Rainfall Shocks and Child Health in Rural Pakistan[Γ]

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Abstract

I examine the direct reduced form effect of fluctuations in rainfall during agricultural periods preceding pregnancy, during pregnancy and the first year of life on child height in rural areas of Pakistan. I investigate both the short and the long run impact of pre-pregnancy, pre-natal and early life exposure to rainfall, when a child is 4 and 13 years of age, on average. Given the widespread canal irrigation system prevalent in the country, I also investigate how fluctuations in river water flows affect child health. The model is estimated using ordinary least squares. Rainfall data is provided by Pakistan Meteorological Department (PMD), while child level data is from Pakistan Panel Household Survey (2001, 2010). I find that fluctuations in rainfall during the pre-pregnancy period have the most lasting effects on stature of children in the short and long run. A mother who was exposed to a 1 standard deviation reduction in rainfall during the pre-pregnancy period, her child grew up to be 0.17 standard deviations (0.53 cms) shorter by age four. With time, the adverse impact of pre-pregnancy rainfall on height, was only partially compensated. By 13 years of age, the child continued to be 0.12 standard deviations (0.83 cms) shorter, on average. I also find that the average effect of fluctuations in pre-pregnancy rainfall on height of children was smaller in districts that had access to irrigation facilities.

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1. Introduction

Human capital accumulation is a key driver for attaining long run economic growth (Schultz, 1961; Becker, 1962; Mincer, 1958; Mankiw et. al., 1992). Yet, one of the main challenges that developing countries face today is an insufficient level of human capital. Exposure to weather induced shocks (like droughts, famines, floods, tsunamis etc.) is cited as a major factor that affects investment in human capital (Murdoch, 1995). The extent to which human capital investments are affected depends on the ability of poor households to smooth consumption through *formal credit* or *insurance markets* (Udry 1990), *government social protection schemes* or *informal risk sharing mechanisms*[1] (Fafchamps, Udry, Czukas 1998; Jacoby and Skoufias, 1997). While, poor households engage in some degree of consumption smoothing they are unable to safeguard themselves completely against the adverse effects of weather shocks in developing countries (Townsend 1994; Alderman and Paxson, 1994; Murdoch, 1995; Dercon, 2002; Fafchamps and Lund, 2003). Furthermore, if these shocks are experienced during gestation or early life, they are especially costly, having adverse effects on child health (Mendiratta, 2015; Rochas and Soares, 2015), educational attainment (Shah and Steinberg, 2014), adult health and socio-economic status (Maccini and Yang, 2009), as well as labor market productivity and income. Thus, weather-induced shocks have significant short and long run consequences on human capital investments and welfare of poor households in developing countries. The present study is also motivated by a global wave of climate change, due to which, the frequency and severity of weather shocks is expected to rise in the future. Therefore it is important for governments in developing countries to come up with effective strategies in order to minimize the adverse effects of weather shocks.

This is the first paper that examines the short and long run impact of pre-pregnancy, pre-natal and early life exposure to fluctuations in rainfall on child health in rural areas of Pakistan. Pakistan is well suited for this research because of several reasons. It is an agrarian economy, where agriculture accounts for 20.88 percent of GDP and 43.5 percent of the employed labor force. It is the chief source of livelihood for 61 percent of the population (approximately 117 million people) residing in rural areas of the country (Economic Survey 2014-15). Agricultural activity is dependent on rainfall, though this dependence varies across different parts of the country. Pakistan has the second lowest HDI ranking (147), and one of the highest maternal (170), neonatal (46), infant (66) and under-5 child mortality (81) rates in South Asia[2].

I work with a continuous measure of exposure to rainfall shocks, and look at fluctuations in rainfall during the agricultural season(s) preceding pregnancy, during gestation and over the first year after a child's birth. Motivated by the presence of a widespread canal irrigation system that supports agricultural activity in the central, eastern and southern parts of the country, I also investigate how fluctuations in river water flows (which determine water availability through irrigation), over and above rainfall variability affect child health. The analysis focuses on a single dimension,

[1] Informal risk sharing mechanisms include ex-ante diversification of income, ex-post informal borrowing, utilizing asset holdings, increasing labor supply of family members, and (or) cutting back on health and education expenditure in the household.

[2] These estimates are from World Development Indicators Database for year 2015. In case information for that year was missing, estimates are for the most recent year available in the database. Child mortality rates are for per 1000 live births.

which captures long-term investments in child health; that is height. I specify a reduced form model to study the relationship between rainfall and child height. The model is estimated using ordinary least squares technique for two time periods; short and long run when a child is 4 and 13 years of age, on average. The model uses rainfall data provided by Pakistan Meteorological Department (PMD), and child level data from two waves of Pakistan Panel Household Survey (PPHS) conducted in 2001 and 2010 respectively.

The PPHS dataset provides information on households, which span across all four provinces of the country. The wide geographical spread of PPHS dataset makes it unique in several ways. Firstly, there is a wide climatic variation across the districts under study from valleys in Karakoram Mountains in the north, to canal irrigated plains and desert landscapes in the center to coastal regions in the south. Secondly, sources of water for agricultural activity vary greatly across the survey districts; from arid districts in the north to canal-irrigated colonies in the center to arid desert areas spread over western parts of the country. Thirdly, cultural and social practices, which have implications for intra-household allocation of resources, are diverse across the districts under study. The wide geographical, climatic and cultural variations across the survey districts, can be useful in establishing external validity of the findings between rainfall variation and child health in rural Pakistan.

I find that fluctuations in rainfall during the pre-pregnancy period have the most lasting effects on stature of children in the short and long run. When rainfall was 1 standard deviation below normal during the agricultural season preceding a mother's pregnancy, her child grew up to be 0.17 standard deviations, equivalent to 0.53 cms shorter by four years of age, on average. As the child grew older, the adverse impact on height, of pre-pregnancy rainfall, was only partially compensated. By 13 years of age on average, the child continued to be 0.12 standard deviations, i.e. around 0.83 cms shorter relative to someone whose pre-conception period was not marked by a similar reduction in rainfall.

In the short run, the impact of pre-pregnancy rainfall fluctuations on stature is sensitive to prevalent irrigation facilities, age of the child at the time of data collection, and condition of the child's house. The average effect of fluctuations in pre-pregnancy rainfall on height of children was smaller in districts that had access to irrigation facilities. On average, a twenty percent increase in cultivated area under irrigation is expected to have offset 0.06 standard deviations reduction in child height, in response to a 1 standard deviation decrease in rainfall during the pre-pregnancy period. The impact of rainfall fluctuations in the pre-pregnancy period was smaller for children who were four years or older when the first round of data was collected in 2001, probably because these children got a chance to recoup part of their lost stature since their birth. Finally, children from poor households, living in un-cemented houses experienced 0.4 standard deviations reduction in stature relative to children residing in cemented houses who experienced only 0.18 standard deviations decrease in height. These results are not sensitive to a series of robustness checks conducted in the paper.

The analysis in this paper is helpful in identifying the most crucial interval within the critical growth period, during which fluctuations in rainfall are expected to have lasting short and long run effects on physical growth of children. These findings inform us at a time when 33 percent of the population in Pakistan, approximately 64 million individuals, are less than 15 years of age (Economic Survey 2014-15). They can guide public policy on the design and timing of well-targeted and effective interventions to improve the state of maternal and child health in the country and to make this mass of 64 million children vital assets for attaining long run economic growth.

This paper is related to the literature on weather shocks and their impact on welfare of households in developing countries. This strand of literature has shown that lack of rainfall leads to crop failure, decline in per hectare yields and a reduction in agricultural income (Rao, Ray, and Subbarao 1988; Burgess et al. 2011). Other studies have shown short and long term effects of weather induced shocks on human capital outcomes. In Brazil, in-utero exposure to negative rainfall shocks is linked with lower birth weight and a higher mortality rate (Rocha and Soares, 2015). In India, exposure to positive rainfall shocks during gestation and the first three years of life is associated with a greater probability of enrolling in school, a lower probability of repeating a grade and a higher level of cognitive development as measured by children's performance on verbal and numeracy tests (Shah and Steinberg, 2014). In Indonesia, women who experienced higher rainfall during their birth year attained better health and a higher level of schooling as well as socio-economic status as adults (Maccini and Yang, 2009). Contrary to this strand of literature, there is another sub-set of studies which documents a negative relationship between rainfall and human capital accumulation. Mostly in the context of Africa and Mexico, these studies find that excess rain may negatively impact human capital accumulation due to a higher incidence of water-borne diseases and the subsequent rise in morbidity, greater labor force participation of mothers in the agricultural market, and adverse effects of excessive rainfall on crop output (Kim, 2010; Kudamatsu et al., 2010; Skoufias et al. 2011; and Aguilar and Vicarelli, 2011).

This study is also linked with the literature on early child health and nutrition. Starting with Barker's 'fetal origins' idea (1998a, 1998b), it is now well established that early life is a critical period for growth and development. Nutritional insults during this critical period of growth are likely to have long run implications for the child's income, productivity, educational attainment, physical as well as mental health status during adulthood. These long run effects are expected to work through two main pathways. Firstly, inadequate nutrition is likely to affect current health, which is expected to have an adverse effect on future health status, labor market productivity, and income earning potential. Many studies have shown that children with poor health and nutrition during early years grow up to be shorter (Hoddinot and Kinsey, 2001; Alderman, Hoddinot and Kinsey, 2006) and more vulnerable to chronic health diseases (Fogel, 1994; Schultz, 1999; Steckel, 1995; Strauss & Thomas, 1998, Behrman and Rosenzweig, 2004). The second mechanism is predicted to work through schooling and learning; nutritional deficits (for example protein deficits) during early life have been associated with impaired growth of the brain, affecting cognition, and learning (Morgane et al., 1993; Linnet et al., 2006; Mara, 2003 and Shenkin et al., 2004). Adverse nutritional conditions during gestation and early life may also delay entry into school, increase the probability of dropping out of school, as well as reduce years of schooling (Glewwe, Jacoby, and King 2001; Almond and Currie, 2010, Currie, 2009 and Glewwe and Miguel, 2008).

A review of existing literature on rainfall shocks and child health reveals some caveats. To begin with much of this literature relies on a discrete measure of rainfall shock based on aggregate annual deviations in rainfall from the long run average. Using a discrete variable to measure exposure to shock has two main limitations; (i) it loses precision in measuring extent of the shock and (ii) it is sensitive to the cut-off points used for classifying an area as affected or not affected by the shock. Similarly, looking at aggregate annual deviations in rainfall can also be problematic for two reasons. Firstly, if we expect that the dominant pathway through which rainfall variation affects child health is through its impact on agricultural production[3], prices and income in rural areas, then the focus of analysis should be fluctuations in rainfall over the course of an agricultural season, rather than a year. This is because seasonal fluctuations in rainfall should matter in determining the quality of harvest during each crop cycle. Secondly, by looking at annual deviations, we are discounting the possibility of the presence of heterogeneous effects of rainfall shocks during the critical growth period. It is possible that during early life of the child, exposure to fluctuations in rain during some intervals may have more lasting effects than exposure at other periods. Economists have primarily been concerned with studying the effects of exposure to adverse shocks during in-utero and early life. While this period is of great significance there is some epidemiological evidence that shows that maternal health during the period preceding a child's conception has an important bearing on child's health at birth (Bloomfield et al., 2006). In spite of the significance of this period, it has not been studied explicitly in the current literature. A final caveat of extant studies on shocks and child health is that they do not take into account fluctuations in water availability through canal irrigation. This becomes problematic while studying regions in which agriculture is not entirely dependent on rainfall.

The study makes several contributions while addressing caveats within the current literature; i.e. wide use of discrete variables to capture exposure to shocks, reliance on aggregate annual deviations, lack of salience to the pre-pregnancy period, and not accounting for deviations in water available for irrigation purposes in contexts where agriculture is supported by irrigation. I use continuous measures of rainfall shocks and study how fluctuations in rainfall during agricultural periods preceding pregnancy, during pregnancy and the child's first year of life affect height in the future. In addition to rainfall, I also control for deviations in river water flows, which determine water availability for irrigation purposes in large areas of the country. Finally, this is the first study, which explores the direct reduced form relationship between rainfall variation and child height in the context of rural Pakistan. The wide geographic, climatic and cultural variation in households covered by PPHS ensures representativeness of findings for rural Pakistan.

The rest of this study is organized as follows: Section 2 lays out the conceptual framework for examining the relationship between rainfall shocks, and child health at different time horizons, Section 3 discusses data and outlines some background

[3] Burgess et. al. (2011) show that adverse weather conditions in rural areas of India affect mortality rates through their impact on agricultural production, wages and prices. Pakistan falls in the same climatic belt as India, a water scarce country with climate largely ranging from being arid to semi-arid. On the basis of this, it may be expected that agricultural output-wages-prices channel is more likely to hold in the context of rural Pakistan relative to the one working through changes in the disease environment.

characteristics of the area under study. The empirical framework used for the analysis is laid out in Section 4. Section 5 contains a discussion of the main results as well as a series of tests to assess the robustness of findings while Section 6 concludes the paper.

2. Conceptual Framework

In this section, I will outline the conceptual framework used for studying child health. I will heavily draw on previous work by Grossman (1972), Hoddinott and Kinsey (2001) and De (2011).

According to Grossman (1972) health can be considered a 'consumption' as well as an 'investment' commodity. The former implies that having better health gives direct utility to individuals. In addition to direct benefits, it serves as an important input for increasing productivity, time spent in labor market activities, and income. Child health has been studied through a health production function (equation 1), where the total stock of health at a particular point in time (H_1) is a function of some initial stock of health capital(H_0), household characteristics(h_1), inputs invested in child health (i_1), time invariant child (c) and parental (P) characteristics and external factors such as prevalent health infrastructure (I_1) as well as disease environment (D_1) in the child's community.

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

In turn, the initial stock of a child's health (H_0), (equation 2), depends upon household and parental characteristics (h_0 and P), health inputs received by the child (i_o), environmental factors (E_0), (equation 3), such as weather shocks (sh_0), disease environment (D_0), and the initial level of health infrastructure in the community (I_0), as well as unobserved child, household and community level factors[4] (η^i, γ^h, ρ^c) that the child may be exposed to during early life.

