuenning, M. and Lucchetti, L., 2012. Persistent impact of natural disasters on child nutrition and schooling: Evidence from the 1999 Colombian earthquake.

Centers for Disease Control and Prevention (CDC), 2020. How are Children Different from Adults? *National Center on Birth Defects and Development Disabilities.* [online] Available at: https://www.cdc.gov/childrenindisasters/differences.html [Accessed 8 June 2021].

Central Bureau of Statistics of Indonesia. (2021). Indonesia Monthly Earnings 1991 to 2020 [Statistics]. Available at: https://www.ceicdata.com/en/indicator/indonesia/monthly-earnings [CEIC]

Cochrane, H.C., 1975. *Natural hazards and their distributive effects: A research assessment.* Institute of Behavioral Science, University of Colorado.

Consultative Group on Indonesia. Meeting, 2006. *Preliminary Damage and Loss Assessment: Yogyakarta and Central Java Natural Disaster.* Consultative Group on Indonesia.

Cuaresma, J., Hlouskova, J. and Obersteiner, M., 2008. Natural disasters as creative destruction? Evidence from developing countries. *Economic Inquiry*, 46(2), pp.214-226.

Currie, J. and Almond, D., 2011. Human capital development before age five. In *Handbook of Labor Economics* (Vol. 4, pp. 1315-1486). Elsevier.

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

David, A.C., 2011. How do international financial flows to developing countries respond to natural disasters?. *Global Economy Journal*, 11(4), p.1850243.

De Mel, S., McKenzie, D. and Woodruff, C., 2008. Mental health recovery and economic recovery after the tsunami: High-frequency longitudinal evidence from Sri Lankan small business owners. *Social Science & Medicine*, 66(3), pp.582-595.

Dewey, K.G. and Begum, K., 2011. Long-term consequences of stunting in early life. *Maternal & child nutrition*, 7, pp.5-18.

Duflo, Esther. 2001. "Schooling and Labor Market Consequences of School Construction in Indonesia: Evidence from an Unusual Policy Experiment." *American Economic Review*, 91 (4): 795-813.

Frankenberg, E., Friedman, J., Gillespie, T., Ingwersen, N., Pynoos, R., Rifai, I.U., Sikoki, B., Steinberg, A., Sumantri, C., Suriastini, W. and Thomas, D., 2008. Mental health in Sumatra after the tsunami. *American journal of public health*, 98(9), pp.1671-1677.

Frankenberg, E. and D., Thomas. 2000. The Indonesia Family Life Survey (IFLS2): Study Design and Results from Waves 1 and 2. DRU-2238/1-NIA/NICHD. *RAND Corporation*.

Galasso, E. and Wagstaff, A., 2019. The aggregate income losses from childhood stunting and the returns to a nutrition Intervention aimed at reducing stunting. *Economics & Human Biology*, *34*, pp.225-238.

Gupta, P. & Huang, B., 2018. In-kind transfers and child development: evidence from subsidized rice program in Indonesia. *Asian Development Bank Institute Working Paper Series.*

Haas, J.E., Kates, R.W. and Bowden, M.J., 1977. Reconstruction following disaster. In *Reconstruction following disaster*. US The Massachusetts Institute of Technology.

Hayes, G.P., Smoczyk, G.M., Villaseñor, A.H., Furlong, K.P. and Benz, H.M., 2020. Seismicity of the Earth 1900–2018 (No. 3446). *US Geological Survey*.

Heckert, M., 2015. A spatial difference-in-differences approach to studying the effect of greening vacant land on property values. *Cityscape*, 17(1), pp.51-60.

Hoddinott, J., Alderman, H., Behrman, J.R., Haddad, L. and Horton, S., 2013. The economic rationale for investing in stunting reduction. *Maternal & child nutrition*, 9, pp.69-82.

Hoddinott, J., Maluccio, J., Behrman, J.R., Martorell, R., Melgar, P., Quisumbing, A.R., Ramirez-Zea, M., Stein, A.D. and Yount, K.M., 2011. The consequences of early childhood growth failure over the life course. *Washington, DC: International Food Policy Research Institute Discussion Paper*, 1073, p.5.

