Socioeconomic Consequences of Birth Year Rainfall Shocks: Evidence from Rural Nepal

By

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Abstract

Epidemiological literature suggests that extrauterine environment has important implications for development of infants into adolescence and adulthood. To test this hypothesis, this paper studies the persistent impact of early-life rainfall shocks on adult and youth socioeconomic outcomes in Nepal. I use the exogenous spatial and temporal variation in historical rainfall patterns in the 1951-1991 period to identify the causal effect. I find that negative shocks in the year of birth is associated with reduced future productivity and earnings from education for females. Furthermore, there is some evidence to suggest that higher birth year monsoon rainfall is associated with foregone education and more work for adults from marginalized backgrounds, but with increased years of education and fewer months of work for those from non-marginalized backgrounds. This has important policy implications regarding targeted agricultural insurance and safety net programs.

1. Introduction

Early life extrauterine environment has important implications for development of infants into adulthood, especially in rural, rainfed subsistence agricultural settings where rainfall shocks are one of the most important risk factors. Due to lack of sufficient irrigation infrastructure, agricultural production is highly dependent on favorable weather conditions, mainly on timing and availability of rainwater. Adverse natural climatic phenomena directly upset the agriculture and food supply through their effect on harvests and thus, affect food security. Mitigating risks of such severity or adapting to extreme circumstances when mitigation is onerous could limit the ability of households to sufficiently provide infants and children with adequate nutrition during early years of life. Improper nurturing during these critical years could then lead to worse future wellbeing.

To contribute to the climate-economy literature, this paper studies the persistent impact of early-life weather conditions on future socioeconomic outcomes. This is the first attempt to estimate the degree to which rainfall fluctuations in the year of birth influence socioeconomic outcomes of adults in the context of rural Nepal. Analysis of youth outcomes of school-aged population is also conducted to determine whether the consequences of birth year rainfall shocks can be detected earlier in life. Intense and erratic seasonal or monsoon rainfall, reduced off-season rainfall, fluctuating stream flow along with flooding and droughts have vastly affected the agricultural households of the country (Menon 2009; Joshi et al. 2011). While evaluating the consequences of rainfall shocks in a country with imperfect agriculture insurance and credit markets deserves its own research merit, Nepal also provides a good case study of the world's poorest countries that have experienced extreme effects of climate change.

For the purposes of this study, I match individuals from the 2001 Nepal Census with the historical rainfall information for their birth district and year. I use the exogenous spatial and temporal variation in historical rainfall patterns in the 1951-1991 period to identify the causal effect of birth year rainfall shocks. Because of missing information on birth month and household location in the census data, I define birth year rainfall as the total rainfall in the monsoon season of the calendar year of birth and use the rainfall measure from the grid point that is closest to the birth district's centroid. To address the consequent measurement error in the birth year rainfall variable, I use an instrumental variables strategy using data from second and third closest grid point as instruments. Although the instruments could also suffer from similar measurement error, errors in the instrument measures do not directly affect individual's socioeconomic outcomes. Further, I argue that the income effect of volatile rainfall in the area of birth affects the outcomes of subsistence households more than the price effect due to declining regional agricultural production as a consequence of shocks in neighboring areas. Conventional F-tests verify the strength of the chosen instruments for rainfall measured at the closest station.

Controlling for birth district and birth year fixed effects, and district-specific linear time trends, I find that a 50 percent higher birth year rainfall relative to the district norm leads Nepalese individuals (females) to 0.05 (0.09) more years of schooling and 1.7 percentage points higher likelihood of being literate. This positive relationship holds even when accounting for the effects of rainfall in the years before and after birth. Empirical results from specification using indicators for quintiles of monsoon rainfall – with respect to district-specific trend as an independent variable instead of approximated deviation from the norm – also support this finding. For both males and females, being in the top quintile is statistically significantly associated with greater years of schooling in comparison to being in the bottom quintile. There is some evidence to suggest that higher birth year monsoon rainfall is associated with foregone education and more work for adults from marginalized backgrounds but with increased years of education and fewer months of work for those from non-marginalized backgrounds. Positive birth year rainfall shock also tends to decrease the years of education and assets of children born to marginalized households.

The rest of the paper is organized as follows: Section 2 reviews relevant literature, Section 3 contextualizes the effect of variation in weather patterns in Nepal, Section 4 shows the data and summary statistics, Section 5 describes the empirical framework, Section 6 elaborates the main results, Section 7 discusses some robustness checks, and finally, Section 8 concludes.

2. Literature Review

The epidemiological literature on the impact of extrauterine shocks on future socioeconomic outcomes implying that reallocation of resources early in life could compensate for entrenched inequality in genetic and economic endowments has garnered continued academic interest. The rapidly expanding climate-economy literature, including the effects of postnatal environment, has proven to describe a general phenomenon after multitudes of early life experiences have been shown to matter in determining a wide range of adult outcomes (Almond and Currie, 2011; Dell et al., 2014; Almond et al., 2016). Particular emphasis is given to the impact of rainfall shocks, as fluctuations in rainfall is more likely to lead to reduced agricultural production that could adversely affect outcomes through economic channels (Jayachandran 2006; Yang and Choi 2007; Hidalgo et al. 2010). Among others, Godoy et al. (2008) find that rainfall variability during the second to fifth years of life is negatively associated with adult female height, though the amount and variation of rainfall during gestation and year of birth only weakly affected adult height. Maccini and Yang (2009) study the effect of rainfall shocks around the time of birth on adult health, education and socioeconomic status of Indonesian people. Their analysis suggests that females born in a year with unusually low rainfall in their community, which tend to cause negative income shocks given that these are rural agricultural communities, ended up doing worse later in life (in terms of educational attainment, health status, asset ownership, and a few other metrics of wellbeing) in comparison to females who were born in years with normal rainfall in their community.

