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Natural Disasters, Self-Insurance, and Human Capital Investment

Evidence from Bangladesh, Ethiopia, and Malawi

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ABSTRACT

This paper uses panel data from Bangladesh, Ethiopia, and Malawi to examine the impacts of disasters on dynamic human capital production. Our empirical results show that accumulation of biological human capital prior to a disaster helps children maintain investments during the post-disaster period. Biological human capital formed in early childhood (for example, good long-term nutritional status) helps insure resilience to disasters by protecting schooling investments and outcomes, even though disasters have negative impacts on the actual investments (for example, by destroying schools). In Bangladesh, children with more biological human capital are less adversely affected by flood, and the rate of investment increases with the initial human capital stock during the post-disaster recovery process. In Ethiopia and Malawi, where droughts are relatively frequent, repeated drought exposure reduces schooling investments in some cases, with larger negative impacts seen among children who embody less biological human capital. Asset holdings prior to disaster (especially intellectual human capital stock in the household) also help maintain schooling investments to at least the same degree as the stock of human capital accumulated in the children prior to the disaster. Our results suggest that as the frequency of natural disasters increases due to global warming, the insurance value of investments in child nutrition will increase. Public investments in child nutrition therefore have the potential to effectively protect long-term human capital formation among children who are vulnerable to natural disasters.

Keywords: disasters, human capital, nutrition, schooling, self-insurance, Bangladesh, Ethiopia, Malawi

1. INTRODUCTION

It has been increasingly recognized that child growth in early childhood has long-term impacts on subsequent human capital formation and labor-market outcomes (for example, Alderman, Hoddinott, and Kinsey 2006; Hoddinott et al. 2008; Yamauchi 2008). Disasters can dramatically reduce child nutrient intake, leading to malnutrition and therefore lower formation of biological human capital in early childhood (for example, Hoddinott and Kinsey, 2001; del Ninno and Lundberg 2005). In this context, however, many important questions have not been empirically addressed.

Investments in human capital can take different forms, including investment in biological human capital (for example, health and nutritional status) and intellectual human capital (schooling and cognitive skills) (Behrman et al. 2008).

Once biological human capital is formed at the early stage, however, we might ask: How resilient is it to the adverse impacts of disasters? Does it help maintain the formation of other forms of human capital (for example, intellectual human capital acquired through schooling) at subsequent stages, even in the face of disasters? After disastrous distortions due to natural hazards, do healthy children recover faster? Do disasters affect the inequality of attained intellectual human capital among children by differentially interrupting the formation of biological human capital? And finally, do some types of human capital serve as insurance, effectively protecting the accumulation of other forms of human capital in the face of disasters?

The question of whether human capital is robust to natural hazards, such as floods, droughts, and earthquakes, provides more extensive insights. First, in contrast to physical capital, human capital is portable and remunerable in different locations.[1] Therefore, unless the natural hazards are extremely sudden and unexpected, agents can potentially avoid damage to human capital.

Second, biological human capital (especially health and height attained from adequate nutrient intake and other inputs into child health) accumulated prior to a disaster could increase the survival probability and resilience to disaster among both adults and children. For example, it is plausible that healthy children are less likely to become sick even in unsanitary environments, such as those often found immediately after a disaster. Therefore, the actual exposure to natural hazards (damages) may depend on the stock of biological human capital accumulated in the pre-disaster period.

Third, after a disaster, the rate of investment in child schooling could depend on the pre-disaster stock of their health capital, since the expected returns to schooling investment are high among healthy children due to the complementarity between knowledge and health capital. Thus, the accumulation of biological human capital prior to a disaster may help maintain the investment in a dynamic context. The convergence to the original path (recovery) is expected to be faster among children who already embody larger stocks of human capital. Moreover, if disasters are frequent, the inequality of human capital may increase in the long run.[2]

The above second and third points suggest the possibility of poverty traps; the impacts may be asymmetric between children with and without enough human capital,[3] and the pre-disaster accumulation of human capital accumulation enables the continuation of human capital investments during the recovery process. Therefore, inequality in the initial stock of human capital may exacerbate any divergence in

[1] Educated adults can migrate to maintain the returns to their human capital (for example, to urban labor markets), thereby helping to mitigate the impact of a natural disaster on the household income. Children can also mobilize their human capital to different locations, but this strategy will decrease their subsequent human capital accumulation. If returns to human capital are high because of frequent natural disasters, however, the incentive to invest in human capital becomes strong. This can increase the accumulation of human capital in the long run, despite the negative effects of disasters on income (which at least temporarily decreases investments in human capital).

[2] The inequality between the affected and unaffected areas must be conceptually separate from the inequality within the affected areas. Natural hazards increase the former but not necessarily the latter, as the effects to the latter depend on the mechanisms through which the disaster affects the dynamics of human capital formation.

[3] Recent macroeconomic studies show the relationship between natural hazards and growth performance. In Noy (2008), the illiteracy level increases the negative impact of natural disasters on GDP growth.

human capital accumulation, owing to perturbations caused by natural hazards. In the present paper, we empirically test these hypotheses.

Our empirical analysis uses panel data from household surveys conducted by the International Food Policy Research Institute (IFPRI) in Bangladesh, Ethiopia, and Malawi (see del Ninno et al. 2001; Gilligan and Hoddinott 2005; Quisumbing 2005; Sharma 2005). Each country provides a natural experiment with natural hazards through which we can test the above propositions. Bangladesh had a severe flood in 1998, and both Ethiopia and Malawi experienced large droughts in 2001 (followed by a flood in 2001-2002 in Malawi). Among these countries, there are differences in the pattern of natural hazards; while the 1998 flood was a single severe event for many households in our Bangladesh sample, droughts were rather frequent in Ethiopia and Malawi (notably, however, the 2001 drought was the most severe in both cases). Although the initial rounds of data collection were conducted at different times in each country, they include information on anthropometry for children aged below 60 months before or immediately after the disaster in each case. By coupling this with information on child schooling obtained in the post-disaster survey round(s), we can estimate transition equations for human capital formation from the preschool to school-age stages.

The paper is organized as follows. The next section describes a simple model for describing how natural hazards affect human capital formation in the early childhood and school-age stages. Sections 3 and 4 discuss the econometric framework and data, respectively.

Section 5 reports our empirical results, which show that the accumulation of human capital prior to disaster helps children maintain investments in the post-disaster period. Biological human capital formed in early childhood (nutritional status) helps insure children against disasters by increasing schooling investments and outcomes, even though the disasters may negatively impact the investments itself. In Bangladesh, children with more biological human capital are less affected by the adverse effects of flood, and the rate of investment increases with the initial human capital stock during the post-disaster recovery process. In Ethiopia and Malawi, where droughts are relatively common, frequent drought exposure reduces schooling investments in some cases, with larger negative impacts seen among children who embody less biological human capital. However, asset holdings prior to the disasters, especially with regard to intellectual human capital stock in the household, help maintain schooling investments to the same degree as the stock of human capital accumulated in the children prior to the disaster.

