Natural Hazards and Child Health

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Abstract

This paper examines how the occurrence of various natural disasters affect health status of children using data from Guatemala. Despite a large literature on child health there is relatively little work on how shocks from natural hazards affect the health of children and with climate change it is likely that more and more households will experience changes and possible increases in the risk of natural disasters. Using three rounds of DHS data combined with a long time series on hazards the paper controls for both time and area specific effects, while pinpointing when and where a particular shocks occurred. This is done for children from birth to 59 months at the time of the survey. Child health is proxied by height for age and weight for height and direct information on recent symptoms of illness. The effect of shocks from these hazards are generally negative and often very large.

1 Introduction

This paper examines how natural disasters affect health status of children using data from Guatemala. Despite a large literature on child health there is relatively little work on how shocks from natural hazard affect the health of children. Many natural hazards, such as hurricanes, floods and droughts, occur frequently in many developing countries and are potentially very destructive. Furthermore, with climate change it is likely that more and more households will experience changes and possible increases in the risk of natural disasters. If these changes lead to deteriorations in child health and/or increases in child mortality this will have strong effects on long term growth and social development. This is made more likely by the fact that children often bear a disproportionally large share of the burden when a shock forces households to focus resources on their most productive members.

As discussed in Strauss and Thomas (1995) and Wolpin (1997) there is a large literatue on the determinants of child health and mortality in developing countries. Despite this large literature, there is surprisingly little that directly deals with the potentially adverse effects of shocks from natural hazards. Foster (1995) showed for Bangladesh that floods lead to substantial lower weight for the children affected and argued that credit market imperfections were the main factor behind the differences in how children's weights responded. More recently Baez and Santos (2007) examined the effects of the hurricane Mitch in Nicaragua on children's health, schooling and labour force participation and found that those affected by the hurricane were more likely to be undernourished and that the distribution of nutritional status worsen, especially for those in the bottom of the distribution.

The extent to which conditions early in a child's life affect later outcomes have attracted substantial interest in recent years.[1] In general the conclusion is that early childhood malnutrition can have significant effects on performance in school, and hence presumably on

[1] See, for example, Glewwe and King (2001), Glewwe, Jacoby, and King (2001), Alderman, Hoddinott, and Kinsey (2006) and van den Berg, Lindeboom, and Portrait (2007). In addition there is some evidence that conditions while in utero can affect later outcomes as shown by Behrman and Rosenzweig (2004) and Almond (2006).

earnings later in life, although it is difficult to pinpoint an exact period in the child's life that is more critical than others. One paper that looks directly at outcomes in adulthood is Maccini and Yang (2008), which show that the amount of rainfall experienced during early life have statistically significant effects on self-reported adult health for women, but not for men. Women who experience a rainfall that is 20 percent above average are also slightly higher (0.57 cm) and tend to be more educated and end up living in household with more assets. Furthermore, as discussed in Strauss and Thomas (1998), there is a substantial return to height in labour markets, even after controlling for education. Hence, natural hazards have the potential to impact not only children's current health status, but also how they fare in school and perform in the labour market when adults.

Beside the direct effect on income and child health there is emerging evidence that natural hazards might affect a broader set of decisions than previously thought both through the risk of being hit by a shock and the actual shocks. Pörtner (2008), for example, examines how households' decisions on fertility and investments in education respond to hurricane risk and shocks.[2] He shows that an increase in risk leads to higher fertility for households with land, while households without land reduce fertility. For both types of households higher risk is associated with higher education but the effect is largest for households without land. Being hit by an hurricane shocks, however, lead to decreases in both fertility and education. There is a compensatory effect later in life for fertility, but not for education, indicating that births "lost" to shocks can be made up but lost schooling cannot.

This paper makes a number of contributions to the literature. First, it covers many different types of hazards rather than focusing on one very large disaster like Mitch as in Baez and Santos (2007) or the floods in Foster (1995). This is important since, as shown by van den Berg and Burger (2008) in a paper also on the effects of hurricane Mitch in Nicaragua, some households appeared to have been harder hit by the preceeding drought than the hurricane itself.[3] Secondly, by using three rounds of demographic and health

[2] This is done using a subset of the natural hazards data described below.

[3] Because of data limitations it is not possible for the authors to examine the effect of the drought in

surveys combined with the long time series on hazards it is possible to control for both time (year) and area (department) specific effects and therefore better identify the effects of the different hazards. With area fixed effects any unobservable area characteristics that might be correlated with both the propensity of getting hit by a specific shock and child health outcomes are eliminated while still retaining a substantial amount of variation in exposure to shocks due to the use of the three surveys. Importantly, it means that the results do not rely on the use of the comparision of areas, as done in Baez and Santos (2007) which uses difference-in-difference between areas hit by Mitch and those not hit. The year dummies control for, for example, the economic conditions prevalent at the time of the survey and the level of development.

2 Data and Estimation Strategy

The data used here come from two sources. The Data on health outcomes and characteristics of children and households come from three demographic and health surveys from Guatemala, while the information about shocks are based on data from UNICEF. This section discusses both data set, starting with the latter.

The data on shocks were collected for a report on natural disasters and vulnerability in Guatemala (UNICEF 2000). The raw data is a listing of natural disaster events, mostly drawn from written sources such as newspapers, with information on the type of event, the date, the area hit, the source of the information and a short description of the event. For most of the disasters the information cover very long periods of time. A major advantage of the data is that information is available at departmental level which, together with the long time span, allows a relatively precise measure of the shocks a household is exposed to.

Three major types of hazards are covered in the data: Seismological, hydrometeorological and geophysical. The former includes volcanic eruptions, earthquakes and tremors. While earthquakes and other seismic activity occur frequently in Guatemala it is unlikely that

details.

climate change will directly or indirectly affect the rate or severity of these hazards. Included in the geophysical part are crevices formation, land settlement, landslides, erosion and forest fires. These hazards and shocks are all interesting and relevant for the climate change debate and how climate change might affect child health, but unfortunately there is not enough data to reliably estimate the effects of these hazards on health, since these hazards were only included in the later years of the hazard survey. In addition, there is also a question of whether these hazards are exogenous events or affected by choices made by people in terms of where they locate and their farming patterns. Hence, focus here is on the hazards included in the hydrometeorological category: Strong winds, flooding, heavy rain, hurricanes, frost/freezing and droughts.[4]

Exposure to hazards is measured as the number of shocks that has occurred during a given period preceeding the month the interview took place in.[5] In addition the hazard variable is interacted with a subset of the other explanatory variables (described below) to allow for differences in the effect of the hazards depending on characteristics of the households affected by them.[6]

The data on child health comes from the three rounds of the Guatemalaian Demographic and Health Survey (DHS) conducted in 1987, 1995 and 1998.[7] DHSs are designed to be nationally representative surveys focusing on fertility, contraceptive use and access, and child health and mortality.[8] The main data of interest are the anthropometric measures, such as weight and height, since they provide, at least indirect, information on children's health

[4]In addition the category includes overflows (rivers, lakes etc.), thunderstorms, hail storms, tempests and strong currents but there is insufficient information in the data to estimate the effects of these hazards on child health.

[5]The month of the interview is not included both to allow the shocks to affect child health and to ensure that the shock did not occur after the interview date.

[6]An alternative way of measuring shocks is to use a dummy variable for whether one or more shocks occurred during a given time frame. The main advantage of this is that it minimises the risk of double counting a shock which may be listed twice but is really the same shock. The disadvantages are that, especially for longer time frames, it will potentially lead to an overestimate of the effects of shocks and throws away variation. There is, however, relatively little difference between the two measures and the results for the dummy variable estimations are available on request.

[7]A DHS style survey was collected in 2002, but since the hazard data set only covers the period up to 1999 that survey is not used here.

[8]The 1987 DHS did not cover the Petén, which is the northernmost department in Guatemala.

status through two measures calculated from them: Height for age and weight for height. In addition to the anthropometric measures there is direct information available about three symptoms: Diarrhea, fever and cough. For all three the question asked is whether the child had the specific symptom anytime during the last two weeks.

As is standard in most studies of child health the anthropometric variables are converted into Z-scores, which is the deviation of a child's value from the median value of the reference population divided by the standard deviation of the reference population.[9] Height for age is the best indicator of whether a child is growing as it should and is therefore considered a good measure of long-term health.[10] Children with low heights for their age are considered stunted. Weight for height, which is a measure of wasting, is better seen as an indicator of current health since low weight for height is often associated with acute starvation or severe disease, although it is also possible that it can result from chronicly unfavourable conditions. Hence, focus here will be on height for age and weight for height.[11] Generally, Z-scores two standard deviations below the reference median is considered severly stunted or wasted (Gorstein, Sullivan, Yip, de Onis, Trowbridge, Fajans, and Clugston 1994).

The 1987 DHS collected anthropometric information for all children of women who were permanent residents of the household and between three and 36 months of age. The two later surveys measured all children present in the household who were between zero and 59 months of age, but to ensure consistency across rounds all children who did not have their permanent residence in the house were dropped. Furthermore, since the hazards are most likely to affect children in rural areas due to exposure and living conditions all children from

[9] The creation of the reference population is described in detail in World Health Organization (2006). Children from USA, Ghana, Norway, Oman and Brazil were used for the construction of the growth standard and an important difference between the old and new growth standard is that it shows that there is little difference in how children grow in different countries if they are exposure to a healty diet and environment and good health care. Specifically, only about 3% of variability in length is due to differences among sites compared to 70% due to differences among individuals (World Health Organization 2006, p. 1).