In addition to the income channel, Bhalotra (2010) finds that disease exposure and parents' opportunity cost are some other ways through which rainfall shocks can influence infant mortality in India. Negative fluctuations in rainfall during the time in utero are shown to be associated with poor infant health condition at birth and lower academic performance later in Northeast Brazil (Rocha and Soares, 2015). Thai and

Myrskylä (2014) add a dimension to analyze the effect of rainfall shocks on child health by considering regional and individual characteristics and find that positive rainfall shocks make only children born in rainfall-dependent regions better off, not others. Similarly, Rocha and Soares (2015) conclude that negative rainfall shocks are significantly associated with shorter gestation periods, higher infant mortality and lower weight at birth in semiarid Brazilian households. Cornwell and Inder (2015) show that early life rainfall positively affects Indonesian children's height-for age, especially in urban areas, through both nutrition and disease effects. The negative effects of extreme winter on the growth trajectory of children in Mongolia is found to be persistent, lasting for up to four years after the shock (Gropp and Kraehnert, 2016). Dinkelman (2016) further shows that early childhood exposure to droughts increases later-life physical and mental disability rates by 3.5 to 5 percent in low-income settings in Africa. In addition to reducing age-standardized height and weight, drought exposure in years around birth can also decrease adult satisfaction with life (Abiona, 2017). Rosales-Rueda (2018) similarly concludes that children affected by floods early in life, especially during the third trimester, are not only shorter five to seven years later, but also have lower cognitive test scores.

3. Nepalese Context

Nepal is extremely dependent on its agricultural sector, which is why it is vulnerable to climate change (Bocchiola et al, 2019; Piya et al, 2019). In 2017, agriculture generated over 26.2 percent of the country's GDP and provided over 80 percent of total employment (World Bank, 2018). 29.4 percent of the land area of the country is agricultural but only 16.4 percent is arable (World Bank, 2009). Less than a third of the total agricultural land was irrigated in 2010 (World Bank, 2018). Ecologically, Nepal consists of three east-west strips – the Himalayas, the Hills and the Terai (alluvial, tropical flat lands). 55 percent of the total arable land lies in the Terai, 37.5 percent in the Hills and 7 percent in the Mountains (Bhattarai, 1998). Abruptly rising into the snow line, the Himalayas are mountainous region situated above 4000 meters in altitude and comprises of 16 districts. The Hills located south of the mountainous regions goes as low as 400 meters in altitude and has 39 districts. The Terai with the lowest elevations extends to the Indian border and includes the southernmost flat, intensively farmed Gangetic Plains. The Terai is the sub-tropical belt and the most cultivable, fertile and productive land in Nepal with the majority of the country's agricultural industries.

With significant spatial and temporal variations, Nepal received 1343.3 mm of rainfall per year on average, ranging from 75.8 mm to 4387.2 mm, between 1951 and 2007. The summer monsoon approaches from the Bay of Bengal to the West and it is the wettest period when approximately 75-80 percent of the total annual rainfall occurs within a few months (June-September) time (Menon, 2009). Typically, the western regions of the country receive smaller amount of rainfall than the eastern part during monsoon, due to decreasing moisture gradient in the wind advancing from the east. Seasonal average rainfall is the lowest during winter, which lasts from November to April, and variability of rainfall is higher in the post-monsoon season than in the monsoon season (SMRC, 2006). Summer rainfall is increasing by 2.2 mm every year whereas winter rainfall is decreasing by 0.63 mm every year (Malla, 2008).

The irregularities in seasonal monsoon rainfall across the country particularly have significant impact on the overall agricultural production (Piya et al, 2019). Intensified monsoon has reduced ground water retention by accelerating overflow, causing floods and landslides and destroying properties of the poor, and frequent drought has disturbed crop production throughout the farming year. The quantity of wheat and barley produced in 2009 dropped by 14.5 and 17.3 percent respectively relative to previous years, and agricultural yields in some districts in the western regions, which received less than half of the average rainfall between November 2008 and February 2009, dropped by more than 50 percent (WFP, 2009). According to Regmi (2007), the eastern plains in Terai faced rain shortfall in 2005/06 by early monsoon and agricultural production reduced by 12.5 percent on a national basis. He further notes that around 10 percent of cultivable land was left fallow due to rain deficit and at the same time, the western part of Terai experienced substantial amount of rain with floods, which reduced yields by 30 percent that year. Such volatility in rainfall, and consequently food production, has direct consequences for the income and livelihood of subsistence farming households. For instance, Menon (2009) demonstrates that differences in rainfall across Nepal affects the behavior and occupational choices of households. She finds that people in areas with highly fluctuating rainfall are less likely to work in the agricultural sector given the head is involved in agriculture.

4. Data

Cross-sectional measures of adult and youth socio-economic outcomes are from the 2001 Nepal Census data made available by the Integrated Public Use Microdata Series (IPUMS), University of Minnesota. The census data, which has detailed facts on age, gender, district of birth, educational status, literacy, occupation, industry, mortality of children, and so on for 2,583,245 individuals, provides a sizeable set of observations. Considering the fact that the effect of rainfall uncertainty is likely to be prominent in rural agriculture-dependent households, I omit observations from urban cities containing more than 50,000 people (as of 1981 Nepal Census for people born before 1981 and as of 1991 Nepal Census for people born after 1981).

From the remaining sample, I match all adults aged 25 to 50 (born in 1951-1976) and youths aged 10 to 20 (born in 1981-1991) to the historical rainfall data for their district and year of birth, which comes from the Terrestrial Precipitation: 1900-2010 Gridded Monthly Time Series Version 3.02 published by the Department of Geography, University of Delaware. This data set is constructed by interpolating the rainfall values of monthly total rain gauge-measured rainfall to a 0.5 degree by 0.5-degree latitude-longitude grid, where the grid points are located on the 0.25 degree. I assign a rainfall measure taken from the grid point that is closest to the district's centroid to each birth district-year combination. This assigned rainfall value is the same for all individuals within the same birth district and birth year cohort.