2. A SIMPLE MODEL

This section introduces a simple model in which parents decide how much to invest in child biological human capital (health) and intellectual human capital (schooling), resulting in labor market returns. (In this paper, we use ”health” and ”biological human capital” interchangeably; similarly, we also use the terms ”schooling,” ”knowledge capital,” and ”intellectual human capital,” interchangeably.)

For simplicity, we treat the age distribution of children as exogenous and assume that children enter the labor market in the final stage. Health is formed in the first stage,[4] while schooling investment is undertaken in the second stage.

In the preschool stage, per capita consumption and shocks determine health capital as

$$h^1,\ h^1 = f(c_1, D_1) + \varepsilon_1,$$

where c_1 is per capita consumption in the household and D_1 is disaster measured at t = 1, and ε_1 is an idiosyncratic health shock. For simplicity, we assume that health capital accumulates only until age a^*, when the child enters the schooling stage. The investment component $f(c_1,D_1)$ is characterized by the properties $\frac{\partial f}{\partial c_1} > 0$, $\frac{\partial^2 f}{\partial c \partial D_1} 0$, and $\frac{\partial f}{\partial D_1} < 0$. For simplicity, we assume that $c_1 = y(k, D_1)$, meaning that income is exogenously determined by disaster occurrence and capital stock k at $t = 1$.

At the second stage, knowledge capital h^2 accumulates with schooling investments s. The knowledge production function is given as

$$h^2 = g(s, h^1, D_2) + \varepsilon_2,$$

where D_2 is the disaster measure in the second stage. Depending on the exact timing of the disaster, D_2 can decrease or increase the marginal productivity of schooling investment. This relationship also depends on health capital. For example, healthy children can recover faster from disasters, since the marginal value of time in school can increase faster in the catch-up period for healthy children, that is, $\frac{\partial^2 g}{\partial s \partial D_2} > 0$. However, a disaster is also expected to directly decrease the formation of human capital through the destruction of school facilities and transportation infrastructure. In this case, the effectiveness of investment decreases following a disaster, $\frac{\partial^2 g}{\partial s \partial D_2} < 0$.

The complementarity between schooling and health is captured by $\frac{\partial^2 g}{\partial s \partial h^1} > 0$. This complementarity (or substitutability) implies that parents want to observe attained health capital among their children in order to optimize decisions on how to allocate schooling investments. Due to the sequential nature of human capital investments, parents can predict future outcomes of child human capital and their labor-market returns from the outcomes of early-stage nutrition and health investments.[5] This issue is also important when we consider how disaster affects child human capital, because parents can endogenously control the impacts on children by adjusting resources among siblings.

The household budget constraint in the second stage is

$$c_2 + ps = y(k, D_2) + w(h^1, D_2)\left[T - s\right] + b(k, D_2),$$

[4] Nutrient intake until 3 years old is regarded as very important in forming child biological or health capital, as measured by the height-for-age Z-score. Although the weight-for-age Z-score fluctuates over time (age) due to changes in nutrient intake (that is, consumption) and morbidity, the height-for-age Z-score is less likely to change after the age of 3. In the context of dynamic human capital production, therefore, child biological human capital is measured by the height-for-age Z-score.

[5] Cunha et al. (2004) summarize some key concepts in the sequential development of child human capital, focusing on cognitive and noncognitive development. Their analysis does not directly include health and nutritional status as part of human capital in child development. This exclusion of health capital from the analysis yields a framework that focuses on the human capital production function, and the complementarity and substitutability of different inputs (for example, early childhood and schooling stage). Children also work in the labor market, where health capital has economic returns. This institutional setting creates implications that offset the health-schooling complementarity effect.

where $w(h^1, D_2)$ is child wage, T is time endowment for the child, p is school fee, $b(k, D_2)$ is an intertemporal transfer conditional on disaster occurrence, and y is exogenous household income (determined by capital stock and disaster). It is assumed that the child's wage increases with health capital, that is, $w_h \geq 0$.[6] We assume that the child cannot work during the preschool stage, but can work in the labor market when he or she enters school.[7] Note that we treat $b(k, D_2)$ as exogenous; the details of this transfer are discussed below.

Parents maximize the objective function,

$$\max_{s} E\left[u(c_2) + \beta V\left(W(h^1, h^2) - b(k, D_2)\right) \mid h^1, D_2\right],$$

which captures the discounted sum of the expected utilities from consumption over time and the final-period returns from children. The discount factor β has an interpretation of altruism to children, who have an increasing and concave utility function V. We assume that

$$W(h_1,h_2) = R_1h_1 + R_2h_2,$$

where R_1 and R_2 are financial returns to health and knowledge capital, respectively. In this version, since we do not have uncertainty in the future returns to human capital, we omit the expectations operator below. If the wage function is strictly concave, parents have incentives to equalize human capital among their children.

Suppose that $b(k, D_2)$ is determined to equalize the discounted marginal utilities between the two periods. For example, agents may borrow cash from their relatives. For the sake of easing tractability, we assume that agents have to pay back this loan in the next period after disaster recovery. In this setting, we have

$$\lambda^* = u'(c_2^*) = \beta V'(c),$$

where λ^* is the Lagrange multiplier associated with the budget constraint. This condition means that the marginal rate of intertemporal substitution is equal to unity.

The first order condition for schooling investment at the second stage is

$$u'(c_2^*)\left[w(h^1, D_2) + p\right] = \beta V'(c)\frac{\partial g}{\partial s}(s, h^1, D_2)R_2,$$

that is,

$$w(h^1, D_2) + p = MRS * \frac{\partial g}{\partial s}(s, h^1, D_2)R_2,$$

where

$$MRS = \tfrac{\beta V'(c)}{u'(c)}.$$

The income effect is captured by an increase in MRS with D_2, while the substitution effect is derived from a decrease in the wage rate. As discussed, we do not know whether D_2 increases or decreases $\tfrac{\partial g}{\partial s}$. These conditions provide the schooling investment function

$$s = s(k,h_1,D_2).$$

Note that this problem is trivial at the first stage, since exogenous income and disaster shocks determine investment in health capital.

[6] It is also important to note that the income opportunity in the child wage is not necessarily related to labor markets, as it may also capture activities such as childcare and self-employment.

[7] Several reservations follow. First, we assume that income from siblings, parents, and credit are pooled in the household budget constraint, and are therefore perfectly substitutable. Second, to describe the income process, the model does not assume a production function in which adult and child labor inputs are not perfectly substitutable. Third, the utility function does not include leisure, which is imperfectly substitutable between household members (for example, Pitt and Rosenzweig 1990).