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

Where

$$E_0 = (sh_0, D_0, I_0) \qquad (3)$$

Existing literature sheds lights on possible channels through which rainfall shocks may affect child health. While it is possible to discuss likely channel(s) through which rainfall shocks may affect child health, but due to data constraints, it will not be possible to underpin the precise channel(s) with certainty. For negative rainfall shocks, studies have documented two main channels through which child health may be affected adversely. The first of these is the impact of water scarcity on child health through its effect on agricultural production, prices and income in rural areas (Burgess et. al. 2011). The second pathway through which a negative rainfall shock may adversely affect child health is by reducing access to safe drinking water, and

[4] Unobserved factors like 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.

subsequently increasing the incidence of infectious diseases (Rochas and Soares, 2015). On the contrary, some studies have shown that a positive rainfall shock may also be harmful for child health due to its effect on maternal time spent at home, incidence of water-borne diseases, and adverse effects of excess water on agricultural production (Kim, 2010; Kudamatsu et al., 2010; Skoufias et al. 2011, Aguilar and Vicarelli, 2011).

3.0 Data and Summary Statistics

The paper is based on data from three main sources; District level monthly rainfall data comes from Pakistan Meteorological Department (PMD), information on various district level characteristics, is extracted from Provincial Reports of Agricultural Census, 1990, while child and household level data is provided by Pakistan Panel Household Survey (PPHS) for years 2001 and 2010 respectively. The PPHS data spans 14 districts, spread across all four provinces of Pakistan (Figure 3.1). The module containing child health information was administered with ever-married women between 15-45 years who had given birth over the preceding 6 years. The PPHS (2001) sample comprises of 2295 children, who were 1 year or older at the time of the survey.

There is a high prevalence of stunting in the sample of children being studied (Table 3.1). Approximately 60 percent of the children fall in the category of severely or moderately malnourished. Only about one third of the children are adequately nourished. Furthermore, the children under study seem to belong to poor families; a large majority of them are malnourished as discussed above, 87 percent of the mothers are illiterate, another 8 percent have completed primary or less and approximately 63 percent live in a non-cemented house. The sample comprises of an almost equal percentage of boys and girls (Table 3.2).

3.1 Background

Pakistan is an agrarian economy, with agriculture serving as an important source of livelihood across all provinces. According to the Agricultural Census, 2010, approximately, 46, 50, 62 and 99 percent of all households in Sind, Punjab, KP and Balochistan are classified as agricultural households. These include Farm Households[5] as well as Livestock Holders[6].

The climate across most regions of the country is predominantly semi-arid. Within this broad category of climate classification, Pakistan Agricultural Research Council has divided the country into 10 ecological zones on the basis of physiographic characteristics, soil type, agricultural land use and climate. The districts under study fall in various ecological zones, ranging from arid, rain-fed northern districts like Dir and Attock to canal irrigated central districts of KP and Punjab like Mardan, Faisalabad, Hafizabad, and Vehari to canal irrigated sandy desert districts of Southern

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[5] According to the most recent round of Agricultural Census (2010), "Farm Households include households operating any farm area for agriculture purpose irrespective of its ownership and whether operated individually or jointly with other households. Farm household may or may not have any livestock."

[6] According to Agricultural Census (2010), "Livestock Holder is a household having at least one head of cattle and / or buffalo, 5 sheep and / or goats but not operating any farm area."

KP, Southern Punjab and Northern Sindh such as Lakki Marwat, Bahawalpur, Muzaffargarh and Nawab Shah. Within this diverse mix of ecological zones from north to south of the country, there is varying dependence on rainfall.

Pakistan experiences the monsoon season between June and September each year. More than 50 percent of the annual rainfall is received during these summer months (Table 3.3). The degree of dependence on rainfall in these areas hinges upon the availability of canal irrigated water and sub-soil water, accessible through tube-wells. Barring northern districts of Punjab, the rest of the province, receives water through one of the best canal irrigation systems in the world. The canal network extends into Sindh and is the mainstay of agricultural activity in this province. Additionally some areas of Punjab and Sind also benefit from a shallow sub-soil water surface which has made tube-wells an effective means of irrigating land. Given the wide availability of canals and tube-wells in Punjab and Sind, dependence on rainwater is not as severe as in some other areas of North Punjab, KP and Baluchistan that are primarily rain-fed. Figure 3.2 shows percentage of cultivated area, which is irrigated in the sample of study districts.

The agricultural calendar followed across the country can be broken down into two main cropping seasons: Kharif and Rabi. In general, Kharif crops are sown during early summer and harvested in late to early winter, while Rabi crops are sown in early winter and harvested in late to early summer. Cotton, rice, sugarcane, maize and Kharif vegetables are the principal crops grown during the Kharif season while wheat, gram, and Rabi vegetables are the major crops in Rabi season (Agricultural Census Report, 2010). The precise duration of each season varies across as well as within provinces, depending upon the area and the crop being planted. A district wise crop calendar for the areas under study and the main crops grown in each season is shown in Table 3.4.

4. Empirical Framework

I want to understand how fluctuations in rainfall during the pre-pregnancy period, gestation, and the first year after birth may affect a child's physical growth in the short and long run. This is expressed in equation (4.1), where y_{ihdp} is the height-for-age z score observed for child i in household h, district d and province p. Two main factors motivate the use of height-for-age z score as the outcome indicator. Firstly, it has been widely used in the child health as a suitable measure for capturing a person's long-term health. Secondly, the literature has documented that height is correlated with various outcomes during adulthood.

With details on birth, gender and stature of children provided in Pakistan Panel Household Survey (PPHS) Data, the height-for age z score has been estimated using a STATA macro package (2007) provided by the World Health Organization (WHO). The conversion to z score allows a comparison of each child in PPHS with the median child of the same age and gender in the National Centre for Health Statistics (NCHS)/WHO international reference population from United States. A positive (negative) y_i denotes the number of standard deviations by which child i is taller (shorter) than the median child from the reference population. Superscript t denotes two time periods; the short run and the long run. For the short run, I use height-for-age z score measured in 2001 as the dependent variable. For studying long run effects, the dependent variable is height-for-age z score observed in 2010.

$$\boldsymbol{y}_{ihdp}^{t} = \alpha + \beta.\boldsymbol{R} + \varepsilon_{ihdp} \qquad (4.1)$$

On the right hand side, the main variable of interest is rainfall during the year prior to birth and the birth year. Existing studies in this area use annual deviations in rainfall to study the effects of rainfall shocks (Maccini and Yang, 2009; Björkman-Nyqvist, Martina, 2013). The drawback of this approach is that it is likely to suffer from a 'smoothing' effect. By focusing on average annual deviations in rainfall, seasonal variations are smoothed out. This may dampen the effect of rainfall shocks on height as positive deviations may be offset by negative deviations, thus cancelling the effect of each other. A second drawback of this approach is that it does not allow us to comment on the importance of the timing effect in studying the impact of rainfall on the outcome indicator. In the conceptual framework section, we saw that agricultural production is a dominant channel through which the effects of rainfall may transmit onto children's height. These considerations motivate me to define rainfall variables according to agricultural seasons observed in each child's birth district.

In Pakistan, there are two main growing periods during a typical agricultural year. These are kharif (meaning autumn) and Rabi (meaning spring). Kharif crops are typically grown during the summer months and harvested during the autumn months while Rabi crops are generally cultivated during the winters and harvested during spring. Thus, the kharif season normally runs from April to September while the Rabi season extends between October and March. This only provides a general picture of the cropping pattern in Pakistan. There are regional variations in the onset of the kharif and Rabi season. For instance, the kharif and Rabi season commences earlier in districts of Sindh, compared to northern districts of Punjab and Khyber Pakhtunkhwa. Owing to this geographical heterogeneity in cropping patterns across the country, I use the following step-wise approach in order to get an accurate measure of rainfall.

The sample of children surveyed in PPHS was born between 1995 and 2001. Using district wise data on crop area as a percentage of total cropped area from Agricultural Census 1990[7], I first identify the main kharif and Rabi crops grown in each child's birth district. A crop, which has the highest share of cultivated area in each season, is classified as the main kharif and Rabi crop. Next, I find a district wise crop calendar for the key kharif and the rabi crop identified in the preceding step. Table 3.4.1 shows key kharif and Rabi crops and the months over which they are grown for all the sample districts. Wheat is the most widely grown Rabi crop, while cotton and rice are the most common Rabi crops cultivated in the sample districts.

I then synchronize each child's month and year of birth with the kharif and rabi months in the child's birth district. This enables me to identify four agricultural seasons around the time the child is conceived and born. As an example, consider the sub-sample of children born in Faisalabad between January and December 1995, the four seasons of interest used for constructing the rain variables are shown in Table 4.1.

[7] The next round of Agricultural Census statistics were collected in 2000. Using this data did not change the main kharif and Rabi crops identified for each child's birth district through the 1990 Census.

In equation (4.1), $\boldsymbol{R}$ is thus a vector of four rainfall variables, where R_{1dp}^{BC} denotes rainfall in the last agricultural season before conception, R_{2dp}^{IU} shows rain in the agricultural season while the child is in-utero[8], R_{3dp}^{AB1} represents rain during the first agricultural season after birth, while R_{4dp}^{AB2} is rain during the second agricultural season after the child's birth. Subscripts d and p denote district and province respectively. All the rainfall variables have been standardized (as shown in equation 4.2) and represent deviations from long run average rainfall over the given study period. $\sum_m R_{dp}$ is the sum of monthly rainfall over the kharif (or rabi) months in district *d*, province *p*, $\overline{R_{dp}}$ shows long run average rainfall during the kharif (or rabi) season, while $\sigma^{R_{dp}}$ represents standard deviation of rain over the same time period.

$$R_{dp} = \frac{\sum_m R_{dp} - \overline{R_{dp}}}{\sigma^{R_{dp}}} \qquad (4.2)$$

I assume that exposure to inter-district as well as intra-district variations in rain is exogenous relative to children's height for age z score, conditional on controlling for all those factors which may be correlated with height-for-age or rainfall during the period of study. Thus, I modify equation (4.1) so that the basic estimating equation controls for background characteristics as shown in equation (4.3), where $\boldsymbol{X}$ is a vector of child, maternal, household and community characteristics. These include child's gender, age and age square, maternal height, maternal education, condition of the child's dwelling, land ownership status of the household, family's dependency ratio and ratio of district population to health facilities in 1994 (the year preceding the birth of the eldest child in the sample). The term ρ_p represents province fixed effect dummy variables in order to control for time invariant unobserved heterogeneity at the province level, while ε_{ihdp} is the error term. As explained before, *t* represents two time periods; short and long run, using the 2001 and the 2010 rounds of data respectively. I cluster standard errors at the village level[9]. y_i; Height-for-age z score is a continuous variable, so I estimate the basic specification (equation 4.3) using ordinary least squares estimation strategy.

$$\boldsymbol{y}_{ihdp}^{t} = \alpha + \beta_1 R_{1dp}^{BC} + \beta_2 R_{2dp}^{IU} + \beta_3 R_{3dp}^{AB1} + \beta_4 R_{4dp}^{AB2} + \delta.\boldsymbol{X} + \rho_p + \varepsilon_{ihdp} \qquad (4.3)$$

After controlling for background characteristics and provincial fixed effects, I will explore whether the impact of rainfall fluctuations on child height is sensitive to presence of irrigation facilities in the district, as well as various child, parental, household characteristics.

Following a multi-step approach which involved (i) looking at deviations in rainfall over shorter spans of time instead of annual fluctuations and (ii) following a district

[8] Depending on the child's month and district of birth, some children experience two harvests while in-utero. For instance, children born in January or in the months from May to August in Faisalabad experience two harvests as shown in Table 4.1. For such children, R_{2dp}^{IU} denotes average rainfall over both agricultural seasons.

[9] With only 14 districts in the sample, it is not possible to cluster standard errors at the district level.

instead of a national crop calendar for identifying agricultural seasons allows me to define the rain variables more precisely than would otherwise have been possible. However, there may be a possibility of some measurement error in the rain variables. This is because using district level rain variables implicitly assumes that the magnitude of the rain shock is the same for all households within the district. In reality, it is possible to have geographical differences in patterns of rain within the district. I expect this measurement error to be random. While it will not invalidate OLS estimates, it is expected to produce 'attenuation' or downward bias in β.

5. Results

5.1 Short and Long Run Results

Short run refers to the time when children are between 1 and 6 years of age. Long run refers to the time when children are between 9 and 15 years of age.

I estimate the model given in equation 4.3. The impact of rain shocks on height-for-age z score in the short run is shown in column 1 of Table 5.1. Here the dependent variable is children's height-for-age z score observed in 2001 when the first round of PPHS data was collected. The first important finding which can be observed from column 1, Table 5.1 is that rain during the last season before the child is conceived has a significant and positive effect on height-for-age z score. An increase in rain in the last season before conception is associated with an increase in height of children in the short run. Children in districts where rain was 1 standard deviation higher than the normal during the last season before their conception, are 0.17 standard deviations taller compared to children conceived in districts where a similar increase in rainfall did not occur. The second important finding which emerges from column 1, Table 5.1 is that rain during the season of birth has a significant and positive effect on height-for-age z score. On average children who experienced a one standard deviation increase in rainfall during the birth season grew up to be 0.14 standard deviations taller in the short run compared to their counterparts who did not experience an increase in rainfall. The birth season rainfall variable is only marginally significant (at 10 percent) and has a smaller coefficient compared to rain in the last season before conception. A third important observation that can be drawn from column 1, Table 5.1 is that rain in the agricultural season(s) while the child is in-utero and during the second agricultural season after birth does not affect height-for-age z score significantly.

Originating with Barker's ideas about 'fetal origins', it is now well established both in the field of epidemiology as well as economics that nutritional deficiencies during gestation can have lasting effects on a person's life. In light of this stream of literature, one would have expected that rain shocks while the child is in-utero would have significant effects on a child's height in the future but contrary to a priori expectation the in-utero rain variable is insignificant. It would be wrong to interpret this result as implying that gestation is not an important period for development. Instead, the insignificance of this rain variable may be explained by noting that our model only captures changes in rainfall, but not changes in consumption. While it serves as a proxy of the quality of harvest in the child's birth district, it does not inform us about the intra-household pattern of consumption. Therefore, it is possible that a decrease in rain during gestation may not necessarily translate into a decrease in consumption of the expectant mother, because once the family is aware of the pregnancy, it may use alternative mechanisms to ensure that the expectant mother's nutrition is not compromised during this time. More importantly, insignificance of the in-utero rain variable could be explained by the fact that rain is likely to have a lagged effect on income (more on this below). Below normal rain during gestation may have no significant effect on short and long run height if it was preceded by a good harvest in the previous season which allowed the household to realize positive income gains by the time the child was conceived.

