178

Working Paper

Young Lives

Early-life Exposure to Weather Shocks and Human Capital Accumulation

Evidence from the Peruvian Highlands

Alan Sanchez

www.younglives.org.uk

APRIL 2018

Early-life Exposure to Weather Shocks and Human Capital Accumulation: Evidence from the Peruvian Highlands

Alan Sanchez

ISBN 978-1-912485-03-1

A catalogue record for this publication is available from the British Library.

Core-funded by

UKaid
from the British people

Young Lives, Oxford Department of International Development (ODID), University of Oxford, Queen Elizabeth House, 3 Mansfield Road, Oxford OX1 3TB, UK

Tel: +44 (0)1865 281751 • Email: younglives@younglives.org.uk

Contents

The authors

Alan Sánchez holds a PhD in Economics from the University of Oxford. He is a Senior Researcher at GRADE (the Grupo de Análisis para el Desarrollo) in Lima, the Principal Investigator for Young Lives Peru, and a part-time lecturer at Universidad de Piura in Lima. He has published studies on the determinants and impacts of human capital from early life throughout childhood, adolescence and early adulthood in the context of developing countries, and on the impact of social and labour market policies in Peru. Before joining GRADE, he worked at the Economic Research Division of the Banco Central de Reserva del Peru (Central Bank of Peru).

Acknowledgements

I would like to thank Stefan Dercon, Måns Söderbom, Albert Park, John Hoddinott and Francis Teal, who all provided comments on an earlier version of this paper. Any remaining errors and inaccuracies are my own.

Summary

This working paper uses Young Lives data to investigate the impact of early-life exposure to unusually low temperatures (below long-term averages) on the formation of human capabilities in a cohort of children born in the Peruvian Andes. The empirical strategy uses differences in exposure to temperature levels across children within clusters, generated by differences in date of birth, at the month precision, in areas where frosts are widespread.

The results are consistent with the notion that early-life adversity can have implications on child development; however, the impacts found differ by age period and gender. A one standard deviation increase in the number of unusually cold months the child is exposed to during the first three years of life reduces height-for-age at the age of 5 by 2.7 per cent, but the impact fades away by the age of 8. On average, no impact is found on cognitive achievement and socio-emotional competencies. However, exposure is negatively associated with cognitive achievement for girls, with a standardised coefficient of -1.5 per cent. Overall, the results suggest that exposure to unusual weather variations can have implications for child development, but recovery is possible in some dimensions and the impact can vary by gender.

1. Introduction

The first few years of life are considered a sensitive period of motor, socio-emotional, and cognitive development (Martorell 1999; Thompson and Nelson 2001; Grantham-McGregor et al. 2007). In developing countries, children younger than 5 years old are exposed to risk factors that in some cases prevent them from attaining their developmental potential (Walker et al. 2007). Climate risk is one such factor. In the presence of moderate or severe natural hazards, faced with limitations on smooth consumption (Morduch 1995; 2004) poor households are often forced to reduce investments in human capital (Dercon 2010). A group of studies have measured the impact of weather shocks during the early childhood period on the formation of human capabilities, as well as on economic and social outcomes during adulthood. Hoddinott and Kinsey (2001) and Dercon and Hoddinott (2004) found that the 1994-5 drought in rural Zimbabwe led to a slowdown in physical growth for children aged 12-24 months during the time of exposure. Alderman et al. (2006) found analogous results due to exposure to the 1982-4 droughts in the same country; moreover, their analysis showed that this exposure was associated with losses in terms of years of completed schooling. Maccini and Yang (2009) found that early-life exposure to rainfall above local standards in rural Indonesia led to poorer health, lower schooling attainment and lower socio-economic indicators during adulthood for women. More recently, Molina and Saldarriaga (2017) found that in the Andean region, increases in temperature levels during the foetal period are associated with a reduction in birth weight.

Due to their recurrent nature, understanding the consequences of weather shocks is important for the design of social policies – safety nets and insurance programmes – in developing countries, particularly in the context of changes in climate patterns (Baez et al. 2013). While the existing evidence shows that early-life exposure to weather shocks can be harmful for human capital accumulation, few studies have been able to trace the impact of these types of events over different childhood periods. This matters since recent evidence shows that both nutritional as well as cognitive catch-up after early-life deprivation is possible (Outes and Porter 2013; Crookston et al. 2010; 2013), implying that shocks that occur during the first 1,000 days might not necessarily have long-term implications. This working paper looks to contribute to the literature by tracing, throughout early and mid-childhood, the nutritional, cognitive and socio-emotional impact of early-life exposure to unusually low temperatures (compared to local standards) on a cohort of children born in the Peruvian highlands, an area where frosts are widespread.

Peru is divided in three climatic zones: the Amazonian jungle in the east, the Pacific coast in the west, and the highlands in the centre, running from north to south. The majority of Peruvians classified as poor live in the highlands. Cold temperature events are common in this part of the country and have important economic consequences. According to official figures from the Peruvian Institute of Civil Defense, between 1995 and 2005, of the 1,678 emergencies across the country, 54 per cent were related to frosts, 32 per cent to snow storms, and 14 per cent to hailstorms (Government of Perú 2006).[1]

1 For instance, in 2004 an abrupt, short-lived, temperature decrease hit virtually all the highlands; an even more severe but less widespread frost took place in 2002, affecting the southern highlands. In both cases this led to a disruption in household income-earning activities through household-level losses (crop failure, death of livestock) and analogous community-level losses. In 2002 and 2004 official figures show that 27,000 and 31,000 square metres of cultivated areas were lost, respectively, and, in 2004, 770,000 animals died due to these events (Government of Perú 2009; 2006).

A Peruvian Government study that used data from more than 360 weather stations over a period of 50 years showed that these events are common in the country's history, are of a variable intensity, and are not entirely seasonal (Government of Peru 2005), thus making them difficult to predict. Since the poor population in Peru is geographically concentrated in the Andean region (where 40 per cent of Peru's total population live), measuring its impact is relevant for the design of social policy as this is precisely the type of population that have difficulties achieving smooth consumption in the presence of aggregated shocks.

To look at the impact of early-life low temperature events on human capital formation, in this study I link individual-level outcomes of children sampled in Peru by Young Lives to temperature data from weather stations located in, or nearby, their areas of origin. The analysis focuses on children that grew up in areas located 3,150 to 3,850 metres above sea level. According to information from community questionnaires, around half of these households were affected by frosts between 2002 and 2006. Exposure to unusually low temperatures (in what follows, 'exposure to cold months') is defined as the number of months during the first 36 months of life during which a child was exposed to temperature levels below the long-term average of the locality. The model was extended to test the impact of exposure during the in-utero period. Outcome variables considered are nutritional status (proxied by height-for-age), vocabulary achievement, and self-esteem. All these dimensions have been shown to help explain later differences in labour market outcomes (Maluccio et al. 2009; Bowles et al. 2001; Heckman et al. 2006).

A reduced-form approach is used to test the impact of exposure to cold months on each dimension. To deal with endogeneity due to geographical location, I use differences in exposure to low temperature levels across children within clusters, generated by differences in date of birth, at the month precision. Month of birth and year of birth fixed effects are also included in the specification; the former controls for the possibility that families might time the birth of their children, whereas the latter controls for time trends. In terms of the endogeneity of geographical location, it is important to note that mortality before the age of 5 is very low in the selected communities (at around 1.2 per cent), which suggests that selection due to mortality is not of great concern. Furthermore, the analysis shows that selection due to migration as a consequence of temperature variation is unlikely.

