Rainfall Shocks and Children's Well-being in India[Γ]

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Abstract

Using a continuous variable to capture deviations in rainfall, we analyze the direct reduced form effect of a drought during a child's critical period of development on indicators of physical growth and cognition. We use the Young Lives Dataset on Andhra Pradesh, India and find that in the short run, exposure to the drought decreases weight-for-age without having any effect on children's height-for-age. While stature is unaffected in the short run, we find that children who experienced the drought during early life, grow up to be shorter and exhibit a lower score on numeracy and language tests compared to children who did not experience the drought. But, by the time children have reached 8 years of age, the negative effect of the drought on cognition disappears showing that the adverse impact of the drought on stature is more persistent compared to its impact on cognitive development. We also find that presence of a government assistance program in the child's community during the drought period is helpful in partially offsetting the negative effects of the drought.

JEL Classification Codes: O130, I15
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1 Introduction and Motivation

Households in developing countries frequently experience risk and uncertainty. This risk stems from exposure to multifarious aggregate or idiosyncratic shocks. Evidence shows that such shocks are associated with large fluctuations in household income (Murdoch, 1995). If households can smooth income (by diversifying into production activities which entail low levels or risk) or consumption (through borrowing, saving and insurance mechanisms) then income fluctuations are not likely to translate into welfare loses for shock-exposed households. While formal mechanisms such as credit and insurance markets (Udry, 1990) and informal mechanisms, ex-ante measures like diversification of income or ex-post measures like informal borrowing, utilizing asset holdings (Fafchamps, Udry, Czukas 1998), increasing labor supply of family members, including children, cutting back on health and education expenditure in the household (Jacoby and Skoufias, 1997) may help in achieving some degree of consumption smoothing, but it is far from perfect.

Thus, rural households in developing countries are not completely insulated from risk created by adverse economic shocks (Townsend; 1994, Alderman and Paxson; 1994, Murdoch, 1995, Dercon, 2002, Fafchamps and Lund; 2003). The degree of consumption smoothing will depend upon the effectiveness of formal and informal risk sharing mechanisms. Moreover, some risk coping measures such as labor supply and human capital investment decisions regarding children in shock-exposed households may be extremely costly in terms of their long run implications (Jensen, 2000).

Weather shocks are considered as a significant threat to developing countries. High temperatures have been associated with lower economic growth rates in poor countries (Dell et. al., 2009). Moreover, weather shocks have resulted in far greater income losses, as measured by GDP per capita, in the developing world compared to the developed world (Raddatz, 2009). If anything, these threats are expected to rise in the future. There is strong evidence to suggest that climate change will increase the frequency and severity of weather shocks in years to come (IPCC, 2013). It is predicted that by the end of this decade, climatic changes will reduce the world's agricultural output by 16% with a large impact on some major staple food crops like rice, cotton and maize (Malik, Awan and Khan 2012). The negative effect of climate change and weather fluctuations on production, output and income in poor countries, is expected to exceed the impact on rich countries (Dercon, 2014, IPCC, 2012).

While weather shocks can be quite varied in nature, we study one particular type of weather shock i.e. *droughts*, which are induced by moderate to severe rainfall shortages in the context of Andhra Pradesh, India. Droughts emerge as the most frequent type of shock affecting welfare of households across many developing countries (de la Fuente and Dercon 2008). The geographical region is well suited for this study as rural households in this area predominantly depend upon agriculture for livelihood. The agro-climatic landscape of this region can be described as semi-arid. The area falls in the monsoon belt and major cropping seasons closely follow the onset of monsoon rains. Thus, agricultural production is strongly contingent on the level and timing of rainfall. A dry period is associated with a sharp dip in agricultural output, and a high risk of food insecurity. Low levels of rainfall and high temperature conditions adversely affect agricultural yields of major crops, depress agricultural wages and increase agricultural prices in India (Burgess et. al. 2011).

We will investigate a direct reduced form effect of exposure to a drought on physical growth and cognitive development at different points in a child's life. The main research questions that we aim to answer are as follows: (i) what are the contemporaneous effects of exposure to a drought on child's height and weight during early life (ii) Do the effects on physical growth persist in the medium and long run? (iii) What are the consequences of exposure to drought during early life on children's cognitive development in the medium and long run (iv) Are the negative effects of the drought on children's physical growth and cognitive development offset by the presence of a government poverty alleviation program in the children's community during the drought period?

The research objective underlying this study is motivated on four main accounts: (a) Firstly, climatic fluctuations are likely to pose grave challenges to welfare of rural households in developing countries, where formal credit and insurance markets are imperfect, and government social protection programs are inadequate. Since covariate shocks such as droughts tend to affect an entire community rather than a single household, the degree of protection offered by informal risk coping strategies is also quite limited. There is also little doubt now that well targeted public action campaigns can help poor households in insulating themselves against the harmful effects of negative shocks (Dreze and Sen 1998, de la Fuente and Dercon 2008). Thus, a detailed study of the consequences of a drought can provide important lessons to governments and international development agencies for devising appropriate safety net programs that can help mitigate the negative consequences of such events in developing countries like India. Secondly, the concentration on early childhood is motivated by a rich literature on child health that emphasizes the importance of adequate nutrition during early life in determining long run health status, educational attainment, productivity and income. Thirdly, a large body of work establishes human capital formation as a key driver of economic growth. Early work by Schultz (1961) and Becker (1962) showed that human capital is an input similar to physical capital in the output production function. Thus a high level of human capital is associated with a high growth rate of income in much the same way as a higher stock of physical capital. At the micro level, differences in income across individuals can be explained by differential investments in human capital (Mincer, 1958). Studies have also shown that a large share of cross-country differences in income can be attributed to differences in quantity and quality of human capital (Mankiw et. al. 1992). Weil (2005) shows that one tenth of the income differential across countries can be explained by differences in health. According to human capital theory, human capital is a function of innate and acquired capabilities (Mincer 1981). These in turn are considered to depend on investments in health, education and job training undertaken over the course of an individual's lifetime. This paper will focus on one particular dimension of human capital i.e. health[1]. Fourthly, in spite of the significant importance of human capital, poor performance on health continues to be a major challenge for many developing countries like India.

A distinguishing feature of this study is the manner in which exposure to drought has been measured. In the extant literature on shocks, exposure to a drought has predominantly been captured through a discrete dummy variable, which takes on a value of 1 for households (and

[1]Bleakley (2010) provides a review of studies documenting the importance of health in determining human capital outcomes in developing countries.

or individuals) who experience the drought but 0 otherwise (Hoddinot et. al.; 2001, Alderman et. al., 2006; Handa, S Peterman, Amber, 2006; De, 2011;Outes-Leon, I Porter, Catherine Sanchez, A, 2011; Mendiratta, 2012). Using a discrete variable to measure exposure to a drought can be problematic because of two main concerns: the first of these is the loss in variation of data. By using a dummy variable all geographical units with a value of 1 are treated as being uniformly hit by the drought. In reality, the severity of the drought is likely to vary across geographical units. Thus variation in drought intensity is lost when a dummy variable is used to capture exposure to a drought. The second concern relates to the choice of an appropriate threshold for constructing a dummy variable. Mostly authors resort to the official definition of a drought to determine the cut-off point for exposure to drought. This approach becomes problematic when rainfall deviation from the long run average across several geographical units is clustered around the threshold such that a slight rounding off could push the geographical unit from drought affected to the pool of non-drought-affected units or vice versa. In such instances, use of a discrete variable could lead to some degree of arbitrary classification of drought and non-drought affected regions.

Existing studies in the child health literature have analyzed the relationship between early childhood nutrition and various health and schooling outcomes later in life (Handa, S Peterman, Amber, 2006; Tesfu, Solomon Tesfay, 2010; Aubrey, Frederic, 2012). Due to the endogenous nature of the early life health variable, many of these studies have used exposure to shocks measured by exogenous variation in rainfall as an instrument to identify the causal effect of childhood nutrition on future health and schooling outcomes (Tesfu, 2010; Aubrey, 2012). Studies, which have employed this approach, do not tend to focus on the first stage analysis i.e. the relationship between rainfall and endogenous child health. We believe, that the first stage as well as the reduced form second stage is of interest in its own right as it can reveal important insights about the right kind of interventions, which could avert adverse effects of rainfall shocks. At present, large-scale school feeding programs are in place across many developing countries. These programs have been launched on the premise that they would encourage greater school participation, improve nutritional outcomes, and enhance learning. Existing evidence on the effectiveness of such programs in improving schooling and nutritional outcomes is mixed. An in-depth reduced form analysis of rainfall fluctuations during a child's critical growth period and future health outcomes can reveal important insights about the timing and appropriate mix of interventions, which are desirable. For instance a strong and highly significant first stage and reduced form second stage may suggest the need for addressing nutritional deficiencies much earlier (while the child is still in his critical growth phase rather then when he has started school) as well the need for reducing dependence on rain-fed agriculture in rural areas and promoting a diversified cropping system, so that variation in rainfall and its subsequent impact on agricultural production, rural income and children's health outcomes can be minimized. This may call for augmenting school-feeding with nutritional interventions starting earlier than the school entry-age and programs that safeguard agricultural households against risk created by unpredictable fluctuations in rainfall through measures such as reliable access to irrigation facilities, crop varieties that have low water requirements, and a diverse crop base.

Two particular studies, which analyze the direct effect of rainfall shocks while employing a continuous measure for rainfall fluctuations are (Maccini and Yang, 2009) and (Björkman-Nyqvist, Martina, 2013). Maccini and Yang (2009), only focus on long run effects of rainfall conditions during the year of birth on height, education attainment and socio-economic status during adulthood. Björkman-Nyqvist, Martina (2013), on the other hand, focuses on short run effects, by using district level annual rainfall data for the preceding year in order to identify the causal effect of income shocks on children's enrollment and academic performance during the current year in Uganda. The present study departs from these existing studies in that, it uses data that tracks children thrice over the course of a decade. This enables a detailed study of the short as well as the long run effects of exposure to a drought due to a rainfall deficiency on various dimensions of a child's health. A detailed study of short run effects is important for devising appropriate and timely interventions, which can help in averting the adverse consequences of droughts. But, it is equally important to study longer term effects because previous work in the context of Zimbabwe, Ethiopia, and Tanzania shows that timely public interventions immediately following the shock reduced mortality rates but were not effective in protecting households from long run consequences on important dimensions such as education (de la Fuente and Dercon 2008). Therefore findings from this study can provide important lessons for short-term recovery and for long-term protection of shock-exposed households in the post-drought period.

Another novel aspect of this study is that we try to assess how presence of a government assistance program in the child's community during the period of drought was effective in offsetting the deleterious effects of the drought in the short, medium and long term. Two other studies, which look at this issue, are De (2011) and Singh, Park and Dercon (2012). De (2011) studies the long run effect of a drought on height for age z score and the impact of a large scale government program in compensating for the nutritional deficit created as a result of the drought. This study departs from De's work in a number of important ways. To begin with, contrary to De (2011), this paper employs a continuous measure of the drought – using a discrete measure is problematic for reasons discussed earlier in this section. De (2011) only examines the *long run* effect of the drought and the compensating effect of the government program on children's height. In addition to height, I look at how the drought and presence of a government program affected an additional dimension of child health i.e. cognitive development in the *medium* and *long* run. Finally, this paper studies the pure reduced form effect of the drought but it is not clear whether De (2011) is estimating a long run reduced form impact of the drought on child height as, in addition to the drought variable, the model also includes lagged height, recorded immediately after the drought period.

The rest of the paper is organized as follows. Section 2 provides a conceptual framework and a background to Andhra Pradesh. Section 3 discusses the data used for this study. The empirical framework is specified in Section 4. Section 5 presents the results while Section 6 concludes.

2 Conceptual Framework and Background

2.1 Conceptual Framework

In order to understand health outcomes, studies in this area have sketched out a health production function (Grossman (1972), Glewwe and Jacoby (1995), Glewwe and Miguel (2008), De; (2011), Strauss and Thomas 1998), which shows that health outcomes at a particular point in time (H_1) are a function of the child's initial stock of health capital (H_0)[2], time invariant child characteristics (C), and parental or principal care giver's characteristics (P), household characteristics (h_1), investment and inputs in child's health (i_1), prevalent disease environment (D_1) and existing health infrastructure in the community (I_1).

$$H_1 = (H_0, C, P, h_1 i_1, D_1, I_1) \qquad (1)$$

This initial stock of health is in turn determined by a host of factors. (a) household characteristics (h_0), (b) characteristics of parents or the child's principal care giver (P), (c) investment or health inputs which the child receives (i_0), (d) environmental factors (E_0), (e) while η^i, γ^h, ρ^c capture unobserved child, household/parental and community/cultural unobserved factors such as innate healthiness of the child, genetic immunity, innate growth potential etc., parent's health knowledge and cultural norms prevalent in the community which influences intra-household food allocation. Environmental factors stem from (a) shocks experienced by the child and his family (b) the disease environment (D_0), and the initial level of health infrastructure prevalent in the community.

$$H_0 = \left(h_0, P, i_o, E_0\ , \eta^i, \gamma^h, \rho^c\right) \qquad (2)$$

Where

$$E_0 = (sh_0, D_0, I_0) \qquad (2a)$$

In this paper, we focus on two dimensions of health: (i) physical growth as measured by anthropometric indicators; height and weight (ii) cognitive development as measured by test scores.

2.2 Background on Andhra Pradesh

Andhra Pradesh is located in the southeastern part of India. It is considered to be the fifth largest state of India with an area of 275000 Sq. km approximately. According to the census of 2011, the state comprised of a total population of 84.6 million people (84,580,777 individuals)[3]. On the east, the state borders with the Bay of Bengal. Thus, the state is known for its long coastline.

Prior to June 2014, the state of Andhra Pradesh comprised of 23 districts spanning over three regions namely, Coastal Andhra, Rayalaseema and Telangana (Figure 1 A). Each of the three geographical regions was further classified into distinct agro-climatic zones in accordance to the rainfall and temperature of each region. For example, the Telanganga region was divided into the Northern, Central, and Southern Telangana zones, the Rayalaseema region was classified into the Scarce Rainfall zone and the Southern zone while Coastal Andhra

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[2] According to Heckman (2006), the concepts of self-productivity (skill levels in the past determine skill levels in the future) and dynamic complementarities in the context of skills formation (skill levels in the past increase the productivity of future investments) can also be applied to stocks of physical health capital.

[3]http://www.census2011.co.in/census/state/andhra+pradesh.html

comprised of four different agro-climatic zones; the Krishna zone, Godavari zone, North Coastal zone and the High Altitude Zone (Figure 1 B).

On June 2, 2014, the Telangana region comprising of 10 districts was given the status of an autonomous state. Thus, the new state of Andhra Pradesh comprises of thirteen districts only. In this paper, reference will be made to the old state of Andhra Pradesh, before the split took place as it corresponds with data collection under the Young Lives Survey.

The climate of Andhra Pradesh predominantly ranges from being arid to semi-arid. In Coastal Andhra however, the climate ranges between humid and semi-humid. On average, normal rainfall during a year is equal to 940 mm. The state receives two monsoons during the year: the South-West monsoon (during the months of June to September) which contributes 66 percent to the total annual rainfall. The second monsoon period i.e. the North-East monsoon occurs during the months of October to December and contributes around 24 percent to the total annual rainfall. Some limited amount of rainfall (about 10 percent of the annual average rainfall) occurs during the remaining part of the year.