A comparison of coefficients on the four rain terms helps us understand the importance of timing in thinking about the effects of rainfall. The insignificance of rain during in-utero and in the second season after birth coupled with the marginal significance of rain during the birth season shows that changes in rain during the last season before the child is conceived is most critical in affecting children's stature. Since this variable captures rain variation ***before*** a child was conceived and born, it is possible to comment on the underlying channel through which it affects children's height. In section 2, I discussed 4 pathways through which fluctuations in rain may affect a child's stature; these included economic effects through output and prices, as well as non-economic effects transmitting through the prevalent disease environment and maternal time inputs invested in the child. Since changes in pre-conception rainfall take place before a child has been conceived or born, it is reasonable to expect that changes in pre-conception rain will affect a child's height through the economic channel; quality of the harvest before conception will affect household income and (or) prices[10]. Both factors may influence maternal consumption, nutrition and through that her child's health once she has conceived. On the contrary, there is no reason to believe that variation in before-conception rain would affect human capital outcomes in the future through non-economic channels such as the disease environment and time inputs.

The long run results, with height-for-age z score in 2010 as the dependent variable, are shown in column 2 of Table 5.1. I find that the short run impact of rain during the birth season on child's height is transitory, dissipating in the long run. On the other hand, the impact of rain during the last season before conception remains persistent. A 1 standard deviation increase in rainfall during the last season before conception is expected to increase height-for-age z score by 0.12 of a standard deviation. Thus a shortfall of rain right before a child has been conceived is expected to have deleterious effects on physical growth, both in the short and the long run. Part of the before-conception-rain effect on stature which manifests in the short run seems to be offset as we move from the short run to the long run. This is evident as we compare the magnitude of β_1 in the short and long run regression. Though the significance level remains at 5 percent, the magnitude of β_1 is smaller in the long run regression compared to the short run regression. This suggests that it is possible for children to adapt and adjust to early life shocks during the growth years.

5.1.1 Is the relationship between rainfall and height linear?

[10] Tiwari, Jacoby, Skoufias (2013) make a similar argument in their paper on rain shocks and child nutrition in Nepal. For children up to 3 years of age, they show that rain during the last completed monsoon season purely captures the income effect while rain during the current monsoon season encompasses the effect on income as well as the prevalent disease environment.

As a next step, I check whether it is correct to model height-for-age z score as a linear combination of rainfall during agricultural seasons surrounding the child's conception and birth. Rainfall is good for height. However, it may be the case that beyond a certain threshold, further increments in rainfall increase height at a decreasing rate. In order words, it is possible that rain shares a non-linear relationship with height-for-age- z score. In order to analyze this, specification (4.3) is augmented with quadratic rainfall terms for each of the four seasons being studied and the results are shown in column 3 (for short run) and column 4 (for long run) in Table 5.1. I find that none of the quadratic rain terms are significant. On this basis, it seems correct to specify height as a linear function of the rainfall variables.

5.1.2 Do positive and negative rain shocks have the same effect on children's stature?

Does the positive sign on the rainfall variables in Table 5.1 suggest that more rainfall is always good for height? It is important to ask this question because existing literature provides mixed results on the relationship between rainfall shocks, and human capital. On the one hand, studies have shown that lack of rainfall has an adverse impact on agricultural production (Rao, Ray, and Subbarao, 1988; Burgess et. al. 2011; Auffhammer, Ramanathan, and Vincent, 2012), child mortality, birth weight and physical growth (Kumar et. al. 2016; Rocha and Soares, 2015; Burgess et. al. 2011), adult health and socio-economic status (Maccini and Yang, 2009), and cognitive development (Shah and Steinberg, 2014). On the contrary, some studies have shown that excess rainfall may increase the incidence of water-borne diseases, and child mortality (Kim, 2010; Kudamatsu et al., 2010) with adverse effects on physical growth and cognitive development (Skoufias et al., 2011; Aguilar and Vicarelli, 2011).

During the time period under study, rainfall variables comprise of both positive and negative deviations. A negative rainfall shock may affect child health adversely either through its impact on agricultural production, income and prices in rural areas or through its impact on the disease environment, quality of drinking water and prevalence of infectious diseases. On the contrary, a positive rainfall shock may have harmful effects on child health by reducing (increasing) the time mothers spend at home (in the agricultural labour market), increasing the incidence of water-borne diseases or by destroying the crop (if it occurs during the cultivation and growth period). In light of these mixed results in the literature, I test whether positive and negative deviations from the long average have the same effect on height, I disaggregate each of the four rainfall variables and re-estimate specification (4.3). The short run results are shown in column 1 while the long run results in column 2 of Table 5.1 B. For each of the four agricultural seasons, I run F tests to check the null hypothesis that positive rain deviations have the same effect as negative deviations on children's height (shown at the bottom of Table 5.1B). On the basis of the F tests, I fail to reject the null for all the rainfall variables. This is not surprising in the context of a water-scarce country, in which the agro-climatic conditions range between arid and semi-arid. Moreover, if we take a closer look at rainfall patterns between 1994 and 2001 (as shown in Figure 5.1), we find that while positive fluctuations in rain were moderate, there were no sharp negative variations in any of the regions under study.

Table 5.1B also reveals that children born in districts where rain was in excess of the long run average before they were conceived are taller on average in the short run (column 1). However this effect disappears by the time children are between 9 and 15 years of age (column 2, Table 5.1B). On the other hand, an increase in rainfall preceding conception of children in districts where rain was less than the long run average, had a stronger impact on children's height in the long run, though the coefficient is less significant (column 2, Table 5.1B). Another way of thinking of this result is that the effect of a negative rain shock before conception during conditions of low rainfall (relative to the long run average) on children's height is persistent and greater in magnitude compared to rainfall fluctuations when they are above the long run average.

5.2 Can access to irrigation mitigate adverse effects of rainfall shocks?

Pakistan is endowed with a widespread canal irrigation system (Figure 5.2). Water is provided by the Indus System of rivers (comprising of River Indus and its western tributaries) through a vast network of dams, barrages and canals (as shown in Figure 5.2). 65 percent of the country's total area falls in the Indus River Basin (Frenken, 2012). This encompasses all of Khyber Pakhtunkhwa and Punjab, large parts of Sind and eastern parts of Baluchistan. Water in the Indus River and its tributaries comprises of water from rains, winter-snow and glaciers as they melt during summers (Frenken, 2012).

In 1960, India and Pakistan signed the Indus Water Treaty in order to settle a water dispute between the two countries regarding the use of Indus waters. According to the treaty, India was granted unrestricted rights for using waters of the three eastern tributaries namely Ravi, Sutlej and Beas, while Pakistan was authorized the use of western tributaries; Chenab and Jhelum. During the early decades after independence, several disputes related to inter-provincial sharing of water for irrigation purposes surfaced on the political front. Motivated by these disputes, a Water Apportionment Accord was passed in 1991, after reaching a consensus on the distribution of water across the four provinces. According to the accord, Punjab, Sind, KP and Baluchistan are allocated 55.94, 48.76, 5.78 and 3.87 million acre feet (MAF) every year. Of these annual flows, 37.03, 33.94, 3.48 and 2.85 MAF of water is received by Punjab, Sind, KP and Baluchistan during the Kharif season while the remaining water is released during the Rabi season. Any remaining river supply which includes flood water is distributed according to the following percentages; 37 percent each for Punjab and Sind, 14 percent for KP and 12 percent for Baluchistan (Ahmad, 2010). Given the division of rivers between India and Pakistan (according to the Indus Water Treaty) and given the fixed formula for water-sharing across provinces (in accordance with the Water Apportionment Accord), the total amount of water available for irrigation during a typical agricultural year depends on river flows in Indus and its western tributaries i.e. Chenab and Jhelum.

Of the sample of fourteen districts which are being studied, nine have access to canal irrigation. In the presence of artificial sources of water for agriculture, it is possible that the extent to which children are affected by the adverse consequences of rainfall fluctuations depends on access to canal irrigation facilities. Furthermore, for these irrigated districts, it is important to recognize that in addition to rainfall, variations in river water flows around the time a child is conceived and born may also be important in affecting agricultural production.

In order to test whether the effect of rainfall shocks varies by the extent of irrigation facilities, I interact rainfall variables with district level indicators on percentage of cultivated area that is irrigated (extracted from Provincial Agricultural Census Reports 1990) and re-estimate specification (4.3). Results for this augmented specification are shown in Table 5.2 (column 1 for short run and column 2 for long run). Three main observations can be made from these results: First, that before-conception rainfall and birth season rainfall emerge as significant. Secondly, availability of irrigation facilities for agriculture may be a successful strategy for protecting children against the negative short run consequences of rain shocks. This is evident from the statistically significant and negative coefficient on the interaction term between rainfall and irrigated land ratio (column 1, Table 5.2). Finally, on average, children are taller in districts with access to irrigation facilities as shown by the significant and positive coefficient on irrigated land ratio (column 1, Table 5.2).

Moreover, in districts where irrigation facilities are available, in addition to rainfall shocks, it is also important to account for changes in river water flows because in these areas river water flows play a critical role in determining water availability as well as quality of the harvest during each agricultural season. Keeping this in mind, I look at deviations in river water flows in the Indus River and its western tributaries between fiscal year 94 and fiscal year 2001 (shown in Table 5.3). As a rule of thumb, I look at deviations in annual river flows for two years. These are (i) for the year which affected the last harvest before a child was conceived and (ii) for the subsequent year. In irrigated districts, depending upon a child's month of conception and the prevalent crop calendar, for some children, the two river flow variables represent deviations in water in the **year of conception** and the **year of birth**, while for other children they represent fluctuations during the **year before conception** and the **year of conception and birth**. For children born in unirrigated districts, both river water variables take on a value of zero. Specification (4.3) is augmented with the two standardized river flow variables and re-estimated. The results are presented in column 3 (short run) and column 4 (long run) of Table 5.2.

Inclusion of the river water variables does not change the pattern of significance of the four rain variables; only before-conception rain is significant while all other rain variables remain insignificant in both short and long run results. Moreover, inclusion of the river water variables increases the coefficient on before-conception rain from 0.173 and 0.118 in the baseline results (columns 1 and 3, Table 5.1) to 0.182 and 0.126 (columns 3 and 4, Table 5.2) for both the short and long run regression respectively. On their own, none of the river water variables are significant in the short run. In the long run, children born in districts with a higher river flow in the year before conception grow up to be taller on average.

Additionally, I run two diagnostic tests; the first is to ensure that modelling a linear relationship between height-for-age z score and river water flows is correct and the second is to check whether positive fluctuations (over and above the long run average) have the same effect on height for age z score as negative deviations in river water flows below the long run average. These results are shown in Table A1

(Appendix A), and A2 (Appendix A) respectively. None of the quadratic river flow terms are significant in the short or the long run regression, supporting the assumption of a linear relationship between river water flows and height-for-age z score (Table A1). Moreover, there is no statistical difference between positive and negative river flow terms in the short or the long run (Table A2).

5.3 Heterogeneous Effects of Rainfall Shocks

In this section, I study whether the effects of rainfall shocks on child height are sensitive to own, maternal and household characteristics. For this purpose, I augment the baseline model (equation 4.3) with interaction terms between rainfall and the variable of interest to gauge whether the effect of rainfall shocks is sensitive to when the child was conceived, child's age, gender, maternal health status, maternal education, whether the child belongs to a farm household, condition and land ownership status of the house.

5.3.1 Does it matter whether the child belongs to the young or the old age cohort at the time of survey?

Evidence from the existing literature suggests that height by the age of 4 years is a good predictor of stature during adulthood (Mortell et. al. 1994). As mentioned earlier, the sample of children under study were between 1 and 6 years of age during the first round of data collection in 2001. This suggests that children in the older cohort (i.e. those between 4 to 6 years) have passed the critical period of early growth and may have had some time to recoup part or all of the negative growth effects of exposure to rain shocks around the time they were conceived and born. To test for this effect, a dummy variable equal to 1 if the child was more than 4 years of age at the time of the survey in 2001 (0 otherwise) is interacted with each of the four rain variables. The baseline model (equation 4.3) is augmented with the 'old cohort' dummy variable as well as the rain*old cohort interaction terms. Short run results are shown in column 1 of Table 5.4, while long run results in column 1 of Table A4 (Appendix A). The pre-conception rain variable along with its interaction with 'old cohort' dummy emerge as significant. The sign on the interaction term is opposite relative to the rain variable, and the magnitude of the coefficient is only slightly smaller than the coefficient on pre-conception rain. These results suggest that older children were able to compensate for the negative growth effects. By 2010, all the children have passed through their crucial growth years, and so we find no differential effect of variations in pre-conception rain on height of children between those who belonged to the old and the young cohort in 2001 (column 1, Table A4, Appendix A).

5.3.2 Does it matter whether the child is male or female?

Contrary to extant studies, my findings do not support presence of a pro-male gender bias in the allocation of food and other inputs which determine a child's nutrition at an early age. This is evident from the insignificant interaction terms between rainfall variables and a dummy, which is equal to 1 (0) if child is a male (female) in both the short and long run regressions (column 2 of Table 5.4 and A4)

5.3.3Does it matter whether the season before the child's conception is Kharif or Rabi?

So far I find that rainfall fluctuations in the last season before conception have a significant effect on children's stature in the short run. This effect remains persistent in the long run. A related question, which arises, is that, does the impact of rainfall variation during the last season preceding conception, vary by whether this season is Kharif or Rabi? This question is of interest for two main reasons. The first relates to the Kharif and Rabi cropping pattern prevalent in the country. Two of Pakistan's leading export commodities i.e. cotton and rice are grown during the Kharif season. Between 1990 and 2000, cotton and rice accounted for 51% and 6% of the country's total exports, on average[11]. During the winter season, wheat is the main Rabi crop in Pakistan and serves as the primary staple food for the people. Since Rabi is associated with growth of a food crop while Kharif with cultivation of cash crops, it is possible that the income effect associated with rain-induced fluctuations of agricultural production will be stronger for the Kharif season. The second reason is related with distribution of rain through the agricultural year. With the exception of Dir, Lakki Marwat and Mardan, more than 50 percent of annual rainfall occurs during the monsoon season spread over June to September (Table 3.3). Variation in summer rainfall has immediate consequences in terms of affecting agricultural production during the Kharif season. Additionally, in irrigated districts, it also plays an important role in determining water availability in Indus System's canal irrigation network. This is because in accordance with the Water Apportionment Act, Indus River System Authority (IRSA) allocates water to each province on a fiscal year basis (running from July to June). Therefore in irrigated districts, it is reasonable to expect that variation in rain during the summer months will not only impact production of the Kharif crop but will also have an effect on the subsequent winter crop. In order to test whether the effect of rainfall shocks is sensitive to the type of agricultural season which prevails before the child is conceived and to explore how the timing of a child's conception affects stature in the future, equation (4.3) is augmented with a dummy variable equal to 1 (0) if the last season before conception was Kharif (Rabi), as well as with interaction terms between rainfall variables and the Kharif season dummy. These results are shown in column 3, Table 5.4 (for short run) and column 3, Table A4 (for long run).