The left panel in Table 1 below provides the summary statistics for some of the relevant adult socioeconomic variables used in the study. The adult sample consists of 726,571 individuals, among which, 363,196 (49.99 percent) are males and 363,375 (50.01 percent) are females. 43 percent are literate, and 64.4 percent have no education or only attended pre-school. A mere 17.1 percent of the sample has had 10 or more years of formal education. 23.5 percent had no work in the year before the census. 59.2 percent have no access to electricity and 47.9 percent do not get piped drinking water. 87.3 percent of the people in the sample own their own dwelling. Similarly, the right panel in Table 1 provides the summary statistics for some of the relevant youth socioeconomic variables used in the study. The youth sample consists of 518, 696 individuals, among which about 51 percent males and 49 percent females. 75 percent were literate, and 59 percent are enrolled in school. On average, youths have 4.2 years of formal school and worked for 2.3 months in the year before the census.

I define rainfall in one's year of birth as the total rainfall in the monsoon season (June to September) of the calendar year of birth, as the census data does not include information on peoples' months of birth. Monthly rainfall data is also used to compute the monsoon rainfall in each of the three years before and after the year of birth, and mean monsoon season rainfall (norm) for every district for the 1948–2010 period. The independent variable for this analysis is the natural log of monsoon rainfall in the birth year minus the natural log of mean monsoon rainfall in the given district. This variable should be interpreted (approximately) as the percentage deviation from mean rainfall (for example, a value of 0.01 means rainfall was approximately one percent higher than normal). Table 1 below also summarizes the absolute and approximate percentage deviation in birth year rainfall from district norm for adults and youths in the census sample.

Table 1: Summary statistics of rainfall shocks and socioeconomic outcomes (Nepal Census 2001)

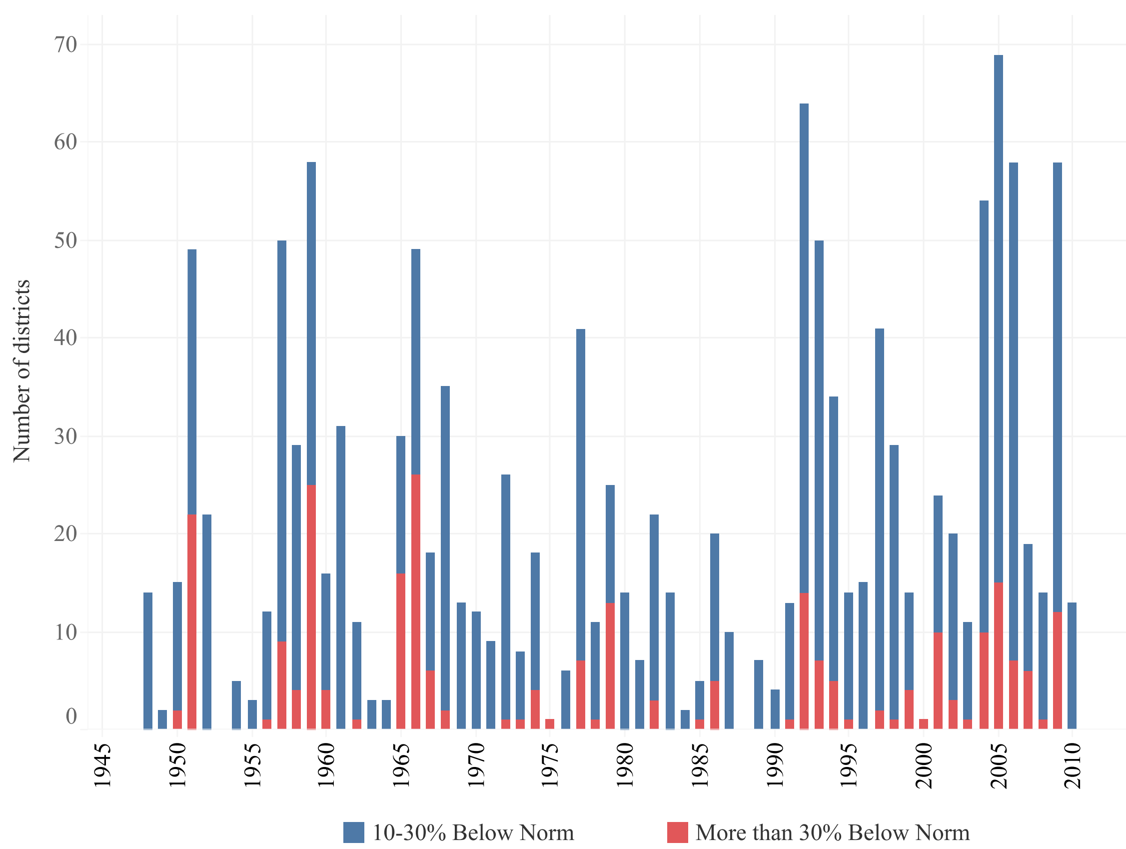
Adults born in 1951-1976				
	Women			
	Mean	*Min*	*Med*	*Max*
Age	35.6	25	35	50
Deviation (mm)	23.4	-963	20.8	1212
Deviation (%)	-0.01	-3.42	0.01	1.38
Months worked	5.18	0	5	12
Asset Index	3.16	0	3	8
Years of school	1.48	0	0	13
Literacy	0.26	0	0	1
	Men			
Age	36	25	35	50
Deviation (mm)	23.0	-963	13.1	1212
Deviation (%)	-0.01	-3.42	0.01	1.38
Months worked	9.19	0	12	12
Asset Index	3.22	0	3	8
Years of school	4.36	0	3	13
Literacy	0.60	0	1	1

Children born in 1981-1991				
	Girls			
	Mean	*Min*	*Med*	*Max*
Age	14.7	10	15	20
Deviation (mm)	84.2	-608	64.1	748
Deviation (%)	0.05	-1.43	0.05	0.70
Months worked	2.25	0	0	12
Years of school	3.66	0	3	13
Literacy	0.67	0	1	1
	Boys			
Age	14.6	10	14	20
Deviation (mm)	82.6	-608	62.2	748
Deviation (%)	0.05	-1.43	0.05	0.70
Months worked	2.30	0	0	12
Years of school	4.77	0	5	13
Literacy	0.83	0	1	1

Notes: The adult (children) sample includes individuals born in rural areas between 1951 and 1976 (1981 and 1991) inclusive. Asset index is the sum of eight asset variables (indicators for ownership of house, radio, television, modern toilet with flush, and access to electricity, cooking gas, tap water and drainage facility). Years of school is the total number of completed years of formal education. Deviation (mm) is the absolute difference of monsoon rainfall from the district norm and Deviation (percent) is the difference in log rainfall in monsoon season minus log of district norm. Norm is district-specific mean monsoon rain for the 1948-2010 period.