Statistics Indonesia, 2016. Profile of the People of Indonesia, Supas Result 2015.

International Labour Organization (ILO), 2008. Security in Indonesia: Advancing the Development Agenda.

Kaplan, D., 2010. Natural disasters and differential household effects: Evidence from the May 2006 Java Earthquake. *Unpublished manuscript*.

Kellenberg, D.K. and Mobarak, A.M., 2008. Does rising income increase or decrease damage risk from natural disasters?. *Journal of urban economics*, 63(3), pp.788-802.

Kusumastuti, R.D., Husodo, Z.A., Suardi, L. and Danarsari, D.N., 2014. Developing a resilience index towards natural disasters in Indonesia. *International journal of disaster risk reduction*, 10, pp.327-340.

LaFave, D. and Thomas, D., 2017. Height and cognition at work: Labor market productivity in a low income setting. *Economics & Human Biology*, *25*, pp.52-64.

Lokshin, M. and Radyakin, S., 2012. Month of Birth and Children's Health in India. *The Journal of Human Resources*, 47, pp. 174–204.

Lozoff, B., 2007. Iron deficiency and child development. *Food and nutrition bulletin*, 28(4_suppl4), pp.S560-S571.

Maccini, S. and Yang, D., 2009. Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall, *American Economic Review*, 99(3), pp. 1006–1026.

McGovern, M.E., Krishna, A., Aguayo, V.M. and Subramanian, S.V., 2017. A review of the evidence linking child stunting to economic outcomes. *International journal of epidemiology*, 46(4), pp.1171-1191.

National Research Council, 2000. From neurons to neighborhoods: The science of early childhood development.

Olden, A. and Møen, J., 2020. The triple difference estimator. *NHH Dept. of Business and Management Science Discussion Paper, (2020/1).*

Pawirodikromo, W., 2018. The estimated PGA map of the Mw6. 4 2006 Yogyakarta Indonesia earthquake, constructed from the Modified Mercalli intensity IMM. *Bulletin of the New Zealand Society for Earthquake Engineering*, 51(2), pp.92-104.

Paudel, J. and Ryu, H., 2018. Natural disasters and human capital: The case of Nepal's earthquake. *World Development*, *111*, pp.1-12.

Sawada, Y. and Shimizutani, S., 2008. How do people cope with natural disasters? Evidence from the Great Hanshin-Awaji (Kobe) earthquake in 1995. *Journal of Money, Credit and Banking*, 40(2-3), pp.463-488.

Skidmore, M. and Toya, H., 2002. Do natural disasters promote long-run growth?. *Economic inquiry*, 40(4), pp.664-687.

Strauss, J., Beegle, K., Sikoki, B., Dwiyanto, A., Herawati, Y. and Witoelar, F., 2004. The third wave of the Indonesia Family Life Survey (IFLS3): Overview and field report. *NIA/NICHD*.

Strauss, J., Witoelar, F., Sikoki, B. and Wattie, A.M., 2009. The fourth wave of the Indonesian Family Life Survey (IFLS4): overview and field report. *RAND Corporation*.

Strauss, J., Witoelar, F. and Sikoki, B., 2016. The fifth wave of the Indonesia family life survey: overview and field report (IFLS5). Santa Monica, CA: *RAND Corporation*.

USGS, 2021. M 6.3 - Java, Indonesia. [online] Earthquake.usgs.gov. Available at: https://earthquake.usgs.gov/earthquakes/eventpage/usp000ej1c/executive [Accessed 1 June 2021].

United Nations World Food Programme, 2021. [online] Available at: https://www.wfp.org/countries/indonesia [Accessed 1 June 2021].

Yang, D., 2008. Coping with disaster: The impact of hurricanes on international financial flows, 1970-2002. *The BE Journal of Economic Analysis & Policy*, 8(1).