The impact of rainfall shocks is not sensitive to the timing of a child's conception, as evident from the insignificance of all interaction terms in both the short and the long run regression. But, on average, children who were conceived after a kharif season are taller compared to children conceived after a Rabi season (column 3, Table 5.4). This positive effect on short run height dissipates by age 13, which is the average age of children surveyed in 2010 (column 3 of Table A4). Similar findings on the presence of significant effects of a child's timing of birth on health have been documented in some existing studies (Rocha and Soares, 2015; Kumar et. al. 2016). Furthermore, I find that the impact of a child's timing of conception is uniform across all provinces (Table A3). This is evident from the insignificant interaction terms between type of before conception season and provincial dummy variables implying that the impact of being conceived after a Kharif season, on child height, does not vary across provinces.

[11] UN Comtrade Data (2014)

5.3.4 Does it matter whether the child belongs to a wealthy household?

Are children from rich households able to compensate for the negative effects of shocks? To test for this, I include interaction terms between rainfall variables on the one hand and condition of the house as well as the household's land ownership status on the other. Children living in un-cemented houses are more vulnerable to rainfall shocks compared to children residing in cemented houses; as is evident from the significant and positive coefficient on the interaction term between pre-conception rainfall and condition of house dummy variable (column 1, Table 5.5). But, this disadvantage disappears by the time children grow up as shown by the insignificant interaction terms in the long run regression (column 1, Table A5). On the contrary, ownership of land does not help offset the adverse effects of rainfall shocks, in the short (column 2, Table 5.5) or the long run (column 2, Table A5).

5.3.4 Does it matter if the child mother belongs to a farm household?

Does the effect of rainfall shocks vary by whether a child belongs to a farm or a non-farm household? If a negative rainfall shock affects child health through changes in agricultural production, farm households may face an income and price effect. The income effect will come through a reduction in crop supply. This may further induce a price effect; prices will rise in response to the negative rainfall shock and reduction in supply. This may or may not offset the negative income effect depending on whether it is a cash or a food crop and whether it is used for fulfilling subsistence needs of the household. Non-farm households on the other hand, will only be affected by higher prices in response to a negative rainfall shock. Finally, any effect of a negative rainfall shock on child health working through changes in the prevalent disease environment is not expected to vary between farm and non-farm households. In light of these various mechanisms, it is difficult to predict, a priori, whether farm households will be more or less severely affected by rainfall shocks.

In order to test for this heterogeneous effect, I augment equation (4.3) with interaction terms between rainfall variables and a dummy variable equal to 1 if the household cultivated its own land, rented in, or sharecropped land and re-estimated the model. Results for these augmented specifications are shown in column 3 of Table 5.5 (for short run) and column 3 of Table A5 (for long run). The impact of negative rainfall shocks on height of children is not sensitive to whether the child belongs to a farm or a non-farm household, as shown by the insignificant interaction terms. One possible explanation for this finding could be that even though non-farm households do not experience an income shock, they may still be affected indirectly, as a lot of non-farm income is linked with farm incomes through provision of services to farmers.

5.3.5 Does it matter if the child's mother is healthy and educated?

Are healthier and more educated mothers able to safeguard their children against adverse consequences of rain shocks? Using maternal height as a proxy for mother's health, I interact it with rain variables and re-estimate the model. None of the interaction terms are significant in the short (column 4, Table 5.5) or the long run regression (column 4, Table A5), indicating that the effect of exposure to rain shocks does not vary by maternal health.

To measure maternal education, I construct a dummy variable which takes a value of 1 if the mother has received any education and 0 if she is illiterate, and interact it with the rain variables. Results for these augmented specifications with maternal education interactions are shown in column 5 of Table 5.5 (for short run) and columns 5, Table A5 (for long run). Our results may be attributed to lack of variation in the maternal education variable. Approximately 87 percent of mothers in the sample have never attended school, while only 8 percent have completed primary school or less. Compared to maternal education, there is greater variation in paternal years of schooling (with around 50 percent of fathers report to have never attended school, 20 percent have completed primary school or less, another 22 percent have completed between 6 to 10 years of school, while 8 percent have completed eleventh grade or more). Even when I include father's education in the model, it does not have a significant effect on child height (Table A6 in the Appendix).

5.4 Robustness Checks

5.4.1 Rain shocks during cultivation and growth period

For a child, adequate nutrition during certain time periods is critical for growth and development. In much the same way, sufficient water during particular phases of the agricultural season will be essential for a good harvest. Broadly, the lifecycle of a crop is likely to go through two main stages; the cultivation and growth phase and the harvest phase. During the cultivation and growth phase, adequate water supply is crucial for ensuring a good quality of the harvest. Higher (lower) than normal rain shocks are considered beneficial (destructive) for crop yields during this phase. However, once the crop is ready to be harvested, it is not clear what will be the impact of rain fluctuations on crop yield. For some water intensive crops such as rice, rain shocks may have no impact on the crop while for other crops, such as cotton, higher than normal rain shocks may have disastrous effects on the crop. Due to this, it is possible that I am introducing noise in the rainfall variables by measuring deviations over a six months period. In an attempt to measure rainfall shocks more precisely, I limit my focus to the cultivation and growth period only. For each agricultural season, I exclude the harvest months (shown in Table 3.4), and reconstruct the rainfall variables to represent deviations from the normal during the cultivation and growth period only. Results with cultivation and growth rainfall variables are shown in column 1 (short run) and column 2 (long run) of Table 5.6. Switching from a six month interval to the cultivation and growth period does not alter the basic results which were observed in Table 5.1. Only the before-conception rain variable emerges as significant while all other rain variables are insignificant (Table 5.6). A priori expectation was that moving to a more precise measure of the shock will strengthen the relationship between rain and height-for-age z score. But, this is not the case. Contrary to the results in Table 5.1, the coefficient as well as the significance level of before-conception rainfall variable falls when focusing on the cultivation and growth period.

5.4.2 Placebo Test

I am looking at how a child's stature is impacted by rain fluctuations in agricultural seasons around the time a child is conceived and born. Is this relationship true or merely a spurious correlation driven by some other factors which are not being accounted for in the model? In order to rule out this possibility, I conduct a placebo test by replacing rainfall in agricultural seasons surrounding children's conception and birth with Rabi and Kharif rainfall in 1989 and 1990. Since these variables will capture rainfall for a time when none of the children in the sample were born, I expect that these variables should have no impact on height. The short and long run results with the placebo rain variables are shown in columns 3 and 4 of Table 5.6. The model passes the placebo test successfully, as revealed by the insignificant rain variables in the regression.

5.4.3 Selection bias due to attrition

A caveat of the dataset used in this study is that it has a high rate of attrition. Out of a sample of 2295 children in round 1, information on 988 children is missing for 2010. If there is a systematic pattern in the sub-sample of children, which were not covered in the 2010 survey, it would bias the sample under study and distort inference. In order to explore this further, I look at summary statistics of children who were covered in both rounds of the survey (Table 5.7A, Panel A) as well as those who were surveyed in the first but not in the third round (Table 5.7A, panel B). A t test on sample averages for each dimension shows that the average is statistically different from 0 for maternal education, landownership status and household's dependency ratio. Since I get a statistically significant difference in averages for these three characteristics, I investigate this issue further through regression analysis in order to check whether non-response in the 2010 round of data is random.

For this purpose, I construct a dummy variable, which takes a value of 1 if the child was surveyed in 2001 but not in 2010, and 0 if he (she) was surveyed in both years. I regress the child's participation status in the 2010 round of data collection on rain deviations, individual, household and community characteristics as well as provincial fixed effect dummies. Almost all the right hand side variables emerge as insignificant (Table 5.7 B), suggesting that OLS parameter estimates do not suffer from selection bias caused due to attrition. Two particular variables which do emerge as significant in these regressions are a household's dependency ratio; children from households with a higher dependency ratio are more likely to have participated in both rounds. If attrition was caused due to migration, it may be possible that large families were less likely to move, and hence more likely to have participated in both rounds. Results also show that households in Khyber Pakhtunkhwa are less likely to have participated in both rounds. One possibility could be that the law and order conditions deteriorated in the province between 2001 and 2010. During the nine years between PPHS (2001) and PPHS (2010), terrorist activities and subsequent military operations grew profoundly in Khyber Pakhtunkhwa. This might have had two implications; enumerators may have faced difficulties in carrying out data collection and many of the missing households may have relocated to other regions because of large-scale internal displacement in Dir district and due to widespread Taliban activities in Lakki Marwat.

5.4.4 Are mothers timing fertility decisions?

Given the significance of the pre-pregnancy rainfall, it is possible that positive rainfall shocks may be leading women to conceive and those children might be ending up with better health. To explore this further, I look at whether mothers in the sample are practicing birth control. If we find that not many people are engaged in family planning, then one can argue that having children is more random, and that birth decisions are not sensitive to rain. Some statistics on the prevalence of birth control are given in Table 5.8. The use of family planning does not seem to be widespread in the sample.

6. Conclusion

The objective of this study was to examine the direct reduced form effect of rainfall fluctuations around the time of conception and birth on physical growth of children in rural areas of Pakistan. The study used child level data from various rounds of Pakistan Panel Household Survey and rainfall data from Pakistan Meteorological Department. The model was estimated through ordinary least squares while controlling for a range of child, maternal and household characteristics. This study makes several contributions to the existing literature on weather shocks and child health: it is the first paper on Pakistan which examines the relationship between rainfall fluctuations and child health, explicitly studies the effect of rainfall fluctuations during the pre-pregnancy period (in addition to gestation and the birth year), it investigates rainfall fluctuations with respect to agricultural seasons in order to take into account their impact on crop production, it examines deviations in river flows (over and above fluctuations in rainfall), and it uses data which has a wide geographical and climatic spread, ensuring representativeness and external validity of the results.

Fluctuations in rainfall during the pre-pregnancy period have the most lasting effects on stature of children in the short and long run. When rainfall was 1 standard deviation below normal during the agricultural season preceding a mother's pregnancy, her child grew up to be 0.17 standard deviations shorter by four years of age, on average. As the child grew older, the adverse impact on height, of pre-pregnancy rainfall, was only partially compensated. By 13 years of age on average, the child continued to be 0.12 standard deviations shorter relative to someone whose pre-conception period was not marked by a similar reduction in rainfall. The average effect of fluctuations in pre-pregnancy rainfall on height of children was smaller in districts that had access to irrigation facilities.

The economic channel, working through crop production, income and prices, seems to be the most likely mechanism that explains the effect of fluctuations in pre-pregnancy rainfall on stature of children in rural Pakistan. Since the pre-pregnancy rainfall shock took place before the child was conceived, it is unlikely that it affected height through changes in the prevalent disease environment. This argument can also be supported by the significant heterogeneous effect of pre-pregnancy rainfall by extent of irrigation. Irrigation reduces dependence on rain-fed agriculture. If the economic channel was not the main mechanism underlying the relationship between pre-pregnancy rainfall and child height, access to irrigation would not have emerged as an effective strategy for offsetting the negative effects of pre-pregnancy rainfall shocks. Existing literature has shown that in India, agricultural production is the main channel through which weather shocks affect child mortality rates (Burgess et. al. 2011). Like India, Pakistan is a water-scarce country and falls in the same geographic and climatic belt as India. Thus, it may be reasonable to postulate that, in Pakistan, weather shocks affect human capital outcomes through the same channel as in India.

I do not find a significant effect of rainfall fluctuations on child height during gestation. This may be because in spite of the negative rainfall shock, the family did not compromise on the nutritional requirements of the mother during pregnancy. It may also be due to the expected time lag between rainfall fluctuations and receipt of income, which will take place only after the crop has been harvested. Therefore a family's income level and ability to access food, medicines, or health care services will most likely depend upon rainfall during the agricultural season before the mother started expecting her child. As discussed earlier, I do find significant lasting effects of pre-pregnancy rainfall fluctuations on child height.

These findings have public policy implications for promoting the process of human capital accumulation in developing countries like Pakistan. They reveal the importance of timing and the need to have a more specific targeting criteria while designing an intervention. Since the time before pregnancy emerges as the most critical period, interventions that specifically target women of child bearing age as well as expectant mothers may be more effective than interventions which provide a general cover to all households below a certain minimum threshold of income. For example, a government social protection scheme can provide insurance directly to a household with a woman of child-bearing age or an expectant mother either through cash transfers and (or) food supplements in order to compensate for adverse rainfall conditions over the agricultural season before the mother started expecting her child. They also call for a greater emphasis on promoting access to irrigation in order to reduce the vulnerability of agricultural production on the magnitude and timing of rainfall. This will not only have immediate benefits like improvement in child and maternal health indicators but may also facilitate the process of achieving higher levels of educational attainment, labor productivity and economic growth in the long run.