Rainfall patterns vary across the three regions of the state. On average, Coastal Andhra receives the highest (around 1078 mm), followed by Telangana (around 907mm) while Rayalaseema receives the lowest level (around 714 mm) of average annual rainfall during a year[4]. There is also significant hetrogeniety in the degree of rainfall, which occurs across the 3 regions during the monsoon period. South-West Monsoon brings the greatest amount of rainfall in Telangana (716mm), followed by Coastal Andhra (620 mm) and then Rayalaseema (407mm). On the other hand, the North-East monsoon rains are strongest in Coastal Andhra (324mm), followed by Rayalaseem (238mm) and then Telanganga (129mm)[5].

Districts on the western border of the state, spanning over Rayalaseema and the southern Telangana regions are considered to be vulnerable to droughts. These districts include Chittoor, Cuddapah, Anantapur, Kurnool, Mahboobnagar, Rangareddi, Nalgonda and Medak.

The level of agricultural production per hectare varies significantly across the three regions of Andhra Pradesh. Agricultural production levels are highest in Southern Coastal Andhra followed by Telanganga and North Coastal Andhra, while they are lowest in the Rayalaseema region. There is also significant hetrogeniety in the extent of irrigation facilities across the regions. Total area under irrigation as a percentage of net area sown is highest in Coastal Andhra (56.7 percent), followed by Telanganga (41.2 percent) while it is lowest in Rayalaseema (20.8 percent)[6].

To summarize, prevalence of rain-fed agriculture over half of the total cropped area on the one hand, and heavy reliance on tube-wells and wells for irrigation, on the other, makes the quantity and timing of rainfall a critical factor in determining agricultural production across the state.

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[4]National Remote Sensing Centre/Indian Space Research Organisation<http://www.nrsc.gov.in/uim_2014_proceedings/papers_ppts/UIM2014_US5_EVinodKumar.pdf>
[5]National Institute of Disaster Managament, (publication)
[6] Authors own calculations based on data from http://www.ap.gov.in/Other%20Docs/IRRIGATION.pdf

2.3 The Drought of 2002

The Meteorological Department in India defines rainfall as **normal** if it is within -19% and +19% of its long run average, **deficient**, if it is between -20% and -59% from the long run average, and **scant** if it falls below -60% compared to the long run average level. Table 1 shows district wise rainfall during the South West monsoon season (June to September) for the drought year as well average rainfall during the South West monsoon season in each district since 1901. A comparison of rainfall during the South West monsoon season in 2002 and average rainfall based on historical trends, gives a picture of the extent of rainfall deficit, which was experienced, in each district.

3 Young Lives Data

3.1 Child and Household Data

The first round of the Young Lives Survey (2002) provides data for a total of 2011 children, spanning over 3 geographical regions of the state, 7 districts, 20 mandals, and 101 communities.

According to the World Health Organization, a child is classified as moderately malnourished if he (she) has a height (weight) for age z score that is between 2 to 3 standard deviations lower than the median child in WHO's healthy reference population. Furthermore, a child is categorized as severely malnourished if he (she) is 3 standard deviations shorter (lighter) compared to a median child from the reference population. According to this criterion, the incidence of moderate and severe malnutrition is high amongst the Young Lives sample of children. In all, approximately 30 percent children are suffering from moderate or severe malnutrition as measured by height for age and weight for age z scores (Table 2). In other words, one-third children under the Young Lives Survey were stunted and (or) underweight at the time of the first round in 2001.

There are also significant differences in anthropometric indicators of height and weight between boys and girls. On average, boys are *taller* (average height for boys is 72.3 cms while 70.9 cms for girls) and *heavier* than girls (average weight for boys is 8.1 kg relative to 7.4 kg for girls). In standardized z score terms, boys exhibit a lower level of nutrition compared to girls, as shown by a lower average height and weight-for-age z score of boys relative to girls (part (i), Figure 2). Moreover, these gender differences are significant at the 1 percent level of significance

The final summary statistics for the sample are presented in Table 3. The first two sections in this table i.e. physical growth indicators and cognitive test scores provide descriptive statistics for the various dependent variables used in the analysis. At the time of the first round conducted in 2002, an average child was 1.54 standard deviation lighter and 1.26 standard deviation shorter compared to a well-nourished median child in the reference population belonging to a similar age-gender category. The second section of the table shows a logarithmic transformation for all the test score variables. The third section shows the main variable of interest i.e. standardized rainfall z score during the drought period, which ranges between - 0.87 and -1.38. The negative range of the drought rain variable demonstrates that all the districts under study experienced a drought. As far as gender composition 53 percent of the children, which were part of the Young Lives Data Collection, were males. 74 percent of the total children reside in rural areas. An average mother in the sample has completed approximately 4 years of schooling.

3.2 Community Data

Agriculture is the main economic activity undertaken in 85 percent of the surveyed communities[7]. Of the total communities, 83 report that agriculture constitutes the main economic activity for residents of that community. Agriculture is also a leading source of employment in 80 percent of the communities; out of 98, 78 communities report that, agriculture employs the largest number of community residents. In the remaining communities, construction and trade provide the leading source of employment. It is worthwhile to work with the full sample i.e. including those communities where agriculture is not the leading source of employment because occurrence of the drought may affect food availability and subsequent nutrition of children living in these communities through the price channel. A more detailed discussion of the possible channels and pathways through which the drought may affect a child's health and nutrition will be done in section 4.

Community survey also provides information on total land area that is arable and that can be irrigated. Out of the total 101 communities, which were surveyed, information on arable land and irrigated land area is available for 80 and 74 communities respectively. A break down of these communities according to various percentages of arable and irrigated land area, along with the main source of irrigation in the surveyed communities is shown in the following figure (parts (i), (ii) and (iii) in Figure 3). Some observations which can be drawn from this data are as follows: (i) *There is a large share of arable land in a majority of the surveyed communities*; in 61 of the 80 communities for which data is available, more than 50 percent of the land is arable. (ii) *Access to irrigation is not widespread*. In 52 of the 74 communities for which data is available, less than 50 percent of the arable land is irrigated. (iii) *Dependence on rain-fed sources of irrigation is high*; in 48 percent of the surveyed communities the main source of irrigation has been reported to be rainwater or tube-wells (which also rely on rainfall). Observations (ii) and (iii) indicate that the timing and quantity of rainfall is critical for undertaking agricultural activities in the surveyed communities. In addition, part (iv) of Figure 3 also provides a snapshot of the degree of market access, which these communities enjoy. In 68 out of the total sample of surveyed communities (equivalent to 69% as shown in the figure), people have access to a functional daily market in which both food and non-food items can be bought and sold. For the rest of the communities, 16 percent enjoy access to a weekly market while the remaining 14 percent of the communities do not have access to a daily or a weekly market.

[7] Community Data is available for 98 out of 101 communities.

4 Empirical Framework

4.1 Contemporaneous Health Effects of the Drought

In order to estimate the contemporaneous effects of the drought on child health, the following empirical model is specified:

$$\boldsymbol{w_{i.d.r}^{2002}} = \alpha + \beta_1.\boldsymbol{D_{d.r}^{2002}} + \delta.\boldsymbol{X} + \gamma.\boldsymbol{Y} + \lambda.\boldsymbol{pci}_{d.r}^{pre-d} + \boldsymbol{\rho_r} + \boldsymbol{\varepsilon}_{i.d.r} \quad (3)$$

$$\boldsymbol{h_{i.d.r}^{2002}} = \alpha + \beta_1.\boldsymbol{D_{d.r}^{2002}} + \delta.\boldsymbol{X} + \gamma.\boldsymbol{Y} + \lambda.\boldsymbol{pci}_{d.r}^{pre-d} + \boldsymbol{\rho_r} + \boldsymbol{\varepsilon}_{i.d.r} \quad (4)$$

Given the multi-dimensional nature of health, the impact of the drought will be studied on two dimensions of a child's physical growth. These are weight (equation 3) and height (equation 4). Weight reflects the short-term physical health status of the child while height represents a long-term measure reflecting past investments in the child's health. Both weight and height have been expressed in the form of z scores. For each age-gender category, $w_{i.d.r}$ (weight-for-age z score) and $h_{i.d.r}$(height-for-age z score of child *i* residing in district *d* and region *r*) provide standardized measures based on the median child from a healthy reference population. This enables a comparison of the extent to which the sample of surveyed children in Andhra Pradesh are stunted and (or) underweight with respect to a healthy reference population in accordance to World Health Organisation standards.

On the right hand side, the main variable of interest is ($D_{d.r}$)i.e. exposure to drought. This is constructed as shown in equation (5), using monthly, district-wise rainfall data for the drought period. ($D_{d.r}$)is a district level indicator, measuring deviation of cumulative rainfall for the months June to September 2002 ($\sum_m R_d$) from each district's long run average rainfall $\overline{R_d}$over the same months and divided by the standard deviation (σ^{R_d}). District-wise long run average rainfall and its deviation are estimated based on historical rainfall patterns from 1901 to 2000.

$$D_{d.r} = \frac{\sum_m \boldsymbol{R}_d - \overline{R_d}}{\sigma^{R_d}} \quad (5)$$

Employing a continuous measure of the drought is an important feature of this study. Past studies on weather shocks have predominantly used a discrete dummy variable to measure exposure to shocks. For instance, Hoddinotet. al. (2001), Alderman et. al. (2006), De (2011), Mendiratta (2012) etc. all use a dummy variable, which takes a value of 1 if an individual (or household) is exposed to a drought and 0 otherwise. There are at least two concerns, which arise from the use of a dummy variable in this context. The first is loss in variation of data. By using a dummy variable all geographical units with a value of 1 are treated as being uniformly hit by the drought. In reality, the severity of the drought is likely to vary across geographical units. Thus variation in drought intensity is lost when a dummy variable is used to capture exposure to a drought. The second concern relates to the choice of an appropriate threshold for constructing a dummy variable. Mostly authors resort to the official definition of a drought to determine the cut-off point for exposure to drought. In most cases, this implies classifying geographical units with a rainfall deviation that is greater than 1 as drought affected areas. This approach becomes problematic when rainfall deviation from the long run average across several geographical units is clustered around the threshold. This appears to be the case for the districts under study. When rainfall during the drought months is standardized using long run average normal rainfall and its standard deviation, for three of the seven districts i.e. Cuddapah, Mahboobnagar, and Hyderabad, the z score is clustered around 1.Thus, using the criteria as the one used by most extant studies of classifying drought-affected districts as those with a rainfall shortage equivalent to one or more than one standard deviation from the long run average would categorize Mahboobnagar as drought affected while Hyderabad as non-affected, even though rainfall deficit in both districts is almost the same (23% in Hyderabad while 24.5% in Mahboobnagar). This motivates, employing a measure of the drought, $D_{d.r}$.

X is a vector of child, maternal and household characteristics. Child characteristics include gender, age at the onset of the drought and age squared. Maternal characteristics include mother's height and educational attainment while household characteristics include household size and wealth status as measured by ownership of durable assets and land. Y, is a vector of community characteristics. This includes (i) population of the community at the time of the survey and (ii) a dummy variable capturing the presence of a government poverty alleviation program in the community before the onset of the drought. In addition, $(pci_{d.r})$ represents log of district level per capita income for the year preceding the drought. This has been controlled for in order to ensure that the estimate of the district level drought variable is not confounded by other changes, which may have taken place in the district prior to the onset of the drought. Finally, (ρ_r) contains regional level dummy variables in order to account for all kinds of unobserved heterogeneity at the regional level. The model will employ robust standard errors and will be estimated using Ordinary Least Squares estimation technique. Moreover, standard errors will be clustered at the village level.

4.1.1 Drought and Physical Growth

As a first step, we will test whether a reduction in rainfall during a drought exert a negative effect on physical growth (as measured by weight and height) of young children who are in their sensitive growth period. The underlying intuition for this hypothesis stems from existing studies which have shown that droughts are likely to reduce agricultural production, wages and increase food prices (Burgess et. al. 2011). As a result, rural agricultural households are likely to be disadvantaged on two possible accounts: due to reduction in availability of food and due to the threat of a dwindling stream of income. Both factors would reduce a poor family's ability to ensure adequate consumption for all members. For this hypothesis to hold, $\beta_1$should emerge as statistically significant with a positive sign in equations (3) and (4).

4.1.2 Drought, Physical Growth & Access to a Government Safety Net Program

In October 2000, the government of Andhra Pradesh, in collaboration with the World Bank launched a large-scale poverty alleviation program under the name of Andhra Pradesh District Poverty Initiative Program (AP-DPIP) also referred to as the Indira Kranthi Patham (IKP). In the first phase, the program was launched across six poorest districts of the state[8] namely Srikakulam, Chittoor and Vizianagaram (in Coastal Andhra), Mahboobnagar and Adilabad (in Telangana) and Anantapur (in Rayalseema). Under the second phase of the program launched in July 2003, outreach to the program was extended to all remaining districts of Andhra Pradesh.

The program had three main objectives: (a) empowering local communities through the creation of self-help groups and provision of a wide range of credit services through such groups in order to help the needy, (b) improving service delivery of existing institutions such as local government departments and their representatives so that their activities promote inclusion of the poor and the marginalized groups in the community and (c) providing financial support for undertaking projects identified by local self-help groups that may provide missing facilities in the local community. In addition to provision of credit[9] through self-help groups, De (2011) reports that a range of other services such as "food security programs; community managed insurance and initiatives for sustainable agriculture; social action programs (daycare and immunisation booths; nutrition centres; community-managed family counseling centers; early child education centres, etc." were also made available as part of the poverty alleviation program.

Given the sequential phasing out of IKP across the state meant that during the drought of 2002, some districts had access to the program while others did not. This provides an opportunity to test whether access to a major poverty alleviation program before the onset of the drought, helped in offsetting the negative effects of the drought on physical growth of children in drought affected households. The community/village data, which was collected in the Young Lives survey, provides information on whether the sampled community was benefiting from IKP or not. Using this data, the models given in (3) and (4) above are estimated separately for program and non-program communities. This is done in order to test whether the drought had less deleterious effects on physical growth of children in communities, which were benefitting from IKP compared to those, which were not part of the program during the drought period.

4.1.3 Heterogeneous Effects of the Drought

As a third step, I test whether the effect of the drought on a child's physical growth varies by the child's age, gender, household's wealth status and mother's level of education. Heterogeneous effects (if any) are of interest and importance because they could help reveal two important insights: (i) which group is most vulnerable when exposed to a drought and (ii) what kinds of coping strategies could be used by households to offset the negative effects of a drought? To that end, the model is augmented with interaction terms between the drought variable and each of the dimensions of interest.

[8]Districts were chosen on the basis of various socio-economic district level indicators such as a) percentage of population below the poverty line; b) infant mortality and hospital beds/100,000 of population; c) female literacy and female school drop-out rate; d) ratio of scheduled caste/tribe in the population; and e) ratio of gross irrigated area to gross cropped area (De, 2011).