10 Appendix

10.1 Pre-Trends

Table 10: Height (cm) Pre Trend 1997-2000

Height (cm) Pre-Trend VARIABLES	(1) Survey	(2) Geographic	(3) Intensity
Treatment1	0.275	-3.709***	-1.308
	(1.456)	(1.035)	(1.419)
Treatment2			-0.394
			(1.521)
Treatment3			-0.477
			(1.182)
Post	0.111	0.0965	0.0605
	(0.258)	(0.266)	(0.263)
Treatment1#Post	0.198	0.739*	0.865
	(0.564)	(0.431)	(0.660)
Treatment2#Post			1.777**
			(0.665)
Treatment3#Post			-0.155
			(0.296)
Observations	4,984	4,984	4,984
R-squared	0.723	0.724	0.723

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 10 shows our investigation of the pre-trend assumption in the 1997-2000 cohorts. We find that there are largely no significant differences in the height of the treatment and control group. Note that in treatment group 2 the coefficient is statistically significant at the 5% level and for the geographic treatment we find the coefficient to be statistically significant at the 10% level.

Table 11: Weight Pre-Trends 1997-2000

Weight Pre-Trend	(1)	(2)	(3)
VARIABLES	Survey	Geographic	Intensity
Treatment1	-0.479	-3.890***	-2.023**
	(0.708)	(0.861)	(0.949)
Treatment2			0.145
			(0.992)
Treatment3			-0.258
			(1.175)
Post	-0.417**	-0.397**	-0.502**
	(0.173)	(0.169)	(0.189)
Treatment1#Post	0.122	0.295	1.081
	(0.293)	(0.503)	(0.673)
Treatment2#Post			3.157
			(2.992)
Treatment3#Post			-0.248
			(0.203)
Observations	4,980	4,980	4,980
R-squared	0.566	0.568	0.568

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 11 shows our investigation of the pre-trend assumption in the 1997-2000 cohorts for the weight variable. We find no statistically significant differences between the treatment and control groups.

Table 12: Anaemia Pre Trend 1997-2000

Anaemia Pre-Trend	(1)	(2)	(3)
VARIABLES	Survey	Geographic	Intensity
Treatment1	0.0131	-0.0109	0.116
	(0.0535)	(0.0586)	(0.0956)
Treatment2			0.0640
			(0.112)
Treatment3			0.0253
			(0.0876)
Post	-0.0159	-0.0143	-0.0131
	(0.0216)	(0.0210)	(0.0220)
Treatment1#Post	-0.0878	-0.0693*	-0.0845
	(0.0592)	(0.0363)	(0.0616)
Treatment2#Post			-0.153***
			(0.0431)
Treatment3#Post			-0.0155
			(0.0181)
Observations	5,994	5,994	5,994
R-squared	0.046	0.046	0.047

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 12 shows our investigation of the pre-trend assumption in the 1997-2000 cohorts for the anaemia variable. Similar to the height variable we find that the geographic treatment group is statistically significant at the 10% level and the intensity treatment group 2 is significant at the 1% level.

10.2 Difference-in-Differences Results

Table 13: Height (cm)

Height (cm)	(1)	(2)	(3)
VARIABLES	Survey	Geographic	Intensity
Treatment1	1.338**	1.594	3.245***
	(0.573)	(1.074)	(1.161)
Treatment2			4.528***
			(0.902)
Treatment3			2.476**
			(0.916)
Post	0.979***	1.032***	1.060***
	(0.236)	(0.232)	(0.235)
Treatment1#Post	-2.080***	-1.668**	-1.233
	(0.263)	(0.740)	(1.502)
Treatment2#Post			-2.797***
			(0.869)
Treatment3#Post			-1.589***
			(0.264)
Observations	3,773	3,773	3,784
R-squared	0.793	0.793	0.791

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 13 shows the difference-in-differences results for our main specification for the height variable. Treatment 2 and treatment 3 are both statistically significant at the 1% level and show a decline in height of 2.8 centimetres and 1.6 centimetres respectively.