The results show that, on average, a marginal increase in exposure to cold months translates into lower height-for-age at the age of 5 (standardised coefficient of -2.7 per cent). However, the point estimate substantially drops and becomes statistically insignificant by the age of 8. On average, there is no evidence of an impact of exposure to cold months on the cognitive and socio-emotional indicators selected. However, there are differential patterns by gender. Even though exposure has a similar impact on height-for-age for boys and girls, only girls are affected from a cognitive point of view, with a standardised impact of -1.5 per cent on a vocabulary achievement test score at the age of 8.

2. Conceptual framework

The basis of the conceptualisation of the production of human capabilities during the childhood period can be found in Behrman and Deolalikar (1988) and Grossman (1972), with Glewwe and Miguel (2007) and Strauss and Thomas (2007) providing more recent treatments. Consider a framework in which the first part of early childhood (the first three years of life as well as the in-utero period) is taken as Period 1, and the remainder of childhood as Period 2. Denote nutritional status accumulated at the end of Period 1 of child i as $N_{1,i}$ and cognitive achievement accumulated at the end of the same period as $C_{1,i}$. At this early stage, $N_{1,i}$ can be taken as a function of parental investments (denoted as $I_{1,i}^{N}$) in the form of inputs such as food and medicines, as well as a function of genetic endowments (denoted as $\mu_{1,i}^{N}$), such that $N_{1,i} = f_{N,1}\ (I_{1,i}^{N}\ ,\ \mu_{1,i}^{N}\ )$. A similar structure can be assumed for $C_{1,i}$, whereby parental investments in education in the form of monetary expenditure and time devoted to the child's education, as well as inherent cognitive ability $I_{1,i}^{C}$ and $\mu_{1,i}^{C}$, respectively, act as inputs for cognitive achievement, so that $C_{1,i} = f_{C,1}(\ I_{1,i}^{C}, \mu_{1,i}^{C})$. The literature suggests a dynamic structure for Period 2 nutritional status, such that $N_{2,i} = f_{N,1}(\ N_{1,i}, C_{1,i}, I_{2,i}^{N})$, where $I_{2,i}^{N}$ represents contemporaneous investments in nutrition.

Similarly, Period 2 cognitive achievement is understood to be a function of lagged nutritional status, lagged cognitive skills, and contemporaneous parental investments in education, $C_{2,i} = f_{C,2}\big(\ N_{1,i}, C_{1,i}, I_{2,i}^{c}\big)$. The child developmental literature implies that, holding everything else constant, parental investments in Period 1 are more productive compared to the same level of investments in Period 2 (Thompson and Nelson 2001; Cunha et al. 2006).

Parents, assumed to derive utility from inter-temporal consumption and child quality – as measured by $N_{2,i}$ and $C_{2,i}$ – can be thought to choose investment levels "as if" they maximise utility, subject to the technology of $N_{1,i}$, $N_{2,i}$, $C_{1,i}$, $C_{2,i}$, budget and time constraints and under the usual regularity conditions. Consider a context in which income per fraction of time and input prices are a function of idiosyncratic shocks. This is the case for agricultural households (Deaton 1992). If households do not have access to insurance or credit markets, when an economic shock occurs in Period 1 such that it substantially damages the household economy by affecting either household income and/or relative prices in that period, it can then affect nutritional status and cognitive achievement in periods 1 and 2 by forcing parents to invest sub-optimally in Period 1. Adverse weather events such as droughts, floods and frosts can be treated as economic shocks from the point of view of agricultural households, as they tend to affect household income sources and might cause shifts in local prices. In particular, weather shocks can plausibly alter a child's nutritional status by reducing the quantity and quality of food available at home. When this happens in Period 1, a sub-optimal investment in nutrition can have an effect on cognitive achievement in Period 2 (Glewwe et al. 2001; Alderman et al. 2006). However, by the same token, weather shocks in Period 1 are also likely to alter monetary expenditure as well as the time, and the quality of time, parents devote to the education of the child (e.g. due to shifts in relative wages). The implication is that the impact of weather shocks on skills does not need to work purely through a nutritional channel.

This sketched model can be expanded to incorporate the impact of early-life weather shocks on socio-emotional competencies, which are also affected by parental investments (Cunha and Heckman 2008). Two important ideas arise from this conceptual framework. First, exposure to weather shocks is likely to affect child development through its negative effect on parental investments (monetary resources available at the household and time devoted to the child). This is especially likely to be the case in agricultural settings, such as in the Peruvian highlands. Second, despite their short-term nature these events can have long-term implications due to the dynamic nature of human capabilities formation.

3. Empirical strategy

The empirical analysis aimed to test the impact of exposure to cold months (during the first 36 months of life) on stock variables reflecting the history of investments in the child. In Peru, this type of weather event is a common occurrence in districts (*distritos*) located in the highlands. However, since poor people are more likely to live in remote areas in the highlands, there is a negative correlation between district altitude and household poverty. For similar reasons, there is a negative correlation between district altitude and child developmental outcomes. Therefore, the existence of a relationship between low temperature shocks and individual outcomes could be plagued by omitted variable bias. To deal with the possible endogeneity of geographical location, the following strategy was used. First, the analysis was restricted to children born in the upper highlands, in areas located at least 3,000 metres above sea level. Second, the analysis exploited within-cluster variation in exposure to low temperature levels during the first 36 months of life, generated by differences in date of birth. This utilises the notion that the first 36 months are considered a sensitive period of child development. Following this idea, a set of equations was estimated as:

$$Y_{ijmt} = \beta T_{ij,0-35m} + \alpha_j + \eta_m + \tau_t + X_i \Gamma + \mu_{ijmt}$$

where Y_{ijmt} stands for an outcome of child i born in cluster j, in month m and in year t. The regressor of interest is $T_{ij,0-35m}$, which represents the number of months within the first 36 months during which the temperature at which child i was exposed was below the long-term average for cluster j. The long-term average for each cluster is defined independently for each month of the year. In doing so, this variable is designed to capture arguably unexpected variation in weather conditions. This is important since there is evidence from different countries that suggests some families time births to adjust to the agricultural cycle, which implies that results purely driven by seasonality could be endogenous.[2] For the other variables, α_j stands for time-invariant cluster characteristics; η_m represents characteristics common to all children born in month m; η_t are characteristics common to all children born in year t; μ_{ijmt} is the error term; X_i is a vector of predetermined characteristics of the child and her family, including child's sex, birth order and ethnicity,[3] mother's age, ethnicity and level of education, gender of the head of the household, household size, whether the household is located in an urban area, and a household access to services index.[4] All of these variables were observed when the child was 1 year old. While this set of control variables is not required in the specification because temperature variation should be orthogonal to household characteristics conditional on location, its addition is useful to improve the precision of the estimates. Therefore, I report results both including and excluding this vector (baseline and extended specification, respectively).

2 See, for instance, Becker (1981) and Razzaque et al. (1990).

3 Ethnicity is measured in terms of a person's native tongue: Spanish, Quechua, Aymara, or other dialect.

4 The access to services index is the simple average of three dummy variables: 1 if the household has electricity, 0 otherwise; 1 if the household has a source of drinking water, 0 otherwise; and 1 if the household has adequate toilet facilities, 0 otherwise.