If $b(k, D_2)$ functions perfectly, MRS is constant. Therefore, we can ignore a possible change in MRS. Otherwise, from the second order condition and the partial derivative of the first order condition of s with respect to D_2, we know that the effect of disaster on schooling investment depends on

$$LHS = \frac{\partial w(h_1, D_2)}{\partial D_2} \leq 0$$

and

$$RHS = MRS \frac{\partial^2 g(s, h_1, D_2)}{\partial s \partial D_2} R + \frac{\partial MRS}{\partial D_2} \frac{\partial g}{\partial s}(s, h_1, D_2) R.$$

Again, the second term in RHS is zero if $b(k, D_2)$ functions perfectly. Schooling investment decreases if $RHS < LHS$.

Next, we examine the possible roles of health capital formed in the pre-disaster period. First, h^1 reduces the negative impact of a disaster on the marginal productivity of schooling (cushioning the shock on schooling investment), and/or increases the marginal productivity of schooling investment when disaster occurs. We may call the latter a “recovery effect”; this is characterized by the condition $\frac{\partial^2 g(s, h_1, D_2)}{\partial s \partial D_2} > 0$ when h^1 is large. Thus, after a disaster, healthy children experience higher schooling investments and catch up faster.[8]

Second, if $b(k, D_2) = 0$, disaster has two direct effects on income, namely through changes in income-generating activity ($y(k, D_2)$) and the wage rate in the labor market ($w(h^1, D_2)$). These effects increase the marginal utility in the second stage, thereby decreasing MRS if all other conditions are equal. Schooling investments decrease if the income effect dominates.

Third, the LHS condition translates to a decrease in wages, which increases schooling investments. The question of real relevance is whether the labor-market effect is larger than the income-reduction effect. Since labor is mobile and the labor market extends beyond the disaster-affected areas, it is reasonable to suppose that the labor-market effect is smaller than the income-reduction effect.

We include health capital in the child-wage function, as health capital can mitigate the shock on the wage rate. If rationing in the labor demand becomes tougher during a period of disaster, it is possible that healthier children may find work more easily compared to less healthy children. In this case, the negative effect of a disaster on the wage rate could be smaller for healthy than less healthy children.

The pre-disaster asset holding, k, can also mitigate the direct impact of a disaster on income in the second stage in two ways: first, asset holdings can be used as collateral for borrowing cash from the credit market ($b(k, D_2)$); and second, assets may directly cushion the impacts of natural disaster, for example, via the ability to secure a water supply through irrigation assets ($y(k, D_2)$).

Finally, we may think about an interesting experiment under the condition $E[D_1 D_2] < 0$. In an extreme situation, let us consider two scenarios: case 1, in which $D_1 = 1$ and $D_2 = 0$, and case 2, in which $D_1 = 0$ and $D_2 = 1$. In case 1, smaller health capital is embodied in the child; thus, schooling investment is decreased if health capital and schooling investments are complementary. In case 2, there is more health capital in the first stage, but a disaster occurs in the second stage, affecting schooling investments. If agents know that shocks are negatively correlated over time and health capital can mitigate the negative impact of disaster on schooling, it is optimal to invest in the child’s health capital in the first stage. We herein omit decisionmaking with regard to nutrient intake, but it would be interesting to empirically investigate this dynamic intertemporal issue with regard to health capital and schooling investments. For example, we predict that a higher probability of future disaster should increase preventive investments in human capital during early childhood.

[8] However, a disaster is generally expected to decrease the effectiveness of schooling investment, for example, by destroying schools. In this case, whether we empirically observe or not depends on the actual timing of observation. For example, the impact is likely to be negative during and immediately after the disaster, but it can be positive once the recovery process has begun. Therefore, the prediction depends on the time frame used in the analysis. In the above model, the second stage occurs nearly 10 years later in the child’s life.

3. ECONOMETRIC FRAMEWORK

In this section, we describe the econometric framework that we use to clarify our hypotheses and test the role of early-stage (biological) human capital in forming (intellectual) human capital stock in a dynamic context in the presence of disasters. We investigate the transition from early childhood nutrition/health status to schooling stages, and use this measure to examine how disasters alter human capital formation in affected and unaffected areas. As discussed fully in the next section, our analysis utilizes data collected after actual natural disasters: the 1998 flood in Bangladesh and the 2001 droughts in Ethiopia and Malawi.

As discussed in the previous section, the use of child schooling to measure disaster impacts may be potentially problematic, since disasters may affect not only marginal utility (through income reduction) but also the opportunity cost of schooling investments (that is, a decrease in labor-market wage). The former decreases schooling investments in order to smooth consumption over time, while the latter increases these investments, since a decrease in the market wage increases the incentive to allocate more time to schooling. However, many disasters are different from economic recessions that do not destroy public goods, such as schools. For example, floods can destroy school facilities, thereby disrupting normal school activities. Severe droughts, such as the ones we analyze herein for Ethiopia and Malawi, cause substantial decreases in crop production; this can threaten food security and human survival, and therefore increases the need for children to earn incomes for their families.

This paper focuses on the role of preschool human capital in overcoming and recovering from the adverse impacts of disasters. As clarified in the model, recovery from disaster may be quicker if the child embodies large (biological) human capital prior to the disaster. Empirically capturing this dynamic process depends on the exact timing of data collection and disaster occurrence. Although the direct effect of a disaster on schooling (or child growth) is negative during and immediately after the disaster, once the recovery process begins, the experience of such a disaster may hasten the rate of investment in schooling. The empirical question we seek to answer herein is under what condition(s) the recovery process begins, and whether the negative impact of a disaster persists over time.

We use grade completed as our measure of child schooling, with child height in the previous period as a key explanatory variable. Controlling for child height (taken as an indicator of investments in biological human capital in early childhood), we look at human capital growth from the preschool to school periods as follows:

$$h^2_{ijl,,t+1} = \alpha + \beta_1 h^1_{ijl,t} + \beta_2 D_{jl} + \beta_3 D_{jl} h^1_{ijl,t} + \sum_k \beta_4^k D_{jl} a^k_{jl0} + village_l + age_i + \varepsilon_{ijl,,t+1}, \tag{1}$$

where $h^2_{ijl,t+1}$ is grades completed up to $t + 1$ for child i in household j and village l, D_{jl} is a disaster indicator (index) or continuous measure (for example, repair cost), $h^1_{ijl,t}$ is child height in t, a^k_{jl0} is pre-disaster asset of type k, $village_l$ is the village-fixed effect (this could be a wider geographic unit than the village, depending on the empirical context), age_i denotes a set of age dummies used to control for age-specific grade progression, and $\varepsilon_{ijl,,t+1}$ is the error term. In the above notations, we use times 0 and 1 and to denote pre-disaster assets (before t) and post-disaster public assistance (before $t + 1$), respectively.