Historical data indicates considerable spatial and temporal variation in total annual rainfall across Nepalese districts (see Figure A1 in the Appendix). Further, the depth and breadth of drought conditions during monsoon fluctuates dramatically. Nearly 70 of the 75 districts have been affected by drought at least once in the 1948-2010 period as can be seen in Figure 1 below. Most of the drought-inflicted districts received 10 to 30 percent lower rainfall than their seasonal norm but there were others where precipitation totaled over 30 percent below normal. Adult outcomes of birth cohorts in such districts could be observably different from that of cohorts born that year in another district which experienced little or positive change in monsoon rainfall. Similarly, cohorts born in years of favorable monsoon could fare better in the long-run than their fellow residents born in the same district during years with scanty rainfall. The overall identification of the lasting effects of birth year rainfall shocks comes from both these comparisons.

Figure 1: Number of districts experiencing drought during monsoon



5. Empirical Strategy

A rainfall value from the grid point closest to the centroid of the birth district is assigned to each birth district - birth year combination. Each individual in the sample is thus associated with a district-level measure of approximate percentage deviation – positive or negative – in birth-year monsoon rainfall from the mean district monsoon rainfall over the 1948–2010 period. Considering this, I have two sources of measurement error: i) rainfall is defined as the total rainfall in the monsoon season of the calendar year of birth and not the total rainfall 12 months after the month of birth and ii) rainfall is measured at the closest grid point to the centroid of birth district, but this measurement is only imperfectly correlated with actual rainfall in the individual's narrowly defined birth locality. These are evident sources of classical measurement error in the early-life rainfall variable, which result in attenuated coefficient estimates that are biased towards zero.

A possible solution to this problem is to instrument for early-life rainfall with alternative measures of the same variable whose errors are likely to be orthogonal to the measurements in the nearest grid point. Thus, I use an instrumental variables strategy using data from second and third closest grid point as instruments for rainfall measured at the nearest point.[1] While data from the second and third closest rainfall stations could also suffer from measurement errors similar to that in the data from the closest station, I argue that errors in the instruments do not directly affect individual's socioeconomic outcomes. It is true that in addition to making a family poorer, drought may also reduce the overall availability of food, consequently raising regional food prices. However, for the purposes of this study, it is safe to expect that though operative, the latter effect will be relatively smaller than the former, since the households under consideration are mostly dependent on subsistence farming. We are more concerned about the income effect of volatile rainfall in the area of birth – as agricultural households produce less food – rather than the price effect – that farmers are able to buy less food – due to declining regional agricultural production as a consequence of rainfall shocks in neighboring areas (see Note A1 in the Appendix).

What I am interested in identifying is an accurately measured shock to rainfall that would affect infant nutrition. The best measure of that shock could be rainfall at the specific location of birth, or it could be a shock measured over a wider set of locations near to the point of birth. Any particular measure of rainfall from the area is going to involve measurement error, due both to recording errors and highly localized idiosyncratic random variation in rainfall. The instrumental variables approach in this paper is estimating the effect of variation in rainfall that is common across three nearby locations. This might be different from OLS because it purges the attenuation bias caused by the measurement error, or because it is including the effects occurring through other channels such as, the effect on one's own income and the effect on general food prices or some

[1] Maccini and Yang (2009) apply a similar IV strategy. Graphical Information Systems (ArcGIS) software was key to sorting of weather stations according to the distance from the centroids of each district. Precisely matching the rainfall data with the census data by birth-year and by geographic information on birth location was essential to achieve the stipulated objective of the paper. Even after instrumenting for rainfall measurement from the closest station, there could still be other measurement error because there is no reporting of the birth month in the census data, implying that the instrumented estimates are understated.

combination of both.

In a multipronged approach, I conduct several econometric analyses to establish a relationship between individuals' exposure to birth year monsoon rainfall and their contemporary economic, educational and occupational status. First, the following standard panel reduced-form linear specification is estimated:

(1) $$Y_{idt} = \beta R_{dt} + \boldsymbol{\gamma_d X_d} + \boldsymbol{\delta_t Z_t} + \boldsymbol{\lambda_d Trend_t} + \pi_{idt}$$

where, Y_{idt} is some measure of adult socioeconomic outcome of an individual *i* born in district *d* and in year *t*, R_{dt} is a measure of the deviation in log monsoon season rainfall from its norm in district *d* and birth year *t*; $\boldsymbol{X_d}$ is a vector of binary indicators for birth districts that control for anything that differs across these districts but are constant over time; $\boldsymbol{Z_t}$ is a vector of birth year indicator variables that control for factors that change over time across all districts in Nepal; $\boldsymbol{\lambda_d Trend_t}$ is a vector of birth district-birth year-specific linear time trends that control for elements that change differently over time across the districts approximately in a smooth linear trend and π_{idt} is the mean-zero error term, which also includes unobserved determinants of adult wellbeing and measurement error. The main coefficient of interest is β that measures how monsoon rainfall in the birth year, R_{dt}, impacts lasting adult outcomes. Birth cohort in a district that experienced a large increase or decrease in rainfall from the norm could be considered as the treatment group and equivalently, birth cohort in another district that experienced little change in rainfall from its norm could be considered as the control group. In addition to this specification, separate regressions including lag and lead rainfall variables are used to account for rainfall fluctuation in up to three years before and after the year of birth.