[10] The discussion of the health measures in this paragraph is based on de Onis and Blössner (1997).

[11] In the data set there is also information on "weight for age" but this measure is more difficult to interpret since it is influenced by both height for age and weight for height and is therefore not used here. Generally, in the absense of significant wasting the results for height for age and weight for age should be relatively similar which is an additional reason these results are not presented here.

urban areas are excluded.

Since children who are twins or triplets have substantially different health and mortality experiences than singletons and 92 children are therefore excluded. Furthermore, children being breastfed are generally less affected by changing circumstances than those weaned and to focus on shocks that occured during the children's life time only children older than two months are used here. In addition, 360 children with extreme measures of either weight or height are dropped as well. In practice extreme is taken to be above or below five standard devaitions from the comparison sample's means (an absolute Z-score above five).[12] Finally, 14 children from households with missing observation on the other explanatory variables (see below) are dropped. This leaves a final sample of 13,393 children between birth and 59 months of age at the time of the interview.[13]

The household and individual level explanatory variables used here are the sex of the child, the age of the child in months at the time of the survey, the age of the mother at the time of the child's birth, her education and literacy levels, the father's education level and ethnicity of the child. For both parental age and education levels the squared of the variables are also included. Unfortunately the data does not have direct information on land ownership, which was shown in Pörtner (2008) to have important implications for responses to risk and shocks. To proxy as best as possible for this a dummy variable is included which is one if either the mother or the father respond that they work on own or family land and zero otherwise. The problem is that there may be land-holding households that are show up as not having land with this definition and that there is no information about the size and quality of the land. For the 1995 and 1998 surveys a wealth index is calculated for all households surveyed, but is not available for the 1987 round. To provide enough variation in exposure to the hazards this variable is therefore excluded.[14]

[12] For comparision, the WHO study sites used to create the child growth standards had relatively few that were below (or above) a Z-score of three.

[13] There are 2,999 from the 1987 DHS, 6,946 from the 1995 DHS and 3,448 from the 1998 DHS.

[14] Even if the wealth index was available for the 1987 survey round there is a potential issue of endogeneity with including the variable.

To capture differences between areas that may directly or indirectly affect child health department dummies are included together with a fourth-order polynomial in the altitude of the municipality.[15] Furthermore, dummies for the survey rounds are included to allow for differences in economic development over time that might affect child health. Ideally, dummies for the month of the survey should be included as well to allow for seasonal difference in health outcomes for children, but there is not enough overlap between the surveys to allow for this and still estimate the effects of the hazards.

Estimation is done using standard OLS, which with the department dummies corresponds to a standard department fixed effects model. One potential issue here is that it is not possible to reliably calculate risk measures for most of the hazards since the time series available are not long enough, which may bias the results (Pörtner 2008).[16] In that case the level of risk will be included in the error term and hence create a correlation between the error term and the shock variable. Which direction the bias will take depends on how risk affects child health directly. If household respond to higher risk by having more children we might expect that effect to be negative for the anthropometric measures because of closer spacing of children and a more binding resource constraint. Obviously, there is a positive correlation between risk and the number of shocks that occur in a department, which means that the bias in this case will be downwards.

The extent to which this bias is a problem depends on the size of the direct (unobserved) effect of risk and how large the correlation between risk and the number of shocks is. This bias is unlikely to be a serious concern here for a number of reasons. First, while higher fertility is often thought to lead to lower child quality this standard interpretation ignores the role of risk. As shown in Pörtner (2008) household with land who face higher hurricane risk have both more children *and* higher human capital investments in the form of schooling,

[15]There are 22 departments in Guatemala with a total of 331 municipalities. As it turns out, not including the department dummies makes the results less precise and sometimes provides less believable results, which it likely due to potential correlation between unobserved characteristics and explanatory variables as discussed below.

[16]Pörtner (2008) also used department dummies and the fourth-order polynomial and still found that both hurricane risk and shocks had significant effects on fertility and education.

while household without land facing higher risk tend to have fewer children and invest more in education than similar households in lower risk areas. Hence, it is not at all clear that the effect of risk on child health is actually negative. Secondly, if the current level of child health and its response to shocks is the results of decisions made by parents in the face of a known level of risk it is entirely possible that higher levels of shocks as a result of climate change will put additional stress on the already limited resources of households. In that case, the estimates of previous natural hazards' effect on child health is likely to be too low (closer to zero) compared to the actual effect of hazards with climate change.

Table 1: Descriptive Statistics

Variable	Mean	SD	Min	Max
Height for age (Z-scores)	−2.45	1.30	−5.00	4.62
Weight for height (Z-scores)	0.20	1.15	−4.87	4.78
Diarrhea within last 2 weeks	0.18	0.39	0.00	1.00
Fever within last 2 weeks	0.31	0.46	0.00	1.00
Cough within last 2 weeks	0.34	0.47	0.00	1.00
Girl	0.50	0.50	0.00	1.00
Child's age in months	30.28	16.52	3.00	59.00
Mother's education	1.60	2.41	0.00	18.00
Mother reads with difficulty	0.24	0.43	0.00	1.00
Mother cannot read	0.56	0.50	0.00	1.00
Mother's age at child's birth	28.80	7.09	15.00	49.00
Father's education	2.30	2.88	0.00	19.00
Father's education missing	0.06	0.23	0.00	1.00
Land	0.36	0.48	0.00	1.00
Indigenous	0.52	0.50	0.00	1.00
1995 survey	0.52	0.50	0.00	1.00
1998 survey	0.26	0.44	0.00	1.00
Altitude (by municipality)	1,187.28	814.12	1.00	3,200.00
Number of Observations[a]		12,661		

[a] 9,996, 9,785 and 9,828 observations for Z-scores, fever and cough, respectively.

Tables 1, 2 and 3 show various descriptive statistics for the sample. Table 1 shows the dependent variables and the individual and household characteristics. Clearly, for both height for age and weight for age the children in the sample are substantially below the WHO baseline for child growth. As mentioned above height for age is a good indicator of longer term health status and here the children in the sample do particularly poorly with a mean Z-score of -2.45. This means that, on average, children in the sample are 2.45 standard deviations shorter than the comparison population for their age and sex. Interesting, in terms of weight for height, which is sometimes considered a good indicator of current health status, the children appear to do well although this is mainly a result of height for age performing so poorly compared to weight for age.[17]

Since there might be difference by sex and by survey Table 2 shows how many children are two standard deviations or more below the growth standard by sex and by survey. Generally, girls do better than boys (about half the sample are girls) in both height-for-age and weight-for-height. While it appears that there was a worsening in girls' height-for-age between the 1987 and 1995 survey this is an artifact of the samples used in the surveys. As mentioned above the 1987 survey only collected information about children aged 2 or less, while the 1995 and 1998 surveys both collected up to age 5. Since older children generally do substantially worse than younger children it therefore appears as if health and not improved from 1987 to 1995, while if we restricted the table to cover the same age group between the surveys there would be a marked improvement from 1987 to 1995 and 1998.

A relatively large number of children have suffered from one or more symptoms in the two weeks before the survey. The lowest is for diarrhea which just under twenty percent had during the last two weeks. For both fever and cough about thirty percent experienced those symptoms.

Education levels for both parents are low on average: Average years of schooling for mothers is only 1.6 and 2.3 for fathers. This low human capital also shows up in the literacy numbers for mothers. More than half of the mothers cannot read and about a quarter can only read with difficulty. For about six percent of the fathers there is no information on years of education or the mother does not know. These are coded as zero education and a

[17] As described in World Health Organization (2006) one finding of the new growth standard study was that race and country of origin has little effect on how children grow if they are fed and cared for to the best standard.

Table 2: Ratio of Children with Z-scores below Two

Sex of child	Survey Round 1	2	3
	Height for Age		
Boy	0.69	0.69	0.66
Girl	0.62	0.66	0.62
	Weight for Height		
Boy	0.02	0.05	0.03
Girl	0.02	0.03	0.02
Observations	2,839	6,566	3,276

dummy is added to allow these observations to remain in the data set. The land variable indicates that 36 percent of the children live in households with land.[18] Finally, just over half the children are indigenous.

Table 3 shows how many children experienced a given number of shocks by survey round for the periods one to six months. Clearly, the 1995 survey round was conducted after a relatively quite period. None of the children had experience hurricanes, dought or frost in the six months period prior to the month they were surveyed in and the prevalence of no heavy rain fall or strong winds were lower than for the other two survey rounds. Only flooding seemed more prevalent for the 1995 survey than the other surveys. Hence, while there appear to be a fair amount of variation in shocks experienced it has to be kept in mind that almost sixty percent of the children in the sample were surveyed in the 2nd (1995) round. This means that it will be more difficult to identify the effect of these shocks. A related issue is that for hurricanes there is little or no variation within survey rounds: No hurricanes hit in either of the two periods for 1995, while just over five percent experienced a hurricane for the 1987 survey and almost everybody in the 1998 survey. Given that survey dummies are included as described above this makes is harder to identify the effect of hurricanes.