4. The data

4.1. Sample characteristics

The study used data from Young Lives, a cohort study tracking 12,000 children in four countries. In Peru, Young Lives sampled 2,052 children (one per household) from 20 randomly selected clusters.[5] The baseline survey took place in 2002, when children were around 1 year old (between 6 and 24 months). Two additional survey waves took place in 2006 and 2009, when the children were between 4 and 5, and 7 and 8 years old, respectively.

Using data from the three surveys and focusing on those children from clusters located in the centre and southern highlands, children from eight clusters were selected for this analysis.[6] The anonymised cluster names are Cajamarca, Huaylas, Huaraz, Dos de Mayo, Huamanga, Lucanas, Andahuaylas and Juliaca.[7] These areas are located between 3,150 and 3,850 metres above sea level, where sudden changes in temperature levels that might have implications for the local economies are a common occurrence. From the 833 children originally enrolled in these areas, five died before the 2006 wave and five more died between the 2006 and 2009 waves (a mortality rate of 1.2 per cent). In total, 784 and 778 children were re-interviewed in 2006 and 2009, respectively, implying attrition rates of 5.9 per cent and 6.6 per cent.[8]

Since we needed to impute information about weather conditions during the first years of life to each child in the selected sample, it was important to be sure about where these children lived, especially between the 2002 and 2006 waves. Therefore, those children whose families moved outside the clusters between the 2002 and 2006 waves (the migrated children) were excluded, since for them we cannot properly impute weather conditions during these years. After accounting for missing values, the final sample used for analysis comprised a balanced sample of 639 children.

Descriptive characteristics are reported in Table 1. Block [a] reports the characteristics of the Young Lives children that do not belong to the eight selected clusters, and Block [b] reports the same characteristics for those children that do. In this comparison, children from the selected clusters come from poorer backgrounds and attain lower levels of achievement in all domains. For instance, at the age of 1, 24 per cent were chronically undernourished,

5 The sampling design was as follows. First, 20 *distritos* were selected at random across the country from an exhaustive list of districts that purposively excluded the top 5 per cent of districts as measured by a district poverty index. Within each district, a starting point was chosen at random and households were visited until 100 households with at least one child aged between 6 and 24 months were identified. When the district was too small to find 100 eligible households, adjacent districts were included in the sample. In total, 27 districts were chosen (see Escobal and Flores (2008) for full details of the sampling procedure).

6 Ex-ante, two clusters located in the northern highlands (Chachapoyas and Morropon) were discarded due to their proximity to the equator line, an area with a different climatic configuration where cold waves (temperatures below zero Celsius degrees) are not observed.

7 The names of the Young Lives clusters are anonymised to protect families' identities. The anonymised cluster names correspond to the province names where the site is located, or the district name if the population is over 120,000.

8 Dercon and Outes-Leon (2008) show that most of the attrition in the sample is due to migration. They also show that while attrition is to some extent non-random, it is unlikely to lead to significant biases. Moreover, attrition levels are relatively modest and small when compared to other longitudinal studies.

compared to 10 per cent in the rest of the sample. To a large extent these differences are driven by the geographical profile of the sample, exclusively in the highlands region, the area of Peru where most of the poor population is located. In particular, the sample over-represents rural areas and the *indigenous*, a section of the population mainly engaged in agricultural activities. In Block [c] and Block [d], those children that belonged to the selected clusters in the 2002 wave are split into those that did not move before 2006 (the sample used for analysis) and those that did. Differences are not statistically significant between these two groups (i.e. migrated and non-migrated children report similar household characteristics and similar outcomes), suggesting that the analysis is unlikely to be biased due to migration.

4.2. Outcome variables

The nutritional outcome considered for the analysis was child's height-for-age z-score (the World Health Organization standard), measured at the age of 5 and again at the age of 8. The use of height-for-age z-score to proxy nutritional status was based on the notion that linear growth retardation is, primarily, the result of an inadequate nutrition over a long period of time. Height-for-age, then, expressed as a z-score was used as a summary variable of a child's nutritional history.

To test the impact of exposure to cold months on cognitive and socio-emotional dimensions, the outcomes considered were the child's score in the Peabody Picture Vocabulary Test (PPVT) administered when the child was aged 5 and 8; and a self-esteem score measured at the age of 8. PPVT is a test of receptive vocabulary: the child hears a word (`boat', `lamp', `cow', etc.) and is then asked to identify which of four illustrations corresponds with the spoken word. Questions vary according to the child's age and results are made age-comparable by using a standardised score that ranges from 55 to 150. The test was available to families in Spanish, Quechua and Aymara, and children were asked to answer the test in the language they felt most comfortable with. The score used in the analysis has been standardised according to its international norm (Cueto et al. 2009).

The self-esteem indicator was measured according to a child's degree of agreement or disagreement with a number of statements related to pride (pride scale), using a four-point Likert scale.[9] The test is an adapted version of the Rosenberg Self-Esteem Scale (Rosenberg 1965), focused on specific dimensions of children's living circumstances (housing, clothing, work, school) in the context of a poor country. The degree of agreement ranges from strong agreement to strong disagreement. The self-esteem indicator was calculated by obtaining an average score across the non-missing values of the questions. It is worth noting that studies using Young Lives data have found that there is a strong association between this self-esteem or pride indicator and household poverty (Dercon and Sanchez 2013; Dercon and Krishnan 2009).

Histograms and descriptive statistics of the selected variables are reported in Figure 1 and Table 1, respectively.

9 The statements are: "I feel proud to show my friends or other visitors where I live"; "I am ashamed of my clothes"; "I feel proud of the job done by the head of household"; "I am often embarrassed because I do not have the right books, pencils or other equipment for school"; "I am proud of my achievements at school"; "I am embarrassed by/ashamed of the work I have to do"; "I am ashamed of my shoes"; "I am worried that I don't have the correct uniform"; and "The job I do makes me feel proud".

