Intergenerational Transmission of Shocks in Early Life: Evidence from the Tanzania Great Flood of 1993

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Abstract

This paper estimates the short, medium and long term effects on health and the subsequent intergenerational transmission of exposure in childhood to the Tanzania Flood of 1993. The identification strategy exploits exogenous variation in the disaster's geographic extent and timing, and the exposure of different birth cohorts to the disaster. Results show that children exposed to the flood have lower height-for-age Z-scores three years after the shock, with larger effects for girls than for boys. Moreover, women who were less than 18 years old during the flood experienced negative health impacts that were persistent even 17 years after the flood. Surprisingly, the children of the women exposed in childhood to the flood have lower height-for-age Z-scores, while the children of the affected men experience no effect on their height-for-age Z-scores. The impacts using GPS information are 32% larger than if exposure is measured at the imprecise regional level. The effects are robust to selective migration.

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1 Introduction

There is growing concern among economists that severe economic conditions early in life may have persistent effects. A number of recent papers have documented the long-lasting effects of such shocks on adult height (Alderman, 2006), on adult socio-economic outcomes (Almond et al., 2005), on adult self-reported health, on child development (Currie, 2009) and on educational outcomes (Maluccio et al., 2009). Surprisingly, there is little attention in the literature to the possibility of the intergenerational transmission of the effects of shocks in early life despite an increasing number of papers showing a significant relationship between parental and child health and education (Ahlburg, 1998; Anger, 2010; Currie et al., 2003; Currie et al., 2007; Coneus et al., 2011).

The Tanzania Flood of 1993 offers a context in which to study how shocks in the early life of one generation may be transmitted to the next generation of individuals. This paper uses household survey data to estimate the short, medium and long term effects on health of exposure in childhood to the flood. Furthermore, now more than twenty years later, it is also possible to determine the intergenerational transmission of the effects of that flood. The 1993 flood was the most costly natural disaster in the history of Tanzania. The damage to infrastructure was extensive generating a recovery cost of USD 6,000,000. Crops and livestock throughout the entire region were also affected. Moreover, disruptions and pollution disturbed the water system and generated outbreaks of diseases affecting 201,543 people.

The identification strategy for this study exploits exogenous variation in the disaster's geographic extent and in the children's birth cohorts who were exposed to the disaster. This paper combines many nationally representative cross-sectional household surveys, three collected in 1996, 2005 and 2010 (3, 12 and 17 years after the flood, respectively) and one collected in 1991 (2 years prior to the flood). This is unique as few studies of natural disasters have data bracketing a flooding event. The children exposed to the flood have lower height-for-age Z-scores three years after the shock, with bigger effects on girls than boys. Those women who were less than 18 years old during the flood experience negative impacts due to the natural disaster as long as 17 years after the flood. The children of the women affected before adulthood have lower height-for-age Z-scores while the children of the men affected before adulthood experienced no effect on their height-for-age Z-scores.

In this context, this paper contributes to the literature of shocks in early childhood in four respects. First, this work provides one of the few micro estimates in the literature of the intergenerational transmission of shocks in early childhood showing how the different impacts observed by gender in the short term may lead to mothers who transmit the natural disaster's health effects to their children and fathers that do not. Second, due to the unique data that includes flood and household GPS information, this paper is able to accurately measure the intensity of the impact using each household's proximity to the disaster area. This approach makes a difference in the estimated effects of flood, with households within 100 kilometers (km) of the flood having 32% larger long term impacts than if imprecise regional measures of exposure are used. Third, the separate estimation of the impact of flood exposure for boys and girls finds that both suffer negative consequences, but girls experience a greater effect in the short term, a result in line with the existing literature.[1] Finally, the triple difference estimation used in this paper provides a more accurate counterfactual comparison than the traditional approach of the literature. The pre-flood data allows the empirical strategy to control for baseline health levels for a given age group and exploits variation in which birth cohorts of children were still growing when they were exposed to the flood.

Specifically, the results of this paper show that flood-exposed children have 0.4 standard deviations lower height-for-age Z-scores 3 years after the disaster. By splitting the sample by gender, the estimates indicate that girls have 0.6 standard deviations lower height-for-age Z-scores, while boys have 0.2 standard deviations lower height-for-age Z-scores. The results also indicate that those girls affected before their 6th year have 2.6 centimeters lower height 12 years after the shock. The effect on girls is persistent even 17 years after the flood. This effect decreases as the age of the affected individual at the time of the flood increases. This work finds that those women younger than 18 years at the time of the natural disaster have 1.2 centimeters less height 17 years after the shock. There is no evidence of impact for women affected after age 18. Finally, the results suggest that the

[1] Neumayer and Plumper (2007) investigate gender differences in disaster-related mortality, and conclude that women generally are more likely to die than men, or at a much younger age, especially when they come from a disadvantaged socioeconomic background. By one estimate, women represented 70 percent of casualties after the 2004 Indian Ocean in Aceh, Indonesia (World Bank, 2011).

children of women affected by the shock when they were less than 18 years old have 0.3 standard deviations lower height-for-age Z-scores, while the children of men affected by the shock when they were less than 18 years old are not affected by the natural disaster. All these results decrease as the distance to the flooded area increases.