We assume that

$$E\left[\varepsilon_{ijl,t+1} a^k_{jl0}\right] = 0 .$$

Pre-disaster assets are also uncorrelated with shocks to schooling investment in $t + 1$. We assume that

$$E\left[\varepsilon_{ijl,t+1} D_{jl}\right] = 0 ,$$

implying that the disaster occurred before $t + 1$, and that actions taken in $t + 1$ are conditioned on this information.

If the shocks are perfectly correlated within a village, the inclusion of village- (area)-fixed effects may lead us to underestimate the impacts of disaster. However, there is a cost of not including village-fixed effects, since unobserved village-specific factors (for example, changes in school availability) often jointly affect child schooling in the village. Furthermore, the actual costs of flood and drought are not evenly distributed among villagers. In the analysis below, we estimate not only the direct impact of disaster, but also the indirect effects through pre-disaster child human capital and asset holdings, which mitigate the above problem.

One advantage of using village-fixed effects is that we can control for possible substitution effects on child schooling through changes in the wage rate in the labor market if labor market conditions are homogeneous at least within the village (area). Therefore, with village-fixed effects, we expect to observe that a disaster has negative effects on schooling (through income effects).

As discussed in the previous section, β_2 and β_3 could be either positive or negative; $\beta_3 > 0$ together with $\beta_2 < 0$ implies that the recovery process from a disaster is faster if the child embodies more human capital in the previous stage (before disaster). If the recovery process is faster for children with more initial human capital, the process will increase the initial inequality in human capital among children. $\beta_3 < 0$ implies that the disaster will decrease the inequality in human capital formation among children (or siblings). After a disaster, it is possible that $\beta_1 = 0$ if the adverse impacts of the disaster are large and/or the destructive forces due to the disaster entirely subvert the dynamic formation of human capital (for example, if all schooling and health facilities are destroyed).

4. DATA

This section describes the data from Bangladesh, Ethiopia, and Malawi that we use to test our hypotheses. IFPRI and its local collaborators conducted panel household surveys in these three countries. The period covered in the panel data includes the occurrence of major natural hazards such as flood and drought.

In Bangladesh, the initial survey round was fielded in late 1998, immediately after the onset of the 1998 flood, followed by two more rounds in April-May 1999 (del Ninno et al. 2001). In 2004, a follow-up survey was conducted in April-May, coinciding with the season of the previous survey rounds (Quisumbing 2005) In Ethiopia, the panel data set builds on the Ethiopian Rural Household Survey, which began in a small sample of villages in 1989, and was expanded to 15 villages in 1994. Several rounds were conducted before 1999. For the child anthropometry data, we use data from the 1997 round. A large drought occurred in 2001; this was followed by the 2004 survey. In Malawi, an initial survey round occurred in 2000. This was followed by the 2001 drought and a subsequent survey round in 2004.

Combining these panel data with information on the natural hazards provides us with an ideal setting to assess the impacts of natural hazards and disasters on human capital formation and the roles of ex-ante actions and ex-post responses.

However, even though we adopt the unique approach described in the previous sections, the exact timing of the natural hazards and surveys will matter when we interpret our empirical results. In Bangladesh, the initial survey round was fielded almost immediately after the 1998 flood. Though the effects of the disaster were gradually realized after the flood, the initial survey round would be expected to capture some effects of flood exposure. The subsequent two rounds, which were conducted within the next year, captured the dynamic changes of the disaster's impact. The timing issue is especially important with regard to the child anthropometry data, especially if we expect that malnutrition led to child weight loss soon after the flood.[9] Therefore, we must pay particular attention to timing when interpreting our empirical results. However, we think that child height is more robust than child weight to shocks.[10] With regard to pre-flood assets, the data are constructed to reflect the pre-flood situation.

In Ethiopia and Malawi, the initial survey rounds took place prior to the 2001 droughts. Thus, the information on child schooling and anthropometry (except for the parts explained by ex-ante actions) are not contaminated by the influence of the droughts. However, potential problems arise from the interval between the 2001 droughts and the 2004 follow-up surveys. Given that the actual drought impacts on income would have occurred in 2001-2002, the interval between the drought and the 2004 survey was rather short, meaning that we might not be able to capture the recovery process of human capital investments.

Malawi suffered a large flood in 2001-2002, after the 2001 drought. However, our preliminary analysis indicates that the impacts of the flood are rather small, compared to the effects of the drought. Therefore, we focus on the 2001 drought in Malawi for our empirical analysis. However, the abovementioned concern regarding the interval between natural hazards and the follow-up survey also holds.

The differences in the time structure of the hazards and the initial and follow-up rounds change the way in which we interpret our empirical results. In Bangladesh, we may underestimate the initial disaster impacts on child human capital because the first round, which was conducted immediately after the flood, already reflects some of the most immediate impacts. However, this survey is ideal for capturing the recovery dynamics of human capital starting immediately after the flood. We can also use the three rounds conducted within a year of the flood to reveal short-term changes in child anthropometry. Therefore, the Bangladesh setting provides both long-term and short-term dimensions. In Ethiopia and

[9] Similarly, grades completed were not affected at the initial round, but attendance rate (in terms of days attended per total number of school days) was already changed immediately after the flood.

[10] Child weight is sensitive to short-term morbidity, which is an issue in the case of floods. Waterborne diseases and diarrhea typically increase in the aftermath of a flood. In our analyses, we use the height-for-age Z-scores in the range of -6 to 6.

Malawi, the interval between the droughts and the follow-up survey was rather short. However, this setting is suitable for investigating the short-run impacts on human capital investments.

The 2004 surveys conducted in all three countries include retrospective information on past disasters. This helps us determine the frequency of disasters experienced by households up to 2004. The frequency is defined as the empirical average of incidences in the period from the initial round to the last round. Our preliminary work shows that Ethiopia and Malawi experienced several droughts between the initial and follow-up rounds. In Bangladesh, however, the 1998 flood was the single most devastating incident experienced by many of the households in our sample.[11] Standardizing the frequencies by the interval between the initial round and the 2004 follow-up survey, we obtain the following distributions for the three countries (Table 1).

Table 1. Estimates of future disaster probabilities

	Number of incidences			
Country/disaster	**Zero**	**One**	**Two**	**Three**
Bangladesh: flood	0 (453)	0.14 (323)	0.29 (7)	
Ethiopia: drought	0 (594)	0.20 (394)	0.40 (215)	0.60 (54)
Malawi: drought	0 (389)	0.25 (228)	0.50 (101)	0.75 (36)

Notes: Numbers of households are shown in parentheses. Probabilities are defined as the empirical average of disaster incidences (measured yearly) in the period between the initial and final survey rounds.