Figure 1. *Histogram of key variables*

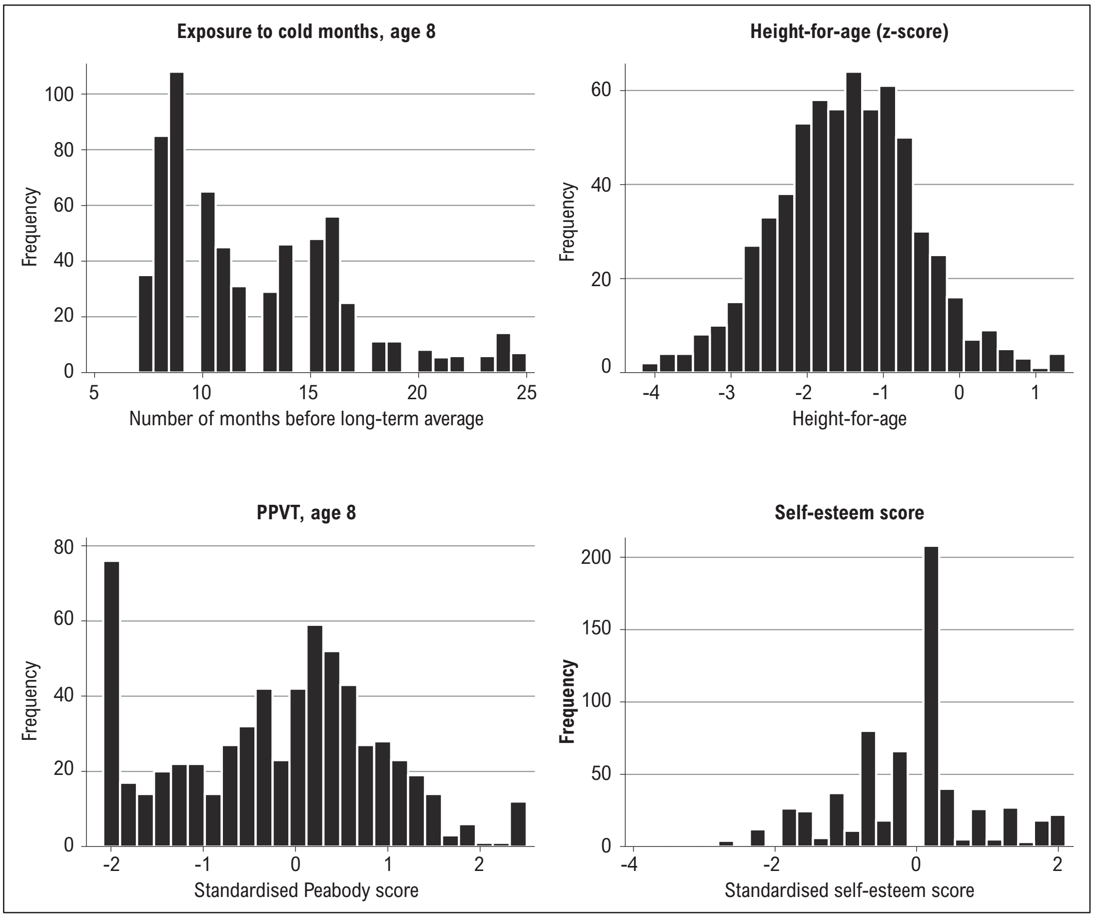

Table 1. *Sample characteristics*

	(a) Rest of Young Lives households		(b) Households located in highlands		Diff.	(c) Sample		(d) Rest of households in highlands		Diff.
	Mean	S.D.	Mean	S.D.	p-value	Mean	S.D.	Mean	S.D.	p-value
Household characteristics										
% of indigenous	0.948	0.222	0.592	0.492	0.000	0.584	0.493	0.671	0.473	0.147
% Hh. head main occupation is agriculture	0.292	0.455	0.459	0.499	0.000	0.473	0.500	0.329	0.473	0.019
Mother's years of education	8.634	3.786	6.354	4.76	0.000	6.327	4.772	6.575	4.643	0.676
Access to services index, 2002	0.714	0.315	0.588	0.34	0.000	0.588	0.339	0.592	0.347	0.911
Consumer durables index, 2002	0.305	0.223	0.227	0.196	0.000	0.229	0.196	0.218	0.188	0.663
Housing quality index, 2002	0.5	0.27	0.395	0.229	0.000	0.392	0.226	0.416	0.259	0.395
Household size, 2002	5.665	2.35	5.779	2.331	0.313	5.812	2.33	5.479	2.316	0.246
Community characteristics										
% of rural households	0.234	0.423	0.487	0.500	0.000	0.488	0.500	0.466	0.502	0.707
% of hh. located in the highlands	0.000	0.000	1.000	0.000	.	1.000	0.000	1.000	0.000	.
Child characteristics										
PPVT standardised score, age 4	0.120	0.983	-0.094	0.947	0.000	-0.098	0.946	-0.070	0.957	0.823
PPVT standardised score, age 7	0.156	0.884	-0.180	1.099	0.000	-0.194	1.112	-0.054	0.971	0.300
Self-esteem standardised score, age 7	0.069	1.031	-0.105	0.956	0.000	-0.121	0.970	0.030	0.813	0.203
Height-for-age z-score, age 1	-0.464	1.291	-1.181	1.213	0.000	-1.185	1.187	-1.174	1.446	0.962
Height-for-age z-score, age 4	-1.252	1.103	-1.789	1.004	0.000	-1.790	1.003	-1.811	1.037	0.850
Height-for-age z-score, age 7	-0.909	1.043	-1.479	0.946	0.000	-1.476	0.924	-1.530	1.139	0.630
% of malnourished children, age 1	0.116	0.321	0.243	0.429	0.000	0.241	0.428	0.274	0.449	0.520
% of female	0.498	0.500	0.488	0.500	0.676	0.495	0.500	0.438	0.500	0.371
% of children with pneumonia, 2006	0.116	0.321	0.104	0.306	0.301	0.099	0.298	0.151	0.360	0.169
Number of observations	1074		712			639		73		

4.3. Temperature data

Daily temperature data of weather stations was provided by the Peruvian Institute of Meteorology (SENAMHI) for the period January 1999 to December 2008. Both daily-minimum and daily-average temperature levels were observed. In total, data from 16 weather stations were made available, with the stations located either in the selected clusters or in nearby clusters. Two stations were excluded from the analysis due to several years of missing values. The data from the remainder stations were used as follows. When a station was located in a cluster this station was selected to impute temperature in that cluster. When no weather station existed in a cluster, an average of the temperature levels measured by weather stations in the surrounding districts was used. Table 2 provides descriptive statistics of the average and minimum daily temperature levels measured according to this procedure in the clusters between January 1999 and December 2008. The summary statistics indicate that average levels vary across clusters, and temperature levels below zero occur in some of these areas.

Table 2. *Daily average and minimum temperature in Young Lives clusters (in degrees Celsius): 1999-2008*

		Altitude	N. of daily observations	Minimum temperature				Average temperature			
				Mean	S.D.	Min.	Max.	Mean	S.D.	Min	Max
(1)	Cajamarca	3154.1	3071	7.86	3.04	-2.3	13.8	14.69	1.44	8.6	22.4
(2)	Huaylas	3180.7	3079	6.36	2.06	-2.0	11.0	15.05	2.28	6.6	25.3
(3)	Huaraz	3591.2	2621	6.40	2.26	-2.0	11.5	14.38	2.59	1.0	26.5
(4)	Dos de Mayo	3622.3	3254	11.56	2.93	1.8	18.3	17.75	2.52	12.0	26.5
(5)	Huamanga	3755.4	3285	6.60	1.93	-1.3	11.5	13.54	1.36	8.3	18.4
(6)	Lucanas	3573.9	3095	5.07	2.35	-4.8	10.6	11.36	1.51	4.2	18.8
(7)	Andahuaylas	3641.9	3285	8.25	2.17	1.0	13.2	14.42	1.54	8.0	19.3
(8)	Juliaca	3854.3	3285	1.60	3.49	-10.7	7.2	8.70	1.99	1.4	13.2

Note: The data correspond to monthly averages of time-series daily data.

In order to identify the impact of unusually cold months during the first 36 months of life, the daily temperature data were collapsed into monthly averages.[10] Each monthly observation was then re-expressed in deviations with respect to the long-term average corresponding to that month in that cluster.[11] Subtracting the month mean is important for two reasons. First, only when the monthly temperature level is below the local standard it can be deemed unusually low. Second, as mentioned earlier, evidence from different countries suggests some families time births to adjust to the agricultural cycle, which implies that results purely driven by seasonality could be endogenous. This is only partially taken into account by including month of birth dummies, because agricultural seasonal cycles might differ by cluster.