In addition to literature on the effects of natural disasters on socio-economic outcomes, the results of this work are also related to previous research on gender bias during early childhood. Much of the literature finds evidence favoring boys over girls (see Neumayer and Plümper, 2007 for evidence that disasters lower the life expectancy of women more than that of men, that the stronger the disaster, the stronger this effect on the gender gap in life expectancy, and that the higher a woman's socio-economic status, the weaker this effect on the gender gap in life expectancy). In line with the literature, this paper finds differential gender impacts of the flood on children's health: Girls were more affected than boys.

There are several plausible mechanisms by which the Tanzania flood may influence the intergenerational transmission of health effects, but this paper is able to confirm that one of the main mechanism for the transmission of the impact is the poor performance of affected females in the marriage market. In addition, exposed women have less years of education. In particular, this work finds that those women exposed to the flood have poorer educational performance but also less educated husbands than women unaffected by the flood; presumably they marry men who would not have married otherwise.

The remainder of the paper is organized as follows. Section 2 provides an overview of the Tanzania Flood and sketches the spatial and temporal event data for the disaster. This section also describes the survey data used in the analysis and explains the key variables. Section 3 describes the empirical identification strategy, and Section 4 presents the main results as along with robustness tests. Section 5 concludes.

2 Data

2.1 Tanzania Flood of 1993

In February of 1993 there was unusually heavy rainfall with flash floods affecting more than 10 villages in the Lushoto and Korogwe districts of the Tanga region of northeastern

Tanzania, as shown in Figure 1. The flood affected 201,543 people (UNISDR, 2011), killing 54 individuals, seriously injuring 30 persons, and destroying the homes of 2,900 people.

The damage to infrastructure was extensive, with 270 km of roads and 13 bridges washed away. Two schools and five health facilities were destroyed. The crops and livestock of the entire region were also affected (UNDHA, 1993a). These damages in infrastructure directly affected health. In particular, disruptions and pollution crippled the water system causing outbreaks of diseases including, for example, pneumonia and cholera.

The Tanzanian government estimated the damages at USD 3,510,000, making the flood of 1993 the most costly natural disaster in the history of Tanzania. However, other estimates of the damages, from the Tanga regional development director, calculated the rehabilitation costs in over than USD 6,000,000 (UNDHA, 1993b).

2.2 Demographic and Health Survey and geospatial disaster information

The Tanzania Demographic and Health Survey (DHS) data from 1991, 1996, 2005 and 2010 are used. These data come from nationally representative cross-sectional surveys that provide information on anthropomorphic measures and the nutritional status of mothers in the age range 15-45 and children under five. The 1991, 1996 and 2010 Tanzania DHS collected detailed information on the date of birth, GPS location, and height of 5,341, 4,458 and 7,320 children born before, during, or after the flood, respectively. The DHS data from 1991 and 2005 includes information on the date of birth, GPS location, and height of 5,143 and 10,005 adult women, respectively.

In particular, the anthropomorphic measure for children younger than five years is expressed in terms of Z-scores (standard deviation scores) for height, a system widely recognized as the best for analysis and presentation of anthropometric data for young children (World Health Organization, 1995). Adult height is measured in centimeters, which is considered the best measure for adult height.

The DHS indicates the current region of residence of each respondent as well as the GPS location of each village and information about the amount of time that each individual had lived there. The fact that the data indicates the migration history of respondents at the time of the flood is important in order to deal with the effects of a potential bias due to selective migration, since the region of current residence may not capture the exposure of households that moved after the flood.

2.3 Preliminary Observations

Table 1 summarizes the child characteristics, the adult characteristics and the household characteristics of affected and non-affected regions using 1991 as the baseline year. Affected and non-affected regions are balanced pre-event. In particular, the anthropometric Z-scores of the children are presented along with other variables that measure whether the parents are alive or absent. The table shows no difference in any of the characteristics between exposed and non-exposed children at the baseline year.

In the middle part of Table 1, adult characteristics such as childhood place of residence, height, marital status, religion and years of education are presented. The adult characteristics between the affected and non-affected regions show no statistical differences.

Finally, this table analyzes the differences in household characteristics between affected and non-affected regions. In the remainder of Table 1, variables that measure land ownership, gender of the head of household and distance to the closest health center are checked. As shown in the table, household characteristics are not statistically different across regions.

3 Empirical identification strategy

The empirical identification strategy for this study relies on a comparison of the mean differences in Z-scores and height of individuals from different age groups in affected and non-affected regions, as surveyed before and after the natural disaster. This strategy compares by age the height of impacted individuals who were in their childhood when the natural disaster occurred to the height of individuals in non-affected regions, as surveyed before and after the disaster.

In particular, this paper uses a triple difference estimator (DDD) to observe three sets of potential control groups for the analysis of data from before and after the flood. These control groups were comprised of individuals unaffected by the flood either because they were in non-affected regions, because they were part of a non-affected cohort or because they were surveyed before the disaster occurred. For instance, in order to estimate the short- term effects, the control group is composed of children 3-4 years old in non-affected regions (Control 1), children 0-2 years old in 1996 (who were not yet born in 1993) in affected regions (Control 2) and children 0-2 years old in non-affected regions (Control 3). This paper uses all three control groups for the DDD method. The implicit assumption is that differences across age groups and in average height would be similar across affected and non-affected regions in the absence of the natural disaster. Based on the triple difference regressions, the estimation is the following:

$$\begin{aligned} Height_{icjt} =& \beta_1(Young\,Cohort_c * Affected\,Region_j * DHS\,wave_t) \\ &+\beta_3(Young\,Cohort_c * Affected\,Region_j) \\ &+\beta_2(Young\,Cohort_c * DHS\,wave_t) \\ &+\beta_4(Affected\,Region_j * DHS\,wave_t) \\ &+\alpha_c + \delta_j + DHS\,wave_t + X_{icjt} + \mu_{icjt} \end{aligned} \tag{1}$$

where $Height_{icjt}$ is the height for an individual i from the cohort c in region j surveyed in period t, $Young\,Cohort_i * Affected\,Region_j * DHS\,wave_t$ is a binary variable indicating whether an individual was in his young cohort (born before the flood) in a region affected by the flood and surveyed after it occurred, α_c are cohort fixed effect, δ_j are district fixed effects, $DHS\,wave_t$ is an indicator for being in the last DHS wave of data, X_{ijt} are individual control variables that include gender fixed effects, and μ_{ijt} is a random, idiosyncratic error term. The coefficient β measures the flood impact on individuals' outcomes for those who were alive at the time of the flood in the affected regions.

To address the possibility that the affected region variables could be measured with error or might be correlated with village or household level characteristics that influence child health, this paper uses the GPS information on village location in relation to the affected areas. Children's exposure is measured by taking advantage of information on the distance from the flooded area of each surveyed village. To classify the intensity of flood exposure, the distance to the nearest flood location (even if it crosses region boundaries) is used. This empirical strategy starts by identifying villages within 100 km of the flood location, then those within 200 km and 300 km. These distances are used to define binary variables to indicate households living close to the flooded areas. Then the following modified Equation 1 replacing $Affected\,Region_j$ with dummy variables that indicates the distance to the flooded areas ($0 - 100km\,to\,the\,flood_j$, $101 - 200km\,to\,the\,flood_j$ and

$201 - 300km\, to\, the\, flood_j$) is estimated:

$$
\begin{aligned}
Height_{icjt} = & \\
& + \beta_1(Young\,Cohort_i * DHS\,wave_t * 0 - 100km\,to\,flood_j) \\
& + \beta_2(Young\,Cohort_i * DHS\,wave_t * 101 - 200km\,to\,flood_j) \\
& + \beta_3(Young\,Cohort_i * DHS\,wave_t * 201 - 300km\,to\,flood_j) \\
& + \beta_4(Young\,Cohort_i * DHS\,wave_t) \\
& + \beta_5(Young\,Cohort_i * 0 - 100km\,to\,flood_j) \\
& + \beta_6(Young\,Cohort_i * 101 - 200km\,to\,flood_j) \\
& + \beta_7(Young\,Cohort_i * 201 - 300km\,to\,flood_j) \\
& + \beta_8(DHS\,wave_t * 0 - 100km\,to\,flood_j) \\
& + \beta_9(DHS\,wave_t * 101 - 200km\,to\,flood_j) \\
& + \beta_{10}(DHS\,wave_t * 201 - 300km\,to\,flood_j) \\
& + \alpha_c + \delta_j + DHS\,wave_t + X_{icjt} + \mu_{icjt}
\end{aligned}
\tag{2}
$$

Because the same identification strategies for the estimation of all direct effects of the flood are used for each year's data set, this analysis is able to detect the transmission of effects of the flood. It can thus compare the outcomes of those children whose parents were affected in their childhood (before their 18th birthday) with children whose parents were not affected in their childhood. The following regression can then be estimated:

$$
\begin{aligned}
Height_{icjt} = & \beta_1(Parent\,Young\,Cohort_i * Affected\,Region_j * DHS\,2010_t) \\
& + \beta_2(Parent\,Young\,Cohort_i * Affected\,Region_j) \\
& + \beta_3(Parent\,Young\,Cohort_i * DHS\,2010_t) \\
& + \beta_4(Affected\,Region_j * DHS\,2010_t) \\
& + \alpha_c + \delta_j + DHS\,2010_t + X_{icjt} + \mu_{icjt}
\end{aligned}
\tag{3}
$$

where $Height_{icjt}$ is the height for an individual i from the cohort c in region j surveyed in period t, $Parent\,Young\,Cohort_i * Affected\,Region_j * DHS\,2010_t$ is a binary variable indicating whether a child has a parent less than 35 years old (those who are less than 35 years old in 2010 were less than 18 years old at the time of the shock) in a region affected by the flood and surveyed in the DHS 2010, α_c are parent cohort fixed effect, δ_j are district fixed effects, $DHS\,2010_t$ is an indicator for being surveyed in the DHS 2010, X_{ijt} are individual control variables that include child gender fixed effects and child age fixed effects, and μ_{ijt} is a random, idiosyncratic error term. The coefficient β_1 measures the flood intergenerational transmission of the impact on individuals' height for those with parents affected.

4 Empirical results

4.1 Short term effects, three years after the shock

Table 2 presents baseline regressions for the DDD estimation of the flood impact on height-for-age Z-scores in 1996 (three years after the flood). This table focuses on children in the age range 3-4. Since the DHS has only anthropometric information for children 0-4 years old, the only children alive in 1993 are the children 3-4 years old in 1996 (those children were 0-1 year at the time of the shock). The first column of Table 2 shows the effect of the flood on the height-for-age Z-scores when exposure to the natural disaster is defined based on the region of residence of each child (as outlined in equation 1.) Column 2 show the effect of the flood on height-for-age Z-scores when exposure to the flood is defined based on the geographic location of the household and its proximity to the flood affected area (as outlined in equation 2).