[9]Women in rural households, which were classified as being below the poverty line, were considered eligible for loans.

a) Differential Effects of the Drought within the Critical Growth Period:

Since all the children in the sample were within the first seventeen months of their life, at the time the drought started, they were all going through a critical period of development. That is why a nutritional shortfall is expected to have strong effects on physical growth. We go a step further and posit that even within this age range, some children may be more vulnerable to the shock than others. This would be attributed to differential nutritional intake requirements for children at various stages during this critical phase of development. To test for this the drought rain variable is interacted with child's age in months. Additionally, it may also be the case that children who have transitioned to a solid diet may be more vulnerable to a drought compared to children who are primarily dependent on the mother's milk for their nutrition. Thus, to test whether weaned children experience differential effects of the drought compared to those who are not yet weaned, we interact the drought exposure variable with a categorical variable that is equal to one if the child is more than seven months of age and zero if younger. The cut-off has been kept at seven months because that is the average age in the sample, at which children have been reported as being weaned on to a solid diet.

b) Differential Effects of the Drought across Gender

Many studies have shown that the impact of shocks such as a drought may be sensitive to the gender of the child (Behrman, 1988; Rose, 1999; Alderman and Gertler, 1997; Cameron and Worswick, 2001; Duflo, 2003; Jayachandran, 2006). When resources become scarce, parents may exhibit a gender bias in intra-household resource allocation. Existing studies in the context of South Asia have shown that in most instances, this bias works against females. Girls faced a higher incidence of malnutrition in the face of a drought compared to boys in Rajhisthan, India (Singh, Madhu B., Lakshminarayana, J., Fotedar, R., Anand, P. K., 2006).The adverse effects of natural disasters on physical growth are smaller for boys compared to girls in rural India (Datar, Liu, Linnemayr and Stecher, 2013). On the contrary, in Indonesia, positive rainfall shocks around the time of birth are associated with better health, education and socioeconomic outcomes for adult females but not males (Maccini and Yang, 2009). In order to test for the presence of heterogeneous gender effects in this sample, equations 3 and 4 are augmented with an interaction term between the drought and a dummy variable equal to one (zero) if the child is a male (female).

c) Differential Effects of the Drought by Maternal Education

Next, we postulate that the adverse consequences of the drought may be partially or completely offset for a child who belongs to an educated mother. Studies have shown that maternal education and nutrition are important inputs into a child's health production function (Glewwe and Jacoby; 1995, Hoddinot and Kinssey; 2001, Tesfu; 2010). Maternal education may reflect the mother's health knowledge and behavior, which may determine how she allocates food, and non-food inputs such as age-appropriate vaccinations and timely delivery of medical care if the child is sick. To test for this hypothesis, the drought rain variable is interacted with mothers completed years of school and model (3) and (4) is re-estimated including the interaction term.

d) Differential Effects of the Drought by Wealth

Existing studies have shown that when resources become scarce in the event of a shock, rural households with limited access to credit may use asset sales to cope with the binding resource constraint (Jodha; 1978, Deaton; 1991, 1992, Rosenzweig and Wolpin; 1993, Udry; 1995). As a result, wealthy households may be able to insulate themselves partially (or fully) from the negative effects of the shocks. To test whether this is the case in the context of the 2002 drought in Andhra Pradesh, I focus on two dimensions of wealth i.e. landholding and assets. For the former, I focus on the total landholding owned by the household. For the latter, a wealth index is use to capture the household's socio-economic status which is a weighted average of three main sub-components. These are: (i) the housing quality (HQ) index, (ii) consumer durable (CD) index and (iii) the services index. The HQ index is based on the number of rooms per person and the main materials used for the walls, roof and floor in the household. The CD index is based on ownership of durable assets. The set of assets considered for constructing the CD index are: radio, refrigerator, bicycle, television, motorbike/scooter, car, mobile phone, landline telephone, fan, wardrobe, and clock. Finally, the services index captures whether the household has access to electricity, the source of drinking water, type of toilet facility and the main type of fuel used for cooking by the household. To test for differential effects by wealth levels, the model is augmented with interaction terms between the drought rain variable on the one hand and land and socio-economic wealth variables on the other.

4.2 Medium and Long Term Effects of the Drought

After exploring contemporaneous effects, the next step will be to study the medium and long run effects of the drought on child health. In this part of the analysis, focus will be made on two dimensions of child's health: (i) physical growth and (ii) cognitive development.

In order to the assess the impact of a drought during early life on medium and long run physical growth outcomes of the child, the dependent variable ($\boldsymbol{h_{i.d.r}^{t}}$) will be height for age z score of child *i* in district *d* and region *r* at the time of the second follow-up (*t*= 2007) and the third follow-up (*t*= 2009) as shown in 6. As before, for each age-gender category, height for age z score expresses that child's height with reference to the height of a median child belonging to the World Health Organization's healthy reference population. In order to study the longer run physical growth effects of the drought, analysis will only focus on child height as it is considered a long-term measure reflecting past investments and (or) deprivation in health and nutrition. Weight on the other hand, only captures short run changes in health status. Therefore, it will be excluded from this part of the analysis.

$$\boldsymbol{h_{i.d.r}^{t}} = \alpha + \beta_1.\boldsymbol{D_{d.r}^{2002}} + \beta_2.\boldsymbol{R^{post-d}} + \delta_1.\boldsymbol{X} + \delta_2.\boldsymbol{Y} + \lambda.\boldsymbol{pci}_{d.r}^{pre-d} + \boldsymbol{\rho_r} + \boldsymbol{\varepsilon}_{i.d.r} \quad \textbf{(6)}$$

$where\ t = 2007\ \&\ 2009$

Secondly, the impact of early life exposure to a drought on a child's cognition will be studied.

For this purpose, the following model, as shown by equation 7, is specified.

$$Log(\boldsymbol{s}^{\boldsymbol{t}}_{\boldsymbol{i.d.r}}) = \alpha + \beta_1.\boldsymbol{D}^{\boldsymbol{2002}}_{\boldsymbol{d.r}} + \beta_2.\boldsymbol{R}^{\boldsymbol{post-d}} + \delta_1.\boldsymbol{X} + \delta_2.\boldsymbol{Y} + \lambda.\boldsymbol{pci}^{pre-d}_{d.} + \boldsymbol{\rho_r} + \boldsymbol{\varepsilon}_{i.d.r} \quad \textbf{(7)}$$

$$where t = 2007 \,\&\, 2009$$

Many studies have lent credence to the Barker's hypothesis; the period of gestation is critical for growth and development. Thus, any nutritional deficiency experienced during this time will result in long lasting effects on the individual's well being in later life. A related strand of literature looks at the consequences of shocks experienced during the first 2-3 years of life. Motivated by this strand of literature we postulate that apart from the impact on a child's future health, there may be consequences of early life exposure to a drought on various other aspects of human capital such as cognitive ability, entry into school and grade progression once in school. There are multiple pathways through which this might be the case. These are as follows: A nutritional deficiency during early life, a period critical for the child's growth and development may affect cognition directly by impeding development of the brain and important functions associated with brain activity. This cognitive growth impairment is likely to persist during later life. Malnourishment during an early age may also affect long run cognition indirectly by affecting a child's current and future health. This may cause late entry into school as well as frequent and long absences from school, which could affect knowledge, and learning of the child during school years. In case of both the direct and indirect channel, one would expect a negative impact of drought exposure on long run cognitive abilities.
But if apart from reducing income, production and resources, the drought also changes the relative price of mother's time then the long run consequences of the drought on cognition are likely to be more complex. If wages decrease in the aftermath of a drought and mothers stay at home for longer, this may increase the length of time they nurse the child. Recent evidence in the medical literature has shown that the duration of breast-feeding is associated with an improvement in cognitive development of children in the UK (Quigley, Hockley, Carson, Kelly, Renfrew, Sacker; 2012). If this channel holds, then one would expect a positive impact of the drought on cognition. Given these opposing directions, a priori the relationship between drought exposure and cognitive test scores appears to be ambiguous because it is difficult to predict which of the pathways discussed previously would be driving the results.

Assessment of children's' cognitive abilities under the Young Lives Survey is undertaken through 3 kind of tests. These are: a Mathematics Achievement Test, a Peabody Picture Vocabulary Test (PPVT), and an adapted version of the Early Grade Reading Assessment (EGRA) test. The last component was only administered during the third round while the former two components were administered twice – once in early 2007 and then in late 2009, when these children were 5 and 8 years of age, on average.

The numeracy test in round 2 was based on assessing mathematical concepts relating to quantity such as *few*, *most*, *almost*, *half*, and *as many*. The numeracy test in round 3 had two components: In the first part, children were asked oral questions which comprised of recognition of numbers, simple addition, subtraction and multiplication questions. In the second component, a Math computing booklet was given to the student with a set of questions to be solved. The enumerators recorded number of questions answered by the end of four minutes and then by the end of eight minutes. In the PPVT test, the test administrator would say out a word and show four pictures to the child. The child was required to choose a picture which best suited with the word spoken by the test administrator. In addition to PPVT, an adapted version of the early grade reading assessment (EGRA) test was administered during round 3. The EGRA test is a comprehensive instrument covering all aspects of a child's verbal abilities. The test was composed of an untimed listening and reading comprehension items as well as timed word and passage reading items. For each of the timed reading items, the score was based on number of words correctly read by the child in 60 seconds. In the listening comprehension, the field administrator would read the passage after which the child was asked to answer questions related to the passage. For reading comprehension, each child was asked to read a passage quietly and then answer questions based on the passage.

On the right hand side, the main variable of interest is exposure to drought in 2002 (as shown by $\mathrm{D}_{\mathrm{d.r}}^{2002}$, measured in the same manner as explained in the last section). In order to ensure that the effect of the drought on height and cognition is not confounded by rainfall patterns during the post-drought period, an additional district level variable ($\boldsymbol{R}^{\boldsymbol{post-d}}$) is included in these models (equations 6 and 7). $\boldsymbol{R}^{\boldsymbol{post-d}}$ contains deviation of rainfall from the long run average over all monsoon seasons occurring after the drought till the time of the second (third) follow-up in 2007 (2009). The models also include log of district level per capita income for the year preceding the drought, ($\boldsymbol{pci}_{d.r}^{pre-d}$) in order to ensure that, the effect on height and cognition is not driven by other changes, which may have taken, place before the drought.

As in equations 3 and 4, X is a vector of child, maternal and household characteristics in equations 6 and 7. Equation 6 contains the same controls as equations 3 and 4. In equation 7, child characteristics include some additional child specific controls. These are: child's school entry age, and dummy variables to capture: (i) type of school, and perceptions about (ii) the quality of child's school and (iii) performance of the child in school[10].

Maternal characteristics include mother's height and educational attainment while household characteristics include household size and wealth status as measured by ownership of durable assets and land. Y, is a vector of community characteristics. This includes (i) population of the community at the time of the survey, (ii) a dummy variable capturing the presence of a government poverty alleviation program in the community before the onset of the drought, and dummy variables to capture presence of a (iii) private primary and a (iv) private secondary school in the child's community at the time of the second follow-up in 2007 (when children were of school-going age).

Finally, (ρ_r) contains regional level dummy variables in order to account for all kinds of unobserved heterogeneity at the regional level. The model will employ robust standard errors and will be estimated using Ordinary Least Squares estimation technique. Moreover, standard errors will be clustered at the village level.

[10] Type of school is measured by a dummy variable, which takes a value of 1 if the child's school is private and 0 if it is public. Perceptions about quality of the child's school are measured by a dummy variable, which equal to 1 if parents perceive quality of name's school to be excellent or good. Perceptions about the child's performance are measured by a dummy variable, equal to 1 if parents think their child is performing excellent or good in school.

5 Results

5.1 Contemporaneous Health Effects of the Drought

Table 4 shows the contemporaneous effects of the drought on physical growth indicators; height for age (column 1) and weight for age (column 2).

Results show a direct relationship between rain and anthropometric indicators; height and weight, implying that a decrease in rainfall is expected to decrease a child's height and weight for age. While this relationship emerges as significant for weight (column 2), it is insignificant in the height equation (column 1). On the basis of the estimation results, it can be predicted that a one standard deviation decrease in rainfall during the South West monsoon season, equivalent to 130.3 mm of rainfall, is expected to decrease a child's weight for age by 0.63 of a standard deviation.

5.2 Robustness

As a next step, we check the robustness of results presented in the last section. In order to test whether the relationship between standardized rainfall during the drought months and the child's anthropometric indicators is linear, we augment models 3 and 4 with squared rain terms. Results in columns 1 and 2 of Table 5, show that the squared rain term is insignificant in both the height and weight regression.

The standardized rainfall variable in equations 3 and 4 only accounts for rainfall during the drought months but does not take into account rainfall during prior seasons starting from the time when the child was conceived. It is important to test whether the significance of the drought rain term remains robust once rainfall in the pre-drought period is included in the model. This is because numerous extant studies on child health establish the importance of the in-utero period for a child's wellbeing. Thus by not including this variable, it is not clear whether the significance of the drought rain term captures the effect of the drought per se or whether it captures the cumulative effect of rainfall patterns since the child was conceived. To test for this, equations 3 and 4 are augmented with an additional variable (referred to as rain in the pre-drought period), which is expressed as a z score. It captures the district wise deviation of rainfall from the long run average level for all previous South West monsoons (which also correspond with the kharif growing season) that have occurred since the child was conceived[11]. Results from the augmented model are shown in columns 3 and 4 of Table 5. The coefficient on the rain variable for the pre-drought period is insignificant in both the height and the weight regressions. Moreover, inclusion of the pre-drought variable in the model has hardly any effect on the coefficient and significance of the drought rain variable in both the height and weight regressions.

As a next robustness check, equations 3 and 4 are augmented with the child's birth weight. The main objective is to test whether the significance of the drought rain variable continues to

[11]South-West monsoons accounts for 66 percent of the total annual rainfall in Andhra Pradesh. For young children, (i.e. less than 9 months of age) this variable captures rainfall deviation for the first South-West monsoon season since conception. For older children, (i.e. more than 8 months of age) this variable captures rainfall over past two South West monsoon seasons, which have occurred between the child's conception and the onset of the drought.

hold after controlling for birth weight. These results are shown in columns 5 and 6 of Table 5. As expected birth weight emerges as a highly significant determinant of child's physical growth as given by height and weight for age z score. This indicates that on average, children who weighed more at birth are taller and heavier compared to the ones who weighed less at birth. Inclusion of birth weight does not affect the parameter estimate on the drought rain variable in the height regression. In the weight regression, on the other hand, the coefficient on the drought rain variable increases such that a 1 standard deviation reduction in rainfall from the long run average is expected to reduce weight for age z score by 0.74 (i.e. by three quarters of a standard deviation). This indicates that the significant negative effect of the decrease in rainfall during the drought period is not being driven by the child's initial health at birth. It is also worth noting, that addition of the birth weight variable results in a sharp reduction of the sample size. This owes to the fact that information on birth weight has been reported for less than half of the surveyed children. Thus, while controlling for birth weight appears to improve the fit of the model, it is not included in the main specification in order to keep the full sample.

In columns 7 and 8 of Table 5, a placebo test is conducted in order to establish that the significant impact of the drought rain variable is driven by the drought itself and not by any other district level factors. In order to conduct the placebo test, the drought rain variable is replaced by a placebo district level standardized rainfall variable (expressed as a z score). This placebo rain variable is calculated for the South West monsoon season, which precedes April 2000, that is the time when the eldest child in this sample was conceived. Thus, the placebo rain variable is constructed for June to September 1999[12]. Columns 7 and 8 of Table 5 show that the placebo rain variable is insignificant in both the height and weight regressions. This lends credence to the fact that the drought rain variable in weight regression shown in Table 4 is capturing the effect of the drought per se and not the effect of other factors at the district level.