The final variable used for the analysis was the number of months during the first 36 months of life during which the month temperature was below the long-term average. Following this definition, the average exposure to unusually cold months during the first 36 months of life was 12.4 months, with a standard deviation of 4.3 (Table 3). Figure 1 shows the distribution of this variable.

10 The monthly average is the mean of daily averages from the first to the last day of the month.

11 Monthly long-term averages were calculated using the full range of data available (1999 to 2008).

Table 3. *Average exposure to unusually cold months*

	Mean [1]	Std. dev [2]	Min. [3]	Max. [4]
Pregnancy period	4.39	2.62	0.00	9.00
First year of life	4.48	2.14	1.00	10.00
Second year of life	3.16	1.98	0.00	9.00
Third year of life	4.72	3.21	0.00	11.00
First three years of life	12.36	4.34	7.00	25.00

5. Results

In the following tables, the key variables on both sides of the regressions (exposure to cold months, height-for-age, PPVT, and self-esteem) are standardised within the sample. Clustered standard errors are reported. To deal with a possible under-estimation of the standard errors when a clustering procedure is used and the number of clusters is small, bootstrap-based standard errors are also estimated (Cameron et al. 2008). I use the wild-bootstrap procedure suggested by Cameron et al.,[12] as this is found to be superior to other bootstrap methods previously suggested in the literature (see, for instance, Bertrand et al. 2004). In the following tables, both clustered standard errors and the p-value of the wild bootstrap-based procedure are reported, but only the latter is considered for inference.

Table 4. *Impact of number of unusually cold months on height*

	Height-for-age at age 5		Height-for-age at age 8	
	[1]	[2]	[3]	[4]
Baseline specification				
Months exposed, pregnancy		0.003		-0.022
		(0.018)		(0.032)
(Wild bootstrap p-value)		[0.879]		[0.690]
Months exposed, years 1 to 3	-0.034*	-0.034*	-0.012	-0.015
	(0.013)	(0.014)	(0.013)	(0.014)
(Wild bootstrap p-value)	[0.097]	[0.093]	[0.416]	[0.402]
R2 adjusted	0.234	0.232	0.159	0.158
Extended specification				
Months exposed, years 1 to 3		0.011		-0.016
		(0.019)		(0.023)
(Wild bootstrap p-value)		[0.697]		[0.652]
Months exposed, years 1 to 3	-0.027*	-0.026*	-0.004	-0.006
	(0.011)	(0.011)	(0.011)	(0.012)
(Wild bootstrap p-value)	[0.097]	[0.097]	[0.748]	[0.622]
R2 adjusted	0.285	0.284	0.225	0.224
Number of observations	639	639	639	639
Cluster fixed effects	Yes	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes	Yes

Notes: Variables are standardised within the sample. *, **, *** denote significance at 10 per cent, 5 per cent, and 1 per cent levels, respectively. The significance level reported corresponds to the wild bootstrap-based procedure.

12 Adapted from the STATA code provided by Doug Miller on his website (http://faculty.econ.ucdavis.edu/faculty/dlmiller/statafiles).

Table 4 reports the results when the dependent variable is height-for-age (from here onwards, 'height'). Columns [1] and [3] show the impact on height at the age of 5 and 8, respectively. In the preferred model specification (the extended specification), the results provide evidence of a negative linkage between exposure to cold months and height at age 5, with a standardised coefficient of -2.7 per cent. This result is consistent with previous findings linking adverse weather events with disinvestments in early nutrition (Hoddinott and Kinsey 2001; Alderman et al. 2006). However, by the age of 8 the standardised coefficient reduces to -0.4 per cent and is no longer statistically significant. In columns [2] and [4], the specification is extended to test the importance of exposure to unusually cold months during the pregnancy period, but no evidence was found that this period is relevant.

Although the fact that the impact on height fades away at the age of 8 might come as a surprise, this is consistent with an important body of evidence obtained using data from Young Lives that shows catch-up growth (growth recovery) in the Peru Young Lives sample during the same period (Crookston et al. 2010; 2013). In light of this, what our results show is that even though exposure to early-life adverse weather events can affect height in the short term, recovery at a later stage is possible.

Table 5 presents the results looking at the impact on cognitive and socio-emotional dimensions. In the preferred model specification, all coefficients are statistically insignificant. From here, it would seem that exposure did not have an impact on cognitive and socio-emotional dimensions, either directly or indirectly through a nutritional channel. We revise this argument in Section 5.1, when looking at the heterogeneous impact by gender.

Table 5. *Impact of number of unusually cold months on cognitive and socio-emotional outcomes*

	PPVT at age 5		PPVT at age 8		Self-esteem (pride scale) at age 8	
	[1]	[2]	[3]	[4]	[5]	[6]
Baseline specification						
Months exposed, pregnancy		-0.032 (0.031)		0.017 (0.019)		-0.025 (0.014)
(Wild bootstrap p-value)		[0.694]		[0.561]		[0.353]
Months exposed, years 1 to 3	-0.021 (0.023)	-0.025 (0.025)	-0.020 (0.010)	-0.018 (0.010)	-0.026 (0.020)	-0.029 (0.018)
(Wild bootstrap p-value)	[0.551]	[0.609]	[0.124]	[0.152]	[0.459]	[0.288]
R2 adjusted	0.306	0.306	0.346	0.346	0.079	0.078
Extended specification						
Months exposed, pregnancy		-0.026 (0.025)		0.027 (0.016)		-0.011 (0.02)
(Wild bootstrap p-value)		[0.552]		[0.259]		[0.715]
Months exposed, years 1 to 3	-0.013 (0.025)	-0.016 (0.026)	-0.005 (0.008)	-0.001 (0.01)	-0.018 (0.018)	-0.02 (0.017)
(Wild bootstrap p-value)	[0.637]	[0.659]	[0.528]	[0.898]	[0.471]	[0.472]
R2 adjusted	0.406	0.406	0.483	0.483	0.103	0.102
Number of observations	639	639	639	639	639	639
Cluster fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Variables are standardised within the sample. *, **, *** denote significance at 10 per cent, 5 per cent and 1 per cent levels, respectively. The significance level reported corresponds to the wild bootstrap-based procedure.

While the age period considered for exposure is relatively narrow, the developmental literature suggests that even within this period there are periods of higher vulnerability. To test the importance of age of exposure, the treatment variable was disaggregated to distinguish between exposure during the first, second and third year of life, respectively. Table 6 shows the results for the preferred specification and for the five outcomes of interest: height (at the age of 5 and 8), PPVT (at the age of 5 and 8) and self-esteem (at the age of 8). Conclusions are similar to those above: exposure to cold months only has an effect on height at the age of 5. In particular, the results suggest that the third year of life is the key period of exposure. However, when the Bonferroni test was used to individually test differences between each of the other year coefficients, the results did not reveal any statistically significant difference between them.