In Table 2, column 1 suggests that the flood reduced the height-for-age Z-scores of those children in age group 0-1 in the affected region by 0.443 standard deviations in comparison with non-affected children.[2] In column 2 equation 2 is estimated, coding as exposed those children within 100 km, 200 km and 300 km of the affected areas of the flood. As shown in Table 2, the size of the effect increases with greater proximity to areas affected by the flood. In particular, column 2 shows that the flood reduces height-for-age Z-scores of those children within 100 km of the affected areas in the age group 0-1 by 0.462 standard deviations in comparison with non-affected children[3]. For those children that live farther than 100km from the flooded areas, there is no statistical evidence of any impact of the

[2] Similar results have been found on Weight Z-Score, Weight for Height-standard Z-Score and Body Mass Index-standard Z-Score.

[3] We consider "non-affected children" as those who live more than 300km from a flooded area.

flood.

Columns 3 to 6 explore the heterogeneity of the flood impact by gender. In line with the literature on shocks that generally finds a large negative bias against girls, this study of the shock of a natural disaster shows all children negatively impacted by exposure, but the effect on girls in particular is greater. Specifically, females alive at the time of the shock in the affected region have 0.622 lower height-for-age Z-scores after the shock, while males alive at the time of the shock in the affected region have 0.230 lower height-for-age Z-scores after the shock. Moreover, in a fully interacted model, the equality of coefficients for females and males is rejected. Finally, when proximity to the natural disaster is used to code exposure, the same bias against girls is found. The flood reduces the height-for-age Z-scores of those males 0-1 year at the time of the shock by 0.652 standard deviations, and it reduces the height-for-age Z-scores for boys in the same age group by 0.249. However, the last coefficients is not statistically significant. Similarly, no statistically significant effects for girls or boys within 101 to 300 km of the affected areas of the flood are found.

4.2 Medium term effects, 12 years after the shock

Table 3 analyzes the effect of the flood by age at the time of the flood twelve years later. This table presents the baseline regressions for the DDD estimation of the flood impact on height in 2005, focusing on females in the age ranges of 15-18, 19-22, 23-26, 27-30 and 31-34 years. This means that at the time of the disaster in 1993, these females were in the age groups 3-6, 7-10, 11-14, 15-18 and 19-22 years respectively. The youngest group of focus comprises those that are 15 years old, since DHS only has height information for females 15-45 years old. Each row in column 1 corresponds to different control groups.

As seen in column 1, those females in the flood region affected by the shock when they were 3-6 years old are 2.594 centimeters shorter after the shock than females in the control groups. The results for age groups 7-10, 11-14, 15-18 and 19-22 are presented, respectively. The intensity of the effect on females who were older at the time of the shock decreases with age; the effect is non-significant for those females affected after their 18th year. These results are in line with the existing literature on shocks in early childhood that show that the younger the child is when affected, the greater the long-term effect.

Since in column 1 it is shown that the most greatly affected group comprises those individuals younger than 18 years, analysis of the 2005 data for this group (columns 2 and 3) yields estimates of the the medium term impact on affected individuals who were 15-30 in 2005. In order to be consistent with previous tables, the estimates of Equations 1 and 2 for those younger than 18 years at the time of the shock are presented. Column 2 shows that the flood reduced the height of females in the affected region in the age group 3-18 by 0.966 centimeters. In column 3, Equation 2 is estimated, coding as exposed those individuals within 100, 200 and 300 km of the affected areas by the flood, respectively. From this analysis it is possible to see the size of the effect increasing with proximity to areas affected by the flood. In particular, column 3 shows that the flood reduced the height of females within 100 km of the affected areas in the age group 3-18 by 1.408 centimeters in comparison with non-affected females. The shock is shown to reduce the height of females within 101 to 200 km by 0.911 centimeters while there is no evidence of impact for those living between 201 to 300 km of the flooded areas.

4.3 Long term effects, 17 years after the shock

In order to estimate the long term impact of the flood, Table 4 estimates the effect using the baseline regressions for the flood impact on height in 2010 (seventeen years after the flood). This table focuses on females in the age ranges of 17-19, 20-23, 24-27, 28-31, 32-35 and 36-39 years in 2010. In other words, at the time of the disaster in 1993, these females were in the age groups 0-2, 3-6, 7-10, 11-14, 15-18 and 19-22 years respectively.

As shown in column 1, those females affected by the flood when they were 0-2 years old are 3.599 centimeters shorter after the shock than females in the control groups. The results for the age groups 7-10, 11-14, 15-18 and 19-22 are presented. As for the medium term effects, the intensity of the impact decreases on the age at the time of the shock of affected females. Again, he effect is non-significant for those females affected after their 18th year.

To be consistent with previous tables, the estimates of equations 1 and 2 for the age group younger than 18 years at the time of the flood are presented. Column 2 shows that the flood reduced the height of females in the affected region in the age group 0-18 by 1.182 centimeters. In column 3, equation 2 is estimated coding as exposed those individuals within 100, 200 and 300 km of the affected areas of the flood. The results suggest that the flood reduces the height of females within 100 km of the affected areas in the age group 0-18 by 1.565 centimeters in comparison with non-affected females. This effect is decreasing with the age at the time of the flood of the affected women.