Figure 3.1 Survey Districts

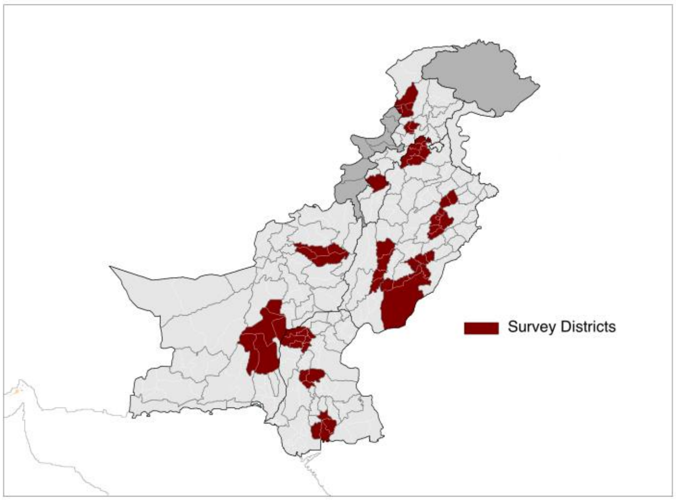


Figure 3.2 Percentage of cultivated area that is irrigated (Agricultural Census 2010)

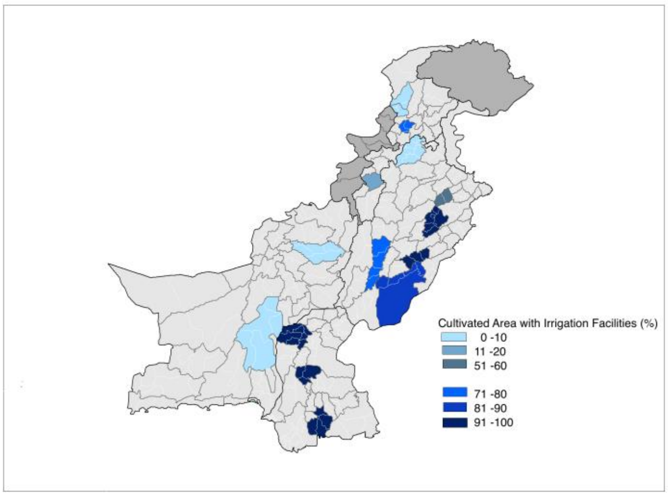


Table 3.1: **Prevalence of Stunting**

Category	WHO Cut-offs	Percentage of Children in each category
Severe Malnutrition	z=<-3	43.37
Moderate Malnutrition	-3<z=<-2	20.39
Normal Nutrition	-2<z=<+2	31.45
High Nutrition	z>+2	4.79

This table shows percentage of stunted children in PPHS (2001) sample of 2295 children.

Table 3.2: **Summary Statistics**

Variable	Obs.	Mean	Std. Dev.	Min	Max
hfa_zscore_2001	2290	-2.38	2.19	-6.00	5.97
z-rain in last season before conception	2290	0.31	1.12	-1.20	4.88
z-Rain in season(s) during gestation	2290	0.21	1.33	-1.92	6.23
z-rain in first season after birth	2290	-0.03	1.00	-1.73	4.88
z-rain in second season after birth	2290	-0.09	0.94	-1.73	4.88
District population/health facilities (1994)	2295	8484.22	3135.00	896.88	15069.36
Age of child in months at time of survey, R1	2290	43.83	17.96	12	83
Male	2295	0.51	0.50	0	1.00
Log of maternal height	2295	5.02	0.14	1.79	6.16
Highest grade attended by mother	2295	0.71	2.22	0	16
Un-cemented house	2295	0.62	0.48	0	1
Owns Land	2295	0.52	0.50	0	1
HH dependency ratio	2295	1.47	0.85	0.09	7
Punjab	2295	0.33	0.47	0	1
Sind	2295	0.34	0.47	0	1
Khyber Pakhtunkhwa	2295	0.21	0.40	0	1
Baluchistan	2295	0.12	0.33	0	1

Ratio of total district population divided by number of health facilities (1994)
D=1 if child lives in an un-cemented house in R1, 0 if katcha/pakka or cemented
D=1 if household owns land in R1, 0 otherwise
HH dependency ratio: members<15 & >64/members>14 & <65

Table 3.3 Percentage of Annual Rainfall during the Monsoon Season

District	Average Monsoon Rain (as % of annual rain)
Faisalabad	71.90
Attock	60.45
Hafizabad	74.28
Vehari	64.53
Muzaffargarh	60.67
Bahawalpur	65.30
Badin	81.19
Nawab Shah	73.04
Larkana	54.81
Dir	31.04
Mardan	48.42
Lakki Marwat	46.53
Loralai	65.99
Khuzdar	50.83

For each district, the table shows rain during the monsoon season from June to September, as a percentage of total annual rain between January and December. These are average percentages for the period 1975 to 2012. **Source**: Author's own calculation based on data from Pakistan Meteorological Department.

Table 3.4 District Wise Crop Calendar

District	Kharif Crop	Rabi Crop	Jan^{t+1}	Feb^{t+1}	Mar^{t+1}	Apr^{t+1}	May^t	Jun^t	Jul^t	Aug^t	Sep^t	Oct^t	Nov^t	Dec^t
Punjab														
Attock	Maize	Wheat												
Haifzabad	Rice	Wheat												
Faisalabad	Rice	Wheat												
Vehari	Cotton	Wheat												
Bahawalpur	Cotton	Wheat												
Muzaffargarh	Cotton	Wheat												
Sind														
Larkana	Rice	Wheat												
NawabShah	Cotton	Wheat												
Badin	Rice	Wheat												
Balochistan														
Khuzdar	Cotton	Wheat												
Loralai	Vegetables	Wheat												
Khyber Pakhtunkhawa (KP)														
Lakki Marwat	Fodders	Wheat												
Mardan	Maize	Wheat												
Dir	Maize	Wheat												

^For districts of KP, the month of May denotes May^{t+1} instead of May^t.

Rabi cultivation and growth period
Rabi harvest
Kharif cultivation and growth period
Kharif harvest

Table 4.1 Agricultural Seasons of Interest

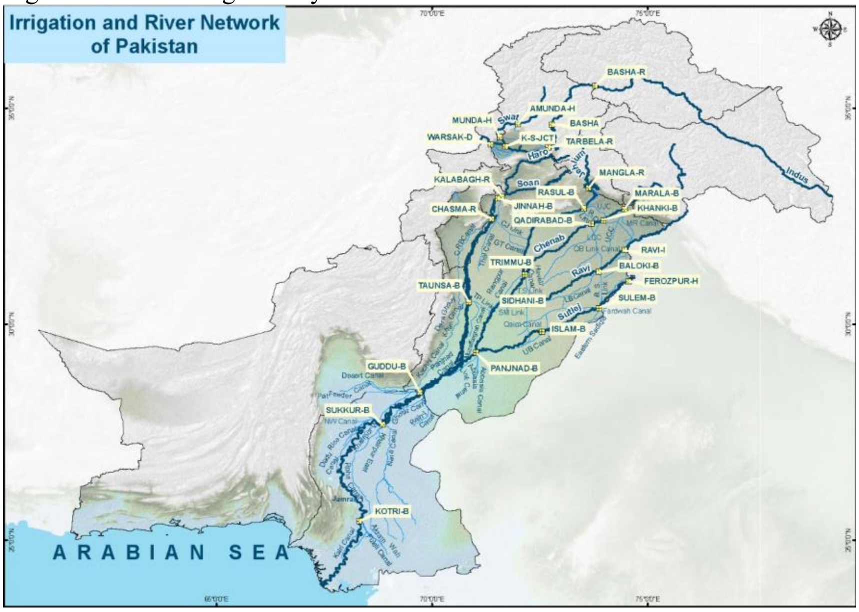
	CONCEPTION		BIRTH	
KH^{t-2} SEASON	$(Apr)^{t-1}$	RB^{t-1} KH^{t-1} SEASONS	$(Jan)^{t}$	RB^{t} KH^{t} SEASONS
	CONCEPTION		**BIRTH**	
RB^{t-1} SEASON	$(May\text{-}Jul)^{t-1}$	KH^{t-1} SEASON	$(Feb\text{-}Apr)^{t}$	RB^{t} KH^{t} SEASONS
	CONCEPTION		**BIRTH**	
RB^{t-1} SEASON	$(Aug - Oct)^{t-1}$	KH^{t-1} RB^{t} SEASONS	$(May\text{-}Aug)^{t}$	KH^{t} RB^{t+1} SEASONS
	CONCEPTION		**BIRTH**	
KH^{t-1} SEASON	$(Nov^{t-1} - Feb^{t)}$	RB^{t} SEASON	$(Sep\text{-}Nov)^{t}$	KH^{t} RB^{t+1} SEASONS
	CONCEPTION		**BIRTH**	
KH^{t-1} SEASON	(Mar^{t})	RB^{t} KH^{t} SEASONS	$(Dec)^{t}$	RB^{t+1} KH^{t+1} SEASONS

As an example, this table shows the four agricultural seasons of interest for the sub-sample of children born in Faisalabad. The seasons have been identified according to each child *i*'s month and year of birth as well as the crop calendar for kharif and rabi crops prevalent in the district. The superscript *t* represents the year in which child *i* was born. For a child born in January 1995, the last season before conception was kharif 1993, the two seasons while the child was in-utero were rabi 1994 and kharif 1994, while the first two seasons after birth were rabi 1995 and kharif 1995. As a final step, I constructed standardized rainfall variables for each of these four seasons. The same approach was followed for identifying agricultural seasons of interest around the time of birth and for constructing rainfall variables for children born in all other sample districts.

Figure 5.1 Pattern of rain during the study period (by region)

The sample of children under study were born between 1995 and 2000. Standardized rain has been calculated by taking the difference of aggregate monthly rain over the agricultural season from the long run average and dividing it by the standard deviation. The duration of the kharif and rabi season is defined according to the district-wise crop calendar shown in Table 3.4.

Figure 5.2 Canal Irrigation System in Pakistan



Source: Indus River System Authority (IRSA) 12

12 http://pakirsa.gov.pk/irsapublic/

Table 5.1 A: Short and Long Run Effects of Fluctuations in Rainfall on Child Height

Dependent Variable: Height-for-age z score	(1)	(2)	(3)	(4)
	Overall Sample	Overall Sample	With Quadratic Rain Terms	With Quadratic Rain Terms
Pre Pregnancy Rainfall	0.173**	0.118**	0.262**	0.154*
	(0.0722)	(0.0522)	(0.131)	(0.0785)
Prenatal Rainfall	0.0506	-0.0444	0.135	-0.0778
	(0.0547)	(0.0406)	(0.0905)	(0.0624)
Post birth First Season Rain	0.139*	0.0402	0.109	0.0468
	(0.0823)	(0.0517)	(0.145)	(0.0710)
Post birth Second Season Rain	0.0142	0.0149	0.101	0.103
	(0.0883)	(0.0395)	(0.149)	(0.0723)
Square(Pre Pregnancy Rainfall)			-0.0319	-0.0358
			(0.0358)	(0.0259)
Square(Prenatal Rainfall)			-0.0329	0.0190
			(0.0243)	(0.0157)
Square(Post birth First Season Rain)			0.0197	-0.00326
			(0.0416)	(0.0286)
Square(Post birth Second Season Rain)			-0.0274	-0.0184
			(0.0410)	(0.0261)
District population/Health facilities (1994)	3.82e-05	-3.87e-06	2.19e-05	-7.02e-06
	(5.90e-05)	(4.19e-05)	(6.12e-05)	(4.20e-05)
Age (months)	0.0445**	0.0235***	0.0530**	0.0239**
	(0.0184)	(0.00860)	(0.0209)	(0.00935)
Square(Age)	-0.0007***	-0.0003***	-0.0007***	-0.0003**
	(0.000185)	(0.000106)	(0.000201)	(0.000110)
Male	0.0922	0.0133	0.0913	0.00801
	(0.120)	(0.0885)	(0.119)	(0.0878)
Log(Maternal Height)	-0.956	-0.0547	-0.915	-0.0544
	(1.575)	(0.299)	(1.573)	(0.298)
Maternal Education	0.0862	0.0321	0.0883	0.0330
	(0.0546)	(0.0250)	(0.0547)	(0.0253)
Un-cemented house	-0.175	0.0174	-0.186	0.0213
	(0.212)	(0.0974)	(0.212)	(0.0970)
HH owns land	0.317*	0.0294	0.313*	0.0324
	(0.180)	(0.0920)	(0.179)	(0.0933)
HH dependency ratio	0.183**	-0.00711	0.183**	-0.0101
	(0.0858)	(0.0589)	(0.0859)	(0.0603)
Sind	0.00503	-0.383*	0.0713	-0.371*
	(0.316)	(0.214)	(0.337)	(0.213)
Khyber Pakhtunkhwa	1.189***	-1.324***	1.093***	-1.344***
	(0.302)	(0.163)	(0.304)	(0.168)
Baluchistan	-1.943***	-0.311	-2.058***	-0.364
	(0.457)	(0.414)	(0.472)	(0.412)
Constant	-0.0722	-1.193	-0.140	-1.129
	(7.979)	(1.561)	(7.920)	(1.537)
Observations	2,290	1,302	2,290	1,302
R-squared	0.098	0.102	0.100	0.105
F Test(pre-pregnancy rain and its square)			3.26**	2.84*
F Test(prenatal rain and its square)			1.13	0.86
F Test(post birth first season rain and square)			2.78*	0.32
F Test(post birth second season rain and square)			0.24	1.09

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Columns 1 and 3 present short run results while long run results are presented in columns 2 and 4. The dependent variable for the short (long) run regressions is height-for-age z score in 2001 (2010). The regressions were estimated with OLS. Standard Errors are shown in parentheses and are clustered at the community level. F tests are conducted to check joint significance of rainfall and its square terms.

Table 5.1 B: Impact of Positive and Negative Rainfall Fluctuations

Dependent Variable: Height-for-age z score	(1)	(2)
Positive Pre Pregnancy Rainfall	0.183**	0.0466
	(0.0802)	(0.0694)
Negative Pre Pregnancy Rainfall	0.171	0.249*
	(0.324)	(0.145)
Positive Prenatal Rainfall	-0.0301	0.0150
	(0.0675)	(0.0527)
Negative Prenatal Rainfall	0.315	-0.168
	(0.194)	(0.121)
Positive Post birth First Season Rainfall	0.208**	0.00372
	(0.0844)	(0.0701)
Negative Post birth First Season Rainfall	-0.0249	0.121
	(0.284)	(0.133)
Positive Post birth Second Season Rainfall	-0.0197	-0.0209
	(0.0840)	(0.0578)
Negative Post birth Second Season Rainfall	0.184	0.209
	(0.261)	(0.171)
District population/Health facilities (1994)	2.85e-05	-8.26e-06
	(6.18e-05)	(4.20e-05)
Age (months)	0.0560**	0.0246**
	(0.0230)	(0.00975)
Square(Age)	-0.0008***	-0.0003**
	(0.000218)	(0.000116)
Male	0.0893	0.0125
	(0.119)	(0.0879)
Log(Maternal Height)	-0.900	-0.0638
	(1.577)	(0.302)
Maternal Education	0.0864	0.0323
	(0.0543)	(0.0253)
Un-cemented house	-0.180	0.0192
	(0.213)	(0.0964)
HH owns land	0.314*	0.0345
	(0.179)	(0.0930)
HH dependency ratio	0.187**	-0.0112
	(0.0857)	(0.0599)
Sind	0.0586	-0.361*
	(0.347)	(0.213)
Khyber Pakhtunkhwa	1.131***	-1.325***
	(0.306)	(0.170)
Baluchistan	-1.950***	-0.361
	(0.462)	(0.409)
Constant	-0.312	-0.978
	(7.868)	(1.561)
Observations	2,290	1,302
R-squared	0.100	0.106
F Statistic(pre pregnancy: positive = negative)	0	1.2
F Statistic(prenatal: positive = negative)	2.25	1.58
F Statistic(post birth season 1:positive = negative)	0.55	0.5
F Statistic(post birth season 2: positive = negative)	0.51	1.25

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Columns 1 presents short run results while column 2 presents long run. The dependent variable for the short (long) run regression is height-for-age z score in 2001 (2010). The regressions were estimated with OLS. Standard Errors are shown in parentheses and are clustered at the community level. F tests are conducted to check whether the positive fluctuations in rainfall are significantly different from negative fluctuations in rainfall.