Because the 1998 flood was unusual in its severity and duration, instead of using a disaster measure based on frequency of occurrence for Bangladesh, we use a flood exposure index that measures flood severity (del Ninno et al. 2001). In this measure, the exposure is grouped into the categories of none, moderately exposed, severely exposed, and very severely exposed. In addition, the Bangladesh data provide some details of the flood impacts, including the water depth, the number of days the house was covered by water, repair costs, and the number of days household members spent evacuated from their home. The former two measures are objective, but the latter two could be endogenous. Repair costs are actual expenditures, so this involves household decisions and asset holdings. The number of days evacuated is correlated with the number of days covered by water, but it also measures the length of time household members stayed safely away from the disaster. Thus, this measure is higher among those who had resources allowing them to relocate temporarily away from the flood (for example, by evacuating to other regions). Thus, although these measures principally capture disaster impacts, we may need to be careful when interpreting the results.

[11] Floods are a normal part of the agricultural cycle in Bangladesh. However, the 1998 floods were exceptional both for their severity and duration. Unlike normal floods, which cover large parts of the country for several days or weeks during July and August, the 1998 floods lasted until mid-September in many areas, covering more than two-thirds of the country and causing over 2 million metric tons of rice crop losses (equal to 10.45 percent of target production in 1998/99) (del Ninno et al. 2001).

5. EMPIRICAL RESULTS

Flood Impacts on Nutritional Status—Bangladesh

Using the 1998 flood in Bangladesh, we can investigate the short-run impacts on child weight within a year post-flood. As described in the previous section, the 1998 survey started immediately after the flood, and traced individuals for a year through three rounds of data collection. Our analysis uses rounds 1 and 3 to compute changes in the weight-for-age and weight-for-height Z-scores. Flood exposure is measured by water depth, the number of days covered by water, repair costs, and the number of days household members spent away from their homes (as discussed in the previous section). Table 2 reports the estimation results.

Table 2. Short-run effects of Bangladesh flood on child weight

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Dependent	**Weight-for-age Z-score from rounds 1 to 3**				**Weight-for-height Z-scores from rounds 1 to 3**			
Flood variable	**Depth**	**Days**	**Repair cost**	**Out of home**	**Depth**	**Days**	**Repair cost**	**Out of home**
Flood	-0.0425 (1.050)	-0.0060 (1.890)	-0.0001 (2.100)	-0.0006 (0.290)	-0.0414 (0.790)	-0.0030 (0.750)	-0.0001 (1.970)	0.0043 (2.070)
Union-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	272	272	272	272	256	256	256	256
Number of unions	21	21	21	21	21	21	21	21
R-squared (within)	0.0281	0.0441	0.0456	0.0239	0.0209	0.0213	0.0287	0.0231

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with union clusters. Female indicator and age dummies are included in all specifications.

Columns 1 through 4 show the impacts of the flood on changes in the weight-for-age Z-scores. The estimation controls for union-fixed effects[12] (rather than village-fixed effects), in order to maintain a reasonable number of observations within the unit. Due to the utilized sampling framework, only a few households were sampled per village, and the number of children below 60 months was limited. However, we see that both the number of days submerged and repair cost have significant negative effects on the weight-for-age Z-scores.

In Columns 5 through 8, we use the weight-for-height Z-scores. We see that an increase in repair cost reduces the weight-for-height Z-score, but the number of days evacuated from home is positively associated with the weight-for-height Z-score. It is possible that children who had been evacuated from the affected areas grew better than those who were not evacuated.

Our results (summarized in Table 2) demonstrating the impacts of the 1998 flood on changes in children's anthropometric measures are consistent with those from other studies (for example, Alderman, Hoddinott, and Kinsey 2006). In the preliminary analysis, we did not observe significant disaster impacts on changes in the height-for-age Z-scores over the one-year period.

Human Capital vs. Disasters

In Bangladesh, the utilized measure is obtained from survey round 1 (1998), which was collected immediately after the flood. While one could argue that floods could immediately affect nutritional status, we feel that the endogeneity issue is negligible, given that height was measured right after the flood. This is an advantage of using the height-for-age Z-score rather than the weight-for-age Z-score, as weight can fluctuate substantially over a relatively short period. In Ethiopia and Malawi, since the height-for-age Z-

[12] Union is the administrative unit that is one-level higher than village.

scores were taken from the initial round (prior to the drought), the above concern is less important (see, also, discussions in Section 3).

Bangladesh

In this subsection, we summarize the dynamic impacts of disasters on the transition from early childhood to schooling stages, using examples of flood and drought in Bangladesh, Ethiopia, and Malawi. As discussed in Section 3, we use the height-for-age Z-score to capture preschool biological human capital, which reflects nutrient intake and health inputs during early childhood.

In Table 3, we use water depth, the number of days covered by water, repair cost and the number of days evacuated from home as measures of flood exposure. The dependent variable is grades completed in 2004. Column 1 shows a benchmark result for the effect of height on grades completed. The height-for-age Z-score has a significant and positive effect on grades completed. The specification includes union-fixed effects and age dummies.

Table 3. Dynamic effects of Bangladesh flood on human capital formation 1
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)	(5)
Flood variable		**Water depth**	**Days covered by water**	**Repair cost**	**Out of home**
HAZ 1998	0.1628	0.0839	0.0920	0.1495	0.1450
	(3.270)	(2.220)	(2.780)	(2.880)	(3.090)
Flood		0.2299	0.0083	0.0002	0.0014
		(2.840)	(1.820)	(1.040)	(0.210)
Flood × HAZ 1998		0.0413	0.0022	0.0007	0.0019
		(1.410)	(1.690)	(0.900)	(0.970)
Union-fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observations	209	209	209	209	209
Number of unions	20	20	20	20	20
R-squared (within)	0.3528	0.3846	0.3690	0.3595	0.3600

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with union clusters. Female indicator and age dummies are included in all specifications. HAZ stands for height-for-age Z-score.

Columns 2 through 5 show the effects of flood and child height on schooling. First, we confirm that even with flood variables, the height-for-age Z-score has significantly positive effects on schooling. Second, we find that flood measures have positive effects on schooling (after six years), with water depth and the number of days submerged showing significant positive effects on schooling by 2004. Third and finally, we do not observe any significant interaction between the flood measures and the height Z-score.

Note that these findings seem to contradict our results for short-term changes in child's weight. However, here we are looking at the outcome nearly six years after the flood. Therefore, if the recovery (catch-up) process started sometime before 2004, it is possible that those who were affected by the disaster could grow faster under certain conditions.

Table 4 uses an alternative measure of flood exposure constructed by the IFPRI research team (del Ninno et al. 2001). The results are consistent with those in Table 2. First, in Column 1, the height-for-age Z-score is found to have a significant and positive effect on schooling at the later stage. Severe flood exposure significantly increased schooling within the same union. Second, in Column 2, healthy children (measured by height-for-age Z-score) achieve more schooling in the wake of severe flood exposure. We do not observe a significant direct effect for the height-for-age Z-score, but this measure does significantly influence schooling through flood severity.