Table 6. *Impact of unusually cold months: timing of exposure*

	Height-for-age at age 5 [1]	Height-for-age at age 8 [2]	PPVT at age 5 [3]	PPVT at age 8 [4]	Self-esteem (pride scale) at age 8 [5]
Extended specification					
Months exposed, year 1	-0.026	0.029	0.013	-0.005	-0.045
	(0.020)	(0.020)	(0.019)	(0.017)	(0.020)
(Wild bootstrap p-value)	[0.511]	[0.130]	[0.584]	[0.811]	[0.209]
Months exposed, year 2	0.006	0.024	-0.067	-0.005	-0.042
	(0.026)	(0.022)	(0.048)	(0.024)	(0.027)
(Wild bootstrap p-value)	[0.915]	[0.467]	[0.407]	[0.889]	[0.410]
Months exposed, year 3	-0.033*	-0.037	-0.028	-0.005	0.009
	(0.008)	(0.015)	(0.023)	(0.009)	(0.016)
(Wild bootstrap p-value)	[0.094]	[0.182]	[0.534]	[0.564]	[0.585]
R2 adjusted	0.284	0.225	0.409	0.481	0.102
Number of observations	639	639	639	639	639
Cluster fixed effects	Yes	Yes	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: The temperature variable and the outcome are standardised within the sample. ∗, ∗∗, ∗∗∗ denote significance at 10 per cent, 5 per cent and 1 per cent levels, respectively. For the exposure to cold months variables, the significance level reported corresponds to the wild bootstrap-based procedure.

5.1. Heterogeneous results by gender

In Table 7, results are re-estimated for the five outcomes of interest, including an interaction term between exposure to cold months and the gender of the child (only the preferred specification is reported). In the case of height, an impact is observed at the age of 5 and results suggest the impact is the same regardless of gender. No further impact is observed at the age of 8. In the case of vocabulary achievement (PPVT), the results unmask a differentiated effect by gender. For boys, the coefficient is close to zero in magnitude and statistically insignificant for both age periods. However, an effect on vocabulary achievement is detected for girls. A one standard deviation increase in exposure reduces the PPVT score at the age of 8 by -1.5 per cent of a standard deviation. It is interesting that, for girls, the coefficient for PPVT at the age of 8 is similar in magnitude to that observed at the age of 5, albeit in the latter case is not statistically significant. No evidence of an impact on self-esteem is detected for either boys or girls.

Table 7. *Impact of number of unusually cold months: heterogeneity by gender*

	Height-for-age at age 5 [1]	Height-for-age at age 8 [2]	PPVT at age 5 [3]	PPVT at age 8 [4]	Self-esteem (pride scale) at age 8 [5]
Extended specification					
Months exposed, year 1 to 3	-0.028*	-0.012	-0.002	0.003	-0.03
	(0.011)	(0.014)	(0.026)	(0.008)	(0.019)
(Wild bootstrap p-value)	[0.085]	[0.458]	[0.983]	[0.628]	[0.302]
Months exposed, year 1 to 3	0.002	0.016	-0.022	-0.018**	0.025
	(0.014)	(0.011)	(0.009)	(0.004)	(0.017)
(Wild bootstrap p-value)	[0.915]	[0.158]	[0.262]	[0.033]	[0.235]
Child is female	0.016	-0.158	0.302**	0.098	-0.268
	(0.218)	(0.145)	(0.123)	(0.08)	(0.288)
R2 adjusted	0.284	0.224	0.408	0.483	0.104
Number of observations	639	639	639	639	639
Cluster fixed effects	Yes	Yes	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes	Yes	Yes

Notes: Variables are standardised within the sample. *, **, *** denote significance at 10 per cent, 5 per cent and 1 per cent levels, respectively. For the exposure to cold months variables, the significance level reported corresponds to the wild bootstrap-based procedure.

Gender gaps in child outcomes are not surprising in the developing world. Using data from Young Lives across the four countries, Dercon and Singh (2013) found evidence of gender gaps in cognitive achievement at the age of 8 in Peru and India (pro-boy in both cases). The literature also suggests that in developing countries exposure to early-life weather shocks might have a differentiated impact by gender. To our knowledge, most of the evidence suggests that girls are more likely to be affected by variations in weather conditions. Behrman (1988) found that the nutritional status of girls is more affected by agricultural seasonality than that of boys in India. Rose (1999) found that favourable rainfall shocks increase the likelihood (relative to a boy) that a girl survives until school age in India. More recently, Bjorkman (2013) found that negative deviations in rainfall (from the long-term average) have negative effects on enrolment in primary school for girls but not for boys in Uganda. To our knowledge, gender differential in child outcomes as a result of exposure to shocks is an aspect that has not been explored in the Peruvian context. However, and notably, in a recent study Beuermann and Sanchez (2015) used data from several years of the Peru National Household Survey and found that early-life exposure to cold months during the first three years of life (a definition analogous to that used in this study) has a long-term negative impact for women but not for men on wages and wealth-related measures, echoing findings from Maccini and Yang (2009) for women in Indonesia. It is unclear whether the gender differential observed in the current study is due to gender discrimination within the household that is revealed at times of economic hardship or if, alternatively, the result is due to underlying differences in the production function of cognitive achievement by gender. Although we are unable to uncover the reason behind this gender differential, it is important to stress that our results are aligned with other findings from the literature. In particular, our results are consistent with evidence for Peru that suggests that women are the most affected by exposure to these types of shocks in the long term.

5.2. Pathways of the impact on cognitive achievement for girls

Results show that exposure to cold months has a negative impact on cognitive achievement for girls, but not for boys. The literature suggests that the cognitive impact could be mediated by the impact that nutrition has on cognition. At the same time, adverse weather conditions can also modify the allocation of non-nutritional investments, either during the first three years of life or later through persistent effects on household wealth. In order to discuss possible pathways, we focused on the sub-sample of girls and extended the model specification to account for factors measured at the age of 5 (almost at the end of the early childhood, marking an intermediate period between the time of exposure and the realisation of the final outcomes) that could conceptually mediate the impact observed for girls on PPVT scores at the age of 8.

The intermediate inputs considered were height and PPVT at the age of 5, age of school enrolment, and whether the child had pneumonia during the first few years of life. The inclusion of lagged height and lagged PPVT as inputs in the production of PPVT was consistent with the model sketched in Section 2, whereas whether the child suffered from pneumonia during early childhood was included due to the nature of the adverse event being analysed (although a direct impact on a child´s health due to exposure was not considered in our conceptual model, it cannot be ruled out).[13] Note that, although age of school enrolment is likely to be contaminated by early health and nutrition, its inclusion helps to take into account the direct effect that time spent at school might have on cognitive attainment.[14] In addition to the inclusion of these inputs, contemporaneous household consumption expenditure was also included as a control to take into account persistent effects on household wealth.

13 According to caregivers, 10 per cent of the sampled children had pneumonia before 2006, which could be a consequence of exposure to low temperature levels.

14 Age of school enrolment has been found to be determined by nutritional status (Glewwe and Jacoby 1995) through behavioural as opposed to biological channels (i.e. parents delay the enrolment of stunted children, possibly because they look younger for their age). Arguably, infectious disease can alter the timing of school enrolment.