Second, an alternate specification including indicator variables for different quintiles of monsoon rainfall value is used to check whether the absolute level of rainfall and not just rainfall relative to district norm matters and consequently, to inspect if there are non-linear effects of rainfall on long term outcomes. The impact of drought may be more devastating in areas where rainfall is much lower than the norm than in areas with rainfall that is relatively closer to the norm, thus necessitating an inspection of non-linear effects of rainfall on adult outcomes as well. Monsoon rainfall measurements in all birth district-birth year combinations are first categorized into indicator variables for five quintiles of rainfall with respect to the historical trend for the district. I then regress the outcome variables against the indicators for each of the quintiles except the third quintile (the omitted category, so that coefficients on the indicators for other categories represent the effect relative to this "normal" rainfall category), along with birth district-and-time-fixed effects as well as birth district-specific linear time trends, to see whether there were extreme effects of rainfall in places with high deviation from the norm. The linear specification for this purpose is the following:

(2) $$Y_{idt} = \gamma_0 + \gamma_1 Q_{1dt} + \gamma_2 Q_{2dt} + \gamma_3 Q_{4dt} + \gamma_4 Q_{5dt} + \boldsymbol{\mu_d X_d} + \boldsymbol{\tau_t Z_t} + \boldsymbol{\varphi_d Trend_t} + \varepsilon_{idt}$$

where, Y_{idt} as before is some measure of adult outcome of an individual *i* born in district *d* and in year *t*, Q_{1dt} is an indicator variable for whether birth-year monsoon rain in district *d* and birth year *t* lies in the lowest quintile, Q_{2dt} is an indicator variable for whether birth-year monsoon rain in district *d* and birth year *t* lies in the second lowest quintile, Q_{4dt} is an indicator variable for whether birth-year monsoon rain in district *d* and birth year *t* lies in the second highest quintile, and Q_{5dt} is an indicator variable for whether birth-year monsoon rain in district *d* and birth year *t* lies in the highest quintile; $\boldsymbol{Z_t}$ is a vector of birth year indicator, $\boldsymbol{X_d}$ is a vector of district-fixed effect and $\boldsymbol{\varphi_d Trend_t}$ is the birth district-birth year-specific linear time trends. π_{idt} is the mean-zero error term. The γ_i coefficients measure the effect of rainfall on adult outcomes in each of the four rainfall quintiles relative to that of the district norm, the omitted middle quintile. While birth cohorts for which birth-year monsoon rain in district *d* and birth year *t* lies in Q_{3dt} could be considered as the control group and equivalently, birth cohorts for which birth-year monsoon rain lies in any of the other quintiles could be considered as treatment groups. In addition to this specification, separate regressions including lag and lead variables for each of the rainfall quintiles are used to account for rainfall fluctuation in up to three years before and after the year of birth.

6. Results

Adult Outcomes

First, Table 2 lists the coefficients on the primary independent variable (deviation of log rainfall from the log of mean district rainfall for the 1948-2010 period) obtained from model (1) for Nepalese adults of ages 25 to 50 born between 1951 and 1976. For the full adult sample and separately for males and females, the first three columns give the OLS estimates and the second three columns show the instrumental variable estimates. Robust standard errors with clustering by district of birth are presented in parentheses. I include birth district and birth year fixed effects, as well as district-specific linear time trends in the specification but coefficients on these variables are not reported for brevity. Individual’s long run status is segregated from the mean status in the individual’s birth district as well as the mean outcomes of the individual’s birth cohort. The analysis focuses on the impact of a 0.5 log point change in the rainfall variable when interpreting the magnitude of the estimated coefficients of rainfall.[2]

According to the OLS results in Table 2, I find that higher birth year monsoon rainfall is associated with better educational status for the overall adult sample, but the effect is significant only for females. Specifically, a 0.5 log point increase in rainfall, that is, a 50 percent higher rainfall than the district norm, leads a Nepalese adult individual (female) to be approximately two (three) percentage points more likely to be literate and to attain 0.05 (0.08) more completed years of schooling. The birth year rainfall coefficient for the regression with months worked as the outcome variable is statistically significantly negative for males, implying that a 50 percent increase in rainfall decreases the number of employed months in the previous twelve months by around 0.06. The instrumental variables coefficients shown in Table 2 are different from the OLS estimates, although the implication is largely the same. A 0.5 log point increase in birth year monsoon

2 All estimated regression coefficients of birth year rainfall represent the effect of a one percent change in the independent variable, which is a 100 percent higher rainfall than the district norm. Since doubling the rainfall is a large unit change, I use the effect of a 0.5 percent change instead.

rainfall leads a Nepalese adult individual (female) to be approximately 1.7 percentage points more likely to be literate and to attain 0.05 (0.09) more completed years of schooling. It also leads a Nepalese adult individual (male) to work about 0.04 (0.08) months less. However, no effect is observed on the asset index. The first stage regression results for the instrumental variables estimation of model (1) indicate that there is a positive and statistically significant relationship between rainfall in the nearest grid and each of the included instruments (rainfall measurements in the second-and-third-nearest grid points). The instruments are strong based on conventional tests: the multivariate F-test statistic for excluded instruments is 216.8 for males and 213.8 for females. The coefficients on the instruments in the first stage are 0.41 and 0.52, respectively. Both are statistically significantly different from zero (with standard deviation 0.05), indicating the relevance of the instruments.