In conclusion, all the alternate specifications in Table 5 echo the same story regarding the contemporaneous or short run impact of negative rainfall shocks on child health: in the short run, a reduction in rainfall, as is characteristic during a drought period, is expected to reduce a child's weight for age, without having any effect on the child's height.

5.3 Drought and access to a Poverty Alleviation Program

At the time of the first Young Lives Survey from September to December 2002, communities across three of the surveyed districts were benefitting from the Andhra Pradesh District Poverty Alleviation Program (APDPIP). The poverty alleviation program had been ongoing in these districts since 2001, when APDPIP was first launched in six poorest districts of the state. This implies that some communities from Srikakulam, Mahboobnagar and Anantapur were benefitting from the program during the drought period. To test whether children living in such communities were protected from the negative effect of the drought compared to children residing in communities, which did not have access to APDPIP, we

[12] As a further robustness check, the placebo rain variable is also constructed for June to September 1998, but it continues to remain insignificant in both the weight and height regressions.

estimate equations (3) and (4) separately for communities receiving and those not receiving the program while the drought was ongoing. These results are shown in Table 6.

In the short run, the drought does not affect stature of children in either program or non-program communities. This observation is in line with findings from the pooled sample (shown in Table 4) as evident from the insignificance of the drought rain variable in the height regression for both program and non-program communities (columns 1 and 2, Table 6). Children did not experience a reduction in weight in response to the drought in communities receiving the program (column 3, Table 6). But children residing in non-program communities were not protected from the harmful effects of the drought. This can be inferred from the significant and positive coefficient on the drought rain variable in the weight regression for the sample of children in non-program communities (column 4, Table 6).

5.4 Heterogeneous Effects of the Drought

Next, we investigate whether there is any heterogeneity in the contemporaneous impact of a decrease in rainfall during the drought period on child's height and weight. We test whether the adverse impact of the drought varies by child's age, his (her) probable weaning status, gender, maternal education, and household's level of wealth.

5.4.1 Age in months and probable weaning status

There is high correlation between the age and the probable weaning status variables (approximately 85 percent). Therefore to avoid the problem of multi-collinearity, age and probable weaning status along with their interaction terms are included one at a time in the model[13]. These results are shown in Table 7.

The drought rain variable and the drought rain*age interaction term are both individually and jointly insignificant in the height regression (column 1, Table 7), thus providing no evidence that height of children was affected by the drought. In the weight regression, the drought rain*age variable is individually insignificant but the drought rain variable is individually as well as jointly significant with the drought rain*age interaction term (column 2, Table 7). This provides weak evidence to suggest that weight of children was differentially affected by the drought across various age groups for the sample of children under study.

The drought rain*probable weaning status interaction term is significant in both the height as well as the weight regression (Table 7, columns 3 and 4). As explained in section 4.1.3, probable weaning status of the child is a categorical variable that is equal to one if the child is more than seven months of age, where seven months is the average age of weaning reported in the sample. Based on the results, it can be predicted that on its own, exposure to drought did not have a significant impact on stature of children in the short run. However, when interacted with the probable weaning status of the child, results reveal that children who were older than the average age of weaning were significantly affected by the drought. On average, a one standard deviation decrease in rainfall (about 130.33 mm) during the drought months is

[13] The model is also estimated with both variables included simultaneously in the specification. These results are shown in Table B1, Appendix B.

expected to have decreased height-for-age z score by 0.486 of a standard deviation for children who were above the average age of weaning.

Using coefficients on the rain and rain*probable weaning status variables, along with growth standards from the World Health Organization database for height-for-age and weight-for-age, the extent of loss in height (in cm) was calculated for children at various age groups at the time of the drought. These results are shown in Table 8. For instance a one year old child who experienced a one standard deviation decrease in rainfall during the drought, is likely to be 1.22 cm shorter relative to a child not exposed to the drought as well as compared to a child who is seven months or less and hence not likely to have been weaned on to a solid diet.

In the weight regression, the drought rain variable remains significant even after controlling for the rain*probable weaning status interaction term. The interaction term emerges as significant, indicating that the negative effect of a decrease in rainfall during the drought period is expected to have a stronger negative impact on weight-for-age z score for children who are older than 7 months i.e. above the average age of weaning and hence more likely to have been weaned on to a solid diet. For instance, a one-year old child is likely to be 0.6 kg lighter compared to a six month old child, who is likely to be 0.2 kg in response to a one standard deviation decrease in rainfall during the drought period.

There is a general consensus within the child health literature regarding the importance of the critical growth period. These results contribute to the extant literature on child health by showing that even within the first 18 months of life, some children are likely to be more vulnerable to shocks compared to others. Greater vulnerability of children who have been weaned on to a solid diet may stem in part from the income effect. During a drought, with a decline in agricultural production and income, supply of food may decrease due to the liquidity constraint faced by households that are dependent on agriculture for their income. Evidence has shown that apart from income, food prices may also be affected during a drought. Hence as agricultural production goes down, food prices may go up, thus reducing the ability of households to access the same amount of food items as before. So, the income and price effect may explain why children who are above the average age of weaning and have most likely started a solid diet may be more vulnerable during a drought period compared to younger children. A reduction in food availability during a drought period may also affect the nursing mother in which case, the drought may have an equally adverse impact on younger children's nutrition (which lie below the average age of weaning and are solely dependent on their mother's feed). The significance of the interaction term in both the height and weight regression however reveals that the drought exerts a differential impact across both groups of children. This implies that even if nursing mothers experience a negative impact on nutrition due to a drought, the subsequent impact on weight and height of young children is smaller and weaker compared to the impact on elder children that are above the average age of weaning and thus most likely to be deriving a large share of nutrition from a solid diet. This finding resonates the work of Steinberg (2013) who finds that, of all the early life negative rainfall shocks (from in utero till the age of 5), those experienced at age 1 have the strongest negative impact on test scores, grade-for-age, and enrollment.

5.4.2 Gender

The drought rain and gender interaction term emerges as insignificant in both the height and weight regression (columns 1 and 2, Table 9). This indicates that the impact of a decrease in rainfall during the drought period on children's height and weight does not vary across males and females. This is in line with Shah and Steinberg (2013) and Menderitta (2012) who also find that the impact of early life rainfall shocks is not gender sensitive for children in India.

5.4.3 Maternal Education

As a next step, we test whether the impact of a decrease in rainfall during the drought period varies by mother's level of education. To that end, the model is augmented with a drought rain* education interaction term. These results are shown in columns 3 and 4 of Table 9. The interaction term is insignificant in both the height and the weight regressions, indicating that children from more educated mothers are not differentially affected by the drought compared to children from less educated mothers. While the interaction term is insignificant in height and weight regressions (columns 3 and 4, Table 9), both the rain and rain*maternal education variables are jointly significant in the weight regression. This implies that rainfall is in fact important in determining a child's weight-for-age (Column 4, Table 9). One possibility why the interaction term between drought rain and completed years of schooling is not significant could be that the true effect is non-linear because schooling may not lead to substantive learning unless a mother has completed primary school. Instead of using a continuous variable, an alternative approach could be to create discrete categories of the following sort: less than primary schooling, completed primary, less than middle school, completed middle and so on. Keeping in view the extent of variation in the data, with approximately 62 percent of the children in the sample belonging to mothers who have not completed primary school, we construct a single categorical variable, which takes a value of 1 if the child's mother has completed primary or more and 0 otherwise. Upon interacting this categorical variable with drought rain, and after re-estimating the model, we do not find any substantial change in results (shown in Table B2 of the Appendix B). The interaction term remains insignificant in both the height and weight regressions. This suggests that all mothers, irrespective of their education level, always try to do their best in protecting their children against the adverse consequences of a drought.

5.4.4 Assets and wealth

In order to test whether children from wealthier families are protected from the deleterious effects of a decrease in rainfall during a drought, the rain variable is interacted with the total landholdings as well as with the group of asset wealth quintile dummies (columns 1 and 2, Table 10). Asset wealth quintiles are not highly correlated with landholdings[14]. Therefore, both are included simultaneously in the model[15].

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[14] The correlation between landholdings and each of the wealth quintiles starting from the lowest is -7.5, 7, 7.4, -4.8 and -7.6 percent respectively.

[15] The model is also estimated by including asset wealth and land variables separately in the model but there is hardly any improvement in the significance of rain*asset or rain*land interaction terms as shown in Table B3, Appendix B.

All the interaction terms are individually as well as jointly insignificant in the height regression. While the interaction terms are individually insignificant in the weight regression, the drought rain variable along with its interaction terms is jointly significant. These results indicate that the impact of the drought on child's height and weight does not seem to vary by durable asset ownership or landholdings. These findings do not provide much evidence to support the notion that households use assets such as consumer durables and land as a risk coping strategy during hard times.

All of the drought rain interaction terms, i.e. rain with child's age, probable weaning status, gender, maternal education and household's wealth are included simultaneously in the height and weight regression and the models are re-estimated. These results are shown in columns 3 and 4, Table 10. Inclusion of all the interaction terms together wipes away the significance of the drought rain and the rain*weaning status interaction term in the weight regression. Moreover, only the drought rain*probable weaning status interaction emerges as significant in the height regression, reinforcing the results shown in column 3 of Table 5.4A, which indicate that all else equal, children who are more likely to be on a solid diet, experience a negative effect on height-for-age z score in response to a decrease in rainfall during the drought period compared to young children who are solely dependent on their mother's feed for nutrition.

5.5 Pathways

In this section, we try to understand the underlying pathways through which a drought may exert strong contemporaneous effects on a child's physical growth as measured by height and weight. We postulate that a decrease in rainfall during a drought may affect children's height and weight indicators through four possible channels (Figure 4). These are as follows: (i) Income effect, (ii) Price effect (iii) Health behavior effect, and (iv) the Time substitution effect.

A lack of rainfall during a drought is expected to reduce crop yields and agricultural production. Existing literature shows that rainfall patterns are strongly linked with output and agricultural production. In India, Krishna, Rupa, Ashrit, Deshpande and Hansen (2004) find that monsoon rainfall is positively and significantly correlated with total food grain production as well as with the production of major crops such as wheat, rice, sugarcane, groundnut and sorgum. A decline in agricultural production during a drought is expected to have *two* important implications. The first will be: (i) the impact on ***income of households*** that depend on agriculture for their livelihood and the second will be: (ii) the impact on ***prices of food items***. Unlike the income effect, the price channel is likely to affect both agricultural and non-agricultural households. Thus, it may be postulated that a drought is likely to reduce agricultural production and income of households, which rely on agriculture. Secondly, a drought is expected to depress overall supply of output in the market, and bid up prices of food items. Reduction in income of agricultural households on the one hand, and soaring prices of food items on the other may lead to a shortage of food during a drought. Such food shortages may reduce caloric intake, thereby exerting an adverse impact on a child's physical growth.

A reduction in income of agricultural households during a drought period may have additional consequences. For instance, it may lead to a ***change in health behavior*** of the child's caregiver (or mother). Given the binding resource constraint during a drought, the caregiver may not seek vaccinations, medicines or formal medical care (if the child is sick) in an active and timely manner, thereby increasing the child's susceptibility to disease. Therefore, such behavioral changes in the caregiver may impede child's physical growth indicators of height and weight.

In summary, the negative effect of a drought on child's physical growth indicators may be explained by a reduction in household income (income effect), soaring food prices (price effect) or due to behavioral changes, which may reduce the caregiver's probability of seeking appropriate health inputs for the child (health behavior effect).

The community survey in the Young Lives Data provides information on daily wage of adult farm workers. In addition, it provides community level information on prices of three staple food items. These are wheat, rice, and jowar. This information is used to estimate a community level regression model to estimate how a decrease in rainfall during the drought period had an impact on wages (to test for the income effect) and prices of food items (to test for the price effect). In order to investigate the 'health-behavior' channel, we estimate the effect of the drought on the probability of getting the child vaccinated.

A drought is likely to reduce work opportunities and depress wages in the agricultural labor market. This could allow mothers to substitute time expended working outside the home with more time devoted to childcare at home. More time spent at home could also increase the chances of being nursed and the duration for which the mother nurses the child. In fact, Mendiratta (2012) report that during favorable rainfall conditions, mothers are more likely to stop nursing their off spring in order to work on the farm. Baker and Milligan (2008), document a mother's re-joining work as the most important reason for weaning a child off mother's feed. Overall, if the substitution effect were true, one would expect a positive impact of the drought on child's health and nutrition. To examine the substitution effect, we estimate the impact of the drought on number of months, the mother nurses the child.

The results from community level regressions for the impact of a drought on wages and prices are shown in Table 11 while the results from child level regressions on probability of being vaccinated and breastfeeding duration are shown in Table 12.

In the first column of Table 11, the dependent variable is average daily wage of an adult male worker for tilling a farm in his community. The drought rain variable emerges as significant with a positive sign. On the basis of these results, it can be predicted that half a standard deviation decrease in rainfall during the drought period is expected to reduce the average daily wage for tilling by Rs. 57.5. Column 2 (Table 11) shows the effect of the drought on price of staple food items: rice, wheat and jowar. The dependent variable is a price index constructed through principal component analysis using price data for each of the 3 most common staple food items used by the people of Andhra Pradesh. The drought rain variable emerges as significant with a negative sign, implying that a decrease in rainfall during the drought period is expected to raise food prices. Column 1 (Table 12) shows the effect of the drought on probability of getting the child vaccinated. Vaccination is measured by a binary variable which is equal to 1 if the child has received any or all of the following vaccinations: polio, measles and BCG by the time of the survey interview. Given the discrete dependent variable for each child's vaccination status, the model is estimated through a probit estimation strategy and marginal effects are shown in Column 1 (Table 12). While the drought variable emerges as insignificant, the coefficient has the correct sign – a decrease in rainfall during the drought period is expected to reduce the likelihood of the child being vaccinated by 3.5% points. Estimates for the impact of the drought on the duration a child is nursed by his (her) mother are shown in column 2 (Table 12). The dependent variable is given by log of number of months the child is breast fed by his (her) mother. The drought rain variable emerges as insignificant but the sign on the drought coefficient is in line with a priori expectations. The coefficient emerges as negative, indicating that a decrease in rainfall during a drought is, on average, expected to increase the time mothers spend in nursing their infants.

In summary, the results in Table 11 and 12 show that exposure to drought is likely to reduce daily farm wages, and increase price of staple food items. According to a priori expectations, there may be additional consequences of the drought such as the health behavior effect and (or) the time substitution effect. But, results indicate that these latter effects do not seem to play a significant role in explaining the adverse effects of a drought on height and weight indicators of children in the context of Andhra Pradesh, India.

5.6 Medium and Long term health effects of the drought

Results in section 5.1 showed that children exposed to the drought experienced a decrease in weight, but no effect on their stature in the short run. Disaggregated regressions by program and non-program communities in section 5.3 showed that, the adverse effect of the drought on children's weight-for-age occurred in non-program communities only. Furthermore, the discussion in section 5.5 highlighted that the negative effect of the drought on children's height and weight indicators is likely to occur through food prices and daily farm wages.