Table 4. Dynamic effects of Bangladesh flood on human capital formation 2
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)	(5)
Flood variable			**–6 < Haz < -2**	**–4 < Haz < 0**	**–2 < Haz < 6**
HAZ	0.1547	0.0516	0.1043	0.1396	0.0025
	(3.850)	(1.080)	(0.380)	(1.750)	(0.050)
Flood exposure 1	-0.1508	-0.1299	-0.3402	-0.1865	-0.2422
	(0.860)	(0.560)	(0.330)	(0.560)	(1.150)
Flood exposure 2	0.1719	0.5828	1.0593	0.8516	0.4078
	(1.550)	(2.480)	(1.080)	(2.310)	(1.600)
Flood exposure 3	0.4153	0.7200	-0.7561	0.9511	1.0040
	(2.490)	(2.250)	(0.490)	(2.920)	(3.720)
HAZ × flood 1		0.0311	0.0578	0.0404	-0.0387
		(0.400)	(0.170)	(0.440)	(0.290)
× flood 2		0.1953	0.4228	0.2750	-0.0093
		(2.180)	(1.330)	(1.750)	(0.050)
× flood 3		0.1706	-0.1178	0.3691	0.0761
		(1.620)	(0.250)	(2.940)	(0.530)
Union-fixed effects	Yes	Yes	Yes	Yes	Yes
Number of observations	209	209	118	179	90
Number of unions	20	20	18	18	19
R-squared (within)	0.3729	0.3862	0.3262	0.4165	0.5527

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with union clusters. HAZ stands for height-for-age Z-score.

In Columns 3 through 5, we examine the robustness of these findings by altering the range of the height Z-scores used for estimation. To maintain a reasonable number of observations in each estimation, we allow the ranges to overlap in these exercises. The results show that for children with relatively large height-for-age Z-scores, we find positive effects from the 1998 flood and interaction terms with the height-for-age Z-score. In other words, healthier children experience a faster recovery from disaster in the subsequent six years.

In Tables 5 and 6, we investigate how pre-disaster assets affect the impacts of the flood on schooling and early-stage human capital. We use total asset value, maximum education (years of schooling) in the household, land size, household size, and livestock value to represent asset allocation (holdings) before the disaster. The maximum education measure covers all children, thereby including older siblings who may affect income smoothing at the household level. First, Column 1 in Table 5 confirms the above-described finding that flood severity increases subsequent investment in child schooling, indicating that the households that are most severely affected by the flood invest more in child schooling thereafter. In addition, the more assets they hold, the larger the positive impact of the flood on schooling investments. This suggests that households with more assets are better able to play “catch up” with respect to human capital investments. In Column 2, we use more disaggregated measures of household assets, and note with interest that post-flood investments in human capital are higher for households with higher maximum education levels. However, when we include these asset variables, the height effects and direct effects of the flood become insignificant.

Table 5. Dynamic effects of Bangladesh flood on human capital formation 3

Dependent: Grade completed in 2004

	(1)	(2)
HAZ	0.0504	0.0552
	(1.060)	(1.050)
Flood exposure 1	-0.2591	-0.3636
	(1.150)	(0.890)
Flood exposure 2	0.5278	-0.0131
	(1.870)	(0.030)
Flood exposure 3	0.6520	-0.3589
	(1.930)	(0.650)
HAZ × flood exposure 1	0.0238	-0.0268
	(0.310)	(0.350)
HAZ × flood exposure 2	0.1892	0.1750
	(2.040)	(1.520)
HAZ × flood exposure 3	0.1733	0.1074
	(1.650)	(1.020)
Total asset × flood exp 1	2.56E-06	
	(2.000)	
× flood exp 2	8.59E-07	
	(0.570)	
× flood exp 3	1.94E-06	
	(2.050)	
Max educ × flood exp 1		0.0666
		(1.960)
× flood exp 2		0.1078
		(2.140)
× flood exp 3		0.0936
		(3.080)
Land × flood exp 1		-0.0007
		(0.830)
× flood exp 2		-0.0002
		(0.300)
× flood exp 3		-0.0043
		(2.450)
Household size × flood exp 1		-0.0381
		(0.570)
× flood exp 2		-0.0169
		(0.220)
× flood exp 3		0.1097
		(1.180)
Livestock × flood exp 1		2.03E-06
		(0.120)
× flood exp 2		0.00003
		(0.600)
× flood exp 3		7.92E-06
		(0.350)
Union-fixed effects	Yes	Yes
Number of observations	209	209
Number of unions	20	20
R-squared (within)	0.3923	0.4360

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with village clusters. Female indicator and age dummies are included in all specifications. HAZ stands for height-for-age Z-score.

In Table 6, we use water depth, the number of days submerged, repair cost and the number of days evacuated from home to measure the 1998 flood exposure. The results are qualitatively similar to those in Table 5. First, we see that the height effect is robust to various measures of flood exposure in all estimations. Second, we find that total asset value increases the post-flood catch-up effect on human capital investment in the specification based on the number of days covered by water. Third, and more dramatically, the maximum education within the household significantly increases the positive impact of the flood (see Columns 5 through 8).

Table 6. Dynamic effects of Bangladesh flood on human capital formation 4
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Flood variable	**Depth**	**Days**	**Repair cost**	**Out of home**	**Depth**	**Days**	**Repair cost**	**Out of home**
HAZ 1998	0.0856	0.0922	0.1490	0.1516	0.1037	0.1174	0.1597	0.1727
	(2.240)	(2.870)	(2.880)	(3.190)	(2.410)	(2.900)	(2.890)	(3.160)
Flood	0.2071	0.0072	0.0002	0.0027	0.0459	-0.0068	-0.0001	-0.0077
	(2.410)	(1.500)	(1.010)	(0.440)	(0.450)	(1.340)	(0.240)	(0.420)
Flood × HAZ 1998	0.0401	0.0021	0.00008	0.0007	0.0284	0.0012	0.00007	-0.0003
	(1.380)	(1.590)	(1.020)	(0.290)	(0.910)	(0.770)	(0.820)	(0.190)
Flood × asset	3.59E-07	4.46E-08	2.28E-09	-3.57E-07				
	(1.150)	(2.420)	(1.170)	(1.160)				
Flood × max educ					0.0243	0.0012	0.00005	0.0028
					(3.280)	(2.040)	(2.260)	(1.630)
Flood × land					-0.0002	-2.74E-06	-1.65E-06	-0.0002
					(0.740)	(0.230)	(0.710)	(1.170)
Flood × household size					0.0111	0.0014	0.00003	0.0005
					(0.730)	(1.720)	(0.540)	(0.160)
Flood × livestock					-1.87E-07	1.66E-07	-2.06E-08	-3.15E-06
					(0.030)	(0.750)	(0.440)	(3.690)
Union-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	209	209	209	209	188	188	188	188
Number of unions	20	20	20	20	20	20	20	20
R-squared (within)	0.3868	0.3742	0.3627	0.3651	0.4087	0.3891	0.3634	0.3527

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with union clusters. Female indicator and age dummies are included in all specifications. HAZ stands for height-for-age Z-score.