[18] As mentioned above this variable is one if either of the parents respond that they work on own or family land.

Table 3: Distribution of Shocks by Survey for Z-scores Measures

Number of Shocks	1 to 6 Months Prior Survey Round 1	2	3
Frost			
0	100.00	100.00	67.19
1	0.00	0.00	26.92
2	0.00	0.00	5.89
Hurricane			
0	95.03	100.00	1.56
1	4.97	0.00	98.44
Flooding			
0	71.36	40.04	86.05
1	16.34	44.20	5.22
2	3.77	8.22	8.73
3	8.52	0.00	0.00
4	0.00	7.54	0.00
Heavy rains			
0	82.74	91.91	0.00
1	4.97	8.09	99.54
2	12.29	0.00	0.46
Drought			
0	.	100.00	78.05
1	.	0.00	21.95
Strong wind			
0	85.45	96.25	29.46
1	14.55	0.00	65.57
2	0.00	3.75	0.98
Observations	2,839	6,566	3,276

3 Results

This section presents the results for the effect of shocks from natural hazards on children's height for age, weight for height and the three symptoms of illness (diarrhea, fever and cough). Table 4 presents the baseline determinants of child health excluding the hazards. Since the health measures may be related to age in a non-linear fashion and since there are no theoretical predictions for how a child's age is related to its health a fourth order polynomial in age is included.[19] Furthermore, each of main dummy variables (girl, land, indigenous) are also interacted with a fourth order polynomial in age.

Table 4: Baseline Determinants of Child Health

	Height for Age	Weight for Height	Symptom of illness Diarrhea	Fever	Cough
Girl	−0.148	−0.265	−0.096*	−0.109	−0.157**
	(0.173)	(0.169)	(0.053)	(0.074)	(0.076)
Child's age (months)	−0.228***	−0.178***	0.050***	0.039***	0.018
	(0.034)	(0.033)	(0.010)	(0.014)	(0.015)
Child's age^2/100	0.759***	0.921***	−0.314***	−0.266***	−0.135
	(0.215)	(0.210)	(0.064)	(0.089)	(0.092)
Child's age^3/10000	−0.957*	−1.691***	0.675***	0.593***	0.286
	(0.522)	(0.511)	(0.155)	(0.214)	(0.220)
Child's age^2/1000000	0.389	1.023**	−0.487***	−0.437**	−0.197
	(0.426)	(0.416)	(0.125)	(0.173)	(0.178)
Mother's education	0.021	−0.016	0.004	0.003	0.006
	(0.016)	(0.016)	(0.005)	(0.007)	(0.007)
Mother's education^2/100	0.328**	0.332**	−0.033	−0.069	−0.088
	(0.142)	(0.139)	(0.042)	(0.056)	(0.058)
Mother reads with difficulty	−0.124***	−0.028	0.012	0.013	−0.000
	(0.040)	(0.039)	(0.012)	(0.016)	(0.016)
Mother cannot read	−0.175***	−0.097*	0.019	−0.001	−0.021
	(0.054)	(0.053)	(0.016)	(0.022)	(0.022)
Mother's age at child's birth	−0.026**	−0.030**	−0.001	0.003	−0.000
	(0.012)	(0.012)	(0.004)	(0.005)	(0.005)
Mother's age at child's birth^2/100	0.053***	0.049**	−0.000	−0.002	0.001
	(0.020)	(0.020)	(0.006)	(0.008)	(0.008)
Father's education	0.029***	0.018*	−0.003	−0.009**	−0.013***
	(0.009)	(0.009)	(0.003)	(0.004)	(0.004)
Father's education^2/100	0.073	−0.086	0.012	0.065*	0.082**
	(0.084)	(0.083)	(0.026)	(0.034)	(0.035)
Father's education missing	0.003	0.022	−0.001	−0.003	−0.006
	(0.054)	(0.053)	(0.015)	(0.024)	(0.025)
Land	−0.093	0.276	0.017	0.065	−0.120
	(0.181)	(0.177)	(0.056)	(0.077)	(0.079)
Indigenous	−0.170	0.925***	0.044	0.090	0.081
	(0.176)	(0.172)	(0.054)	(0.074)	(0.076)
1995 survey	0.150***	−0.049	0.055***	.	.
	(0.036)	(0.035)	(0.009)	.)	.
1998 survey	0.134***	0.138***	0.007	0.017	0.003
	(0.042)	(0.041)	(0.011)	(0.011)	(0.011)
Constant	0.324	1.083***	0.175**	0.173	0.479***
	(0.266)	(0.260)	(0.080)	(0.110)	(0.113)
4th order polynomial in altitude	Yes	Yes	Yes	Yes	Yes
Girl × age, age^2, age^3, age^4	Yes	Yes	Yes	Yes	Yes
Land × age, age^2, age^3, age^4	Yes	Yes	Yes	Yes	Yes
Indigenous × age, age^2, age^3, age^4	Yes	Yes	Yes	Yes	Yes
Department dummies	Yes	Yes	Yes	Yes	Yes
Observations	9996	9996	12661	9785	9828
R-squared	0.25	0.08	0.07	0.05	0.05
Adj. R-squared	0.25	0.07	0.07	0.05	0.04

NOTE: Standard errors in parentheses; * significant at 10%; ** significant at 5%; *** significant at 1%

The girls do on average significantly better than boys, although most of the effect is captured by the interaction between being a girl and the fourth order polynomial in age

[19]Other functional forms were also considered, but lower order polynomials performed substantially worse.

(not shown in the table).[20] For both mothers' and fathers' more education lead to better child health. This effect can also be seen from mother's literacy: Children whose mothers can read only with difficulty is 0.12 standard deviations below children with mothers that can read, while the effect for mothers that cannot read is -0.18. Land has little effect on the three health measures which may be an indication that the variable does not completely adequately capture whether the household owns land. Indigenous children do substantially worse than non-indigenous children in terms of height for age, even when controlling for the literacy and education level of the mother.[21] It does appear, however, that indigenous children do well in terms of current health conditions (weight for height).

3.1 Natural Hazards' Effects on Anthropometrics

Table 5 draws together the estimated effects of the different hazards on child health.[22] As expected the most substantial effects are on height for age and the effects of most shocks are negative and large. The largest effect is for heavy rain (lluvias) where each shocks leads to a decline in height for age of close to 0.13 standard deviations, and this effect is also strongly statistically significant. Strong winds appear to have an almost as strong effect as heavy rain. While the effect of strong winds is highly statistically significant the effect of hurricanes is much smaller and not statistically significant, which is probably due to the distribution of hurricanes shocks across the survey rounds as discussed above. The third highest effect is for frost (helada) with an estimated effect of 0.1 standard deviations reduction in height for age for each shock. Finally, flooding and drought has a negative effect of around 0.06, but only the effect of flooding is statistically significant.

The results for weight-for-height is more mixed. The only negative and statistically significant effect is for frost, where the effect is close to 0.1 standard deviations. Both

[20] This is not as unusual as one might expect. See Ejrnæs and Pörtner (2004) for an example.

[21] Recall, that the WHO do not find any substantial evidence of different growth patterns for children of different races exposed to "optimal" conditions.

[22] The effect of each shock is estimated separately and the full results are available on request. In general the effects of the other explanatory variables are very similar to those presented in Table 4.

Table 5: The Effects of Number of Shocks on Child Health by Type of Shock[a]

	Height for Age	Weight for Height
Frost	-0.094^{**}	-0.080^{*}
	(0.045)	(0.044)
Hurricane	-0.051	-0.024
	(0.121)	(0.118)
Strong wind	-0.115^{***}	0.008
	(0.035)	(0.034)
Drought	-0.066	0.112^{**}
	(0.056)	(0.057)
Heavy rain	-0.125^{***}	-0.020
	(0.044)	(0.043)
Flooding	-0.064^{***}	0.038^{*}
	(0.020)	(0.020)

[a] Each result is from a separate regression; complete results on request.
NOTE: Standard errors in parentheses; All shocks 1-6 months prior to survey;
* significant at 10%; ** significant at 5%; *** significant at 1%

hurricanes and heavy rain show negative effects but the effects are small and not statistically significant, while the effect for strong winds are essentially zero. The results for droughts and flooding are counter-intuitive in that they are statistically significant and positive. The naive interpretation is that that these hazards tend to improve health; a more likely explanation is that while the shocks affect growth patterns for children the effect is relatively short lived (or that these shocks occured further away from the survey date than the other shocks).

To give an idea of the magnitudes of these effects consider the effects of a one standard deviation difference in height for various ages (aka one z-score).[23] For a boy aged 1 this would be equal to approximately 2.25 cm, while for boys aged 2, 3, 4 and 5 years it would be 3 cm, 3.75 cm, 4.25 cm and 4.75 cm, respectively. The same numbers for girls are 2.75 cm, 3 cm, 3.75cm, 4 cm and 5 cm, respectively. Hence, an estimated effect of 0.1 z-scores would correspond to somewhere between 0.25 and 0.5 cm. This may not seem substantial, but it should be remembered that even though some catch-up is possible an average child is

[23] See Appendix A for charts of the WHO growth standards for boys and girls.

also likely to be affected by a relatively large number of these shocks growing up.