As a next step, two natural questions arise: (i) does the negative effect of the drought on child height and weight persist in the medium and long run? Secondly, (ii) can access to a government assistance program while the drought was ongoing, safeguard children from deleterious medium and long run health effects of the drought.

If a drought reduces the opportunity cost of a mother's time spent at home, this may increase her time with the child and the duration for which the child is breast-fed. The positive effects of breast-feeding on child's health and nutrition are widely accepted in the medical literature. For this channel to hold, one would expect children exposed to the drought during the breast-feeding phase, to be better nourished contemporaneously and in the medium to long run due to being breast-fed for a longer duration. In the last section, we found no evidence to support the presence of a substitution effect following a drought.

The significant and negative contemporaneous effect of the drought on child's weight for age as presented in section 5.1 and 5.3 suggest that the income and (or) price effects are relevant and that during a drought, rationing of food would negatively affect a child's nutrition by reducing consumption. Nutritional deficiency during early life due to the drought is likely to weaken the child, impair physical growth and increase the susceptibility to disease. In this manner, poor health at the time of the drought may well translate into poor health in the future.

To answer these questions, we re-estimate the height and weight regressions, but this time using child's height and weight measurements when the child is 5 and 8 years of age on average for the pooled sample (shown in column 1 and column 4 of Table 13) and then separately for the sample of children residing in program and non-program communities (shown in columns 2 to 3 and 5 to 6 of Table 13).

Results in Table 13 show that the adverse effect of the drought continues to persist in the medium term as shown by a statistically significant coefficient on the drought rain variable (columns 1 to 3). Results for the pooled sample show that, by the time drought-exposed children reached 5 years of age on average, they had 0.81 of a standard deviation lower height-for-age compared to their counterparts not exposed to the drought. This is expected to translate into an approximate 4 cm loss of height for boys and girls by 5 years of age after experiencing a drought during the first 17 months of their life. Disaggregated regressions show that the negative effect of exposure to a drought during early life on height-for-age by 5 years of age is slightly higher in non-program communities compared to those which were receiving the government program (columns 2 and 3, Table 13).

The impact of the drought remains significant in the long run, i.e. when the children are 8 years of age on average (column 4, Table 13). A one standard deviation decrease in rainfall during the drought period when children were passing through a critical growth period had a long run effect of height: it decreased height-for-age z score of children by 0.54; i.e. half of a standard deviation by the time they were approximately 8 years old. This implies that children exposed to the drought during early life grew up to be 3.5 cm shorter, on average, by the time they were 8 years old, compared to their counterparts who did not experience a drought.

In the pooled sample, while the coefficient remains significant and positive in both the medium and long term regressions (columns 1 and 4, Table 13), implying that a decrease in rainfall during the drought period decreased height-for-age, the magnitude of the coefficient is smaller; 0.54 in the long run regression as opposed to 0.81 in the medium run regression (Table 13) and 0.34 in the short run regression (Table 4). These results suggest that by 8 years of age, drought affected children are able to catch up part of the nutrition, which was lost during earlier years. A comparison of contemporaneous health effects of the drought with medium and long-term effects shows that while the adverse impact persists till the long term, the magnitude of the effect weakens over time. This suggests that children are able to catch up some part of the lost growth over time.

The impact on stature in non-program communities persists in the long run, while it seems to go away in the sample of communities receiving the program.

In order to test whether the relationship between the drought rain variable and height-for-age z score is linear, equation 6 is augmented with a quadratic rain term. These results are shown in Table 14. The quadratic rain term is insignificant implying that the relationship is in fact linear. As a final robustness check, the model is augmented with round 2 and round 3 controls variables and it is re-estimated. These results are shown in Table 15. We do not find any substantial change in the magnitude or direction of relationship between height and the drought rain variable as a result of including round 2 and round 3 control variables.

5.7 Medium and Long-Term Effects of the Drought on Cognitive Development

The dependent variable for each of the regressions in Table 16 are as follows: numeracy test score of the child in round 2 and round 3 (columns 1 and 2), Peabody Picture Vocabulary Test (PPVT) score of each child in round 2 and round 3 (columns 3 and 4) and the composite early grade reading assessment (EGRA) test score at the time of the third round. The latter is constructed through factor analysis based on the child's score on each individual component of the test, which included word reading, passage reading and listening plus reading comprehensions. Further details about what each of these three tests entailed are provided in Section 4.2. The distribution of the five test score variables and their logarithmic transformation is shown in Figures 5 and 6.

Results show a significant and negative effect of a reduction in rainfall during a drought, which was experienced during early life, on cognitive outcomes by the time children reach 5 years of age on average. On average, a one standard deviation reduction in rainfall (equivalent to approximately 130.3 mm of rainfall) during June to September 2002 reduced a child's performance on the numeracy test by approximately 4 points and on the verbal PPVT test by approximately 29 points in the medium term, when the children were 5 years of age on average, several years since the child was first exposed to a drought (columns 1 and 2, Table 16). However, further regressions on cognitive test scores from the third follow-up, when children were 8 years of age on average, show no significant effect of the drought on cognitive development (columns 3, 4 and 5, Table 16).

Results from disaggregated cognitive score regressions are shown in Table 17 (for program communities) and in Table 18 (for non-program communities). These results reinforce some of the earlier findings, which were shown in Table 16. Children exposed to the drought of 2002 obtain lower scores on the numeracy and the PPVT test in 2007. This effect is stronger in communities, which were not benefitting from the government assistance program. For instance, a child who experienced a 1 standard deviation decrease in rainfall during the drought period while he (she) was less than 2 years of age, scored approximately 6 points lower on the numeracy test in a non-program community while his (her) counterpart scored 2 points lower on the same test in a program community (column 1 of Table 17 and Table 18). While we find evidence to support that exposure of the drought during early life had a negative effect on medium term cognitive outcomes, there is no such evidence for longer-term cognitive outcomes (as shown in columns 3 to 6 of Tables 17 and Table 18).

All the regressions reported in Tables 16, 17 and 18 have been estimated through an OLS estimation technique. OLS assumes a continuous dependent variable but the test score variables take on non-negative integer values as shown in Table 3. Because test scores are count variables, and hence not entirely continuous as assumed by OLS, we run two diagnostic checks in order to check the robustness of these results. First, a logarithmic transformation for all the cognitive test score variables is used and cognitive test score regressions are re-estimated through OLS. Second, we obtain Poisson regression estimates for the test score regressions. These results reveal that the adverse medium term consequences of the drought on numeracy and verbal test scores are robust to the alternative specification (employing logarithmic transformation for the dependent variable and re-estimating by OLS) as well as to the Poisson estimation technique. In the interest of space, these results are not shown but are available upon request.

Next, we test whether the relationship between the drought rain variable and the cognitive test score variables is linear or non-linear in nature. To that end, we construct a quadratic term of the drought rain variable and re-estimate the test score regressions including the second order term (Table 19). Results in Table 19 reveal that the quadratic rain term is insignificant across all the cognitive test score regressions. This is indicative of a linear relationship between rainfall and cognitive test score outcomes. As a final robustness check, we re-estimate the cognitive test score regressions including control variables (household size, wealth index, landholding) from the second and the third round conducted in 2007 and 2009 respectively. Results from these augmented regressions do not reveal any substantial changes. The significance and direction of relationship between drought exposure and cognitive test scores continues to hold in these estimations.

To summarize, it can be argued that experience of a drought appears to exert an adverse impact on cognitive outcomes in the medium run but this effect seems to disappear by the time children have reached 8 years of age on average (Table 16). Moreover, this medium run adverse impact of the drought on numerical and verbal cognitive outcomes is weaker in the sample of children residing in program communities compared to those in non-program communities. A comparison of results in Table 13 with results in Tables 16, 17 and 18 reveals that a reduction in rainfall during the drought period exerts a significant and adverse impact on height-for-age and cognitive learning as measured by test scores in the medium run. The negative impact of the drought on test scores disappears in the long term. On the other hand, the negative impact of the drought on height persists in the long term, but is only prevalent in non-program communities. While the adverse effect on stature persists, the magnitude of the effect in the long term is smaller compared to the contemporaneous and medium term effect on height-for-age implying that children are able to catch up some part of their lost nutrition as they age over time.

5.8 Robustness Checks

In this section, we discuss some possible factors, which may be influencing the results on the impact of drought-exposure that have been presented so far.

5.8.1. Selective Migration

A decrease in employment opportunities as a result of the drought could have forced some households to migrate to other districts in search of work. Moreover, if the migrated households are the ones that were most adversely affected by the drought, then one may expect that the results of drought exposure on child health and cognition will be biased downwards. Therefore it is important to investigate whether the analysis conducted so far suffers from sample selection caused by selective migration patterns in the aftermath of the drought.

A first glance at the timing of the drought and data collection for the first round as shown in Figure 7 suggests that the possibility of a sample selection bias due to selective migration may be low. This is because there is hardly any gap between the drought months and those in which data was collected for the first round. The drought occurred from June 2002 to September 2002, while data collection for the first round of the survey started from September 2, 2002 and ended on December 31, 2002. Given data collection commenced right after, and for some households even while the drought was ongoing, implies that there may not have been enough time for households to relocate as a family to a new district.

This is further substantiated by the data, which provides id of the community in which the family was residing at each of the three rounds of data collection. Comparing this information across the three follow-up surveys enables to distinguish households/families, which migrated after the first round of data collection was completed in 2002. In addition, the data also provides information on number of years since each family had been living in their respective community. 86% of the families reported that they had been living in the same place all their life.

In order to check whether selective migration patterns had any impact on the relationship between drought and child's physical growth indicators and cognitive outcomes, we construct a dummy variable in order to identify a household, which migrated after the first, round of data was collected in 2002. The dummy variable is equal to 1 if the family reports a different community number relative to the previous follow-up or if the household reports to be living in the respective community for a period of less than 5 years (the second round of data collection was conducted approximately five years after the first round). This identifier for migrated households is interacted with the drought rain variable and the model is re-estimated including the migration identifier as well as the interaction term in order to test whether the impact of the drought on child's physical growth and cognition varies by the family's migration status. These results (in Table 20) show that the adverse effect of drought exposure on child health and cognition continues to hold even after controlling for the migration status of the child's family between successive rounds of data collection.

5.8.2. Selective Mortality

Data contained in the survey has been collected for young children who survived the drought. But if the drought resulted in higher levels of mortality amongst young children and if the surviving children are systematically different from the ones who passed away, then this may cause the results to be biased. Information about the mother's pregnancies and childbirth history is only available in the first round. Approximately 11% of the mothers (221 out of 2011 in all) report that they lost at least one child over the course of their life. While each mother is asked for the number of her children who passed away, the data is not sufficient to identify when these children died. In order to rule out selective mortality patterns as a possible confounding factor, it is important to establish the timing of death of these children. If they died before the onset of the drought, then one can rule out selective mortality patterns as a possible confounding factor. But in the absence of information on timing, it is difficult to say more on this issue. The low attrition rate (only 2%), however, may suggest that the drought did not cause high levels of mortality between the first, second and third wave of data collection.

5.8.3. Language

A large proportion of the cognitive tests are conducted orally. Therefore it may well be that the lower average test score is not being driven by exposure to the drought. Instead, it is being affected by some unobservable factors such as the child and field administrator's inability to effectively communicate with each other. While the ability to communicate is unobservable, some information on language used by the field administrator and the child could be used as a crude proxy to measure the efficiency of their communication during the test. The survey provides information on the language spoken by each party during the interview and test. I use this information to construct a dummy variable that takes on a value of 1, if both the child and the field administrator used the same language during the test, and 0 if they communicated in different languages. One may assume that conversing in the same language would have allowed the field worker to explain test instructions successfully and it would also have enabled the child to understand the procedure and the materials properly. Findings for the augmented model including the language variable are shown in Table 21. It is clear that results on the adverse medium and long-term effects of drought exposure cognition remain robust to the inclusion of language effects.

6 Conclusion

The broad objective of this research was to explore how exposure to a *drought* during *early childhood* affects human capital formation during later life. For that purpose, we looked at the direct reduced form effect of exposure to a drought on anthropometric indicators as measured by height and weight-for-age and on cognitive development as measured by cognitive test scores at various points in a child's life.

The main research questions that this study aims to answer are as follows: (i) what are the contemporaneous effects of exposure to a drought during the critical growth period on child's height and weight; (ii) Do the effects of exposure to drought on child height persist in the medium and long run? (iii) What are the consequences of exposure to drought on child's cognitive development in the medium and long run (iv) Are the negative effects of the drought on a child's physical growth and cognitive development offset by the presence of a government poverty alleviation program in the child's community?

Some main findings, which emerge from this paper, are that in the short run, a reduction in rainfall, as is characteristic during a drought period, is expected to reduce a child's weight for age, without having any effect on the child's height. While stature of a child is unaffected in the short run, the study finds that by 5 and 8 years of age, children who experienced the drought during early life, grow up to be shorter compared to their compared who did not experience a similar shortfall in rainfall. Moreover, drought exposed children also exhibit a lower score, on average, on numeracy and language tests compared their counterparts in the medium run, when children are approximately 5 years old. By the time children have reached 8 years of age on average, this effect disappears. Thus the adverse impact of the drought on stature seems to persist for longer compared to its impact on cognitive development. Finally, the paper also finds evidence for presence of a government assistance program in the child's community in helping to offset some of the negative consequences associated with the drought of 2002.