Table 5.2: Interaction Effects by Irrigated Land Ratio and River Water Flows

	(1)	(2)	(3)	(4)
Pre Pregnancy Rainfall	0.366***	0.168**	0.182**	0.126**
	(0.127)	(0.0829)	(0.0711)	(0.0559)
Prenatal Rainfall	0.0911	-0.0527	0.0289	-0.0407
	(0.0862)	(0.0738)	(0.0564)	(0.0395)
Post birth First Season Rain	0.240**	0.109	0.118	0.0501
	(0.0962)	(0.0748)	(0.0825)	(0.0532)
Post birth Second Season Rain	-0.0282	-0.0441	-0.0131	0.0281
	(0.141)	(0.0649)	(0.0908)	(0.0399)
Pre Pregnancy Rainfall*Irrigated Land Ratio	-0.299*	0.114		
	(0.172)	(0.0844)		
Prenatal Rainfall*Irrigated Land Ratio	-0.000433	0.0140		
	(0.128)	(0.101)		
Post birth First Season*Irrigated Land Ratio	-0.246	-0.141		
	(0.192)	(0.133)		
Post birth Second Season*Irrigated Land Ratio	0.119	-0.0739		
	(0.215)	(0.119)		
Irrigated Land Ratio (1990)	1.353**	0.105		
	(0.537)	(0.296)		
River Water Flows (Year Before Birth)			-0.0641	0.239**
			(0.174)	(0.105)
River Water Flows (Birth Year)			-0.281	-0.154
			(0.173)	(0.105)
District population/Health facilities (1994)	1.76e-05	1.06e-06	4.64e-05	-1.98e-06
	(5.97e-05)	(4.22e-05)	(5.96e-05)	(4.25e-05)
Age (months)	0.0453**	0.0237***	0.0194	0.0268**
	(0.0186)	(0.00859)	(0.0247)	(0.0126)
Square(Age)	-0.0007***	-0.0003***	-0.0005**	-0.0003**
	(0.000186)	(0.000106)	(0.000216)	(0.000123)
Male	0.108	0.0123	0.0974	0.0186
	(0.123)	(0.0875)	(0.120)	(0.0881)
Log(Maternal Height)	-1.018	-0.0878	-0.943	-0.0409
	(1.573)	(0.293)	(1.568)	(0.289)
Maternal Education	0.0907*	0.0328	0.0885	0.0328
	(0.0541)	(0.0252)	(0.0543)	(0.0251)
Un-cemented house	-0.193	0.0180	-0.172	0.0154
	(0.214)	(0.0962)	(0.211)	(0.0981)
HH owns land	0.370**	0.0386	0.320*	0.0241
	(0.174)	(0.0937)	(0.181)	(0.0941)
HH dependency ratio	0.175**	-0.0102	0.183**	-0.00774
	(0.0856)	(0.0590)	(0.0858)	(0.0584)
Sind	-0.313	-0.467*	-0.0569	-0.377*
	(0.360)	(0.238)	(0.314)	(0.215)
Khyber Pakhtunkhwa	1.801***	-1.246***	1.095***	-1.219***
	(0.438)	(0.261)	(0.329)	(0.171)
Baluchistan	-1.263**	-0.178	-2.040***	-0.173
	(0.563)	(0.489)	(0.465)	(0.424)
Constant	-0.548	-1.152	0.179	-1.332
	(7.880)	(1.563)	(7.993)	(1.532)
Observations	2,290	1,302	2,290	1,302
R-squared	0.105	0.104	0.100	0.106

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Columns 1 and 2 include Irrigated Land Ratio and its interaction with rainfall variables. Columns 3 and 4 include deviations in river water flows. Columns 1 and 3 present short run results, while columns 2 and 4 show long run results. The dependent variable for short (long) run regressions is hfa z score in 2001 (2010). The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table 5.3: Water Flows in the Indus River System (1993 – 2001)

Year	Kharif	Rabi	Total Annual	Deviation
FY94	129.18	28.14	157.31	-0.59
FY95	170.32	34.29	204.61	1.40
FY96	160.05	35.70	195.75	1.02
FY97	169.66	29.32	198.98	1.16
FY98	135.86	39.76	175.62	0.18
FY99	154.18	30.46	184.63	0.56
FY00	132.59	27.30	159.89	-0.49
FY01	106.53	20.44	126.97	-1.87

Notes: This table shows rim station inflows in billion cubic meters (BCM). The data has been taken from Indus River System Authority (IRSA). Fiscal year (FY) runs from July to June. Fiscal year 94 denotes July 1993 to June 1994. Deviation has been calculated by taking the difference between annual flows from the long run average level (between 1976-77 and 2008-09) and dividing by the standard deviation for the same time period.

Table 5.4: Short Run Effects of Rainfall Shocks by Age, Gender and Timing of Birth

	(1)	(2)	(3)
	Rain*Age	Rain*Male	Rain*Kharif
Pre Pregnancy Rainfall	0.273***	0.176**	0.262**
	(0.103)	(0.0884)	(0.132)
Prenatal Rainfall	0.0879	-0.00220	0.0335
	(0.0999)	(0.0725)	(0.0653)
Post birth First Season Rain	0.208	0.126	0.150**
	(0.183)	(0.107)	(0.0725)
Post birth Second Season Rain	-0.0369	0.0168	0.00674
	(0.213)	(0.103)	(0.138)
Pre Pregnancy Rainfall*Interaction 1	-0.213*	-0.00337	-0.188
	(0.111)	(0.101)	(0.162)
Prenatal Rainfall*Interaction 2	-0.0456	0.0996	0.0492
	(0.123)	(0.109)	(0.133)
Post birth First Season Rain*Interaction 3	-0.114	0.0247	-0.104
	(0.189)	(0.128)	(0.128)
Post birth Second Season Rain*Interaction 4	0.0789	-0.00709	-0.0830
	(0.227)	(0.141)	(0.158)
Four years or more	0.234		
	(0.266)		
Pre Pregnancy Season was Kharif			0.520***
			(0.137)
District population/Health facilities (1994)	3.92e-05	3.85e-05	5.95e-05
	(5.89e-05)	(5.93e-05)	(5.86e-05)
Age (months)	0.0560***	0.0440**	0.0323*
	(0.0214)	(0.0185)	(0.0185)
Square(Age)	-0.0007***	-0.0006***	-0.0005***
	(0.000210)	(0.000186)	(0.000184)
Male	0.0961	0.0811	0.0845
	(0.120)	(0.125)	(0.121)
Log(Maternal Height)	-1.003	-0.966	-0.911
	(1.582)	(1.584)	(1.564)
Maternal Education	0.0835	0.0870	0.0901*
	(0.0535)	(0.0545)	(0.0525)
Un-cemented house	-0.175	-0.172	-0.173
	(0.213)	(0.211)	(0.212)
HH owns land	0.312*	0.314*	0.301*
	(0.180)	(0.181)	(0.179)
HH dependency ratio	0.181**	0.186**	0.186**
	(0.0855)	(0.0860)	(0.0860)
Sind	0.0533	0.00605	-0.141
	(0.314)	(0.316)	(0.333)
Khyber Pakhtunkhwa	1.185***	1.191***	1.151***
	(0.296)	(0.302)	(0.298)
Baluchistan	-1.912***	-1.939***	-1.775***
	(0.454)	(0.459)	(0.452)
Constant	-0.0469	-0.0158	-0.520
	(7.989)	(8.022)	(7.910)
Observations	2,290	2,290	2,290
R-squared	0.100	0.099	0.104

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2001. Column 1 includes interaction terms between rainfall variables and a dummy variable equal to 1 if the child was four years or older at the time of survey in 2001. Column 2 includes interaction terms between rainfall and a dummy variable equal to 1 if child was male. Column 3 includes interaction terms between rainfall and a dummy variable equal to 1 if the pre-pregnancy agricultural season was Kharif. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table 5.5: Short Run Effects of Rainfall Shocks by Household and Maternal Characteristics

	(1)	(2)	(3)	(4)	(5)
Pre Pregnancy Rainfall	0.188**	0.199**	0.282**	-1.423	0.152**
	(0.0720)	(0.0893)	(0.133)	(6.442)	(0.0584)
Prenatal Rainfall	-0.0823	0.117	0.140	0.724	0.0921
	(0.0738)	(0.0826)	(0.0932)	(2.043)	(0.0599)
Post birth First Season Rain	0.0393	0.163	0.0970	-0.938	0.127
	(0.0909)	(0.130)	(0.123)	(1.394)	(0.0852)
Post birth Second Season Rain	0.127	-0.0782	-0.000385	-14.14	0.0260
	(0.0938)	(0.140)	(0.165)	(10.37)	(0.0993)
Pre Pregnancy Rainfall*Interaction 1	0.227**	-0.0489	-0.185	0.318	0.192
	(0.108)	(0.125)	(0.138)	(1.280)	(0.212)
Prenatal Rainfall*Interaction 2	-0.00802	-0.126	-0.124	-0.136	0.0789
	(0.103)	(0.113)	(0.112)	(0.406)	(0.227)
Post birth First Season*Interaction 3	0.192	-0.0472	0.0669	0.218	0.0448
	(0.126)	(0.168)	(0.139)	(0.280)	(0.195)
Post birth Second Season*Interaction 4	-0.171	0.184	0.0416	2.815	-0.0263
	(0.179)	(0.168)	(0.176)	(2.063)	(0.222)
Mother has some schooling					0.599**
					(0.296)
Farm Household			-0.126		
			(0.162)		
District population/Health facilities (1994)	3.31e-05	3.74e-05	5.29e-05	4.22e-05	3.48e-05
	(5.96e-05)	(5.91e-05)	(6.14e-05)	(5.92e-05)	(5.89e-05)
Age (months)	0.0441**	0.0442**	0.0457**	0.0439**	0.0410**
	(0.0183)	(0.0183)	(0.0191)	(0.0185)	(0.0186)
Square(Age)	-0.0006***	-0.0007***	-0.0007***	-0.0007***	-0.0006***
	(0.0002)	(0.0002)	(0.0002)	(0.0002)	(0.0002)
Male	0.0988	0.0970	0.0914	0.0908	0.0958
	(0.118)	(0.120)	(0.122)	(0.118)	(0.121)
Log(Maternal Height)	-0.944	-0.933	-0.929	-0.258	-0.941
	(1.565)	(1.592)	(1.589)	(1.319)	(1.548)
Maternal Education	0.0889	0.0878	0.0875	0.0883	
	(0.0554)	(0.0548)	(0.0537)	(0.0547)	
Un-cemented house	-0.214	-0.175	-0.138	-0.181	-0.189
	(0.205)	(0.213)	(0.218)	(0.212)	(0.207)
HH owns land	0.320*	0.368**	0.403*	0.323*	0.308*
	(0.179)	(0.178)	(0.210)	(0.181)	(0.179)
HH dependency ratio	0.178**	0.185**	0.175**	0.181**	0.183**
	(0.0854)	(0.0861)	(0.0877)	(0.0860)	(0.0862)
Sind	0.0316	0.00798	-0.0161	0.0147	-8.79e-05
	(0.319)	(0.318)	(0.323)	(0.315)	(0.314)
Khyber Pakhtunkhwa	1.152***	1.186***	1.169***	1.202***	1.195***
	(0.301)	(0.301)	(0.301)	(0.298)	(0.298)
Baluchistan	-2.012***	-1.937***	-1.893***	-1.901***	-1.954***
	(0.462)	(0.457)	(0.456)	(0.445)	(0.455)
Constant	-0.00803	-0.206	-0.343	-3.623	-0.0398
	(7.935)	(8.059)	(8.046)	(6.645)	(7.845)
Observations	2,290	2,290	2290	2,290	2,290
R-squared	0.101	0.099	0.102	0.102	0.100

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2001. In column 1, rainfall variables are interacted with a dummy equal to 1 if child lives in an un-cemented house. In column 2, rainfall variables are interacted with dummy equal to 1 if the household owns land. In column 3, rainfall variables are interacted with a dummy equal to 1 if child belongs to a Farm household. Column 4 includes interactions between rainfall and maternal height while column 5 includes interaction terms between rainfall and a dummy equal to 1 if mother has at least one year of schooling or more. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table 5.6: Rainfall during Crop Cultivation and Growth Period and Placebo Rainfall

	(1)	(2)		(3)	(4)
Pre Pregnancy Rainfall	0.152*	0.0317	Placebo Rain (Rabi 89)	-0.445	0.131
	(0.0833)	(0.0437)		(0.496)	(0.38)
Prenatal Rainfall	0.00491	-0.0221	Placebo Rain (Kharif 89)	-0.257	0.106
	(0.0529)	(0.0351)		(0.194)	(0.286)
Post birth First Season Rain	0.153*	0.0165	Placebo Rain (Rabi 90)	-0.172	0.0748
	(0.0810)	(0.0552)		(0.200)	(0.0765)
Post birth Second Season Rain	0.0310	0.0584	Placebo Rain (Kharif 90)	-0.0136	-0.192
	(0.0896)	(0.0495)		(0.264)	(0.22)
Population/Health facilities	4.04e-05	-3.72E-06	Population/Health facilities	3.18e-05	0.00006
	(5.90e-05)	(0.00004)		(0.000141)	(0.0001)
Age (months)	0.0361**	0.0229***	Age (months)	0.0340*	0.0180**
	(0.0170)	(0.00835)		(0.0182)	(0.00811)
Square(Age)	-0.0006***	-0.0003***	Square(Age)	-0.0006***	-0.0002**
	(0.000176)	(0.0001)		(0.0002)	(0.0001)
Male	0.0902	0.013	Male	0.0830	0.0188
	(0.119)	(0.0884)		(0.125)	(0.0903)
Log(Maternal Height)	-0.938	-0.0669	Log(Maternal Height)	-0.880	-0.0716
	(1.577)	(0.306)		(1.832)	(0.289)
Maternal Education	0.0909	0.0309	Maternal Education	0.0587	0.0231
	(0.0554)	(0.025)		(0.0452)	(0.0293)
Un-cemented house	-0.191	0.0159	Un-cemented house	-0.248	0.0634
	(0.210)	(0.0969)		(0.191)	(0.0998)
HH owns land	0.315*	0.0317	HH owns land	0.253	0.0479
	(0.180)	(0.0913)		(0.172)	(0.0964)
HH dependency ratio	0.180**	-0.0105	HH dependency ratio	0.150*	0.0033
	(0.0861)	(0.0594)		(0.0896)	(0.0579)
Sind	-0.0435	-0.414**	Sind	-0.205	-0.632*
	(0.310)	(0.204)		(0.704)	(0.364)
Khyber Pakhtunkhwa	1.201***	-1.329***	Khyber Pakhtunkhwa	0.858*	-1.466***
	(0.306)	(0.164)		(0.446)	(0.226)
Baluchistan	-1.952***	-0.344	Baluchistan	-1.549	-0.205
	(0.453)	(0.41)		(1.252)	(0.531)
Constant	-0.0360	-1.187	Constant	0.130	-1.709
	(7.979)	(1.609)		(9.293)	(1.64)
Observations	2,290	1302	Observations	2290	1302
R-squared	0.097	0.1	R-squared	0.105	0.11

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Columns 1 and 2 show results with rainfall shocks during the cultivation and growth period. Columns 3 and 4 show results with placebo rainfall variables. Columns 1 and 3 present results for the short run, while columns 2 and 4 show results for the long run. The dependent variable in the short (long) run regressions is hfa z score in 2001 (2010). The regressions were estimated with OLS. Standard errors are shown in parenthesis and are clustered at the community level.