While Table 5 provides a first indication of the effects of the different hazards on child health it is likely that these effects will vary with individual and household characteristics. The introduction of interactions leads to some very interesting changes in the estimated effects of the different hazards. Table 6 presents the estimated direct effects of the hazards and their interactions with being a girl, land and indigenous. To ease interpretation the calculated marginal effects for each group are presented instead of the point estimates for the interaction variables.[24] The "base" group is a non-indigenous boy living in a household without land. In addition, there are three other groups of boys: Those living in households with land, indigenous boys without land and indigenous boys with land. For girls, the groups are the same.[25] Focus here is on the effect of the hazards on height-for-age.

Heavy rain showed the largest combined effects in Table 5. From Table 6 it is clear that this large effect mainly comes from the effects of heavy rain on indigenous children. For all indigenous groups the marginal effect is statistically significant and large at between -0.13 to -0.16 standard deviations per shock. As discussed above 0.1 Z-scores is equivalent to between 0.25 and 0.5 cm depending on age, so these are substantial effects. In addition to the indigenous children only non-indigenous boys without land show a statistically significant effect at -0.11. For the other groups (non-indigenous girls and non-indigenous boys with land) the effect is still large but not statistically significant.

As for heavy rain the effects of strong winds are large for all groups. Non-indigenous boys both with and without land do best, but are still show an effect of around -0.08, although it is not statistically significant. Here again, it is the indigenous children who are affected most by the shock, although the differences between indigenous children and the corresponding groups for non-indigenous are not statistically significant. Indigenous girls both with and without land fare especially poorly with a reduction of around 0.15 Z-scores per shock (both

[24] The full results are available on request. As before, the estimates are done shock by shock.

[25] Note that the marginal effects can all be calculated from the three interactions added. Adding additional interactions, such as shocks interacted with land interacted with indigneous yields little extra explanatory power and are not statistically significant.

Table 6: Calculated Marginal Effects of Shocks on Anthropometrics by Group[a]

	Height for Age	Weight for Height		Height for Age	Weight for Height
Strong wind (boy)	−0.076	0.021	**Flooding** (boy)	−0.052**	0.021
	(2.140)	(0.170)		(3.843)	(0.657)
Latino girl without land	−0.100**	−0.046	Latino girl without land	−0.011	0.037
	(4.046)	(0.872)		(0.156)	(2.000)
Latino boy with land	−0.091	0.094*	Latino boy with land	−0.086***	−0.001
	(2.481)	(2.741)		(7.292)	(0.001)
Indigenous boy without land	−0.123**	0.013	Indigenous boy without land	−0.101***	0.057**
	(4.915)	(0.058)		(11.669)	(3.956)
Indigenous boy with land	−0.138**	0.086	Indigenous boy with land	−0.135***	0.036
	(5.399)	(2.176)		(18.604)	(1.354)
Latino girl with land	−0.116**	0.027	Latino girl with land	−0.045	0.015
	(4.042)	(0.237)		(1.886)	(0.227)
Indigenous girl without land	−0.147***	−0.053	Indigenous girl without land	−0.059**	0.073**
	(7.442)	(1.022)		(4.120)	(6.611)
Indigenous girl with land	−0.163***	0.019	Indigenous girl with land	−0.093***	0.051*
	(7.474)	(0.112)		(8.824)	(2.812)
Drought (boy)	−0.136	0.115	**Hurricane** (boy)	−0.053	0.013
	(1.975)	(1.402)		(0.173)	(0.011)
Latino girl without land	−0.241**	−0.121	Latino girl without land	−0.083	−0.048
	(6.550)	(1.646)		(0.422)	(0.147)
Latino boy with land	0.160	0.147	Latino boy with land	−0.074	0.064
	(2.291)	(1.914)		(0.307)	(0.242)
Indigenous boy without land	−0.120	0.323***	Indigenous boy without land	−0.011	−0.024
	(1.623)	(11.705)		(0.007)	(0.037)
Indigenous boy with land	0.177*	0.355***	Indigenous boy with land	−0.031	0.027
	(2.766)	(11.093)		(0.057)	(0.045)
Latino girl with land	0.055	−0.089	Latino girl with land	−0.103	0.003
	(0.276)	(0.721)		(0.609)	(0.001)
Indigenous girl without land	−0.225**	0.086	Indigenous girl without land	−0.040	−0.085
	(5.344)	(0.783)		(0.100)	(0.468)
Indigenous girl with land	0.071	0.118	Indigenous girl with land	−0.061	−0.034
	(0.418)	(1.141)		(0.218)	(0.071)
Heavy rain (boy)	−0.113**	0.043	**Frost** (boy)	−0.218**	−0.096
	(4.061)	(0.610)		(4.397)	(0.888)
Latino girl without land	−0.090	−0.003	Latino girl without land	−0.150	−0.139
	(2.585)	(0.004)		(2.099)	(1.882)
Latino boy with land	−0.102	0.051	Latino boy with land	−0.107	0.003
	(2.333)	(0.615)		(0.859)	(0.001)
Indigenous boy without land	−0.164***	−0.035	Indigenous boy without land	−0.153**	−0.084
	(8.489)	(0.410)		(6.113)	(1.926)
Indigenous boy with land	−0.153**	−0.027	Indigenous boy with land	−0.041	0.015
	(5.716)	(0.187)		(0.271)	(0.039)
Latino girl with land	−0.079	0.005	Latino girl with land	−0.039	−0.040
	(1.406)	(0.006)		(0.116)	(0.129)
Indigenous girl without land	−0.141**	−0.082	Indigenous girl without land	−0.084	−0.127**
	(6.406)	(2.255)		(1.926)	(4.564)
Indigenous girl with land	−0.129**	−0.073	Indigenous girl with land	0.027	−0.028
	(4.212)	(1.415)		(0.125)	(0.136)

[a] Base is a latino boy without land.

NOTE: F-statistics in parentheses, except for base which shows t-statistics; * significant at 10%; ** significant at 5%; *** significant at 1%

strongly statistically significant). For hurricanes, none of the marginal effects are statistically significant. The estimated effects for non-indigenous girl, both those with land and those without, are relatively large at around -0.1.

The effect of frost for a non-indigenous boy living in a household without land the estimated effect is -0.22, which is statistically significant. Indigenous boys without land also show a statistically significant effect, which, although smaller than that of the non-indigenous boys without land, is still substantial at -0.15. None of the other groups are statistically significant, but the effect for non-indigenous girls without land non-indigenous boys with land are large at -0.15 and -0.1, respectively. Overall, it appears that having land significantly helps mitigate the effects of frost shocks: For all groups without land (indigenous and non-indigenous boys and girls) the corresponding group with land does substantially better in the face of a shock. One possible explanation for this is that while frost might damage the crops landed households are at least partly compensated by a corresponding increase in the price of crops.[26] On the other hand, those without land may end up paying more for agricultural produce and face less demand for their labour during harvest.

Flooding had the lowest estimated overall effect that was still stastically significant among the natural hazards, but as Table 6 shows this masks substantial variations in the effects of flooding between the different groups. Non-indigenous girls (with and without land) experienced very small and statistically insignificant effects of a shock, while the effects for indigenous girls (also with and without land) are statistically significant and larger. For all boys the effect of flooding is statistically significant with the lowest effect being for non-indigenous boys without land (-0.05) and the highest effect for indigenous boys with land (-0.14).

The final hazard is droughts, which did not have a statistically signficant effect when the various groups were combined. One of the issues with estimating the effects of drought is that there is only reliable information in the data for the last two surveys, which means that there

[26]For a net seller of a particular crop this may even increase income.

is relatively little variation. Furthermore, this shock is the most difficult to capture with a simple number since it provides no information about how long or extensive the drought was. According to the estimated effects there is a very large and statistically significant effects for both indigenous and non-indigenous girls without land (-0.24). On the other hand, the effect for indigenous boys with land is positive, large and statistically significant, while the effect for non-indigenous boys with land is almost as large, but not statistically significant.

Only seven results are statistically significant for weight-for-height and six of those are positive, with the only statistically significant negative effect being for frost for indigenous girls without land. As Table 4 shows the baseline estimations do substantially better at predicting height-for-age than weight-for-height, which goes part of the way in explaining why so few effects are statistically significant even in the case of frost, where the combined effect is statistically significant.

In sum, indigenous children both with and without land are most affected by the natural hazards in addition to be worse off in the baseline estimations.[27] Interestingly, non-indigenous girls generally do relatively well compared with non-indigenous boys with few statistically significant effects, although the estimated effects are not small for the girls. Only for strong winds do the non-indigenous girls do somewhat worse than the boys and there the difference is not very large.

As the overall effects presented in Table 5 can cover important differences between different groups it is possible that the results in Table 6 can mask differences within each group. One difference which is of special interest is whether there are differential effects of shocks within a group by age of the child. Hence, the remainder of this part examines whether the effect of shocks vary by age for the different groups. In the interest of space only height-for-age and certain shocks are examined. For all groups the shock is included both as a main effect and interacted with a fourth order polynomial in age.[28] Based on these estimated the predicted marginal effect and the 90 percent confidence interval are calculated using the

[27] Drought is such a special case that it is not incorporated in the summary.
[28] The underlying results are available on request.