4.4 Intergenerational transmission of the shock effects, 17 years after the shock

Table 5 presents the intergenerational transmission of the shock effects. On this table the estimation of Equation 3 is presented using as the affected cohort those children with parents younger than 18 years at the time of the shock.

When coding as affected the children of exposed mothers (Column 1 and 2), this study finds negative and significant effects of the flood on the children of exposed mothers. In particular, in column 1 it is found that children of mothers exposed in the affected regions have shorter height-for-age Z-scores by 0.301 standard deviations. When using proximity to the natural disaster to code exposure, this analysis reveals that mothers affected close to the shock zone transmit a negative effect to their children in height-for-age Z-scores. In particular, columns 2 shows that those children whose mothers were affected before their 18 years old and who were within 100 and 200 km of the flood areas have a reduction in their height-for-age Z-scores by 0.364 and 0.228 standard deviations respectively.

The analogous analysis for fathers in Columns 3 and 4 reveals no statistically significant evidence of intergenerational transmission of health effects. None of the effects reported are statistically significant, even when the affected/non-affected region approach and the GPS information are used.

4.5 Discussion: Mechanisms of intergenerational impacts of the flood

Understanding the mechanisms by which a flood can affect the health of individuals of the subsequent generation is crucial for the creation of adequate policies to protect possible victims and their children from the negative effects of natural disasters. This study finds that those mothers affected by the flood transmit health effects to their children, while fathers affected by the flood do not[4]. Thus, in line with the finding that short-term negative

[4]The documented impact in this paper is net of any assistance since there were not an official relief program for the affected individuals. In addition, given the long range impact, the evidence hints that recovery was slow and incomplete

effects are statistically greater for females than for males, mothers are the channels by which this effect is transmitted to the next generation. The factor that affects females more than males may also be the mechanism affecting the welfare of the next generation of individuals.

This study also finds that those girls who experienced the shock of the flood exhibit poor performance in the marriage market many years later. They find poorer partners with smaller family incomes, and these factors can affect their children's nutrition and health. Two measures help to understand the performance in the marriage market of the deprived females. First, this approach estimates the effect of the flood on the age of the husbands of affected females. It then estimates the effect of the flood on the years of education of the husbands of the affected females. The expectation is that those females were not successful in the marriage market who found older, less educated and thus less economically productive partners.

From Table 6 it is possible to conclude that those girls affected before 18 years have partners 3.109 years older and with 0.521 fewer years of education (the average years of education in the 2010 DHS for Tanzania is 3.791 years) in comparison with the partners of unaffected women. The results using GPS information are stronger than the results using the affected region definition. Thus, the results suggest that the flood affects the marriage market performance of exposed females. Given the evidence found in the literature that poor anthropometric characteristics may negatively affect the matching process in the marriage market (Behrman et al. 1994; Chiappori et al. ,2012), the greater impact of the flood on women is likely to also affect the marriage performance of affected women more than men. Naturally, those children born in poorer households with less educated head of household have a greater probability of having a poor performance in their anthropometric measures. The marriage market is therefore suggested as an important impact mechanism for affecting the children of mothers shocked in childhood by the flood.

4.6 Robustness checks

Two concerns regarding the validity of the estimation are related to the possibility that the flood induced selective fertility and mortality. The impact on fertility and mortality are thus examined. The results show no evidence that affected individuals had different fertility patterns or mortality due to the flood. This study also uses information about household mortality to examine whether exposure to a natural disaster resulted in systematically increased mortality. This overall lack of relationship between flood exposure and fertility and mortality strengthen the main results reported in the paper.

Finally, false experiments are performed by simulating false dates for the flood in the affected region and simulating false location for the flood (This false experiments include experiments coding as exposed cohorts before conception). After several simulations in the affected region and also simulating false locations of the flood for the affected cohorts, this study finds no effects on these false experiments that strengthen our identification strategy or the reliability of the results.

4.6.1 Migration

One additional difficulty in measuring the impact of natural disasters is that migration may occur as a consequence of the shock. Even though the flood can be seen as an exogenous event, it can generate non-random migration. Unfortunately, if the flood affects migration in a non-random way, the results may be biased. Therefore, there is a need to determine whether the results hold even taking this fact into account.

To account for migration, any individual who moved during the flood is assigned to the affected region. For all non-movers, exposure is coded correctly, but there is no information about the residence of movers prior to moving to the region where they were surveyed. For any migrants who moved within the affected region, the exposure is coded correctly. Likewise, for any migrant who moved within non-affected regions the coding is also correct. However, the residence at the time of the flood is misclassified for those migrants who moved from an affected region to a non-affected region.

The DHS provides data for the number of years that individuals lived in the village where they were surveyed, and it is available in the DHS for 1991, 1996 and 2005. With this information it is possible to generate a re-classified migrants as if they were exposed by the flood. In particular, this approach re-classifies those individuals who migrated during 1993 (the year of the flood) as residents of the affected regions. So, in this re-classification, all migrants who moved during the flood are assigned to the affected region (if currently in a non-affected region, then the assumption is that they came from an affected region and they are coded as exposed). Essentially, this means re-coding all individuals who migrated during the year of the flood and currently live in a non-affected region as having been exposed to the flood in an affected region. If the negative impact still holds, the effects are robust to selective migration. Similarly, this paper finds performs a similar exercise for the proximity regressions, assigning movers who moved during the flood to close areas in the first 100 km to the flood.