Table 5.7 A: Summary Statistics

Panel A: Children surveyed in both rounds					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
hfa_zscore_2001	1302	-2.43	2.16	-6.00	5.96
z-rain in last season before conception	1302	0.27	1.02	-1.20	4.88
z-rain in season(s) during gestation	1302	0.21	1.26	-1.92	6.23
z-rain in first season after birth	1302	-0.02	0.95	-1.73	4.88
z-rain in second season after birth	1302	-0.10	0.89	-1.73	4.88
District population/Health facilities (1994)	1307	8649.27	3458.96	896.88	15069.36
Age of child in months at time of survey, R1	1302	43.99	17.87	12	83
Male	1307	0.51	0.50	0	1
Log of maternal height	1307	5.02	0.12	2.92	5.15
Highest grade attended by mother	1307	0.65	1.80	0	14
Un-Cemented House	1307	0.64	0.47	0	1
Owns Land	1307	0.51	0.50	0	1
HH dependency ratio	1307	1.53	0.88	0.14	7
Punjab	1307	0.35	0.48	0	1
Sind	1307	0.35	0.48	0	1
Khyber Pakhtunkhwa	1307	0.14	0.34	0	1
Baluchistan	1307	0.16	0.37	0	1
Panel B: Children surveyed in round 1 only					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
hfa_zscore_2001	988	-2.32	2.22	-6.00	5.97
z-rain in last season before conception	988	0.36	1.19	-1.20	4.88
z-Rain in season(s) during gestation	988	0.20	1.39	-1.92	6.23
z-rain in first season after birth	988	-0.03	1.04	-1.73	4.88
z-rain in second season after birth	988	-0.08	0.99	-1.73	4.88
District population/health facilities (1994)	988	8328.79	2841.53	896.88	15069.36
Age of child in months at time of survey, R1	988	43.60	18.06	12	82
Male	988	0.51	0.50	0	1
Log of maternal height	988	5.02	0.15	1.79	6.16
Highest grade attended by mother	988	0.74	2.56	0	16
Un-cemented House	988	0.62	0.49	0	1
Owns Land	988	0.55	0.50	0	1
HH dependency ratio	988	1.38	0.80	0.09	7
Punjab	988	0.32	0.47	0	1
Sind	988	0.32	0.47	0	1
Khyber Pakhtunkhwa	988	0.27	0.44	0	1
Baluchistan	988	0.09	0.29	0	1

Notes: This table shows summary statistics for the sample of children who were surveyed in both rounds (panel A) as well as the sample of children who were surveyed in round 1 but not surveyed in round 2.
HH dependency ratio: members<15 & >64/members>14 & <65
Dummy variable = 1 if child lives in an un-cemented house in round 1, 0 if katcha/pakka or cemented
Dummy variable = 1 if household owns land in round 1, 0 otherwise

Table 5.7 B: Testing for Attrition Bias

	OLS	Probit (Marginal Effects)
	(1)	(2)
Pre Pregnancy Rainfall	0.00978	0.0114
	(0.0106)	(0.0102)
Prenatal Rainfall	-0.00481	-0.00394
	(0.0113)	(0.00928)
Post birth First Season Rain	-0.000658	0.00345
	(0.0119)	(0.0118)
Post birth Second Season Rain	-0.00588	-0.00697
	(0.0149)	(0.0130)
District population/Health facilities (1994)	4.04e-05	4.39e-05
	(5.90e-05)	(6.01e-05)
Age (months)	0.000699	0.000618
	(0.000737)	(0.000674)
Male	0.0241	0.0261
	(0.0197)	(0.0200)
Log(Maternal Height)	-0.0790	-0.0620
	(0.0771)	(0.0811)
Maternal Education	0.0174	0.0165
	(0.0974)	(0.0975)
Un-cemented house	-0.0501	0.0598
	(0.0372)	(0.0366)
HH owns land	0.0495	0.031
	(0.0376)	(0.0920)
HH dependency ratio	-0.0801***	-0.0826***
	(0.0200)	(0.0121)
Sind	0.0206	0.0186
	(0.0553)	(0.0275)
Khyber Pakhtunkhwa	0.156**	0.159***
	(0.0691)	(0.0272)
Baluchistan	-0.0706	0.0620
	(0.0752)	(0.0811)
Constant	-0.312	
	(0.407)	
Observations	2290	2290
R-squared	0.061	

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. The dependent variable is a dummy equal to 1 if the child was surveyed in 2001 but not surveyed in 2010, and equal to 0 if the child was surveyed in both 2001 and 2010. Column 1 shows OLS estimates while Column 2 shows marginal effects calculated after a probit estimation.

Table 5.8 Percentage of Women Practicing Birth Control

	Number	**Percentage**
Ever married women between 15-45 years of age	2940	
Women who have **ever used any method of birth control in the past** but are not using any birth control at the time of survey	224	7.62%
Women who have **ever used any method of birth control in the past** and stopped using it because they wanted to have another child	55	1.87%

Appendix A

Table A1: Impact of Quadratic River Water Flow Variables on Child Height

VARIABLES	(1) Short Run	(2) Long Run
River Water Flows (Year Before Birth)	-0.189	0.283**
	(0.501)	(0.131)
River Water Flows (Birth Year)	-0.203	-0.127
	(0.184)	(0.108)
Square River Water Flows (Year Before Birth)	0.200	-0.0314
	(0.402)	(0.0685)
Square River Water Flows (Birth Year)	0.171	0.0560
	(0.163)	(0.0744)
Pre Pregnancy Rainfall	0.203***	0.123**
	(0.0700)	(0.0566)
Prenatal Rainfall	0.0491	-0.0340
	(0.0600)	(0.0405)
Post birth First Season Rain	0.116	0.0488
	(0.0850)	(0.0534)
Post birth Second Season Rain	-0.00954	0.0330
	(0.0922)	(0.0397)
District population/Health facilities (1994)	4.39e-05	1.23e-06
	(6.01e-05)	(4.23e-05)
Age (months)	0.00492	0.0246*
	(0.0256)	(0.0133)
Square(Age)	-0.0003	-0.0003*
	(0.000244)	(0.000148)
Male	0.0985	0.016
	(0.120)	(0.0879)
Log(Maternal Height)	-0.980	-0.0518
	(1.572)	(0.288)
Maternal Education	0.0903*	0.0331
	(0.0545)	(0.0252)
Un-cemented house	-0.174	0.0172
	(0.212)	(0.0975)
HH owns land	0.326*	0.0284
	(0.178)	(0.0948)
HH dependency ratio	0.178**	-0.00917
	(0.0856)	(0.0586)
Sind	-0.0529	-0.386*
	(0.311)	(0.214)
Khyber Pakhtunkhwa	1.277***	-1.171***
	(0.347)	(0.201)
Baluchistan	-1.834***	-0.0946
	(0.467)	(0.419)
Constant	0.571	-1.380
	(7.998)	(1.524)
Observations	2,290	1,302
R-squared	0.101	0.107

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Column 1 shows short run results while column 2 presents long run results. In the short (long) run regression, the dependent variable is hfa-z score in 2001 (2010). Square of river water flow variables are included in the model. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level

Table A2 Impact of Positive and Negative Fluctuations in River Water Flows on Child Height

VARIABLES	(1) Short Run	(2) Long Run
Positive River Water Flows (Year Before Birth)	0.122	0.218*
	(0.226)	(0.131)
Negative River Water Flows (Year Before Birth)	-0.807	0.360
	(1.340)	(0.224)
Positive River Water Flows (Birth Year)	0.0725	-0.0616
	(0.301)	(0.166)
Negative River Water Flows (Birth Year)	-0.511	-0.242
	(0.446)	(0.176)
Pre Pregnancy Rainfall	0.217***	0.124**
	(0.0712)	(0.0569)
Prenatal Rainfall	0.0586	-0.0338
	(0.0605)	(0.0410)
Post birth First Season Rain	0.116	0.0507
	(0.0826)	(0.0531)
Post birth Second Season Rain	-0.00570	0.0303
	(0.0900)	(0.0395)
District population/Health facilities (1994)	3.74e-05	8.90e-07
	(6.01e-05)	(4.21e-05)
Age (months)	1.94e-05	0.0254*
	(0.0258)	(0.0134)
Square(Age)	-0.0002	-0.0003**
	(0.000249)	(0.000148)
Male	0.0991	0.0162
	(0.120)	(0.0880)
Log(Maternal Height)	-0.982	-0.0520
	(1.572)	(0.288)
Maternal Education	0.0926*	0.0330
	(0.0546)	(0.0251)
Un-cemented house	-0.179	0.0165
	(0.213)	(0.0975)
HH owns land	0.331*	0.0291
	(0.177)	(0.0945)
HH dependency ratio	0.178**	-0.00890
	(0.0862)	(0.0586)
Sind	-0.0418	-0.383*
	(0.313)	(0.214)
Khyber Pakhtunkhwa	1.401***	-1.179***
	(0.369)	(0.216)
Baluchistan	-1.715***	-0.109
	(0.480)	(0.424)
Constant	0.568	-1.362
	(8.009)	(1.530)
Observations	2,290	1,302
R-squared	0.102	0.107

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Column 1 shows short run results while column 2 presents long run results. In the short (long) run regression, the dependent variable is hfa-z score in 2001 (2010). River water flow variables are disaggregated into positive and negative fluctuations. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level

Table A3: Impact of Pre-Pregnancy Agricultural Season across Regions

VARIABLES	(1) With Last Season*Province Dummies
Pre Pregnancy Rainfall	0.193**
	(0.0752)
Prenatal Rainfall	0.0408
	(0.0565)
Post birth First Season Rain	0.121
	(0.0824)
Post birth Second Season Rain	0.0126
	(0.0912)
Kharif Season before Pregnancy	0.109
	(0.220)
Pre-Pregnancy Season Kharif* Sindh Province Dummy	0.535
	(0.331)
Pre-Pregnancy Season Kharif* KP Province Dummy	0.699
	(0.433)
Pre-Pregnancy Season Kharif* Baluchistan Province Dummy	0.628
	(0.416)
District population/Health facilities (1994)	5.60e-05
	(5.77e-05)
Age (months)	0.0344*
	(0.0182)
Square(Age)	-0.0006***
	(0.0001)
Male	0.0741
	(0.121)
Log(Maternal Height)	-0.981
	(1.556)
Maternal Education	0.0927*
	(0.0540)
Un-cemented house	-0.192
	(0.210)
HH owns land	0.299*
	(0.176)
HH dependency ratio	0.179**
	(0.0874)
Sind	-0.303
	(0.322)
Khyber Pakhtunkhwa	0.813**
	(0.343)
Baluchistan	-2.007***
	(0.464)
Constant	0.0514
	(7.856)
Observations	2,290
R-squared	0.105

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2001. The provincial fixed effect dummy variables are interacted with a dummy equal to 1 if the pre-pregnancy season was Kharif and is equal to 0 if it was Rabi. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table A4: Long Run Effects of Rainfall Shocks by Age, Gender and Timing of Birth

VARIABLES	(1) Rain*Age	(2) Rain*Male	(3) Rain*Kharif
Pre Pregnancy Rainfall	0.183**	0.163**	0.0221
	(0.0802)	(0.0651)	(0.0692)
Prenatal Rainfall	-0.0412	-0.0446	-0.0475
	(0.0605)	(0.0620)	(0.0620)
Post birth First Season Rain	0.0200	0.0202	0.0862
	(0.0821)	(0.0690)	(0.0651)
Post birth Second Season Rain	0.0327	-0.0179	0.120
	(0.0749)	(0.0633)	(0.0781)
Pre Pregnancy Rainfall*Interaction 1	-0.0222	0.0733	-0.0277
	(0.110)	(0.0933)	(0.0949)
Prenatal Rainfall*Interaction 2	-0.00919	0.00491	0.0145
	(0.0859)	(0.0901)	(0.116)
Post birth First Season*Interaction 3	0.0425	0.0387	-0.110
	(0.107)	(0.0996)	(0.101)
Post birth Second Season*Interaction 4	-0.110	-0.110	-0.0244
	(0.107)	(0.0970)	(0.127)
Four Years Old	-0.0110		
	(0.184)		
Kharif Season before Pregnancy			0.0603
			(0.0884)
District population/Health facilities (1994)	-5.80e-07	-4.61e-06	-1.13e-06
	(4.21e-05)	(4.21e-05)	(4.19e-05)
Age (months)	0.0248**	0.0234***	0.0226**
	(0.0112)	(0.00854)	(0.00883)
Square(Age)	-0.0003**	-0.0003***	-0.0003**
	(0.000123)	(0.000105)	(0.000109)
Male	0.0148	-0.0128	0.0178
	(0.0885)	(0.0923)	(0.0892)
Log(Maternal Height)	-0.0456	-0.0625	-0.0756
	(0.298)	(0.296)	(0.311)
Maternal Education	0.0318	0.0326	0.0332
	(0.0250)	(0.0251)	(0.0252)
Un-cemented house	0.0216	0.0189	0.0208
	(0.0965)	(0.102)	(0.0977)
HH owns land	0.0297	0.0240	0.0259
	(0.0928)	(0.0933)	(0.0919)
HH dependency ratio	-0.00549	-0.00730	-0.00553
	(0.0596)	(0.0588)	(0.0596)
Sind	-0.383*	-0.383*	-0.405*
	(0.219)	(0.216)	(0.213)
Khyber Pakhtunkhwa	-1.322***	-1.324***	-1.322***
	(0.164)	(0.163)	(0.163)
Baluchistan	-0.271	-0.313	-0.296
	(0.424)	(0.417)	(0.420)
Constant	-1.255	-1.164	-1.189
	(1.558)	(1.554)	(1.634)
Observations	1,302	1,302	1,302
R-squared	0.103	0.104	0.104