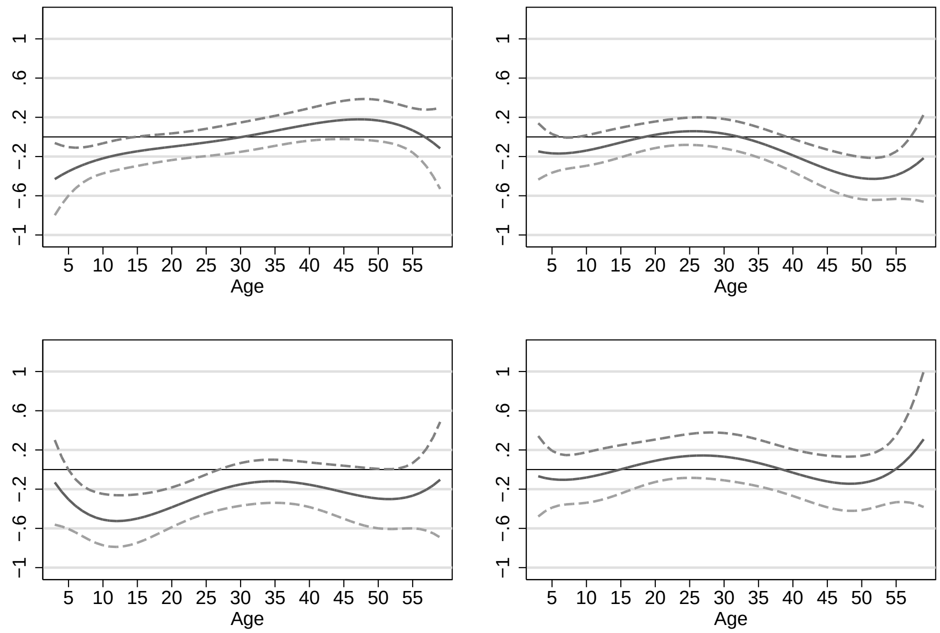
delta method. For all figures boys are on the left and girls on the right. First row is the base category which is non-indigenous without land. Second row has non-indigenous with land; third row indigenous without land and fourth row indigenus with land.

A number of interesting results emerge from Figures 1-4. First, younger boys seems to be much more vulnerable to shocks than girls of the same age. This is especially pronounced from around six months to between 24 and 30 months. Children before age six months seems to be at least somewhat protected, which is likely due to many of children younger than six months still being breastfed. For older children, i.e. more than 30 months, the roles are reversed with girls being more at risk than boys. Furthermore, since the results presented in Table 6 are averages for all ages within a group the fact that the effects of shocks vary by age lead to very substantial impacts.

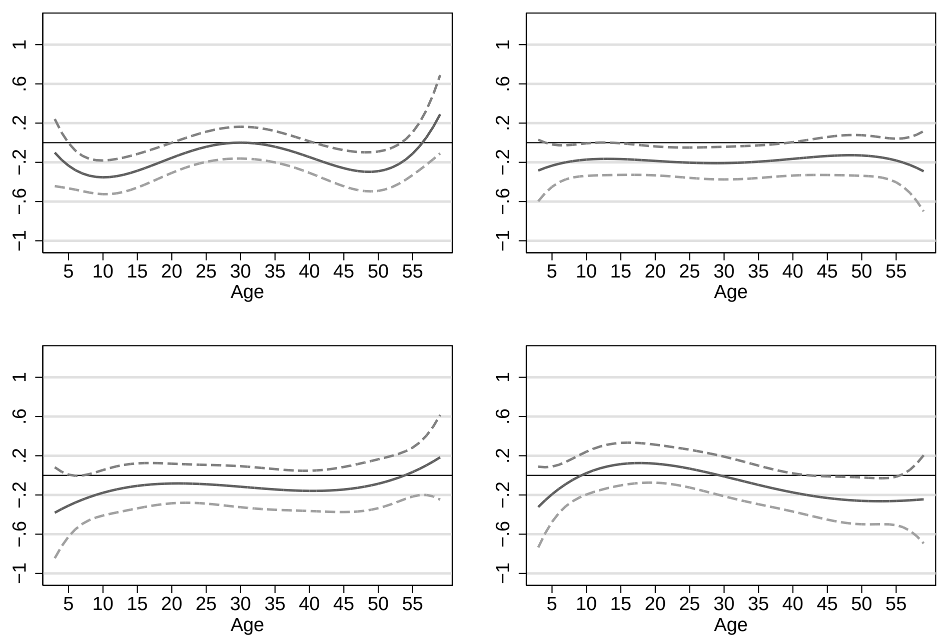
For heavy rain and strong winds the predicted marginal effect of a shock is around -0.3 for a boy around nine months of age, while it is statistically insignificant from around age 24 months until age 59 months. The largest predicted effect for girls is of similar magnitude but the age it is reached at is around 48 months. Interestingly, there appears to be relatively little difference in the shape and position of the curves between the varies groups as long as sex is kept constant, although indigenous girls generally do worse than non-indigenous girls.

The effect of frost is slightly different from the previous two shocks. First, the most pronounced negative effect for boys are indigenous without land, although non-indigenous boys without land also show a statistically significant effect for a small window of ages. For girls, the effect is only statistically significant for very young indigenous girls without land.

Finally, flooding has a more uniform impact across ages than the previous shocks. The effect for boys is statistically significant from around age 6 until 35 months for non-indigenous boys and indigenous boys without land, while it is statistically significant until 46 months for indigenous boys with land. For girls, there is no effect for non-indigenous without land, but the impact is statistically significant for other three groups of girls. Again, the effect become statistically significant earlier than for the other hazards at around 24 months of age