Table 14: Anaemia

Anaemia VARIABLES	(1) Survey	(2) Geographic	(3) Intensity
Treatment1	0.0138	-0.0113	-0.0536
	(0.0371)	(0.0433)	(0.0323)
Treatment2			-0.00948
			(0.0590)
Treatment3			0.0636
			(0.0509)
Post	0.0779***	0.0762***	0.0767***
	(0.0134)	(0.0136)	(0.0137)
Treatment1#Post	0.00613	0.0206	0.0632*
	(0.0199)	(0.0292)	(0.0318)
Treatment2#Post			-0.0429
			(0.0466)
Treatment3#Post			-0.0119
			(0.0136)
Observations	5,578	5,578	5,578
R-squared	0.044	0.044	0.045

*** $p<0.01$, ** $p<0.05$, * $p<0.10$

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 14 shows the difference-in-differences results for our main specification for the anaemia variable. We only find a statistically significant result for treatment 1 at the 10% level. The coefficient suggests that anaemia levels in that group are slightly higher than before.

10.3 Heterogeneity Results

Table 15: Heterogeneity - Urban

Urban VARIABLES	(1) Height	(2) Weight	(3) Anaemia
Treatment1	3.771***	3.679***	-0.117**
	(1.175)	(0.805)	(0.0524)
Treatment2	2.675**	2.314	-0.0712
	(1.052)	(1.454)	(0.0944)
Treatment3	1.433	4.361***	0.00787
	(1.067)	(0.928)	(0.0549)
Post	1.245***	0.877**	0.0630***
	(0.337)	(0.363)	(0.0211)
Treatment1#Post	-2.474	-2.200	0.132*
	(2.131)	(1.937)	(0.0716)
Treatment2#Post	-1.902*	-0.0898	0.227***
	(1.116)	(0.837)	(0.0818)
Treatment3#Post	-0.373	2.344***	-0.159***
	(0.328)	(0.291)	(0.0223)
Urban	0.703	0.671	-0.0289
	(0.487)	(0.419)	(0.0177)
Treatment1#Urban	-1.571	-0.415	0.0687
	(1.925)	(1.052)	(0.0620)
Treatment2#Urban	1.432	2.453	0.0289
	(1.017)	(1.456)	(0.0723)
Treatment3#Urban	0.251	-2.004***	0.00818
	(0.670)	(0.630)	(0.0282)
Post#Urban	-0.168	-0.0502	0.00564
	(0.497)	(0.362)	(0.0282)
Treatment1#Post#Urban	2.142	1.522	-0.113
	(2.623)	(2.164)	(0.0887)
Treatment2#Post#Urban	-0.953	-2.593**	-0.317***
	(1.413)	(1.015)	(0.0897)
Treatment3#Post#Urban	-1.447***	-3.029***	0.187***
	(0.529)	(0.367)	(0.0331)
Observations	4,094	4,084	6,056
R-squared	0.784	0.638	0.036

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level. The matching table shows

Table 16: Heterogeneity - CCT

CCT VARIABLES	(1) Height	(2) Weight	(3) Anaemia
Treatment1	2.984**	3.287***	-0.0825**
	(1.319)	(0.696)	(0.0385)
Treatment2	5.236***	4.554***	-0.0188
	(1.283)	(0.877)	(0.0607)
Treatment3	3.249***	3.293***	0.0557
	(1.056)	(0.942)	(0.0602)
Post	1.067***	0.831**	0.0694***
	(0.255)	(0.316)	(0.0149)
Treatment1#Post	-0.570	-0.989	0.101**
	(1.661)	(1.048)	(0.0435)
Treatment2#Post	-3.187***	-2.794***	-0.0362
	(0.883)	(0.513)	(0.0485)
Treatment3#Post	-2.423***	-1.509***	0.0147
	(0.306)	(0.271)	(0.0158)
CCT	-0.398	-0.688*	-0.0405**
	(0.518)	(0.357)	(0.0177)
Treatment1#CCT	2.081**	0.0171	0.217***
	(0.948)	(0.819)	(0.0752)
Treatment2#CCT	-0.281	1.120	0.133
	(1.296)	(0.966)	(0.177)
Treatment3#CCT	-0.914	-0.677*	0.000241
	(0.552)	(0.386)	(0.0197)
Post#CCT	0.373	-0.117	0.0395
	(0.503)	(0.500)	(0.0302)
Treatment1#Post#CCT	-4.376**	-0.295	-0.263**
	(1.867)	(1.614)	(0.122)
Treatment2#Post#CCT	-2.681*	0.454	0.0301
	(1.458)	(3.497)	(0.390)
Treatment3#Post#CCT	3.253***	3.702***	-0.0780**
	(0.558)	(0.539)	(0.0327)
Observations	3,647	3,645	5,296
R-squared	0.793	0.644	0.047