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Figure 1 A: **Geographical Regions in Andhra Pradesh**

Figure 1 B: **Agro-Climatic Regions in Andhra Pradesh**

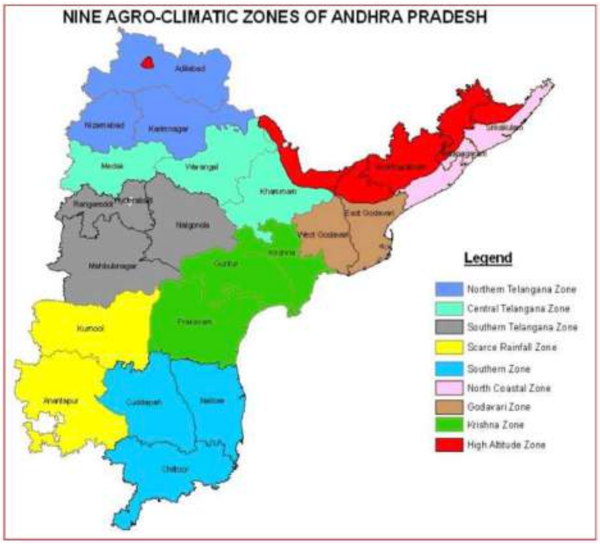
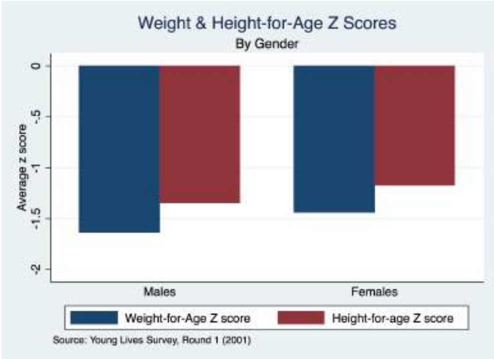
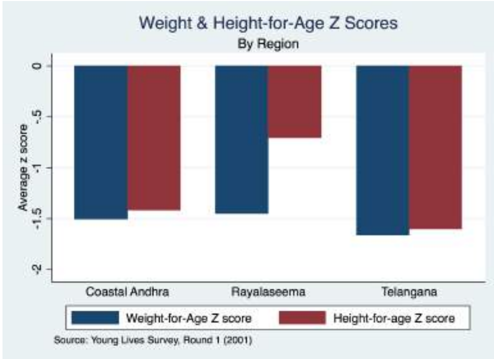


Figure 2: **Descriptive Statistics By Gender and Region**

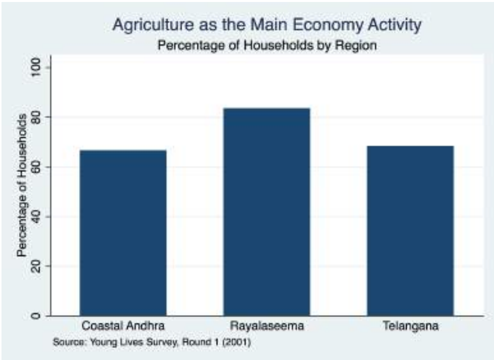
(i)



(ii)



(iii)



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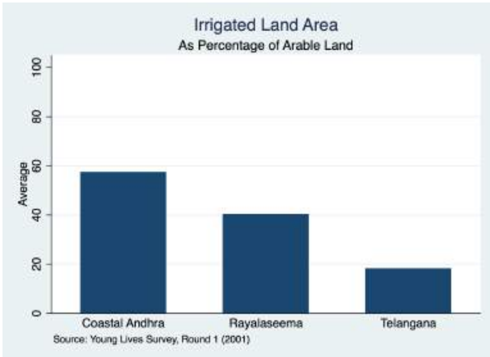
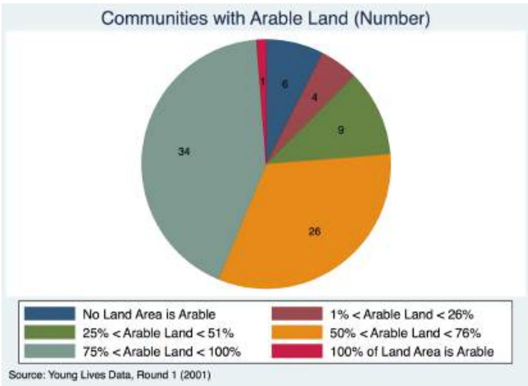


Figure 3: **Number of Communities with Arable and Irrigated Land**

(i)



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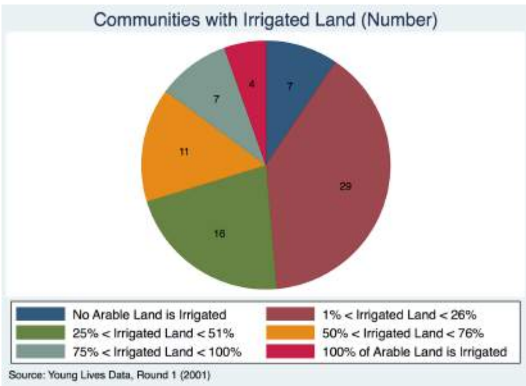
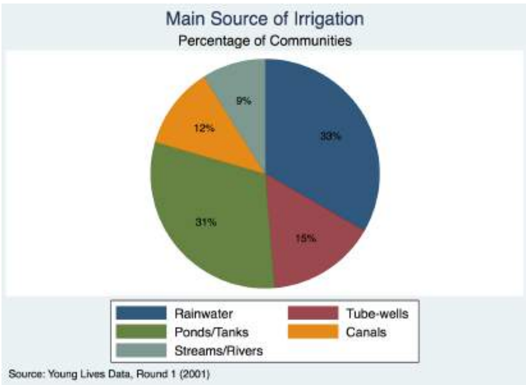
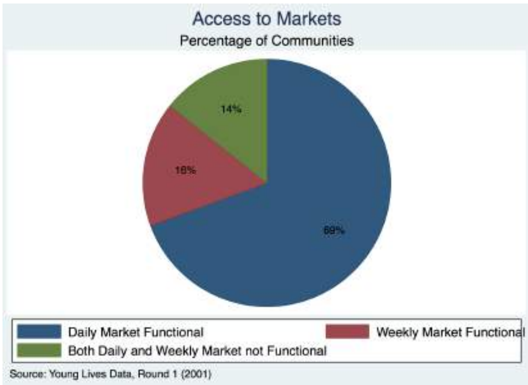


(iii)



(iv)[16]



[16] Due to rounding off to the nearest whole number, the figures in this pie chart add up to 99 instead of 100 percent.

Figure 4: **Underlying Pathways**

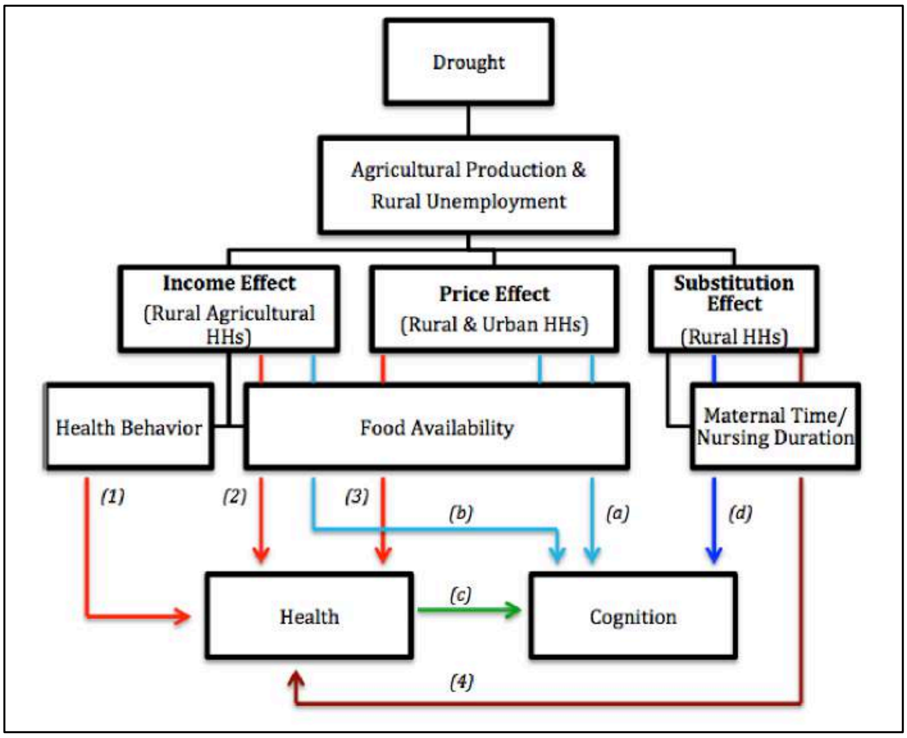
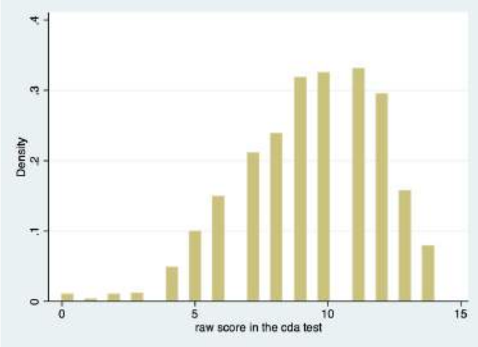
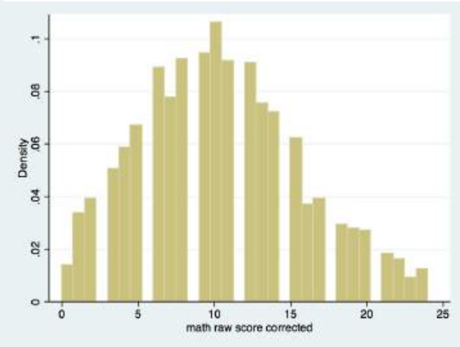


Figure 5: **Distribution of Cognitive Test Score Variables**

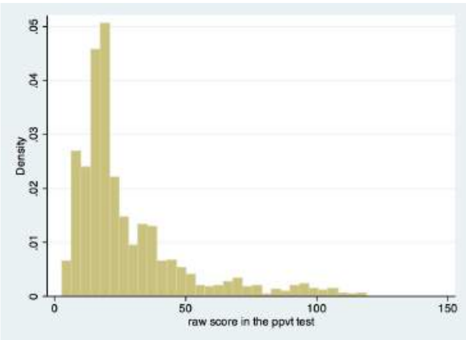
Numeracy Test Score (round 2)



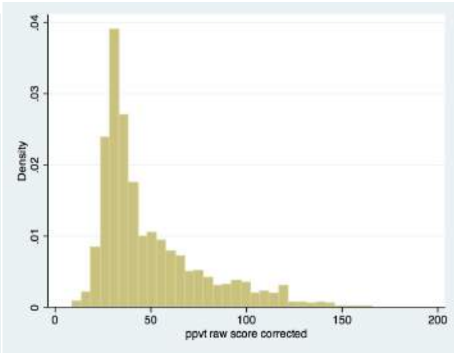
Numeracy Test Score (Round 3)



PPVT Test Score (Round 2)



PPVT Test Score (Round 3)



EGRA Test Score (Round 3)

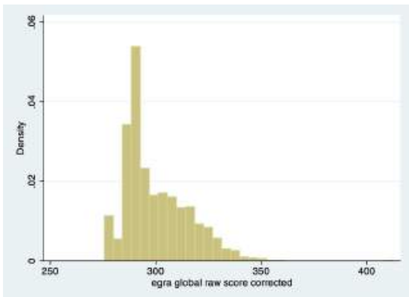
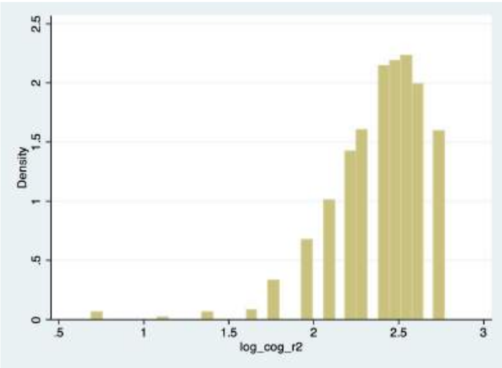
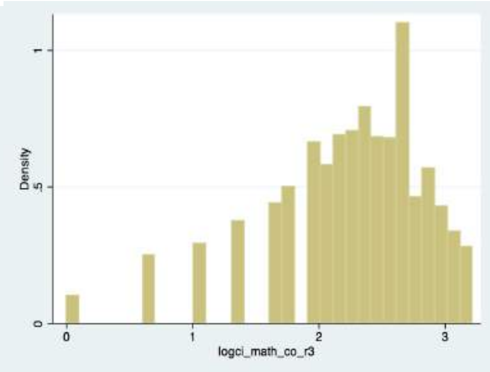


Figure 6: **Distribution of LOG (Cognitive Test Score) Variables**

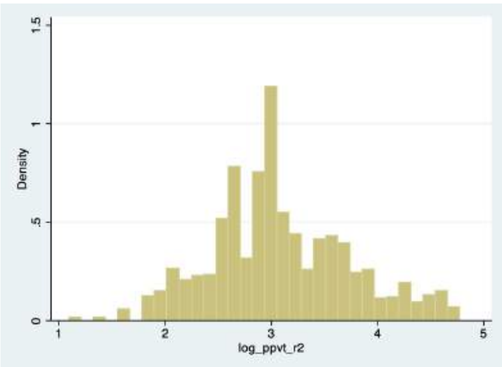
LOG. Numeracy Test Score (Round 2)



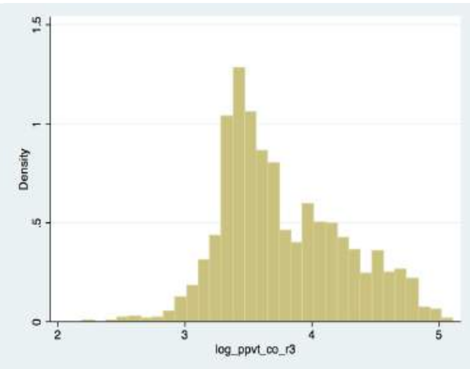
LOG. Numeracy Test Score (Round 3)



LOG. PPVT Test Score (Round 2)



LOG. PPVT Test Score (Round 3)



LOG. EGRA Test Score (Round 3)

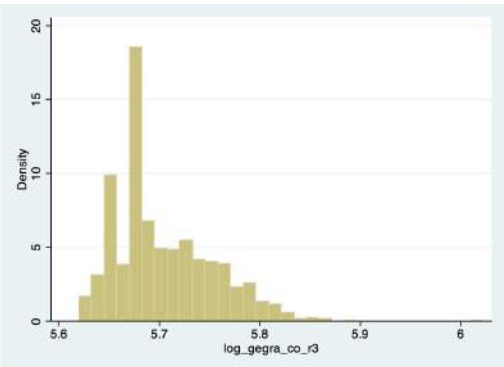


Figure 7 **The Drought of 2002 and Young Lives Data Collection in Andhra Pradesh**

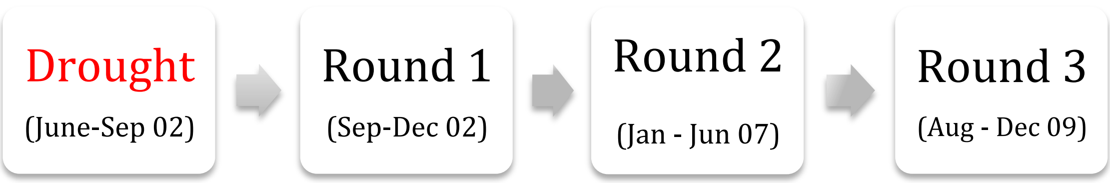


Table 1: **Rainfall During the Drought and Average Long Term Rainfall (District-Wise)**

	Rainfall (2002)	Mean (since 1901)	S.D. (since 1901)	Rainfall Deficit (%)	Rainfall Deficit (z score)
West Godavari	423.4	632.2	150.9	-33.03	-1.38
Srikakulam	496.7	603.9	122.7	-17.75	-0.87
Cuddapah	262.3	367.4	102.6	-28.61	-1.02
Anantapur	235.7	353.0	94.7	-33.23	-1.24
Karimnagar	621.2	764.0	161.8	-18.69	-0.88
Mahboobnagar	359.9	477.0	116.4	-24.55	-1.01
Hyderabad	511.0	664.0	162.8	-23.04	-0.94

Notes: The table shows district wise mean rainfall and standard deviation since 1901. It also shows average rainfall received during the South West Monsoon season in 2002, and the shortfall in rain during this period from the long run average in percentage terms as well as in the form of a z score.

Source: Authors calculations based on rainfall data from India Water Portal

Table 2: **Prevalence of Malnutrition: Stunted and Underweight Children**

		Percentage of children In each category	
Category	**WHO Cut-offs**	**HFA**	**WFA**
Severe Malnutrition	z < - 3	10.13%	9.94%
Moderate Malnutrition	-3 < z =< -2	20.16%	23.24%
Normal Nutrition	-2 < z =< +2	67.55%	66.67%
High Nutrition	z > 2	2.15%	0.15%

Notes: The table shows percentage of stunted and under-weight children in the Young Lives sample comprising of 2011 children .