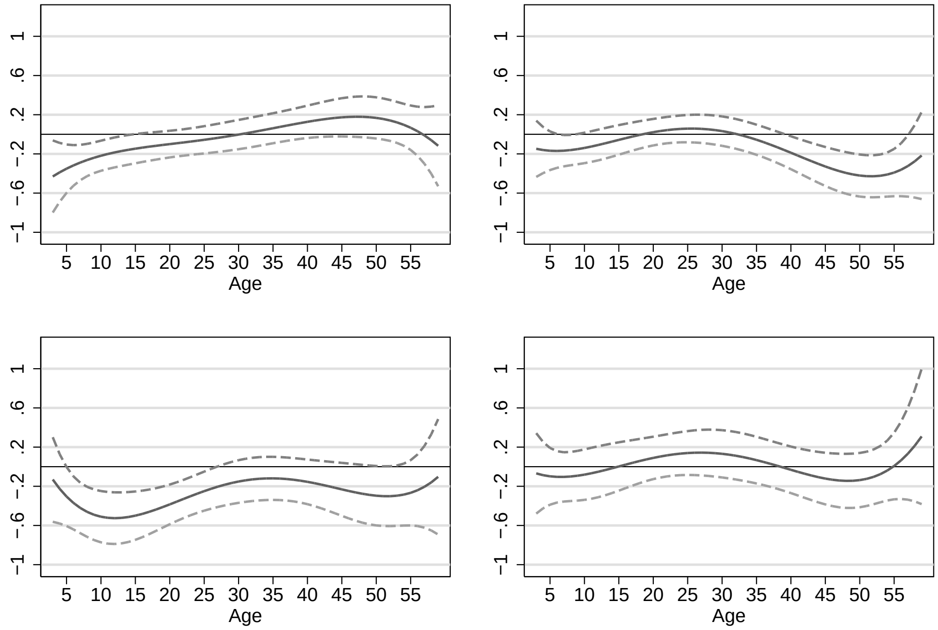


Boys on left, girls on right; top is base, bottom is latino with land

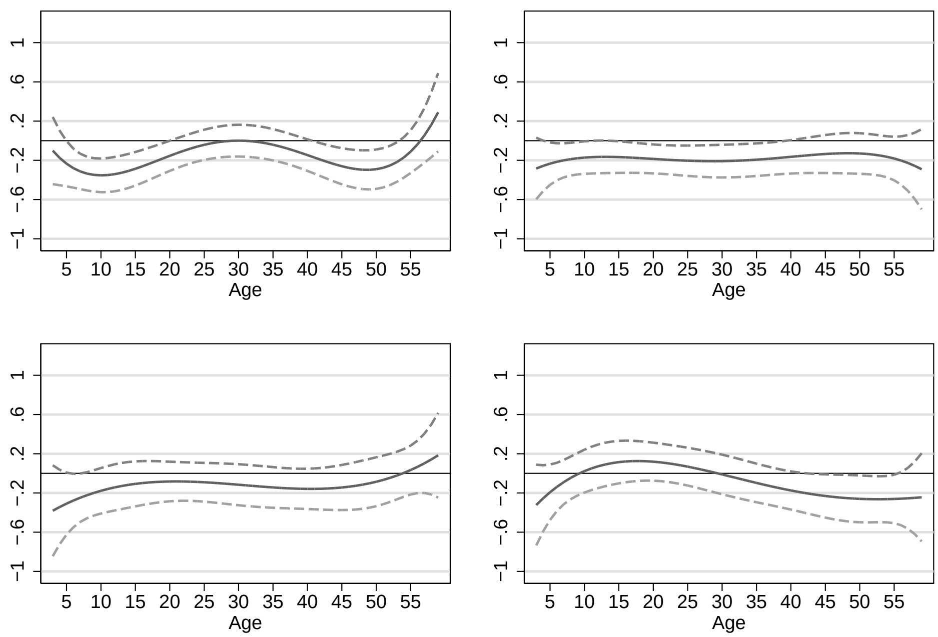


Boys on left, girls on right; top is indigenous, bottom is indigenous with land

Figure 1: Marginal Effect of Heavy Rain Shocks by Age

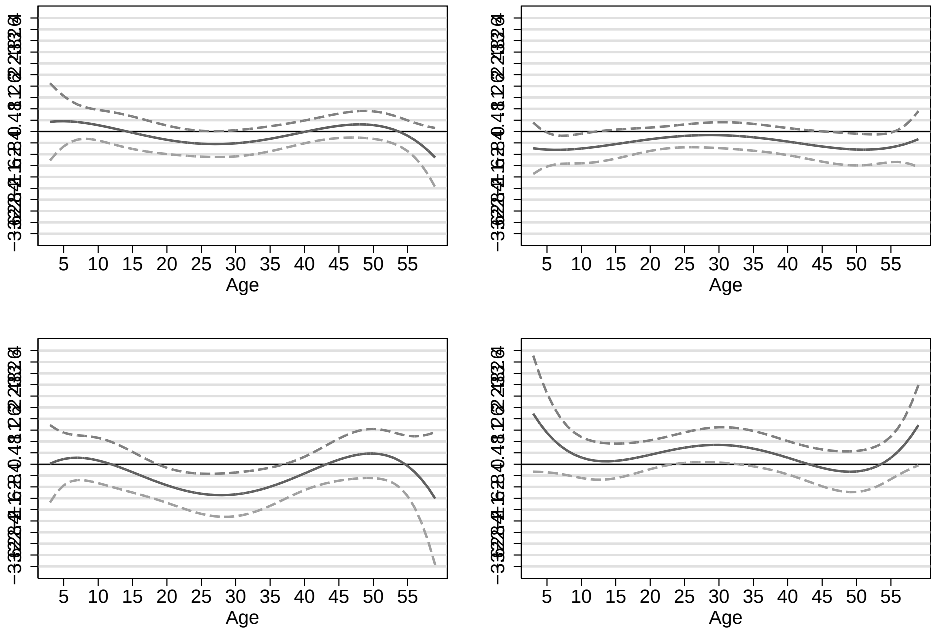


Boys on left, girls on right; top is base, bottom is latino with land

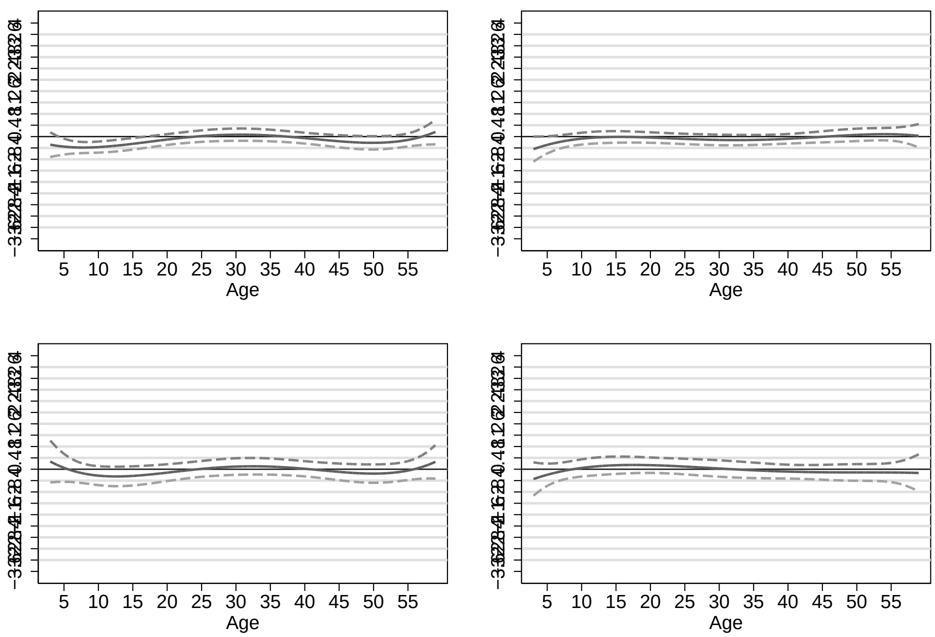


Boys on left, girls on right; top is indigenous, bottom is indigenous with land

Figure 2: Marginal Effect of Strong Wind Shocks by Age

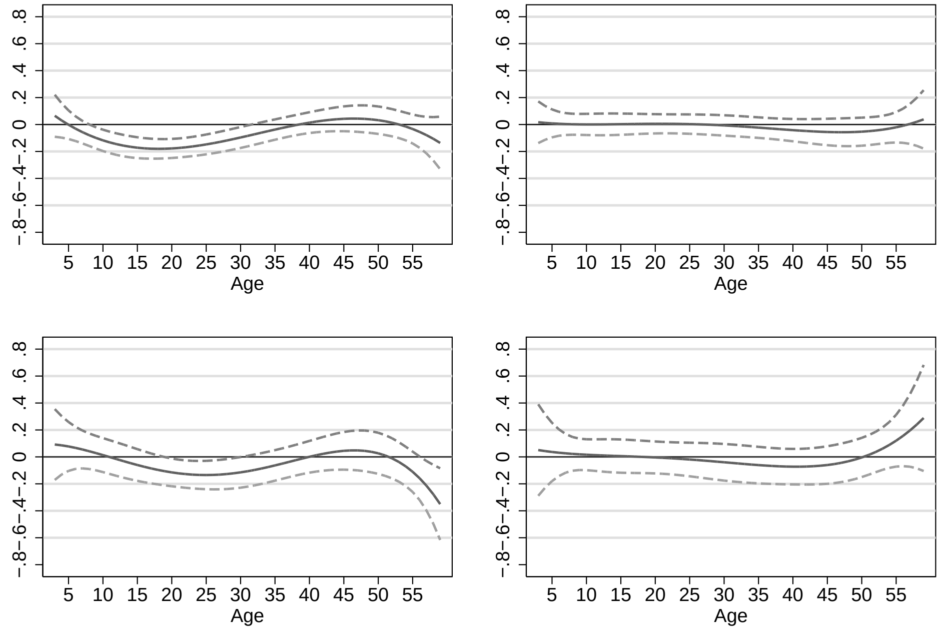


Boys on left, girls on right; top is base, bottom is latino with land

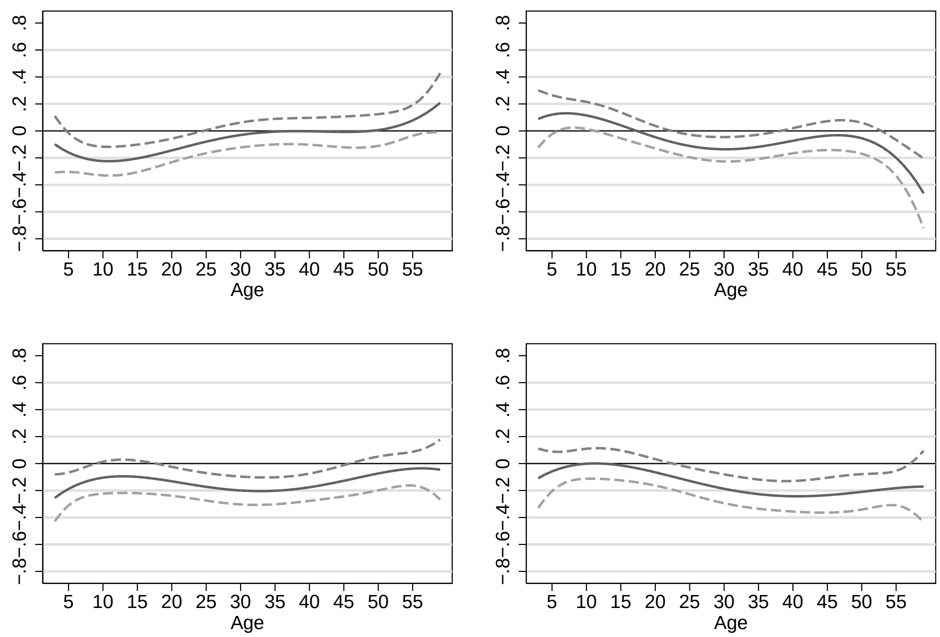


Boys on left, girls on right; top is indigenous, bottom is indigenous with land

Figure 3: Marginal Effect of Frost Shocks by Age



Boys on left, girls on right; top is base, bottom is latino with land



Boys on left, girls on right; top is indigenous, bottom is indigenous with land

Figure 4: Marginal Effect of Flooding Shocks by Age

and staying so until 59 months.