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

Table 17: Heterogeneity - Rice Subsidy

Rice VARIABLES	(1) Height	(2) Weight	(3) Anaemia
Treatment1	2.615*	3.049***	-0.0269
	(1.324)	(1.089)	(0.0421)
Treatment2	3.427***	3.033**	0.00517
	(1.077)	(1.120)	(0.0908)
Treatment3	2.886***	2.706***	0.0425
	(0.922)	(0.914)	(0.0585)
Post	1.122***	0.811*	0.0612***
	(0.382)	(0.404)	(0.0205)
Treatment1#Post	-0.602	-0.810	0.0367
	(1.750)	(0.901)	(0.0412)
Treatment2#Post	-1.366**	-1.449*	-0.0718
	(0.632)	(0.849)	(0.0577)
Treatment3#Post	-2.774***	-0.833*	0.0221
	(0.430)	(0.426)	(0.0195)
RiceSub	-0.433	-0.708	-0.0163
	(0.415)	(0.466)	(0.0179)
Treatment1#RiceSub	0.912	0.287	-0.0488
	(1.649)	(1.342)	(0.0385)
Treatment2#RiceSub	4.172***	3.641**	-0.0187
	(1.251)	(1.749)	(0.110)
Treatment3#RiceSub	0.0562	0.657*	0.0381**
	(0.467)	(0.388)	(0.0175)
Post#RiceSub	0.00902	-0.0164	0.0254
	(0.540)	(0.545)	(0.0238)
Treatment1#Post#RiceSub	-1.124	-0.536	0.0582
	(2.290)	(1.848)	(0.0864)
Treatment2#Post#RiceSub	-4.734***	-3.050*	0.0689
	(1.217)	(1.700)	(0.0999)
Treatment3#Post#RiceSub	2.447***	0.640	-0.0533*
	(0.552)	(0.514)	(0.221)
Observations	3,647	3,645	5,296
R-squared	0.793	0.644	0.045

*** p<0.01, ** p<0.05, * p<0.10

Note: All specifications include the Individual, Household and Location variables detailed in the Empirical Strategy. Robust standard errors in parentheses and are clustered at the district level.

10.4 Matching

Table 18: Matching - Weight

Weight VARIABLES	(1) Survey	(2) Geographic	(3) Intensity1	(4) Intensity2	(5) Intensity3
Untreated	29.90	29.78	28.00	28.81	30.39
	(0.818)	(0.636)	(1.009)	(1.008)	(0.878)
Treated	30.13	29.54	29.01	28.63	31.13
	(0.791)	(0.639)	(1.017)	(1.175)	(0.960)
Observations	202	358	152	92	148

Note: Standard errors in parentheses

Table 19: Matching - Anaemia

Anaemia VARIABLES	(1) Survey	(2) Geographic	(3) Intensity1	(4) Intensity2	(5) Intensity3
Untreated	0.161	0.172	0.168	0.130	0.162
	(0.0315)	(0.0236)	(0.0344)	(0.0408)	(0.0372)
Treated	0.219	0.203	0.202	0.116	0.232
	(0.0355)	(0.0252)	(0.0369)	(0.0388)	(0.0427)
Observations	274	512	238	138	198

Note: Standard errors in parentheses