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2010. Column 1 includes interaction terms between rainfall variables and a dummy variable equal to 1 if the child was four years or older at the time of survey in 2001. Column 2 includes interaction terms between rainfall and a dummy variable equal to 1 if child was male. Column 3 includes interaction terms between rainfall and a dummy variable equal to 1 if the pre-pregnancy agricultural season was Kharif. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table A5: Long Run Effects of Rainfall Shocks by Household and Maternal Characteristics

	(1)	(2)	(3)	(4)	(5)
Pre Pregnancy Rainfall	0.199**	0.101*	0.0236	-6.238	0.132**
	(0.0835)	(0.0572)	(0.0570)	(4.466)	(0.0637)
Prenatal Rainfall	-0.0447	0.107**	-0.0911	-2.249	-0.0625
	(0.0633)	(0.0526)	(0.0731)	(7.264)	(0.0452)
Post birth First Season Rain	0.0361	0.0544	0.0267	2.352	0.000688
	(0.0788)	(0.0623)	(0.0743)	(2.231)	(0.0581)
Post birth Second Season Rain	0.0689	0.0603	0.0895	-0.846	0.0100
	(0.0857)	(0.0693)	(0.101)	(9.205)	(0.0447)
Pre Pregnancy Rainfall*Interaction 1	-0.0891	-0.0143	-0.0160	1.240	0.0394
	(0.103)	(0.129)	(0.0721)	(0.887)	(0.101)
Prenatal Rainfall*Interaction 2	-0.0127	0.109	0.0741	0.438	0.0427
	(0.0931)	(0.0827)	(0.0944)	(1.444)	(0.0966)
Post birth First Season*Interaction 3	0.00565	-0.0343	0.0207	-0.460	0.139
	(0.107)	(0.0920)	(0.0961)	(0.443)	(0.136)
Post birth Second Season*Interaction 4	-0.147	0.0966	0.0543	0.188	-0.176
	(0.110)	(0.0993)	(0.119)	(1.827)	(0.135)
Mother has some schooling					0.195
					(0.150)
Farm Household			-0.0749		
			(0.123)		
District population/Health facilities (1994)	-5.16e-07	-9.00e-06	-9.49e-06	-4.91e-06	8.78e-07
	(4.19e-05)	(4.16e-05)	(4.24e-05)	(4.17e-05)	(4.29e-05)
Age (months)	0.0235***	0.0232***	0.0228***	0.0237***	0.0269***
	(0.00859)	(0.00864)	(0.00871)	(0.00880)	(0.00863)
Square(Age)	-0.0003***	-0.0003**	-0.0003**	-0.0003***	-0.0003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Male	0.0167	0.0123	0.0225	0.0203	-0.0256
	(0.0913)	(0.0898)	(0.0887)	(0.0882)	(0.0874)
Log(Maternal Height)	-0.0679	-0.0495	-0.0816	0.924	-0.00214
	(0.307)	(0.307)	(0.291)	(1.261)	(0.280)
Maternal Education	0.0328	0.0324	0.0326	0.0305	
	(0.0249)	(0.0247)	(0.0250)	(0.0257)	
Un-cemented house	0.0118	0.0150	0.0349	0.0164	0.0158
	(0.104)	(0.0973)	(0.0981)	(0.0980)	(0.0947)
HH owns land	0.0263	0.0639	0.0443	0.0257	0.0440
	(0.0920)	(0.0941)	(0.0916)	(0.0926)	(0.0904)
HH dependency ratio	-0.00365	-0.00510	0.00658	-0.00244	0.0458
	(0.0587)	(0.0594)	(0.0596)	(0.0588)	(0.0655)
Sind	-0.400*	-0.362*	-0.349	-0.376*	-0.390*
	(0.213)	(0.214)	(0.215)	(0.212)	(0.214)
Khyber Pakhtunkhwa	-1.308***	-1.314***	-1.376***	-1.325***	-1.311***
	(0.162)	(0.163)	(0.176)	(0.164)	(0.158)
Baluchistan	-0.288	-0.316	-0.274	-0.255	-0.323
	(0.413)	(0.409)	(0.407)	(0.401)	(0.406)
Constant	-1.206	-1.242	-1.048	-6.162	-1.518
	(1.604)	(1.610)	(1.526)	(6.357)	(1.481)
Observations	1,302	1,302	1302	1,302	1302
R-squared	0.105	0.106	0.109	0.107	0.104

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2010. In column 1, rainfall variables are interacted with a dummy equal to 1 if child lives in an un-cemented house. In column 2, rainfall variables are interacted with dummy equal to 1 if the household owns land. In column 3, rainfall variables are interacted with a dummy equal to 1 if child belongs to a Farm household. Column 4 includes interactions between rainfall and maternal height while column 5 includes interaction terms between rainfall and a dummy equal to 1 if mother has at least one year of schooling or more. The regressions were estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

Table A6: Controlling for Father's Education

VARIABLES	(1) With Paternal Education
Pre Pregnancy Rainfall	0.169**
	(0.0715)
Prenatal Rainfall	0.0495
	(0.0545)
Post birth First Season Rain	0.140*
	(0.0820)
Post birth Second Season Rain	0.0192
	(0.0895)
District population/Health facilities (1994)	3.77e-05
	(5.93e-05)
Age (months)	0.0451**
	(0.0185)
Square(Age)	-0.0007***
	(0.0002)
Male	0.0808
	(0.119)
Log(Maternal Height)	-0.954
	(1.562)
Maternal Education	0.0687
	(0.0538)
Paternal Education	0.0269
	(0.0202)
Un-cemented house	-0.146
	(0.215)
HH owns land	0.290
	(0.184)
HH dependency ratio	0.193**
	(0.0876)
Sind	-0.0105
	(0.316)
Khyber Pakhtunkhwa	1.132***
	(0.302)
Baluchistan	-1.916***
	(0.458)
Constant	-0.181
	(7.899)
Observations	2290
R-squared	0.100

Notes: *, **, *** denote significance at 10%, 5% and 1% respectively. Dependent variable is hfa-z score in 2001. The model controls for father's education. The regression was estimated with OLS. Standard errors are shown in parentheses and are clustered at the community level.

References

Aguilar, Arturo, and Marta Vicarelli. "El Nino and Mexican Children: Medium-Term Effects of Early-Life Weather Shocks on Cognitive and Health Outcomes." *Cambridge, United States: Harvard University, Department of Economics.Manuscript* (2011)Web.

Alderman, H., and CH Paxson. "Do the Poor Insure? A Synthesis of the Literature on Risk and Consumption in Developing Countries. Economics in a Changing World: Proceedings of the Tenth World Congress of the International Economic Association, Moscow, Volume 4, Development, Trade and the Environment. E. Bacha." (1994)Web.

Alderman, Harold, John Hoddinott, and Bill Kinsey. "Long Term Consequences of Early Childhood Malnutrition." *Oxford economic papers* 58.3 (2006): 450-74. Web.

Auffhammer, Maximilian, Veerabhadran Ramanathan, and Jeffrey R. Vincent. "Climate Change, the Monsoon, and Rice Yield in India." *Climatic Change* 111.2 (2012): 411-24. Web.

Barker, David James Purslove. *Mothers, Babies, and Disease in Later Life*. BMJ Publishing Group London, 1994. Web.

Barker, D. J. "In Utero Programming of Chronic Disease." *Clinical science (London, England : 1979)* 95.2 (1998): 115-28. Web.

Barro, Robert J., N. Gregory Mankiw, and Xavier Sala-i-Martin. *Capital mobility in neoclassical models of growth* (1992)Web.

Becker, Gary S. "Investment in Human Capital: A Theoretical Analysis." *The journal of political economy* (1962): 9-49. Web.

Behrman, Jere R., and Mark R. Rosenzweig. "Returns to Birthweight." *Review of Economics and statistics* 86.2 (2004): 586-601. Web.

Björkman-Nyqvist, Martina. "Income Shocks and Gender Gaps in Education: Evidence from Uganda." *Journal of Development Economics* 105 (2013): 237-53. Web.

Bloomfield, F. H., M. H. Oliver, and J. E. Harding. "The Late Effects of Fetal Growth Patterns." *Archives of disease in childhood.Fetal and neonatal edition* 91.4 (2006): F299-304. Web.

Burgess, Robin, et al. "Weather and Death in India." *Cambridge, United States: Massachusetts Institute of Technology, Department of Economics.Manuscript* (2011)Web.

Currie, Janet. "Healthy, Wealthy, and Wise: Socioeconomic Status, Poor Health in Childhood, and Human Capital Development." *Journal of Economic Literature* 47.1 (2009): 87-122. Web.

Dercon, Stefan. "Income Risk, Coping Strategies, and Safety Nets." *The World Bank Research Observer* 17.2 (2002): 141-66. Web.

Fafchamps, Marcel, and Susan Lund. "Risk-Sharing Networks in Rural Philippines." *Journal of Development Economics* 71.2 (2003): 261-87. Web.

Fafchamps, Marcel, Christopher Udry, and Katherine Czukas. "Drought and Saving in West Africa: Are Livestock a Buffer Stock?" *Journal of Development Economics* 55.2 (1998): 273-305. Web.

Fogel, Robert W. *Economic growth, population theory, and physiology: the bearing of long-term processes on the making of economic policy* (1994)Web.

Glewwe, Paul, Hanan G. Jacoby, and Elizabeth M. King. "Early Childhood Nutrition and Academic Achievement: A Longitudinal Analysis." *Journal of Public Economics* 81.3 (2001): 345-68. Web.

Glewwe, Paul, and Edward A. Miguel. "Chapter 56 the Impact of Child Health and Nutrition on Education in Less Developed Countries." *Handbook of Development Economics.* Volume 4 Vol. Elsevier3561-3606. Web.

Grossman, Michael. "On the Concept of Health Capital and the Demand for Health." *Journal of Political economy* 80.2 (1972): 223-55. Web.

Hoddinott, John, and Bill Kinsey. "Child Growth in the Time of Drought." *Oxford Bulletin of Economics and Statistics* 63.4 (2001): 409-36. Web.

Jacoby, Hanan G., and Emmanuel Skoufias. "Risk, Financial Markets, and Human Capital in a Developing Country." *The Review of Economic Studies* 64.3 (1997): 311-35. Web.

Kim, Yeon Soo. "The Impact of Rainfall on Early Child Health." *Job Market Paper. College Park, Maryland, United States: University of Maryland. Available at: http://citeseerx.ist.psu.edu/viewdoc/download* (2010)Web.

Kudamatsu, Masayuki, Torsten Persson, and David Strömberg. "Weather and Infant Mortality in Africa." (2012)Web.

Kumar, Santosh, Ramona Molitor, and Sebastian Vollmer. "Drought and Early Child Health in Rural India." *Population and Development Review* 42.1 (2016): 53-68. Web.

Linnet, K. M., et al. "Gestational Age, Birth Weight, and the Risk of Hyperkinetic Disorder." *Archives of Disease in Childhood* 91.8 (2006): 655-60. Web.

Maccini, Sharon, and Dean Yang. "Under the Weather: Health, Schooling, and Socioeconomic Consequences of Early-Life Rainfall." *Schooling, and Socioeconomic Consequences of Early-Life Rainfall (January 2006)* (2006)Web.

Mara, David Duncan. "Water, Sanitation and Hygiene for the Health of Developing Nations." *Public health* 117.6 (2003): 452-6. Web.

Mincer, Jacob. "Investment in Human Capital and Personal Income Distribution." *The journal of political economy* (1958): 281-302. Web.

Morgane, Peter J., et al. "Prenatal Malnutrition and Development of the Brain." *Neuroscience & Bio behavioral Reviews* 17.1 (1993): 91-128. Web.

Rao, CH Hanumantha, Susanta K. Ray, and Kalanidhi Subbarao. *Unstable Agriculture and Droughts: Implications for Policy.*, 1988. Web.

Rocha, Rudi, and Rodrigo R. Soares. "Water Scarcity and Birth Outcomes in the Brazilian Semiarid." *Journal of Development Economics* 112 (2015): 72-91. Web.

Schultz, Theodore W. "Investment in Human Capital." *The American Economic Review* (1961): 1-17. Web.

Shah, Manisha, and Bryce Millett Steinberg. *Drought of opportunities: contemporaneous and long term impacts of rainfall shocks on human capital* (2013)Web.

Shenkin, Susan D., John M. Starr, and Ian J. Deary. "Birth Weight and Cognitive Ability in Childhood: A Systematic Review." *Psychological bulletin* 130.6 (2004): 989. Web.

Skoufias, Emmanuel, Katja Vinha, and Hector V. Conroy. "The Impacts of Climate Variability on Welfare in Rural Mexico." *World Bank Policy Research Working Paper Series, Vol* (2011)Web.

Steckel, Richard H. "Stature and the Standard of Living." *Journal of economic literature* 33.4 (1995): 1903-40. Web.

Strauss, John, and Duncan Thomas. "Health, Nutrition, and Economic Development." *Journal of economic literature* 36.2 (1998): 766-817. Web.

Townsend, Robert M. "Risk and Insurance in Village India." *Econometrica: Journal of the Econometric Society* (1994): 539-91. Web.

Udry, Christopher. "Credit Markets in Northern Nigeria: Credit as Insurance in a Rural Economy." *The World Bank Economic Review* 4.3 (1990): 251-69. Web.