3.2 Hazards and Illness

The rest of this section examines whether the effects on height-for-age translate into observable symptoms of illnesses. Two cave-ats are in order. First, only the question about diarrhea was asked in all three surveys; the fever and cough questions were only covered in the 1995 and 1998 surveys. Second, while "lost" height is difficult to make up it is easier to gain weight and thereby achive a reasonable weight-for-height which should in turn mean less risk of getting sick. It is also clear from Table 4 that the model can explain relatively little of the variation in symptoms.[29] Table 7 presents the estimated effects of the various hazards on symptoms.[30]

Table 7: The Effects of Number of Shocks on Illness Symptoms by Type of Shock[a]

	Symptom of Illness		
	Diarrhea	Fever	Cough
Frost	0.003	−0.011	0.051***
	(0.013)	(0.016)	(0.017)
Hurricane	0.022	0.067	0.042
	(0.033)	(0.071)	(0.073)
Strong wind	0.010	−0.038**	0.040**
	(0.010)	(0.015)	(0.016)
Drought	−0.020	−0.022	−0.030
	(0.017)	(0.021)	(0.021)
Heavy rain	−0.004	0.250***	0.081***
	(0.012)	(0.030)	(0.031)
Flooding	−0.003	−0.010	−0.025**
	(0.006)	(0.011)	(0.012)

[a] Each result is from a separate regression; complete results on request.
NOTE: Standard errors in parentheses; All shocks 1-6 months prior to survey;
* significant at 10%; ** significant at 5%; *** significant at 1%

[29] In principle these regressions should be estimated using logit or probit, although given that 20 or more precent answer affirmative to the questions the linear probability model should provide a decent approximation.

[30] As above the effects are drawn from separately estimations which are available on request.

It is clear that none of the hazards have any effect on the risk of the child suffering from diarrhea during the two weeks prior to the survey. The results for fever and cough are more interesting. Heavy rain again has the largest effects; a heavy rain shock increases the probability that a child would have a fever during the two weeks before the survey by 25 percentage points and increase the risk of a cough by eight percentage points. While strong winds increases the risk of coughing by four percentage points it appears to *decrease* the risk of fever by the same amount with both effects statistically significant. Finally, frost lead to a statistically significant increase in coughs of about five percentage points.

Finally, to check if the effects on symptoms vary by groups Table 8 presents the predicted marginal effects for the same groups as in Table 6. The hazard with the largest effect above was heavy rain, but as is clear there is vey little variation in the predicted marginal effect on both fever and cough. The same is the case for the other two hazards with statistically significant positive effects, frost and strong winds. Although it is in principle possible that these similar predicted effects cover differences in the response by age for the different groups this is not case. For the three hazards there is little variation in the predicted effect across groups and across ages.[31]

4 Conclusion

Climate change is likely to lead to increased risk in a number of different natural hazards. These changes will affect many different aspects of the economy and the prospect for development. This paper attempts to quantify what the effects will be on a particular area: Child health. As found in the previous literature healthier children are both more likely to survive, do better in school and earn higher wages when adults for a given level of schooling (Strauss and Thomas 1998). Hence, if climate change has substantial negative effects on child health this will reverberate through the society both in the short and long run.

This paper use the three rounds of the Demographic and Health Survey from Guatemala

[31] Figures are available upon request.

Table 8: Calculated Marginal Effects of Shocks on Illnesses by Group[a]

	Symptom of Illness				Symptom of Illness		
	Diarrhea	Fever	Cough		Diarrhea	Fever	Cough
Strong wind (boy)	−0.009	−0.049**	0.024	**Flooding** (boy)	−0.009	−0.033**	−0.054***
	(0.334)	(5.587)	(1.251)		(1.453)	(5.943)	(15.439)
Latino girl without land	−0.007	−0.032	0.059***	Latino girl without land	0.001	−0.036***	−0.062***
	(0.204)	(2.440)	(8.130)		(0.032)	(7.286)	(19.790)
Latino boy with land	0.017	−0.056**	−0.002	Latino boy with land	−0.007	−0.022	−0.029*
	(0.929)	(5.653)	(0.006)		(0.675)	(1.958)	(3.335)
Indigenous boy without land	0.007	−0.039*	0.039*	Indigenous boy without land	−0.009	0.006	−0.006
	(0.205)	(3.021)	(2.739)		(1.207)	(0.217)	(0.167)
Indigenous boy with land	0.033*	−0.046*	0.013	Indigenous boy with land	−0.007	0.017	0.019
	(3.709)	(3.413)	(0.255)		(0.714)	(1.423)	(1.707)
Latino girl with land	0.019	−0.038	0.033	Latino girl with land	0.003	−0.025	−0.037**
	(1.194)	(2.661)	(1.920)		(0.115)	(2.593)	(5.078)
Indigenous girl without land	0.009	−0.022	0.074***	Indigenous girl without land	0.001	0.003	−0.013
	(0.361)	(0.979)	(10.411)		(0.027)	(0.041)	(0.865)
Indigenous girl with land	0.035**	−0.029	0.048*	Indigenous girl with land	0.003	0.014	0.012
	(4.199)	(1.316)	(3.494)		(0.122)	(0.880)	(0.657)
Drought (boy)	−0.035	−0.075**	−0.042	**Hurricane** (boy)	0.017	0.064	0.050
	(1.347)	(4.210)	(1.277)		(0.241)	(0.770)	(0.442)
Latino girl without land	0.007	−0.006	−0.003	Latino girl without land	0.014	0.081	0.055
	(0.050)	(0.027)	(0.007)		(0.153)	(1.249)	(0.542)
Latino boy with land	−0.048	−0.017	−0.028	Latino boy with land	0.035	0.073	0.035
	(2.180)	(0.179)	(0.489)		(0.894)	(0.979)	(0.210)
Indigenous boy without land	−0.035	−0.084**	−0.068*	Indigenous boy without land	0.019	0.044	0.036
	(1.443)	(5.793)	(3.523)		(0.304)	(0.358)	(0.223)
Indigenous boy with land	−0.048	−0.026	−0.054	Indigenous boy with land	0.036	0.053	0.021
	(2.159)	(0.448)	(1.776)		(1.044)	(0.514)	(0.074)
Latino girl with land	−0.006	0.052	0.011	Latino girl with land	0.031	0.090	0.040
	(0.039)	(1.829)	(0.076)		(0.728)	(1.503)	(0.279)
Indigenous girl without land	0.007	−0.015	−0.029	Indigenous girl without land	0.016	0.061	0.041
	(0.052)	(0.187)	(0.605)		(0.202)	(0.698)	(0.294)
Indigenous girl with land	−0.006	0.043	−0.015	Indigenous girl with land	0.033	0.070	0.026
	(0.034)	(1.134)	(0.124)		(0.857)	(0.907)	(0.116)
Heavy rain (boy)	0.003	0.244***	0.103***	**Frost** (boy)	−0.016	−0.030	0.114***
	(0.036)	(47.874)	(8.038)		(0.273)	(0.603)	(8.244)
Latino girl without land	−0.003	0.263***	0.101***	Latino girl without land	−0.021	−0.025	0.076*
	(0.033)	(55.579)	(7.647)		(0.449)	(0.405)	(3.632)
Latino boy with land	0.008	0.225***	0.075*	Latino boy with land	−0.001	−0.051	0.105**
	(0.177)	(36.198)	(3.768)		(0.001)	(1.404)	(5.662)
Indigenous boy without land	−0.007	0.249***	0.090***	Indigenous boy without land	0.003	−0.006	0.068***
	(0.213)	(58.952)	(7.195)		(0.033)	(0.064)	(9.283)
Indigenous boy with land	−0.002	0.230***	0.061*	Indigenous boy with land	0.018	−0.026	0.059**
	(0.016)	(45.926)	(3.080)		(0.622)	(0.840)	(3.990)
Latino girl with land	0.002	0.244***	0.072*	Latino girl with land	−0.005	−0.045	0.066
	(0.013)	(42.822)	(3.537)		(0.027)	(1.150)	(2.342)
Indigenous girl without land	−0.013	0.267***	0.087***	Indigenous girl without land	−0.001	−0.000	0.030
	(0.696)	(67.798)	(6.747)		(0.006)	(0.000)	(1.777)
Indigenous girl with land	−0.008	0.248***	0.059*	Indigenous girl with land	0.014	−0.021	0.021
	(0.206)	(53.919)	(2.831)		(0.375)	(0.566)	(0.520)

[a] Base is a latino boy without land.
NOTE: F-statistics in parentheses, except for base (boy) which shows t-statistics; * significant at 10%; ** significant at 5%; *** significant at 1%

together with data on natural hazards that allows us to pinpoint when and where particular shocks occurred. For each hazard we estimate the effect of the number of shocks that hit the area in the six months prior to the survey month on child health. This is done for children between 3 and 59 months for whom there is anthropometric information or information about symptoms. Child health is proxied by height for age and weight for height with most of the focus on the first outcome, while the three symptoms covered are diarrhea, fever and cough all within the two weeks prior to the survey. The hazards analysed are strong winds, flooding, heavy rain, hurricanes, frost and droughts.