Table 2: Effect of birth year monsoon rainfall on adult outcomes: women and men born in 1951–1976, OLS and IV estimates

	OLS			***IV***		
Outcome	Total	Male	Female	Total	Male	Female
Literacy	0.039**	0.025	0.056**	0.034*	0.012	0.045
	(0.01)	(0.02)	(0.02)	(0.01)	(0.02)	(0.02)
	718588	359623	358965	718388	359535	358853
Years of Schooling	0.102*	0.070	0.145***	0.099*	0.008	0.185***
	(0.04)	(0.06)	(0.03)	(0.05)	(0.07)	(0.04)
	717577	357980	359597	717378	357894	359484
Months Worked	-0.055	-0.121***	0.009	-0.088*	-0.150***	-0.043
	(0.03)	(0.03)	(0.04)	(0.04)	(0.03)	(0.06)
	726480	363151	363329	726278	363063	363215
Asset Index	0.013	0.016	0.009	-0.001	-0.005	0.003
	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.02)
	726480	363151	363329	726278	363063	363215

Cluster robust standard errors in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Notes: Sample is Nepalese individuals born outside of urban areas between 1951 and 1976 inclusive, observed in year 2001. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. Each coefficient (standard error) is from a separate regression of the outcome or dependent variable on birth year monsoon rainfall (deviation of log rainfall in birth district from log of 1948–2010 district mean rainfall). Standard errors clustered by district of birth. All regressions include fixed effects for birth year, birth district, and birth district–specific linear time trends. Asset index is sum of indicators for ownership of eight assets (house, radio, TV, modern toilet with flush, electricity as main source of light, LP Gas or kerosene as main source of cooking, access to tap water and sewage facility). See Table 1 for notes on sample composition and variable definitions.

Second, as an extension of Table 2, I estimate the impact of exogenous birth year monsoon rainfall shocks on adult outcomes, controlling for rainfall in various years around birth. A possible serial correlation in rainfall values across years means some years nearby the birth year may have the actual impact on adult outcomes, creating an omitted variables problem. To account for this, Table 3 reports the instrumental variables regression results, where each regression includes annual log deviation rainfall values in Year -3 (three years before the birth year) through Year +3 (three years after the year of birth) including in utero (Year -1) and birth (Year 0) years. The outcome variables are the same from previous tables: literacy, years of schooling, months of economic work in the last year and asset index. The OLS result for the same is shown in Table A1 in the Appendix.

The results in Table 3 supports the findings from Table 2 above. I find that even when controlling for rainfall in the three years around birth, birth year monsoon rainfall has a positive (negative) and significant effect on adult educational attainment (months worked in the past year). Noticeably, the size of the coefficient on birth year rainfall is slightly larger in comparison to that in Table 2 for the regression with years of education and months worked as outcome variables. A 0.5 log point increase in rainfall leads a Nepalese adult individual (female) to attain approximately 0.06 (0.1) more completed years of schooling. It also leads a Nepalese adult individual (male) to work around 0.05 (0.08) months less. Similar to the results presented in Table 2, no effect of birth year rainfall is observed on the asset index. As for the validity of the instruments for birth year monsoon rainfall at the closest grid point, the test statistic for the multivariate F-test of excluded instruments is 65.6 for males and 75.3 for females. After including rainfall in adjacent years in the specification, the coefficients on the birth year monsoon rainfall are statistically significant and relatively larger. This observation signifies that birth year rainfall has a significant effect on adult outcomes by itself and not merely because it may be correlated with rainfall values in neighboring years. The significance of the effect of rainfall in the years before the year of birth indicates that mother's health together with in utero environmental shocks could be influential in determining adult socioeconomic outcomes. Detailed discussion of implications of in-utero weather shocks however is beyond the scope of this paper as there is no accurate reporting of the month of birth for individuals in the census. The instrumental variables coefficients shown in Table 3 are smaller (larger) in magnitude in comparison to the OLS estimates from Table A1 in the Appendix for regressions with literacy status (years of education) as the dependent variable. The OLS coefficient estimates are more attenuated towards zero due to measurement errors in rainfall in comparison to the IV estimates. Although, the observed pattern of the effect of birth year rainfall is similar.

Third, Table 4 below shows the OLS and IV results from the quintile specification; model (2) in Section 5. This table lists the coefficients on indicator variables for the first, second, fourth and fifth quintiles of birth year monsoon rainfall with respect to the historical trend of the birth district from the regressions with the same socioeconomic outcome variables as before. The average or middle quintile is the omitted category. For each regression, the rainfall coefficient is presented for the full sample and separately for males and females. Robust standard errors with clustering by district of birth are presented in parentheses. I include birth district and birth year fixed effects, as well as

Table 3: Effect of monsoon rainfall in years before and after birth: women and men born in 1951–1976, IV estimates

Outcome	Literacy			Years of School			Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
t - 3	0.004	0.003	0.033	0.042	0.010	0.128*	-0.042	-0.044	-0.051	-0.003	-0.015	0.014
	(0.02)	(0.02)	(0.03)	(0.05)	(0.07)	(0.05)	(0.04)	(0.05)	(0.06)	(0.02)	(0.02)	(0.03)
t - 2	0.020	0.040*	0.007	0.094*	0.095	0.146***	-0.076	-0.113**	-0.011	0.010	0.020	-0.002
	(0.01)	(0.02)	(0.02)	(0.04)	(0.07)	(0.04)	(0.05)	(0.04)	(0.07)	(0.02)	(0.02)	(0.02)
t - 1	0.016	0.005	0.006	-0.004	-0.057	-0.028	0.006	-0.013	-0.058	-0.017	-0.046	0.012
	(0.01)	(0.02)	(0.02)	(0.04)	(0.05)	(0.05)	(0.04)	(0.04)	(0.05)	(0.02)	(0.03)	(0.02)
t = 0	0.034*	0.012	0.046	0.106*	0.003	0.201***	-0.098*	-0.164***	-0.055	-0.000	-0.008	0.007
	(0.01)	(0.02)	(0.02)	(0.05)	(0.07)	(0.04)	(0.04)	(0.04)	(0.06)	(0.02)	(0.03)	(0.02)
t + 1	0.005	-0.004	0.034	0.041	-0.030	0.200***	-0.051	-0.016	-0.028	0.006	0.003	0.014
	(0.02)	(0.02)	(0.02)	(0.07)	(0.10)	(0.05)	(0.05)	(0.06)	(0.07)	(0.03)	(0.04)	(0.03)
t + 2	-0.015	0.001	-0.027	-0.030	-0.010	0.003	-0.078	0.023	-0.070	0.009	-0.002	0.024
	(0.02)	(0.03)	(0.03)	(0.06)	(0.11)	(0.06)	(0.04)	(0.05)	(0.07)	(0.03)	(0.04)	(0.03)
t + 3	0.011	0.005	0.042	0.026	0.015	0.073	-0.050	-0.139*	0.059	0.019	0.028	0.015
	(0.02)	(0.02)	(0.03)	(0.06)	(0.08)	(0.06)	(0.05)	(0.06)	(0.06)	(0.02)	(0.03)	(0.03)
N	716504	358648	357856	715499	357017	358482	724377	362172	362205	724377	362172	362205