As shown in the tables of the appendix (Table A.1 - Table A.2), all results hold. There is a negative and statistically significant effect three years after the shock for exposed children, and as in Table A.1, the effect is greater for females. Negative effects are also found twelve years after the shock for females affected before age 18.

The results for the short and medium run effects are robust to the assumption that all of the movers came from affected areas. This assumption also assigns individuals who were not exposed to affected areas. For this reason, the effects seen in the appendix tables are smaller than those in the original tables. Unfortunately, there are no information available about migration in the DHS survey of 2010 to perform the a similar exercise.

5 Conclusion

The objective of this paper is to estimate the short, medium and long term effects of exposure to the Tanzania Flood of 1993 on the health of individuals affected in their youth, and to estimate the intergenerational transmission of those effects.

This is the first paper able to measure the intergenerational transmission of health effects using the exposure of parents to a particular shock as the exposure classification. The nationally representative Demographic Health Survey data was used to assess the short, medium and long term impacts of the 1993 Tanzania flood on the health status of individuals.

Using a triple difference estimator, this study finds that children affected by the natural disaster were shorter than unaffected children three years after the shock. This effect is greater for girls than for boys. In addition, this paper shows that for those females affected before their 18th birthday it is possible to still find negative effects seventeen years after the shock. This work also finds that females affected by the shock in their youth transmit the effect to their children, while males affected by the shock do not. Finally, this paper shows that the short, medium and long term effects are robust to a possible migration bias.

A critical reason for studying the impact of early childhood shocks on individuals' height is that this health indicator correlates with future health, education, and economic outcomes. Based on other estimates of the links between height-for-age Z-scores, schooling attainment, wages and education, it is possible to speculate on the long-term consequences that follow from the negative health impact of the Tanzania Flood, one of which seems to be poor performance in the marriage market. This study argues that an affected woman's performance in the marriage market is one of the main mechanisms that collaborate to transmit health effects to the next generation.

The results in this paper contribute to a growing literature that estimates the health impacts of natural disasters. The findings in this paper also help to improve understanding of a broader issue, the long-term growth and development consequences of natural disasters. Since malnutrition during a person's early years has been linked to worse economic outcomes in adulthood, the long-term legacy of shocks during childhood is a problem that needs to be addressed with various health, educational and economic intervention. The data and analysis presented in this work provide ample justification for such policies.

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Figure 1: Tanzania Regional Map Indicating Flooded region

Notes: The main flood occurred in Tanga region, which is painted in red on the map.
Map source: CC-BY-SA.

Table 1: Summary statistics and Balance

	Mean		Mean Difference
Variable	Affected region	Control Region	P-value
Child Characteristics			
Height Z-Scores	0.460	-0.114	0.567
Weight Z-Scores	0.817	0.663	0.877
Weight for Height-standard Z-Scores	1.562	1.771	0.832
Body Mass Index-standard Z-Scores	1.729	1.935	0.834
Mother Alive	0.974	0.975	0.893
Father Alive	0.959	0.946	0.111
Absents Parents	0.321	0.331	0.513
Adults Characteristics			
Childhood Place (Large City)	0.000	0.029	0.128
Childhood Place (Small Town)	0.078	0.102	0.489
Childhood Place (Countryside)	0.922	0.869	0.171
Height (cm)	155.845	154.691	0.997
Marital Status (no married)	0.051	0.077	0.402
Marital Status (living together)	0.615	0.550	0.255
Marital Status (widowed)	0.090	0.092	0.943
Marital Status (divorced)	0.205	0.143	0.127
Religion (No Muslim)	0.282	0.219	0.187
Years of Education	2.089	1.980	0.287
Household Characteristics			
Land Ownership	0.994	0.982	0.277
Female Head of Household	0.481	0.497	0.533
Distance to the closest Health center	20.608	21.586	0.101

Notes: Child characteristics are based on children between 0 and 4 years old from the child recode. Adults characteristics and household characteristics are based on the household members recode. Data source: 1991 Tanzania Demographic and Health Survey data.

Table 2: Short term Impacts of Flood Exposure on Children's Height-for-age Z-score

Dependent Variable: Height for Age Z score	All children		Females		Males	
	(1)	(2)	(3)	(4)	(5)	(6)
Young Cohort*Affected Region*DHS 1996	-0.443***		-0.622***		-0.230***	
	(0.047)		(0.061)		(0.063)	
Young Cohort*0-100 km to the flood*DHS 1996		-0.462*		-0.652***		-0.249
		(0.227)		(0.218)		(0.268)
Young Cohort*101-200 km to the flood*DHS 1996		0.167		0.217		0.113
		(0.217)		(0.199)		(0.251)
Young Cohort*201-300 km to the flood*DHS 1996		0.121		0.031		0.203
		(0.198)		(0.214)		(0.211)
Young Cohort*Affected Region	Yes	No	Yes	No	Yes	No
Affected Region*DHS 1996	Yes	No	Yes	No	Yes	No
Young Cohort*Distance indicators	No	Yes	No	Yes	No	Yes
Distance indicators*DHS 1996	No	Yes	No	Yes	No	Yes
Young Cohort*DHS 1996	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,799	9,799	4,906	4,906	4,893	4,893

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, child age fixed effects,child gender and survey year fixed effects. The regressions are based on the 9,799 children between 0 and 4 years old. The variable Young Cohort takes value equal to one if the child is in the age range 3 to 4 (children in the age range 3-4 in 1996 were in the age range 0 to 1 during the flood). Data source: 1991 and 1996 Tanzania Demographic and Health Survey data.