Table 3: **Summary Statistics**

Variable	Obs.	Mean	Std. Dev.	Min	Max
		Physical Growth indicators			
Z scores					
Weight-for-age_r1	1994	-1.54	1.13	-6.61	2.81
Height-for-age_r1	1955	-1.26	1.44	-4.9	4.99
Height-for-age_r2	1943	-1.64	1.11	-6.74	12.82
Height-for-age_r3	1922	-1.44	1.03	-5.19	5.34
		Cognitive test scores			
Numeracy_r2	1927	9.39	2.6	0	14
PPVT_r2	1851	27.45	21.12	3	119
Numeracy_r3	1904	10.29	5.33	0	24
PPVT_r3	1901	49.25	26.71	9	166
EGRA_r3	1854	300	15	275.89	412.82
		Rainfall Variables			
Pre-Drought Rainfall	2011	0.07	0.45	-0.48	1.20
Drought Rainfall	2011	-1.04	0.17	-1.38	-0.87
Post-Drought rainfall (2006)	2011	1.65	2.87	-1.1	5.82
Post-Drought Rainfall (2008)	2011	4.30	3.47	0.35	9.80
		Child Specific Controls			
Age (months)	2011	11.82	3.49	5	21
Male	2011	0.53	0.49	0	1
		Maternal Controls			
Log (Maternal Height)	2011	5.01	0.04	4.64	5.16
Maternal Completed Years of Schooling	2011	3.29	4.45	0	15
		Household Specific Controls			
Second Quintile_r1	2011	0.31	0.46	0	1
Third Quintile_r1	2011	0.27	0.44	0	1
Fourth Quintile_r1	2011	0.19	0.39	0	1
Richest Quintile_r1	2011	0.08	0.27	0	1
Log (Landholding)	2011	0.70	0.82	0	3.58
HH size_r1	2011	5.42	2.35	2	22
Rural_r1	2011	0.74	0.43	0	1
		District/Community Specific Controls			
Log (Per capita district domestic product)	2011	8.73	0.22	8.46	9.00
Log (Population)_r1	2011	7.75	0.73	6.00	10.30
Government Program_r1	2011	0.64	0.47	0	1

Table 4: **Contemporaneous Health Effects of the Drought**

	(1) zhfa_r1	(2) zwfa_r1
Drought Rain 2002	0.340	0.628***
	[0.30]	[0.21]
Pre Drought Log(Per Capita DDP)	0.972***	0.399*
	[0.29]	[0.22]
Age at onset of Drought	-0.0704***	-0.0440***
	[0.01]	[0.01]
Age Squared	-0.00219	-0.00140
	[0.00]	[0.00]
Male	-0.186***	-0.215***
	[0.05]	[0.05]
Log(Maternal Height)	6.272***	4.762***
	[1.08]	[0.83]
Maternal Education	0.0196**	0.0235***
	[0.01]	[0.01]
Second Quintile	0.141	0.0479
	[0.11]	[0.08]
Third Quintile	0.281**	0.177**
	[0.13]	[0.08]
Fourth Quintile	0.238*	0.205*
	[0.14]	[0.10]
Richest Quintile	0.742***	0.543***
	[0.14]	[0.10]
Log(Landholding)	0.109**	0.0884**
	[0.05]	[0.04]
HH Size	-0.0201	-0.0242**
	[0.01]	[0.01]
Rural	0.0423	-0.303***
	[0.19]	[0.11]
Log (Population)	0.00259	-0.121**
	[0.10]	[0.05]
Integrated Rural Development Program	0.0768	0.142**
	[0.10]	[0.06]
_Iregion_r1_22	0.440***	0.0816
	[0.13]	[0.09]
_Iregion_r1_23	-0.161*	-0.140*
	[0.09]	[0.08]
Constant	-41.21***	-27.20***
	[6.01]	[4.29]
N	1955	1994
R-sq	0.175	0.135
adj. R-sq	0.167	0.127

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variables are height and weight-for-age at the time of the first round, administered in 2002. Standard Errors are shown in parentheses and are clustered at the community level.

Table 5: **Robustness Checks: Contemporaneous Impact of the Drought**

	(1) zhfa_r1	(2) zwfa_r1	(3) zhfa_r1	(4) zwfa_r1	(5) zhfa_r1	(6) zwfa_r1	(7) zhfa_r1	(8) zwfa_r1
Rain 2002	1.245*	1.907***	0.310	0.622***	0.345	0.739***		
	[0.70]	[0.45]	[0.31]	[0.21]	[0.36]	[0.27]		
Rain Squared	8.550	8.06						
	[6.77]	[6.75]						
Pre Drought Rain			-0.0819	-0.0152				
			[0.09]	[0.08]				
Log(Birth weight)_r1					1.288***	1.425***		
					[0.22]	[0.19]		
Rain 99							0.0499	0.158
							[0.29]	[0.10]
		-	-	-	-	-	-	
Constant	-37.30***	21.88***	41.24***	27.21***	52.45***	35.96***	39.85***	-26.68***
	[7.66]	[5.15]	[6.00]	[4.30]	[8.68]	[6.42]	[5.89]	[4.11]
N	1955	1994	1955	1994	858	863	1955	1994
R-sq	0.176	0.139	0.175	0.135	0.215	0.204	0.174	0.131
adj. R-sq	0.168	0.130	0.167	0.126	0.197	0.186	0.167	0.123

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variables are height and weight-for-age at the time of the first round, administered in 2002. Standard Errors are shown in parentheses and are clustered at the community level. A quadratic rain term is added in columns (1) and (2). Columns 3 and 4 control for rainfall prior to the drought, while children's birth weight is added as an additional control in columns 5 and 6. A placebo test is run columns 7 and 8. All the controls shown in Table 4 are also included in the model.

Table 6: **Contemporaneous Health Effects of the Drought: (Program & Non-Program Communities)**

	Program (1) zhfa_r1	**Non-Program** (2) zhfa_r1	**Program** (3) zwfa_r1	**Non-Program** (4) zwfa_r1
Drought Rain 2002	-0.266	0.582	0.197	0.659**
	[0.65]	[0.36]	[0.43]	[0.32]
Pre Drought Log(Per Capita District Domestic Product)	1.389***	0.764**	0.789**	0.0886
	[0.44]	[0.35]	[0.32]	[0.34]
Age at onset of Drought	-0.0788***	-0.0558***	-0.0466***	-0.0367***
	[0.01]	[0.01]	[0.01]	[0.01]
Age Squared	-0.00234	-0.00272	-0.000536	-0.00425
	[0.00]	[0.00]	[0.00]	[0.00]
Male	-0.109	-0.314***	-0.186***	-0.256***
	[0.07]	[0.08]	[0.06]	[0.07]
Log(Maternal Height)	5.031***	9.627***	3.878***	7.453***
	[1.30]	[1.03]	[0.95]	[1.13]
Maternal Education	0.0148	0.0189*	0.0213**	0.0219*
	[0.01]	[0.01]	[0.01]	[0.01]
Second Quintile	0.0140	0.284	-0.0189	0.0634
	[0.12]	[0.20]	[0.09]	[0.14]
Third Quintile	0.201	0.353*	0.115	0.319**
	[0.16]	[0.19]	[0.10]	[0.13]
Fourth Quintile	0.162	0.359*	0.0322	0.492***
	[0.17]	[0.21]	[0.12]	[0.15]
Richest Quintile	0.797***	0.747***	0.503***	0.681***
	[0.23]	[0.20]	[0.15]	[0.15]
Log(Landholding)	0.148**	0.0308	0.136***	-0.0226
	[0.07]	[0.08]	[0.04]	[0.06]
HH Size	-0.0368*	0.00601	-0.0378***	0.000880
	[0.02]	[0.02]	[0.01]	[0.02]
Rural	0.607**	-0.202	-0.169	-0.240
	[0.27]	[0.20]	[0.13]	[0.15]
log(Population)	0.0754	-0.0638	-0.110*	-0.149*
	[0.13]	[0.10]	[0.06]	[0.08]
_Iregion_r1_22	0.186	0.445***	-0.154	0.204*
	[0.33]	[0.15]	[0.22]	[0.12]
_Iregion_r1_23	-0.187	-0.271*	-0.164	-0.222*
	[0.15]	[0.13]	[0.11]	[0.13]
_cons	-40.00***	-55.39***	-26.49***	-37.91***
	[7.49]	[5.34]	[4.92]	[6.53]
N	1261	694	1286	708
R-sq	0.172	0.243	0.098	0.234
adj. R-sq	0.160	0.224	0.086	0.215

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in columns 1 and 2 is height-for-age. The dependent variable in columns 3 and 4 is weight-for-age at the time of the first round, administered in 2002. Columns 1 and 3 are estimated for the sample of children residing in program communities during the drought period while columns 2 and 4 have been estimated for the sample of children residing in non-program communities. Standard Errors are shown in parentheses and are clustered at the community level.

Table 7: **Heterogeneous Effects of the Drought: Age and Probable Weaning Status**

	Age only		***Weaning Status only***	
	(1)	(2)	(3)	(4)
	zhfa1_r1	zwfa_r1	zhfa1_r1	zwfa_r1
Drought Rain	0.33	0.605***	0.142	0.547**
	[0.30]	[0.21]	[0.31]	[0.21]
Rain*age(months)	0.022	0.049	--	--
	[0.05]	[0.04]		
Rain*weaning status	--	--	0.344***	0.136*
			[0.11]	[0.08]
	[0.09]	[0.08]	[0.09]	[0.08]
Constant	-41.11***	-26.98***	-40.95***	-27.10***
	[6.01]	[4.33]	[5.99]	[4.31]
N	1955	1994	1955	1994
R-sq	0.175	0.135	0.180	0.136
adj. R-sq	0.167	0.127	0.171	0.127
F test	0.84	5.38***	6.21***	5.49***

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in columns 1 and 3 is height-for-age. The dependent variable in columns 2 and 4 is weight-for-age at the time of the first round, administered in 2002. In columns 1 and 2, the drought rain variable is interacted with age of the child in months. In columns 3 and 4, the drought rain variable is interacted with probable weaning status of the child. Standard Errors are shown in parentheses and are clustered at the community level. F test conducted to test joint significance of drought and interaction terms. All the controls shown in Table 4 are also included in the model.

Table 8: **Heterogeneous Effects of the Drought by Probable Weaning Status**

	Loss in stature (cm)	Loss in weight (kg)
6 months	0.74	0.22
12 months	1.22	0.61
18 months	1.26	0.75

Notes: Probable Weaning status is a dummy variable equal to one if the child is more than seven months of age at the time of the drought. For a 6 months old child, loss in stature (weight) has been calculated using the coefficient on the rain variable. For a 12 and 18 months old child, loss in stature (weight) has been calculated using the regression coefficients on both rain and rain*weaning status variables.

Table 9: **Heterogeneous Effects of the Drought: Gender and Maternal Education**

	Gender		*Mothers education*	
	(1)	(2)	(3)	(4)
	zhfa1_r1	zwfa_r1	zhfa1_r1	zwfa_r1
Drought Rain	0.419	0.610**	0.105	0.407
	[0.33]	[0.25]	[0.37]	[0.27]
Rain*Male Child	-0.150	0.0338		
	[0.32]	[0.26]		
Rain*Maternal Education			0.048	0.0455
			[0.04]	[0.03]
Constant	-41.17***	-27.21***	-41.46***	-27.43***
	[6.02]	[4.30]	[5.96]	[4.28]
N	1955	1994	1955	1994
R-sq	0.175	0.135	0.176	0.136
adj. R-sq	0.167	0.126	0.168	0.127
F test	0.8	4.45**	1.93	6.02***

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in columns 1 and 3 is height-for-age. The dependent variable in columns 2 and 4 is weight-for-age at the time of the first round, administered in 2002. In columns 1 and 2, the drought rain variable is interacted with a dummy variable equal to 1 if the child is a male. In columns 3 and 4, the drought rain variable is interacted with highest grade completed by the mother. Standard Errors are shown in parentheses and are clustered at the community level. F test conducted to test joint significance of drought and interaction terms. All the controls shown in Table 4 are also included in the model.

Table 10: **Heterogeneous Effects of the Drought: Assets and Land**

	Assets and Land		*All Interactions together*	
	(1)	(2)	(3)	(4)
	zhfa1_r1	zwfa_r1	zhfa1_r1	zwfa_r1
Drought Rain	-0.107	0.185	-0.233	0.000608
	[0.59]	[0.41]	[0.63]	[0.43]
Rain*Age			-0.00746	0.0405
			[0.06]	[0.04]
Rain*weaningstatus			0.355***	0.116
			[0.11]	[0.08]
Rain*Male Child			-0.129	0.0649
			[0.32]	[0.24]
Rain*Maternal Education			0.0311	0.0545
			[0.04]	[0.04]
Rain*Quintile 2	0.532	0.708	0.449	0.645
	[0.60]	[0.47]	[0.61]	[0.48]
Rain*Quintile3	0.382	0.463	0.199	0.275
	[0.65]	[0.38]	[0.70]	[0.38]
Rain*Quintile 4	0.909	0.424	0.714	0.146
	[0.64]	[0.48]	[0.74]	[0.50]
Rain*Richest Quintile	0.733	0.67	0.441	0.243
	[0.63]	[0.42]	[0.73]	[0.47]
Rain*Land	-0.324	-0.0482	-0.334	-0.0620
	[0.25]	[0.18]	[0.24]	[0.17]
Pre Drought Log(Per Capita DDP)	0.884***	0.371*	0.856***	0.366
	[0.30]	[0.22]	[0.30]	[0.23]
Age at onset of Drought	-0.0700***	-0.0440***	-0.0332	0.0130
	[0.01]	[0.01]	[0.06]	[0.01]
Age Squared	-0.00233	-0.00152	-0.00135	-0.00119
	[0.00]	[0.00]	[0.00]	[0.00]
Male	-0.185***	-0.215***	-0.320	-0.146
	[0.05]	[0.04]	[0.33]	[0.25]
Log(Maternal Height)	6.225***	4.774***	6.249***	4.765***
	[1.09]	[0.82]	[1.08]	[0.83]
Maternal Education	0.0184**	0.0234***	0.0513	0.0811**
	[0.01]	[0.01]	[0.04]	[0.04]
Second Quintile	0.687	0.772	0.592	0.704
	[0.61]	[0.48]	[0.62]	[0.49]
Third Quintile	0.672	0.643	0.469	0.444
	[0.65]	[0.40]	[0.70]	[0.41]
Fourth Quintile	1.186*	0.632	0.985	0.349
	[0.65]	[0.51]	[0.75]	[0.53]

Richest Quintile	1.512**	1.231***	1.207*	0.787
	[0.63]	[0.45]	[0.74]	[0.49]
Log(Landholding)	-0.24	0.0368	-0.246	0.0253
	[0.27]	[0.19]	[0.26]	[0.19]
HH Size_r1	-0.0212	-0.0246**	-0.0225	-0.0256***
	[0.01]	[0.01]	[0.01]	[0.01]
Rural	0.0241	-0.299***	0.0118	-0.293***
	[0.19]	[0.11]	[0.19]	[0.11]
log(Population)_r1	0.00704	-0.114**	0.00588	-0.121**
	[0.10]	[0.05]	[0.09]	[0.05]
Integrated Rural Development Program	0.106	0.141**	0.115	0.137**
	[0.10]	[0.06]	[0.10]	[0.06]
_Iregion_r2_22	0.415***	0.0914	0.408***	0.0708
	[0.14]	[0.09]	[0.14]	[0.10]
_Iregion_r2_23	-0.182*	-0.147*	-0.188**	-0.154*
	[0.09]	[0.08]	[0.09]	[0.08]
Constant	-40.67***	-27.52***	-40.48***	-27.51***
	[6.01]	[4.23]	[5.95]	[4.29]
N	1955	1994	1955	1994
R-sq	0.177	0.136	0.182	0.138
adj. R-sq	0.168	0.126	0.171	0.127
F test^	1.48	2.98***	1.82**	2.80***

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in columns 1 and 3 is height-for-age. The dependent variable in columns 2 and 4 is weight-for-age at the time of the first round, administered in 2002. In columns 1 and 2, the drought rain variable is interacted with wealth quintile dummies and the household's landholding. In columns 3 and 4, all the interaction terms are included simultaneously in the model. Standard Errors are shown in parentheses and are clustered at the community level. F test was conducted to test joint significance of drought and interaction terms.