These results suggest that there is substitution between early-stage child human capital and household asset holdings, in the sense that households may choose one of the two to mitigate (increase) the impact of the flood on schooling in a dynamic context. In the Bangladesh example, we see evidence for a post-disaster recovery process over the studied 6-year period, with asset holdings and human capital within the household contributing positively to the post-flood recovery process.

Ethiopia

Tables 7 and 8 summarize our estimation results for Ethiopia. In our preliminary analysis, we find that although the 2001 drought had the most widespread exposure, the country also experienced many other, smaller-scale droughts during our study period. Therefore, we assess the impacts of both the 2001 drought and drought frequency on child schooling, using not only the 2001 drought indicator, but also the average likelihood (frequency) of droughts from 1999 to 2004.

Column 1 in Table 7 shows that the height-for-age Z-score has a significant and positive effect on schooling. In Column 2, the estimation controls for household-fixed effects, and confirms that the above finding remains robust despite an upward bias in the estimate. Column 3 adds the 2001 drought indicator and shows that the drought has a marginally significant negative impact on child schooling.

Table 7. Dynamic effects of Ethiopia drought on human capital formation 1
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
						-6 < HAZ < -1	-3 < HAZ < 6
HAZ	0.1447 (3.110)	0.1576 (2.980)	0.1346 (3.160)	0.1596 (3.890)	0.1551 (2.820)	0.1144 (1.460)	0.1395 (1.270)
Drought			-0.2283 (1.740)	-0.4012 (2.140)			
Freq drought 1					-0.6048 (6.110)	-0.7567 (2.120)	-0.6637 (4.550)
Freq drought 2					-0.3817 (1.270)	-0.8730 (1.490)	-0.5127 (1.710)
Freq drought 3					-0.6378 (3.910)	-1.8844 (4.150)	-0.8819 (4.530)
HAZ × drought				-0.0835 (1.660)			
HAZ × freq_drought 1					-0.0514 (0.850)	-0.0345 (0.330)	-0.0936 (0.810)
HAZ × freq_drought 2					-0.0413 (0.570)	-0.1527 (1.090)	0.0254 (0.290)
HAZ × freq_drought 3					-0.3013 (2.850)	-0.7965 (3.830)	-0.0559 (0.330)
Peasant association-fixed effects	Yes		Yes	Yes	Yes	Yes	Yes
Household-fixed effects		Yes					
Number of observations	314	314	303	303	303	238	206
Number of peasant associations	14		14	14	14	14	14
Number of households		143					
R-squared (within)	0.1800	0.2134	0.1852	0.1889	0.2053	0.1899	0.2041

Notes: Numbers in parentheses are absolute t-values obtained using robust standard errors with village clusters. Male indicator and age dummies are included. HAZ stands for height-for-age Z-score.

In Columns 4 and 5, we include interaction terms for the drought(s) and the height Z-score. First, we find that both the 2001 drought indicator and drought likelihood have significant and negative effects on the number of grades completed. Second, it appears that healthier (that is, taller) children experience larger negative impacts from droughts compared to less healthy children. This result is contrary to the findings from Bangladesh, probably due to the difference in time frame. This result implies that the inequality of human capital among children decrease with frequent drought exposure.

Columns 6 and 7 split the sample by height Z-score range; to maintain reasonable numbers of children in both estimations, we allow the ranges to overlap. The results show that the negative impacts of droughts are larger among children who embody less biological human capital in early childhood. This finding is consistent with our hypothesis (also confirmed in the Bangladesh example) that human capital accumulation prior to disasters increases resilience to the adverse effects of disasters.

Table 8 shows the effects of assets. As in Bangladesh, we examine total asset value, maximum education (years of schooling) in the household, land size, household size, and livestock value. Column 1 shows the total asset effect with the 2001 drought indicator. Interestingly, the negative impact of the drought is magnified by asset level. Wealthier households (as measured by total asset value) experience larger negative drought impacts on child schooling compared to poorer households. Again, the height effect remains robust with the drought indicator. Column 2 similarly shows that land size magnifies the negative impact of drought on child schooling.

Table 8. Dynamic effects of Ethiopia drought on human capital formation 2
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)
HAZ	0.1968	0.1825	0.1901	0.1766
	(2.430)	(2.140)	(1.890)	(1.730)
Drought	-0.4115	0.2387		
	(1.470)	(0.400)		
HAZ × drought	-0.1101	-0.0648		
	(1.410)	(0.970)		
Freq drought 1			-0.9498	-0.3970
			(2.730)	(0.800)
Freq drought 2			-0.5109	-2.2311
			(1.180)	(3.610)
Freq drought 3			-0.4469	n.a.
			(1.170)	
HAZ × freq drought 1			-0.1358	-0.1401
			(1.020)	(1.000)
HAZ × freq drought 2			0.0331	0.0629
			(0.450)	(0.560)
HAZ × freq drought 3			-0.4032	-0.4119
			(3.810)	(1.410)
Total asset × drought	-0.0006			
	(2.160)			
× freq_drought 1			0.0003	
			(1.060)	
× freq_drought 2			-0.0007	
			(1.140)	
× freq_drought 3			-0.0079	
			(4.780)	
Max educ × drought		-0.0471		
		(1.090)		
× freq_drought 1				0.0111
				(0.550)
× freq_drought 2				-0.0403
				(0.430)
× freq_drought 3				-0.0964
				(1.530)
Land × drought		-0.2898		
		(2.040)		
× freq_drought 1				-0.1186
				(1.480)
× freq_drought 2				-0.2216
				(1.270)
× freq_drought 3				-3.2820
				(4.280)

(continued)

Table 8. Continued

	(1)	(2)	(3)	(4)
Household size × drought		-0.0154		
		(0.210)		
× freq_drought 1				-0.0552
				(0.900)
× freq_drought 2				0.2245
				(1.840)
× freq_drought 3				0.0354
				(0.440)
Livestock × drought		8.61E-06		
		(0.260)		
× freq_drought 1				5.21E-06
				(0.180)
× freq_drought 2				0.0004
				(3.110)
× freq_drought 3				0.0009
				(0.630)
Peasant association-fixed effects	Yes	Yes	Yes	Yes
Number of observations	166	160	166	160
Number of peasant associations	14	14	14	14
R-squared (within)	0.0959	0.0965	0.1277	0.1972

Notes: numbers in parentheses are absolute t-values obtained using robust standard errors with peasant association clusters. Male indicator and age dummies are included. HAZ stands for height-for-age Z-score.