Table 3: Medium term Impacts of Flood Exposure on Women's Height

Dependent Variable: Height (centimeters)	(1)	(2)	(3)
During Shock Age 3-6*Affected Region*DHS 2005		-2.594***	
		(0.332)	
During Shock Age 7-10*Affected Region*DHS 2005		-1.611***	
		(0.116)	
During Shock Age 11-14*Affected Region*DHS 2005		-1.073***	
		(0.091)	
During Shock Age 15-18*Affected Region*DHS 2005		-0.451***	
		(0.065)	
During Shock Age 19-22*Affected Region*DHS 2005		0.027	
		(0.070)	
During Shock Age 3-18*Affected Region*DHS 2005	-0.966***		
	(0.099)		
During Shock Age 3-18*0-100 km to the flood*DHS 2005			-1.408***
			(0.504)
During Shock Age 3-18*101-200 km to the flood*DHS 2005			-0.911**
			(0.428)
During Shock Age 3-18*201-300 km to the flood*DHS 2005			0.023
			(0.282)
During Shock Age 3-18*Affected Region	Yes	Yes	No
Affected Region*DHS 2005	Yes	Yes	No
During Shock Age 3-18*Distance indicators	No	No	Yes
Distance indicators*DHS 2005	No	No	Yes
During Shock Age 3-18*DHS 2005	Yes	Yes	Yes
Observations	15,148	15,148	15,148

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, age fixed effects, gender and survey year fixed effects. The regressions are based on the 15,148 women between 15 and 45 years old. The height variable is measured in centimeters. Data source: 1991 and 2005 Tanzania Demographic and Health Survey data.

Table 4: Long term Impacts of Flood Exposure on Women's Height

Dependent Variable: Height (centimeters)	(1)	(2)	(3)
During Shock Age 0-2*Affected Region*DHS 2010		-3.599***	
		(0.319)	
During Shock Age 3-6*Affected Region*DHS 2010		-2.508***	
		(0.309)	
During Shock Age 7-10*Affected Region*DHS 2010		-1.663***	
		(0.305)	
During Shock Age 11-14*Affected Region*DHS 2010		-0.970***	
		(0.242)	
During Shock Age 15-18*Affected Region*DHS 2010		-0.437*	
		(0.226)	
During Shock Age 19-22*Affected Region*DHS 2010		-0.052	
		(0.201)	
During Shock Age 0-18*Affected Region*DHS 2010	-1.182***		
	(0.262)		
During Shock Age 0-18*0-100 km to the flood*DHS 2010			-1.565***
			(0.529)
During Shock Age 0-18*101-200 km to the flood*DHS 2010			-1.228**
			(0.458)
During Shock Age 0-18*201-300 km to the flood*DHS 2010			-0.696
			(0.577)
During Shock Age 0-18*Affected Region	Yes	Yes	No
Affected Region*DHS 2010	Yes	Yes	No
During Shock Age 0-18*Distance indicators	No	No	Yes
Distance indicators*DHS 2010	No	No	Yes
During Shock Age 0-18*DHS 2010	Yes	Yes	Yes
Observations	15,049	15,049	15,049

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, age fixed effects, gender and survey year fixed effects. The regressions are based on the 15,049 women between 15 and 45 years old. The height variable is measured in centimeters. Data source: 1991 and 2010 Tanzania Demographic and Health Survey data.

Table 5: Intergenerational Transmission of Flood Exposure on Children's Height-for-age Z-score

Dependent Variable: Height for Age Z score	Affected Mother		Affected Father	
	(1)	(2)	(3)	(4)
Parent Young Cohort*Affected Region*DHS 2010	-0.301***		0.062	
	(0.047)		(0.041)	
Parent Young Cohort*0-100 km to the flood*DHS 2010		-0.364**		-0.038
		(0.133)		(0.102)
Parent Young Cohort*101-200 km to the flood*DHS 2010		-0.228***		-0.069
		(0.023)		(0.059)
Parent Young Cohort*201-300 km to the flood*DHS 2010		-0.043***		-0.051
		(0.007)		(0.179)
Parent Young Cohort*Affected Region	Yes	No	Yes	No
Affected Region*DHS 2010	Yes	No	Yes	No
Parent Young Cohort*Distance indicators	No	Yes	No	Yes
Distance indicators*DHS 2010	No	Yes	No	Yes
Parent Young Cohort*DHS 2010	Yes	Yes	Yes	Yes
Observations	12,661	12,661	12,661	12,661

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, age fixed effects, gender, distance fixed effects, parent's age fixed effects and survey year fixed effects. The regressions are based on 12,661 children between 0 and 4 years old. The variable Parent Young Cohort takes value equal to one if the parent of each children are in the age range 17 to 35 (individuals in the age range 17 to 35 in 2010 were in the age range 0 to 18 during the flood). Data source: 1991 and 2010 Tanzania Demographic and Health Survey data.