Table 8. *Impact of unusually cold months on the Peabody test: channels of transmission*

	[1]	[2]	[3]	[4]	[5]	[6]
Months exposed, years 1 to 3	0.004	0.002	0.001	0.002	-0.001	0.000
	(0.009)	(0.008)	(0.008)	(0.009)	(0.009)	(0.009)
(Wild bootstrap p-value)	[0.717]	[0.799]	[0.947]	[0.797]	[0.964]	[0.989]
Female*exposed, years 1 to 3	-0.017***	-0.011*	-0.017***	-0.017***	-0.016**	-0.011*
	(0.004)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)
(Wild bootstrap p-value)	[0.016]	[0.100]	[0.016]	[0.045]	[0.054]	[0.080]
Child is female	0.092	0.007	0.106	0.094	0.069	0.011
	(0.08)	(0.079)	(0.077)	(0.088)	(0.088)	(0.079)
Height-for-age, at age 5	0.064*					0.042
	-0.036					-0.03
PPVT, at age 5		0.281***				0.269***
		-0.069				-0.067
Age of school enrolment			-0.085			-0.054
			-0.101			-0.1
Child suffered pneumonia				-0.139		-0.056
				-0.117		-0.108
Household expenditure					0.096**	0.079**
per capita, at age 8					-0.043	-0.038
R2 adjusted	0.483	0.527	0.482	0.482	0.489	0.534
Number of observations	639	639	639	639	639	639
Cluster fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year of birth fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Month of birth fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: The temperature variable and the outcome are standardised within the sample. *, **, *** denote significance at 10 per cent, 5 per cent and 1 per cent levels, respectively. For the exposure to cold months variables, the significance level reported corresponds to the wild-bootstrap-based procedure.

Table 8 shows the individual contribution of each of the proposed mediating factors. It is worth highlighting that the impact of cold months for girls substantially reduces in magnitude only when lagged PPVT is included in the model. One plausible interpretation of this result is that exposure to cold months leads to lower PPTV scores at the age of 5 and this in turn translates into lower PPVT scores at the age of 8. At the same time, it should be noted that this does not necessarily lead to the conclusion that a nutritional channel is absent. Cognitive achievement measured at the age of 5 is a stock variable that comprises the history of cognitive as well as nutritional investments made by parents in the child in the very early years. In light of this, the results here are still consistent with a nutrition effect of a short-term nature, the cognitive impact of which might persist over time even though the impact on height eventually fades away.

6. Conclusions

This study provides unique evidence of how events outside of the control of the family can drive the acquisition of human capabilities for those affected by these events early in life. The type of shock that has been analysed here is not a rare event, but a common occurrence in Andean countries, highlighting the importance of analysing the effects of these phenomena. In terms of identification, temperature is a fairly exogenous source of variation in the economic conditions faced by households located in the highlands. The results deal with possible remaining endogeneity through the inclusion of a layer of fixed effects.

The study’s results help us to better understand the consequences of early-life exposure to climate events. The results show that exposure to cold months in the Peruvian highlands has an impact on height during early childhood and this effect disappears later on, possibly due to nutritional catch-up. In addition, exposure to cold months has a cognitive impact for girls but not for boys during mid-childhood. When looking at the possible pathways, the results suggest that the main reason why girls who were more exposed to cold months have a lower cognitive achievement in mid-childhood is because their cognitive achievement had already been compromised at an earlier stage.

Given that the period of exposure analysed was the first three years of life, the fact that cognitive differences due to exposure to unusually cold temperatures were already apparent at 5 years old is striking, and suggests that other forms of parental investments were sub-optimal during the hazardous period.

References

Alderman, H., J. Hoddinott, and B. Kinsey (2006) 'Long term Consequences of Early Childhood Malnutrition', *Oxford Economic Papers* 58.3: 450–474.

Baez, J.E., D. Kronick, and A.D. Mason (2013) *Rural Households in a Changing Climate*, Policy Research Working Paper WPS6326, Washington, DC: World Bank.

Becker, S. (1981) 'Seasonality of Fertility in Matlab, Bangladesh', *Journal of Biosocial Science* 13.1: 97–105.

Behrman, J.R. (1988) 'Nutrition, Health, Birth Order and Seasonality: Intrahousehold Allocation Among Children in Rural India', *Journal of Development Economics* 28.1: 43–62.

Behrman, J.R., and A.B. Deolalikar (1988) 'Health and Nutrition,' in H. Chenery and T.N. Srinivasan (eds.) *Handbook of Development Economics*, Volume 1, 631–711, Amsterdam: North Holland.

Bertrand, M., E. Duflo, and S. Mullainathan (2004) 'How Much Should We Trust Differences-in-Differences Estimates?', *The Quarterly Journal of Economics* 119.1: 249–275.

Beuermann, D., and A. Sanchez (2015) 'The Long-term Effects of Early-life Exposure to Unusually Cold Weather in the Peruvian Highlands', Mimeo.

Bjorkman-Nyqvist, M. (2013) 'Income Shocks and Gender Gaps in Education: Evidence From Uganda', *Journal of Development Economics*, 105(c): 237–253.

Bowles, S., H. Gintis, and M. Osborne (2001) 'The Determinants of Earnings: A Behavioral Approach', *Journal of Economic Literature* 39.4: 1137–1176.

Cameron, A.C., J.B. Gelbach, and D.L. Miller (2008) 'Bootstrap-Based Improvements for Inference with Clustered Errors', *The Review of Economics and Statistics* 90: 414–427.

Crookston, B., M. Penny, S. Alder, T. Dickerson, R. Merrill, J. Stanford, C. Porucznik, and K. Dearden (2010) 'Children Who Recover from Early Stunting and Children Who are Not Stunted Demonstrate Similar Levels of Cognition', *The Journal of Nutrition* 140.11: 1996–2001.

Crookston, B., W. Schott, S. Cueto, K. Dearden, P. Engle, A. Georgiadis, E. Lundeen, M. Penny, A. Stein, and J. Behrman (2013) 'Postinfancy Growth, Schooling and Cognitive Achievement: Young Lives', *The American Journal of Clinical Nutrition* 98.6: 1555–1563.

Cueto, S., J. Leon, G. Guerrero, and I. Munoz (2009) *Psychometric Characteristics of Cognitive Development and Achievement Instruments in Round 2 of Young Lives*, Working Paper 15, Oxford: Young Lives.

Cunha, F. and J.J. Heckman (2008) 'Formulating, Identifying and Estimating the Technology of Cognitive and Noncognitive Skill Formation', *Journal of Human Resources* 43.4: 738–782.

Cunha, F., J.J. Heckman, L. Lochner, and D.V. Masterov (2006) 'Interpreting the Evidence on Life Cycle Skill Formation', in H. Chenery and T.N. Srinivasan (eds.) *Handbook of Development Economics*, Volume 1, 697–812, Amsterdam: North Holland.

Deaton, A. (1992) 'Household Saving in LDCs: Credit Markets, Insurance and Welfare', *Scandinavian Journal of Economics* 94.2: 253–73.

Dercon, S. (2010) 'Risk, Poverty and Human Development: What Do We Know, What Do We Need to Know?', in R. Fuentes-Nieva and P. Seck (eds.) *Risk, Shocks and Human Development on the Brink*, 15–39, Basingstoke: Palgrave Macmillan.

Dercon, S. and J. Hoddinott (2004) 'Health, Shocks, and Poverty Persistence,' in S. Dercon (ed.) *Insurance Against Poverty*, 124-136, Oxford: Oxford University Press.

Dercon, S. and P. Krishnan (2009) 'Poverty and the Psychosocial Competencies of Children: Evidence from the Young Lives Sample in Four Developing Countries', *Children, Youth and Environments* 19.2: 138–163.

Dercon, S. and I. Outes-Leon (2009) *Survey Attrition and Attrition Bias in Young Lives*, Technical Note 5, Oxford: Young Lives.