Columns 3 and 4 use the empirical frequency of droughts, interacted with household assets. At low levels of drought frequency, the direct effects of the droughts are significantly negative. However, this negative effect is significantly magnified by asset level (especially land size) if droughts are very frequent as they were over the period of 1999 through 2004. However, livestock holdings and larger household size seem to help mitigate the negative drought impacts.

In all estimations, the height-for-age Z-score has significantly positive effects on schooling; this effect is decreased only in the context of highly frequent droughts.

Malawi

Tables 9 and 10 summarize our estimation results for Malawi, using the same specification we applied to the Ethiopia data set. Although in this country the drought of 2001 was followed by a flood in 2001-2002, our preliminary analysis shows that the flood had only insignificant impacts, so we focus herein on the 2001 drought.

In Table 9, we examine how the height-for-age Z-score affects drought impacts on child schooling. The results in Columns 1 through 4 show that the height effect is very robust to the drought indicator, but the drought (and its likelihood of occurrence) does not have any significant effect on schooling. This result remains the same even if we use drought frequency (Table 10).

In Columns 5 and 6, we split the sample by height Z-score range. Interestingly, we observe a clear contrast between the two groups. Children who embody less human capital experience significant negative impacts from droughts. The increased frequency of droughts significantly reduces schooling completed among less healthy children. Moreover, a higher frequency of drought decreases the positive effect of the height-for-age Z-score in these children. In contrast, we find that droughts have significantly positive effects among healthy children (with greater height-for-age Z-scores), suggesting that healthier children are better able to invest in human capital after a disaster. This result also supports our proposition that the accumulation of human capital prior to a disaster prevents adverse impacts on human capital formation.

Table 9. Dynamic effects of Malawi drought on human capital formation 1
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)	(5)	(6)
					-6 < Haz < -1	**-3 < Haz < 6**
HAZ	0.0991	0.1024	0.1412	0.1580	0.3962	-0.0304
	(2.610)	(2.760)	(2.290)	(1.920)	(3.590)	(0.390)
Drought		0.1196	-0.1518			
		(0.950)	(0.720)			
Freq drought 1				-0.2949	-0.9321	-0.1167
				(1.220)	(1.860)	(0.640)
Freq drought 2				-0.3396	-0.7459	-0.0021
				(1.240)	(1.910)	(0.010)
Freq drought 3				-0.6638	-4.8691	0.7905
				(1.120)	(3.630)	(3.160)
HAZ × drought			-0.0790			
			(0.910)			
HAZ × freq_drought 1				-0.1110	-0.3262	0.0986
				(1.100)	(1.920)	(0.920)
HAZ × freq_drought 2				-0.0348	-0.1917	0.2316
				(0.300)	(1.160)	(1.730)
HAZ × freq_drought 3				-0.1164	-1.2948	0.9312
				(0.600)	(3.450)	(8.140)
Enumeration area-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Age dummies	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	153	153	153	153	117	115
Number of enumeration areas	40	40	40	40	38	38
R-squared (within)	0.1092	0.1170	0.1328	0.1401	0.2548	0.1591

Notes: Numbers in parentheses are absolute t-values obtained using robust standard errors with enumeration area clusters. Male indicator and age dummies are included. HAZ stands for height-for-age Z-score.

Table 10. Dynamic effects of Malawi drought on human capital formation 2
Dependent: Grade completed in 2004

	(1)	(2)	(3)	(4)
HAZ	0.1441	0.1478	0.1531	0.1524
	(2.290)	(2.210)	(1.900)	(1.770)
Drought	-0.1275	-0.1422		
	(0.710)	(0.410)		
HAZ × drought	-0.0746	-0.0655		
	(0.870)	(0.730)		
Freq drought 1			-0.4651	-0.7350
			(2.050)	(1.690)
Freq drought 2			-0.4036	-0.7895
			(1.650)	(1.960)
Freq drought 3			1.8928	n.a.
			(4.380)	
HAZ × freq drought 1			-0.1308	-0.1203
			(1.330)	(1.180)
HAZ × freq drought 2			0.0156	0.0408
			(0.140)	(0.400)
HAZ × freq drought 3			0.3419	-0.1524
			(2.800)	(1.770)

(continued)

Table 10. Continued

	(1)	(2)	(3)	(4)
Total asset × drought	0.00002			
	(3.130)			
× freq_drought 1		0.00002		
		(2.480)		
× freq_drought 2		0.00003		
		(2.910)		
× freq_drought 3		-0.0003		
		(6.250)		
Max educ × drought			0.0101	
			(0.280)	
× freq_drought 1				0.0434
				(1.420)
× freq_drought 2				-0.0504
				(0.990)
× freq_drought 3				-0.0117
				(0.250)
Land × drought			-0.0099	
			(0.210)	
× freq_drought 1				-0.0211
				(0.360)
× freq_drought 2				0.0022
				(0.060)
× freq_drought 3				n.a.
Household size × drought			0.0167	
			(0.520)	
× freq_drought 1				0.0218
				(0.580)
× freq_drought 2				0.1181
				(3.370)
× freq_drought 3				-0.0166
				(0.280)
Livestock × drought			-5.53E-07	
			(0.060)	
× freq_drought 1				8.93E-07
				(0.190)
× freq_drought 2				0.00007
				(1.980)
× freq_drought 3				-0.0003
				(6.360)
Enumeration area-fixed effects	Yes	Yes	Yes	Yes
Number of observations	152	148	152	148
Number of enumeration areas	40	40	40	40
R-squared (within)	0.1538	0.1348	0.2217	0.2336

Notes: Numbers in parentheses are absolute t-values obtained using robust standard errors with enumeration area clusters. Male indicator and age dummies are included. HAZ stands for height-for-age Z-score.

6. CONCLUSION

This paper examines the impacts of disasters on dynamic human capital production using panel data from Bangladesh, Ethiopia, and Malawi. Our empirical results show that the accumulation of (biological) human capital prior to disaster helps children maintain investments in intellectual human capital in the post-disaster period. Human capital formed in early childhood (nutritional status, proxied by the height-for-age Z-scores) helps insure resilience against disasters by increasing schooling investments and outcomes, despite the negative impacts the disasters may have on the investments itself.

In Bangladesh, children with more biological human capital are less affected by the adverse effects of flood, and the rate of investment in intellectual human capital increases with the initial human capital stock after the disaster, leading to a faster recovery. In Ethiopia and Malawi, where droughts are relatively frequent, drought exposure reduces growth and the inequality of human capital. Human capital stock helps maintain investments in the long run, although highly frequent shocks can disrupt subsequent investments. In all of the studied countries, our evidence shows that children who embody more human capital prior to a disaster are more resilient to the disaster and experience a faster recovery.

Our results suggest that as the frequencies of natural disasters increase due to global warming, the insurance value of investments in child nutrition will increase. Public investments in child nutrition therefore have a greater potential to effectively protect long-term human capital formation among children who are vulnerable to natural disasters.

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