Table 6: Impacts of Flood Exposure on Women's Marriage Market Performance

Dependent Variable:	Husband Age		Husband Education	
	(1)	(2)	(3)	(4)
Young Cohort*Affected Region*DHS 2010	3.109***		-0.521***	
	(0.447)		(0.142)	
Young Cohort*0-100 km to the flood*DHS 2010		3.882**		-1.182*
		(0.808)		(0.672)
Young Cohort*101-200 km to the flood*DHS 2010		1.017**		-0.264
		(0.464)		(0.267)
Young Cohort*201-300 km to the flood*DHS 2010		0.045		-0.122
		(0.960)		(0.333)
Young Cohort*Affected Region	Yes	No	Yes	No
Affected Region*DHS 2010	Yes	No	Yes	No
Distance indicators*Young Cohort	No	Yes	No	Yes
Distance Indicators*DHS 2010	No	Yes	No	Yes
Young Cohort*DHS 2010	Yes	Yes	Yes	Yes
Observations	9,742	9,742	9,742	9,742

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, age fixed effects, gender, distance fixed effects, parent's age fixed effects and survey year fixed effects. Husband age is defined as the age of the husband of each mother in the data base. Husband Education is defined as the years of education of the husband of each mother in the data base. The regressions are based on 9,742 mothers between 15 and 45 years old. The variable Young Cohort takes value equal to one if the individual is in the age range 17 to 35 (individuals in the age range 17 to 35 in 2010 were in the age range 0 to 18 during the flood).Data source: 1991 and 2010 Tanzania Demographic and Health Survey data.

Appendix

Table A.1: Short term Impacts of Flood Exposure on Children's Height-for-age Z-score, based on potential residence at the time of the flood

Dependent Variable: Height for Age Z score	All children		Females		Males	
	(1)	(2)	(3)	(4)	(5)	(6)
Young Cohort*Affected Region*DHS 1996	-0.139***		-0.221***		-0.026	
	(0.049)		(0.068)		(0.058)	
Young Cohort*0-100 km to the flood*DHS 1996		-0.224***		-0.377***		-0.042
		(0.043)		(0.075)		(0.085)
Young Cohort*101-200 km to the flood*DHS 1996		0.148		0.182		0.153
		(0.144)		(0.136)		(0.162)
Young Cohort*201-300 km to the flood*DHS 1996		-0.032		-0.118		0.067
		(0.160)		(0.162)		(0.170)
Young Cohort*Affected Region	Yes	No	Yes	No	Yes	No
Affected Region*DHS 1996	Yes	No	Yes	No	Yes	No
Young Cohort*Distance indicators	No	Yes	No	Yes	No	Yes
Distance indicators*DHS 1996	No	Yes	No	Yes	No	Yes
Young Cohort*DHS 1996	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,799	9,799	4,906	4,906	4,893	4,893

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, child age fixed effects,child gender and survey year fixed effects. The regressions are based on the 9,799 children between 0 and 4 years old. The variable Young Cohort takes value one for children in the age range 3-4 (Those children were in the age range 0-1 during the flood). The individual's place of residence is based on the potential region of residence at the time of the flood, whereby any individual who moved during the flood is reassigned to an affected region regardless of residence at the time of the survey (i.e. for every individual who moved during the flood and is currently residing in a non-affected region, exposure status is reassigned as if the individual had been living in an affected region during the flood). This is a conservative approach to dealing with the bias due to endogenous migration as some individuals who moved during the flood and currently reside in a non-affected region might have been living in another non-affected region during the flood. Data source: 1991 and 1996 Tanzania Demographic and Health Survey data.

Table A.2: Medium term Impacts of Flood Exposure on Women's Height, based on potential residence at the time of the flood

Dependent Variable: Height (centimeters)	(1)	(2)	(3)
During Shock Age 3-6*Affected Region*DHS 2005		-0.983***	
		(0.265)	
During Shock Age 7-10*Affected Region*DHS 2005		-0.747***	
		(0.215)	
During Shock Age 11-14*Affected Region*DHS 2005		-0.637*	
		(0.318)	
During Shock Age 15-18*Affected Region*DHS 2005		-0.404*	
		(0.233)	
During Shock Age 19-22*Affected Region*DHS 2005		-0.354	
		(0.212)	
During Shock Age 3-18*Affected Region*DHS 2005	-0.702***		
	-0.214		
During Shock Age 3-18*0-100 km to the flood*DHS 2005			-1.349***
			(0.465)
During Shock Age 3-18*101-200 km to the flood*DHS 2005			-0.466
			(0.293)
During Shock Age 3-18*201-300 km to the flood*DHS 2005			-0.231
			(0.297)
During Shock Age 3-18*Affected Region	Yes	Yes	No
Affected Region*DHS 2005	Yes	Yes	No
During Shock Age 3-18*Distance indicators	No	No	Yes
Distance indicators*DHS 2005	No	No	Yes
During Shock Age 3-18*DHS 2005	Yes	Yes	Yes
Observations	15,148	15,148	15,148

Notes: Robust standard errors in brackets, clustered at the region level. *Significant at 10%; ** significant at 5%; *** significant at 1%. All regressions include region fixed effects, age fixed effects, gender and survey year fixed effects. The regressions are based on the 15,148 women between 15 and 45 years old. The height variable is measured in centimeters. The individual's place of residence is based on the potential region of residence at the time of the flood, whereby any individual who moved during the flood is reassigned to an affected region regardless of residence at the time of the survey (i.e. for every individual who moved during the flood and is currently residing in a non-affected region, exposure status is reassigned as if the individual had been living in an affected region during the flood). This is a conservative approach to dealing with the bias due to endogenous migration as some individuals who moved during the flood and currently reside in a non-affected region might have been living in another non-affected region during the flood. Data source: 1991 and 2005 Tanzania Demographic and Health Survey data.