Cluster robust standard errors in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Notes: Sample is Nepalese individuals born outside of urban areas between 1951 and 1976 inclusive, observed in year 2001. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. Each column presents coefficients (standard errors) from a separate regression of the dependent variable on various years' rainfall (deviation of log rainfall from log of 1948–2010 district mean rainfall). Year 0 is birth year, year -1 is year prior to birth year, year +1 is year after birth year, and so on. All regressions include fixed effects for birth year, birth district, and birth district-specific linear time trends. See Table 1 for notes on sample composition and variable definitions.

Table 4: Effect of birth year monsoon rainfall (relative to national norm) on adult outcomes: women and men born in 1951–1976, OLS and IV estimates

Outcome	Literacy			Years of School			Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
						OLS						
First	-0.011	-0.010	0.003	-0.027	-0.012	0.001	-0.008	0.007	0.028	0.013	0.016	0.011
	(0.01)	(0.01)	(0.01)	(0.03)	(0.05)	(0.03)	(0.02)	(0.02)	(0.04)	(0.01)	(0.02)	(0.02)
Second	0.011	0.008	0.026*	0.034	0.021	0.078**	-0.027	0.018	-0.014	0.002	0.000	0.006
	(0.01)	(0.01)	(0.01)	(0.03)	(0.05)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
Fourth	0.024**	0.026**	0.031**	0.084**	0.083*	0.111**	-0.057*	-0.054*	-0.004	0.029*	0.037*	0.021
	(0.01)	(0.01)	(0.01)	(0.03)	(0.04)	(0.03)	(0.03)	(0.03)	(0.03)	(0.01)	(0.01)	(0.02)
Fifth	0.013*	0.013	0.026**	0.048*	0.042	0.100***	-0.058*	-0.059*	-0.005	0.012	0.023	0.003
	(0.01)	(0.01)	(0.01)	(0.02)	(0.03)	(0.02)	(0.02)	(0.03)	(0.03)	(0.01)	(0.01)	(0.01)
N	718678	359668	359010	717668	358025	359643	726571	363196	363375	726571	363196	363375
						IV						
First	0.037	0.022	0.080	0.145	0.195	0.154	-0.008	0.015	0.005	0.076	0.007	0.143*
	(0.05)	(0.06)	(0.06)	(0.15)	(0.21)	(0.13)	(0.10)	(0.12)	(0.12)	(0.06)	(0.07)	(0.07)
Second	0.079	0.015	0.149	0.447	0.336	0.578*	0.014	0.049	-0.004	0.098	-0.024	0.217
	(0.09)	(0.10)	(0.11)	(0.25)	(0.34)	(0.26)	(0.20)	(0.20)	(0.22)	(0.09)	(0.12)	(0.12)
Fourth	0.097	0.037	0.152	0.407	0.280	0.533**	-0.004	-0.046	0.021	0.127	0.019	0.233*
	(0.08)	(0.08)	(0.09)	(0.21)	(0.28)	(0.19)	(0.14)	(0.17)	(0.16)	(0.08)	(0.09)	(0.10)
Fifth	0.055	0.038	0.088	0.267*	0.258	0.328*	-0.096	-0.067	-0.073	0.067	0.017	0.118
	(0.05)	(0.05)	(0.06)	(0.13)	(0.17)	(0.13)	(0.11)	(0.11)	(0.12)	(0.04)	(0.07)	(0.06)
N	726571	363196	363375	717668	358025	359643	718678	359668	359010	726571	363196	363375