Table 11: **Underlying Pathways: Income and Price Effect of the Drought**

	Income Effect	Price Effect
	(1)	(2)
	Daily Adult Farm Wage	Price Index
Drought Rain	115.5***	-2.363***
	[39.75]	[0.85]
Pre Drought Log (Per Capita DDP)	84.73**	0.299
	[34.79]	[0.51]
Rural	39.26	0.792**
	[26.59]	[0.36]
Log (Population)	-8.16	0.215
	[7.10]	[0.18]
Integrated Rural Development Program	-3.386	-0.621***
	[10.17]	[0.23]
_Iregion_r1_22	32.22*	-1.068***
	[17.53]	[0.35]
_Iregion_r1_23	-8.546	-0.984***
	[7.00]	[0.17]
Constant	-536.5*	-6.268
	[300.44]	[4.73]
N	85	97
R-sq	0.341	0.538
adj. R-sq	0.281	0.502

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. These are community level regressions. The dependent variable in columns 1 is adult daily farm wage. The dependent variable in column 2 is the price index. Standard Errors are shown in parentheses and are clustered at the community level. F test conducted to test joint significance of drought and interaction terms.

Table 12: **Underlying Pathways: Health Behavior & Time Substitution Effect of the Drought**

	Health Behavior (Marginal Effects)	Time Substitution Effect
	(1) Vaccinated	(2) Log (months nursed)
Drought Rain	0.035	-0.0379
	[0.03]	[0.07]
Pre Drought Log(Per Capita DDP)	-0.018	-0.138**
	[0.03]	[0.05]
Age at onset of Drought	0.002	0.0807***
	[0.00]	[0.00]
Age Squared	0.00003	-0.00276***
	[0.00]	[0.00]
Male	0.009	-0.00223
	[0.01]	[0.02]
Log (Maternal Height)	-0.054	0.196
	[0.10]	[0.19]
Maternal Education	-0.0012	-0.00547**
	[0.00]	[0.00]
Second Quintile	0.0056	-0.0566**
	[0.01]	[0.02]
Third Quintile	0.0070	-0.0374
	[0.01]	[0.02]
Fourth Quintile	-0.00839	-0.160***
	[0.02]	[0.05]
Richest Quintile	0.01126	-0.204***
	[0.02]	[0.06]
Log(Landholding)	0.00137	-0.00325
	[0.01]	[0.01]
HH Size	0.00044	0.0000540
	[0.00]	[0.00]
Rural	-0.011607	-0.0595
	[0.02]	[0.05]
Log (Population)	0.00977*	0.0664***
	[0.01]	[0.01]
Integrated Rural Development Program	0.00747	0.000795
	[0.01]	[0.02]
_Iregion_r1_22		0.147***
		[0.03]
_Iregion_r1_23		0.125***
		[0.02]
Constant		2.090*
		[1.11]
N	2011	1930
R-sq		0.441
adj. R-sq		0.436

Standard Errors are shown in parentheses

*, **, *** denote significance at 10%, 5% and 1% respective

Table 13: **Medium and Long Run Health Effects (Pooled Sample, Program & Non-Program Communities)**

	Medium Term			**Long Term**		
	Pooled	**Program**	**Non-Program**	**Pooled**	**Program**	**Non-Program**
	(1)	(2)	(3)	(4)	(5)	(6)
	zhfa_r2	zhfa_r2	zhfa_r2	zhfa_r3	zhfa1_r3	zhfa1_r3
Drought Rain 2002	0.814***	0.800**	1.001**	0.529**	0.128	1.048***
	[0.26]	[0.37]	[0.43]	[0.26]	[0.37]	[0.36]
Post Drought Rain	-0.0256	-0.0489*	-0.0313	0.0451**	0.0670***	-0.001
	[0.02]	[0.03]	[0.02]	[0.02]	[0.02]	[0.02]
_cons	-36.05***	-35.69***	-42.17***	-35.82***	-31.78***	-47.00***
	[4.25]	[5.37]	[6.19]	[3.65]	[4.64]	[4.86]
N	1843	1206	637	1804	1179	625
R-sq	0.182	0.14	0.271	0.217	0.142	0.36
adj. R-sq	0.173	0.127	0.25	0.209	0.128	0.341

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in columns 1, 2 and 3 is height-for-age in round 2 of the survey. The dependent variable in columns 4, 5 and 6 is height-for-age in round 3 of the survey. Columns 1 and 4 show results for the pooled sample. Columns 2 and 5 show results for the sample of children in program communities while columns 3 and 6 show results for children in non-program communities. Standard Errors are shown in parentheses and are clustered at the community level. All the controls shown in Table 4 are also included in the model.

Table 14: **Medium and Long Run Health Effects (with Quadratic Rain Term).**

	(1)	(2)
	zhfa_r2	zhfa_r3
Rain 2002	1.716*	-1.959
	[0.97]	[1.35]
Rain Squared	5.254	-5.81
	[4.48]	[4.28]
	[0.07]	[0.12]
Constant	-34.97***	-45.58***
	[4.31]	[5.94]
N	1843	1804
R-sq	0.182	0.219
adj. R-sq	0.173	0.210

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 is height-for-age in round 2 of the survey. The dependent variable in column 2 is height-for-age in round 3 of the survey. A quadratic rain term is included in the model. Standard Errors are shown in parentheses and are clustered at the community level. All the controls shown in Table 4 are also included in the model.

Table 16: **Medium and Long Run Effects of the Drought on Cognition (Pooled Sample)**

	(1) cog_r2	(2) ppvt_r2	(3) cog_r3	(4) ppvt_r3	(5) egra_r3
Drought Rain 2002	4.283***	28.78***	-0.0984	-10.33	4.198
	[0.82]	[8.72]	[2.24]	[7.86]	[6.40]
Post Drought Rain	0.135**	-0.478	0.365**	-0.13	0.967*
	[0.05]	[0.63]	[0.18]	[0.60]	[0.49]
Constant	-6.271	-152.4**	-6.37	25.86	200.1***
	[9.58]	[66.17]	[21.30]	[83.81]	[56.71]
N	1805	1735	1734	1725	1685
R-sq	0.169	0.339	0.299	0.221	0.205
adj. R-sq	0.16	0.331	0.289	0.209	0.194

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level. These results are for the pooled sample.

Table 17: **Medium and Long Run Effects of the Drought on Cognition (Program Communities)**

	(1) cog_r2	(2) ppvt_r2	(3) cog_r3	(4) ppvt_r3	(5) egra_r3
Drought Rain 2002	2.580**	-12.41	-0.357	-19.84	11.65
	[1.09]	[10.67]	[3.23]	[15.44]	[8.65]
Post Drought Rain	0.0489	-0.682	0.267	-0.00449	0.168
	[0.06]	[0.74]	[0.21]	[0.89]	[0.51]
Constant	-14.01	-233.9***	-29.19	-21.90	85.93
	[11.67]	[77.56]	[23.93]	[113.23]	[61.47]
N	1180	1134	1135	1129	1104
R-sq	0.153	0.186	0.305	0.236	0.207
adj. R-sq	0.139	0.171	0.290	0.220	0.189

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level. These results are for the sample of children residing in program communities.

Table 18: **Medium and Long Run Effects of the Drought on Cognition (Non-Program Communities)**

	(1) cog_r2	(2) ppvt_r2	(3) cog_r3	(4) ppvt_r3	(5) egra_r3
Drought Rain 2002	5.886***	39.49***	-2.144	-2.242	-3.159
	[1.06]	[13.97]	[4.22]	[7.16]	[8.01]
Post Drought Rain	0.250***	-0.293	0.278	-1.968***	1.134*
	[0.05]	[0.91]	[0.31]	[0.56]	[0.67]
Constant	-2.999	-16.72	9.435	-80.98	306.4***
	[15.13]	[139.56]	[46.76]	[141.32]	[101.09]
N	625	601	599	596	581
R-sq	0.208	0.410	0.356	0.260	0.269
adj. R-sq	0.182	0.390	0.329	0.229	0.238

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level. These results are for the sample of children residing in non-program communities.

Table 19: **Medium and Long Run Effects of the Drought on Cognition (Including Quadratic Rain term)**

	(1) cog_r2	(2) ppvt_r2	(3) cog_r3	(4) ppvt_r3	(5) egra_r3
Rain 2002	-2.887	10.47	-7.848	-8.698	4.192
	[3.22]	[48.92]	[7.23]	[45.09]	[23.30]
Rain Squared	8.113	8.6	-53.67	11.30	-0.0435
	[15.40]	[18.69]	[42.26]	[276.27]	[160.71]
Post Drought Rain	0.0840	-4.786***	0.637**	-0.187	0.967
	[0.14]	[1.77]	[0.32]	[1.79]	[0.88]
_cons	-1.842	218.5*	-43.30	33.64	200.1
	[11.00]	[118.84]	[35.69]	[187.29]	[129.28]
N	1805	1735	1734	1725	1685
R-sq	0.169	0.342	0.299	0.221	0.205
adj. R-sq	0.159	0.333	0.289	0.209	0.193

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. A quadratic rain term is included in the cognitive test score regressions. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level.

. Table 20: **Selective Migration**

	(1) Log(cog_ r2)	(2) Log(PPVT _r2)	(3) Log(cog_ r3)	(4) Log(PPVT _r3)	(5) Log(EGRA _ r3)
Drought Rain 2002	0.440***	0.870***	-0.0275	-0.188	0.0135
	[0.08]	[0.23]	[0.21]	[0.13]	[0.02]
Migrated	0.195	0.885	0.594	-0.0281	-0.000220
	[0.14]	[0.61]	[0.43]	[0.38]	[0.03]
Drought Rain*Migrated	0.291*	0.941	0.510	0.0892	0.00308
	[0.16]	[0.76]	[0.54]	[0.40]	[0.03]

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level.

Table 21: **Language Effects**

	(1) Log(cog_r2)	(2) (Log(PPVT_r2)	(3) Log(cog_r3)	(4) (Log(PPVT_r3)	(5) Log(EGRA_r3)
Drought Rain 2002	0.423***	0.897***	-0.0309	-0.191	0.0146
	[0.08]	[0.23]	[0.21]	[0.13]	[0.02]
Same Language	0.0370	0.144*	-0.0229	-0.000690	0.0155***
	[0.03]	[0.08]	[0.03]	[0.05]	[0.00]

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 and 2 are the numeracy and PPVT test score administered in round 2. The dependent variable in columns 3, 4 and 5 is numeracy, PPVT and EGRA test score administered in round 3. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level.

Appendix B

Table B1: **Including rain*age and rain*weaning status together**

	Age & Weaning status	
	(1)	(2)
	zhfa_r1	zwfa_r1
Drought Rain	0.144	0.543**
	[0.31]	[0.22]
Rain*Age	-0.0176	0.0361
	[0.05]	[0.04]
Rain*weaningstatus	0.354***	0.117
	[0.10]	[0.08]
Constant	-41.01***	-26.95***
	[5.99]	[4.35]
N	1955	1994
R-sq	0.180	0.136
adj. R-sq	0.171	0.127
F test^	4.28***	3.96***
F test^^ (rain & rain*age)	0.13	3.89**
F test^^^ (rain & rain*weaning)	6.35***	4.8***

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable in column 1 is height-for-age and in columns 2 weight-for-age at the time of the first round, in 2002. Interactions terms with child's age in months and probable weaning status are added together in the model. All the controls shown in Table 4 are also included in the model. Standard errors are in parenthesis and they are clustered at the community level.
F test^: conducted to test joint significance of drought and interaction terms.
F test^^: conducted to test join significance of drought rain & rain*age interaction term.
F test^^^: conducted to test joint significance of drought rain & rain*weaning status interaction terms.

Table B2: **Robustness: Categorical Variable for Maternal Education**

	(1) zhfa_r1	(2) zwfa_r1
Drought Rain	0.205	0.484*
	[0.37]	[0.28]
Primary or more	0.361	0.422
	[0.37]	[0.33]
Rain*primary or more	0.250	0.268
	[0.34]	[0.31]
Constant	-41.48***	-27.42***
	[6.05]	[4.32]
N	1955	1994
R-sq	0.174	0.132
adj. R-sq	0.166	0.124
F Test (rain, rain*primaryormore)	1.07	5.26***

Standard Errors are shown in parentheses

*, **, *** denotes significance at 10%, 5% and 1% respectively

F test^: conducted to test joint significance of drought and interaction terms

Table B3: **Robustness Check: Including wealth and land separately**

	With wealth & rain*Wealth interactions		**With land and rain*land interactions**	
	(1)	(2)	(3)	(4)
	zhfa_r1	zwfa_r1	zhfa_r1	zwfa_r1
Drought Rain 2002	-0.338	0.0782	0.487*	0.681***
	[0.59]	[0.39]	[0.28]	[0.22]
Rain_Second Quintile	0.491	0.696		
	[0.61]	[0.47]		
Rain_Third Quintile	0.315	0.437		
	[0.65]	[0.38]		
Rain*Fourth Quintile	0.962	0.424		
	[0.63]	[0.47]		
Rain*Richest Quintile	0.796	0.679*		
	[0.61]	[0.41]		
Second Quintile_r1	0.656	0.771		
	[0.61]	[0.48]		
Third Quintile_r1	0.623	0.637		
	[0.64]	[0.40]		
Fourth Quintile_r1	1.275*	0.665		
	[0.65]	[0.50]		
Richest Quintile_r1	1.608**	1.273***		
	[0.62]	[0.43]		
Rain*_Log(Landholding)			-0.310	0.00275
			[0.25]	[0.17]
Log(Landholding)_r1			-0.207	0.105
			[0.27]	[0.19]
Constant	-40.77***	-27.30***	-41.18***	-27.75***
	[6.17]	[4.30]	[6.14]	[4.40]
N	1955	1994	1955	1994
R-sq	0.174	0.133	0.166	0.127
adj. R-sq	0.165	0.124	0.160	0.120
F Test(rain,rain*wealth)	1.02	2.70**		
F Test(rain, rain*land)			2.31	5.07***

Standard Errors are shown in parentheses

*, **, *** denotes significance at 10%, 5% and 1% respectively.