Dercon, S. and A. Sanchez (2013) 'Height in Mid-childhood and Psychosocial Competencies in Late Childhood: Evidence from Four Developing Countries', *Economics & Human Biology* 11.4: 426–432.

Dercon, S. and A. Singh (2013) 'From Nutrition to Aspirations and Self-Efficacy: Gender Bias over Time among Children in Four Countries', *World Development* 45: 31–50.

Escobal, J. and E. Flores (2008) *An Assessment of the Young Lives Sampling Approach in Peru*, Technical Note 3, Oxford: Young Lives.

Glewwe, P. and H.G. Jacoby (1995) 'An Economic Analysis of Delayed Primary School Enrollment in a Low Income Country: The Role of Early Childhood Nutrition', *The Review of Economics and Statistics* 77: 156–169.

Glewwe, P., H.G. Jacoby, and E.M. King (2001) 'Early childhood nutrition and academic achievement: a longitudinal analysis', *Journal of Public Economics* 81: 345–368.

Glewwe, P. and E.A. Miguel (2007) 'The Impact of Child Health and Nutrition on Education in Less Developed Countries', in T. Schultz and J. Strauss (eds.) *Handbook of Development Economics*, Volume 4, 3561–3606, Amsterdam: North Holland.

Government of Peru (2005) 'Atlas de Heladas', Lima: Government of Peru.

Government of Peru (2006) 'Plan Nacional de Contingencia ante la Ocurrencia de Eventos Frios y/o Heladas', Lima: Government of Peru.

Government of Peru (2009) 'Compendio Estadistico de Prevencion y Atencion de Desastres 2008', Lima: Government of Peru.

Grantham-McGregor, S., Y. Cheung, S. Cueto, P. Glewwe, L. Richter, and B. Strupp (2007) 'Developmental Potential in the First 5 years for Children in Developing Countries', *The Lancet* 369.9555: 60–70.

Grossman, M. (1972) 'On the Concept of Health Capital and the Demand for Health', *Journal of Political Economy* 80.2: 223–255.

Heckman, J.J., J. Stixrud, and S. Urzua (2006) 'The Effects of Cognitive and Noncognitive Abilities on Labor Market Outcomes and Social Behavior', *Journal of Labor Economics* 24.3: 411–482.

Hoddinott, J., and B. Kinsey (2001) ‘Child Growth in the Time of Drought’, *Oxford Bulletin of Economics and Statistics* 63.4: 409–436.

Maccini, S. and D. Yang (2009) ‘Under the Weather: Health, Schooling, and Economic Consequences of Early-Life Rainfall’, *American Economic Review* 99.3: 1006–1026.

Maluccio, J.A., J. Hoddinott, J.R. Behrman, R. Martorell, A.R. Quisumbing, and A.D. Stein (2009) ‘The Impact of Nutrition during Early Childhood on Education Among Guatemalan Adults’, *Economic Journal* 119.537: 734–763.

Martorell, R. (1999) ‘The Nature of Child Malnutrition and its Long-term Implications’, *Food and Nutrition Bulletin* 20.3: 288-292.

Molina, O. and V. Saldarriaga (2017): ‘The perils of climate change: In utero ex-posure to temperature variability and birth outcomes in the Andean region’, *Economics and Human Biology* 24: 111-124.

Morduch, J. (1995) ‘Income Smoothing and Consumption Smoothing*’, The Journal of Economic Perspectives* 9.3: 103–114.

Morduch, J. (2004) ‘Consumption Smoothing Across Space: Testing Theories of Risk-Sharing in the ICRISAT Study Region of South India’, in S. Dercon (ed.) *Insurance Against Poverty*, Oxford: Oxford University Press.

Outes, I. and C. Porter (2013) ‘Catching up from Early Nutritional Deficits? Evidence From Rural Ethiopia’, *Economics and Human Biology* 11.2: 148–163.

Razzaque, A., N. Alam, L. Wai, and A. Foster (1990) ‘Sustained Effects of the 1974-5 Famine on Infant and Child Mortality in a Rural Area of Bangladesh’, *Population Studies* 44: 145–154.

Rose, E. (1999) ‘Consumption Smoothing and Excess Female Mortality in Rural India’, *The Review of Economics and Statistics* 81.1: 41–49.

Rosenberg, M. (1965) *Society and the Adolescent Self-Image*, Princeton: Princeton University Press.

Strauss, J., and D. Thomas (2007) ‘Health over the Life Course’, in T. Schultz and J. Strauss (eds.) *Handbook of Development Economics*, Volume 4, 3375–3474, Amsterdam: North Holland.

Thompson, R., and C. Nelson (2001) ‘Developmental Science and the Media: Early Brain Development’, *American Psychologist* 56.1: 5–15.

Walker, S., T. Wachs, J. Meeks, B. Lozoff, G. Wasserman, E. Pollitt, and J. Carter (2007) ‘Child Development: Risk Factors for Adverse Outcomes in Developing Countries’, *The Lancet* 369.9556: 145–157.

Early-life Exposure to Weather Shocks and Human Capital Accumulation: Evidence from the Peruvian Highlands

This working paper uses Young Lives data to investigate the impact of early-life exposure to unusually low temperatures (below long-term averages) on the formation of human capabilities in a cohort of children born in the Peruvian Andes. The empirical strategy uses differences in exposure to temperature levels across children within clusters, generated by differences in date of birth, at the month precision, in areas where frosts are widespread.

The results are consistent with the notion that early-life adversity can have implications on child development; however, the impacts found differ by age period and gender. A one standard deviation increase in the number of unusually cold months the child is exposed to during the first three years of life reduces height-for-age at the age of 5 by 2.7 per cent, but the impact fades away by the age of 8. On average, no impact is found on cognitive achievement and socio-emotional competencies. However, exposure is negatively associated with cognitive achievement for girls, with a standardised coefficient of -1.5 per cent. Overall, the results suggest that exposure to unusual weather variations can have implications for child development, but recovery is possible in some dimensions and the impact can vary by gender.

Young Lives

An International Study of Childhood Poverty

About Young Lives

Young Lives is an international study of childhood poverty, involving 12,000 children in four countries over 15 years. It is led by a team in the Department of International Development at the University of Oxford in association with research and policy partners in the four study countries: Ethiopia, India, Peru and Vietnam.

Through researching different aspects of children's lives, we seek to improve policies and programmes for children.

Young Lives Partners

Young Lives is coordinated by a small team based at the University of Oxford, led by Professor Jo Boyden.

- *Ethiopian Development Research Institute, Ethiopia*
- *Pankhurst Development Research and Consulting plc, Ethiopia*
- *Centre for Economic and Social Studies, Hyderabad, India*
- *Save the Children India*
- *Sri Padmavathi Mahila Visvavidyalayam (Women's University), Andhra Pradesh, India*
- *Grupo de Análisis para el Desarollo (GRADE), Peru*
- *Instituto de Investigación Nutricional, Peru*
- *Centre for Analysis and Forecasting, Vietnamese Academy of Social Sciences, Vietnam*
- *General Statistics Office, Vietnam*
- *Oxford Department of International Development, University of Oxford, UK*

Contact:
Young Lives
Oxford Department of International Development,
University of Oxford,
3 Mansfield Road,
Oxford OX1 3TB, UK
Tel: +44 (0)1865 281751
Email: younglives@younglives.org.uk
Website: www.younglives.org.uk

Young Lives