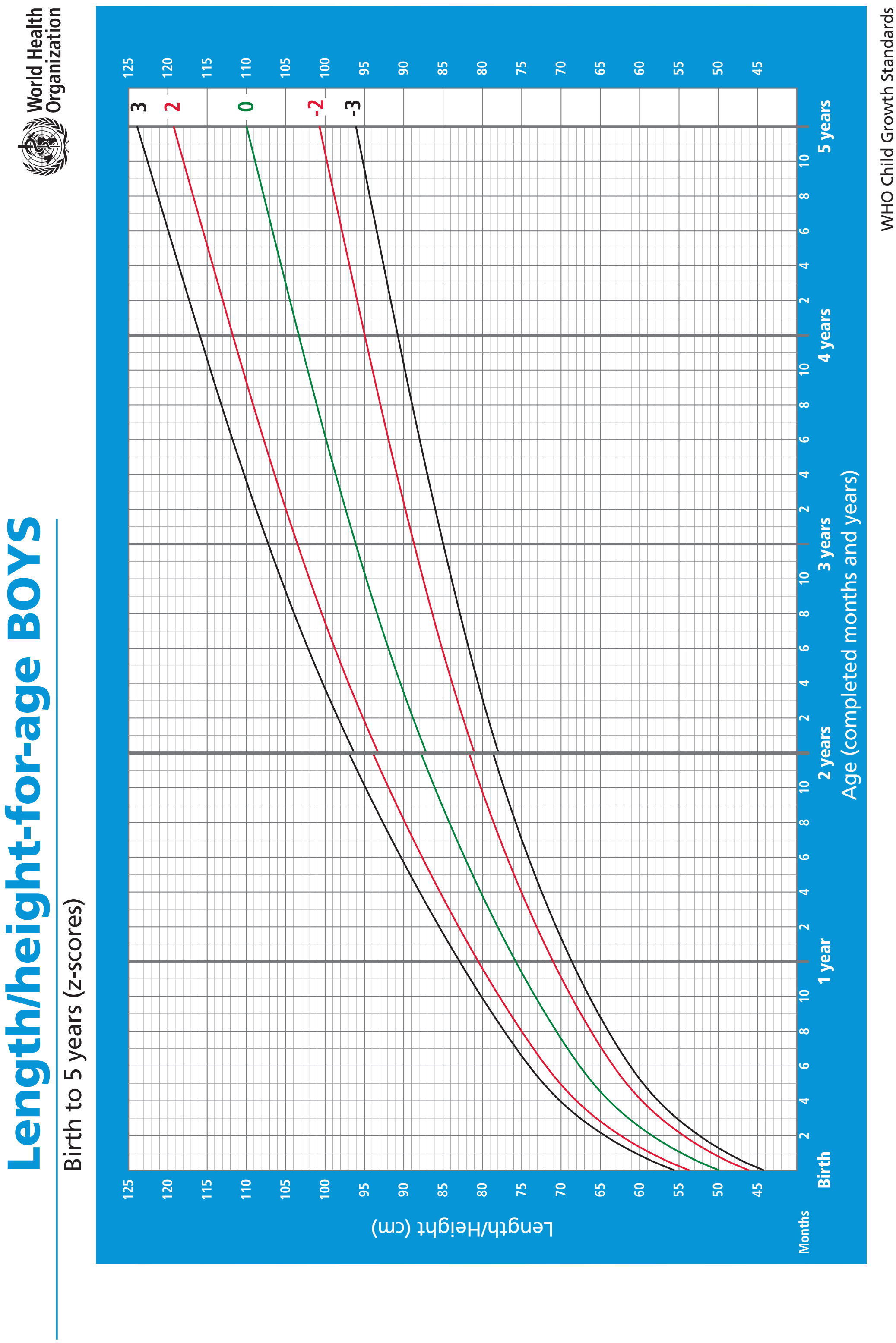
The effects of shocks from these hazards are generally negative and often very large. This is especially the case for shocks like heavy rain, strong winds and frost. The effects are also examined by sex of the children, ethinicity and whether their household has land. These results show that indigenous children both with and without land are most affected by the natural hazards in addition to be worse off in the baseline estimations. Non-indigenous girls generally do relatively well compared with non-indigenous boys, although the estimated effects are not small for the girls.

Analysing the effect of the hazards by groups and age of the child shows that younger boys seems to be much more vulnerable to shocks than girls of the same age. This is especially pronounced from around six months to between 24 and 30 months. Children before age six months seems to be at least somewhat protected, which is likely due to many of children younger than six months still being breastfed. For older children, i.e. more than 30 months, the roles are reversed with girls being more at risk than boys.

The results for weight-for-height and the symptoms are less conclusive than those for height-for-age. Most of the hazards do not appear to have much of an effect on weight-for-height and sometimes have counter-intuitive signs. The same is the case for the three symptoms examined. This is, however, less of a concern here since most of the literature points to height as the most important determinant of long term income and well-being.

Many of the overall estimated reductions in height-for-age are between 0.1 and 0.2 standard deviations or even larger for the results when shocks are interacted with a flexible form for age. These effects are substantial, especially given the already dismal level of child health in Guatemala. On average children in Guatemala are 2.4 standard deviations below the WHO growth standard for height for age. Hence, it will not take large increases in the risk of these hazards to severely disrupt the prospect for long run social development.

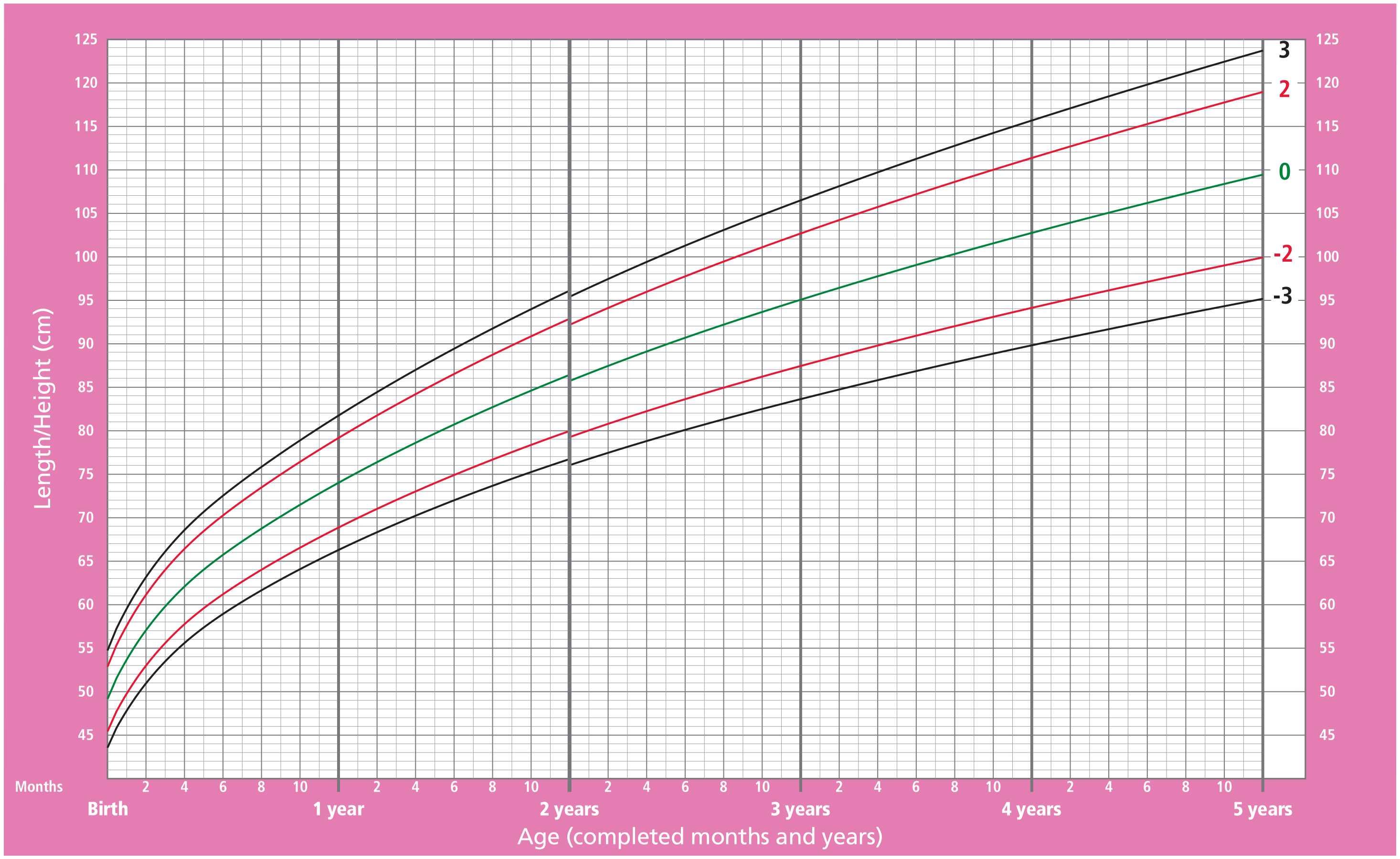
A Growth Standards



Length/height-for-age GIRLS

Birth to 5 years (z-scores)

World Health Organization



WHO Child Growth Standards

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