Cluster robust standard errors in parentheses

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

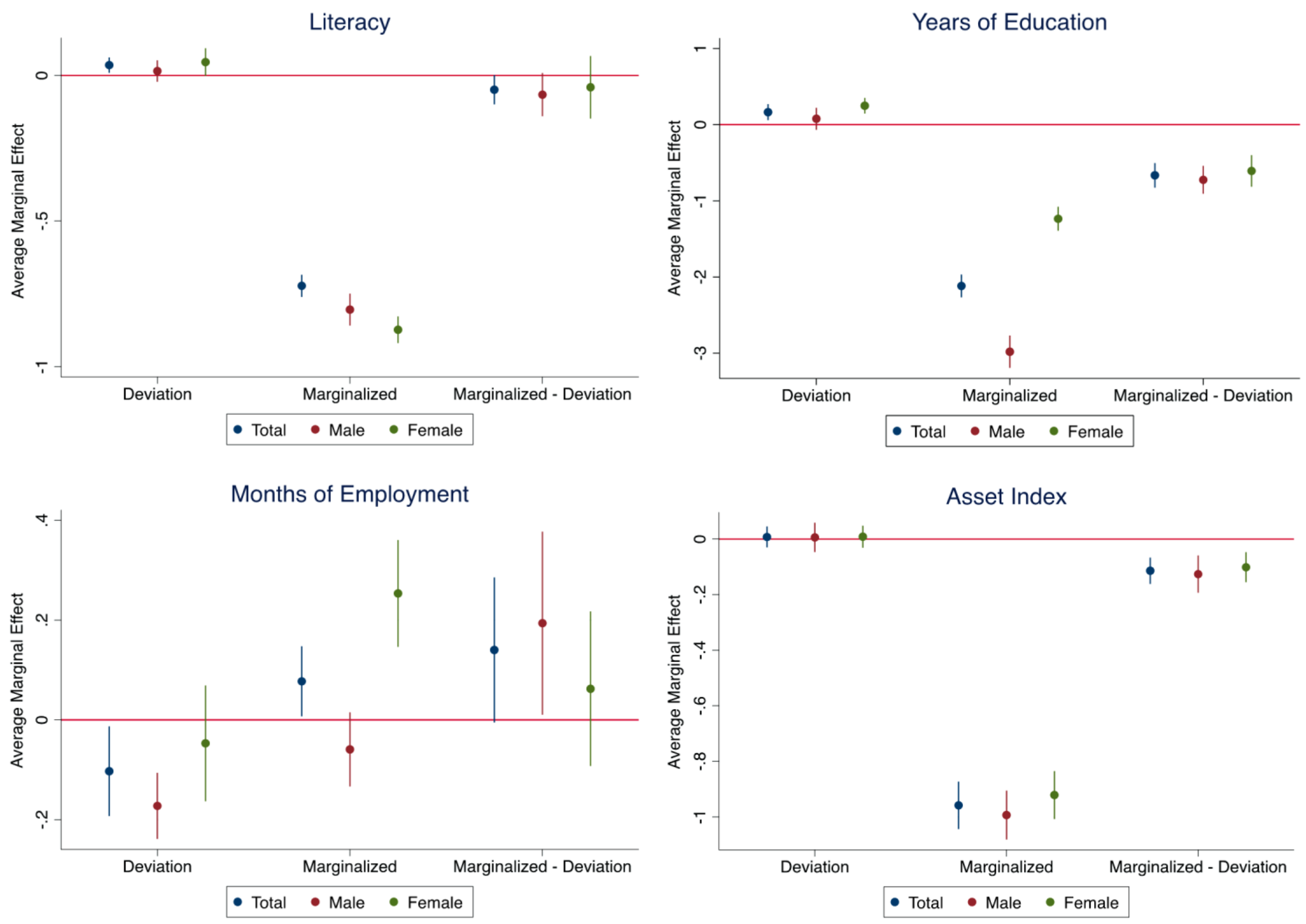
Notes: Samples are individuals born in rural Nepal between 1951 and 1976 inclusive, observed in year 2001. Each coefficient (standard error) is from a separate regression of the outcome or dependent variable on birth year monsoon rainfall (deviation of log rainfall in birth district from log of 1948–2010 district mean monsoon rainfall). Standard errors clustered by district of birth. All regressions include fixed effects for birth year, birth district, and birth district–specific linear time trends. School Enrolment and Literacy are indicators for whether children were enrolled in school and literate respectively. See Table 1 for notes on sample composition and variable definitions.

district-specific linear time trends in the specification but coefficients on these variables are not reported. I find some evidence to support the hypothesis that higher birth year rainfall relative to district norm (i.e. if birth year rainfall lies in the fourth and fifth quintiles) is positively associated with the likelihood of literacy, years of education and asset index, but negatively associated with number of months worked in the past year. The difference in years of education attained and asset index across cohorts with birth year monsoon rainfall in the fifth quintile and the first quintile is statistically significant. The consistent negative association between birth year rainfall and the number of months worked is not as counterintuitive as one might initially perceive it to be, as individuals born in years with higher than average rainfall might have been able to sustain their lives by working less on average during their lifetime than those born in years with lower or average rainfall. However, verifying this view could be a matter of future empirical exercise. The IV results from this analysis should be interpreted with caution, as regions with extremely low rainfall compared to the local average are sparsely populated and thus do not provide enough observations for the study. That combined with less reliable rainfall measurements from the few weather stations in the areas that underlie the gridded rainfall data are a probable source of weak instruments problem.

Fourth, to detail the heterogeneity in the effects of shocks in birth year monsoon rainfall on socioeconomic outcomes of Nepalese adults, I implement a modified version of model (1) that additionally includes an indicator for whether individuals belonged to a government-categorized group of marginalized castes, and an interaction between that indicator and the deviation of birth year monsoon rainfall. Decades of targeted and comprehensive measures to ensure food security and access to basic resources and rights (for instance, rights to public water source, land ownership and commensurate wages), for the most disadvantaged and marginalized groups, has failed to eliminate caste-based religious, occupational and territorial discrimination in Nepal. Such malpractices can hinder access to the agricultural ladder; landlessness to tenancy to owner-operation, and therefore, limit the ability of underprivileged families to provide for their children during the critical years of early life.

Figure 2 below depicts the average marginal effect (with 95% confidence interval) - obtained from the instrumental variable regressions of the modified specification discussed above (see Table A2 in the Appendix) - of birth year monsoon rainfall on adult literacy, years of education, months of employment and asset index for Nepalese adults from marginalized and non-marginalized backgrounds. The coefficient on deviation represents the marginal effect of rainfall on outcomes of the non-marginalized group. The sum of coefficients on deviation and the interaction term represents marginal effect of rainfall on outcomes of the marginalized group. On average, the probability of an adult (female) from a marginalized caste being literate is 0.72 (0.87) lower than that of an individual (female) from a non-marginalized caste. The impact of birth year monsoon rainfall on the likelihood of literacy later in life is statistically indifferent for individuals from both groups. An adult (female) from a marginalized caste, on average, completed 2.1 (1.2) fewer years of education than an individual (female) from a non-marginalized caste. A 50 percent higher birth year monsoon rainfall than the district norm, is associated with approximately 0.25 (0.18) fewer years of education for a marginalized adult (female) but with approximately 0.08 (0.12) additional years of education for a non-

Figure 2: Effect of birth year monsoon rainfall on various socioeconomic outcomes for non-marginalized and marginalized Nepalese adults of ages 25 to 50 born in 1951-1976



Notes: The coefficient plots show the average marginal effects (with 95% confidence interval) of birth year monsoon rainfall, and the interaction between rainfall and an indicator for whether individuals belonged to marginalized group of castes on various socioeconomic outcomes for Nepalese adults of ages 25 to 50 born in 1951-1976. The estimates are obtained from a modified version of model (1) that additionally includes an indicator for whether households belonged to a government-categorized group of marginalized castes and an interaction between that indicator and birth year monsoon rainfall. The coefficient on deviation represents the marginal effect of rainfall on outcomes of the non-marginalized group and the sum of coefficients on deviation and the interaction term represents that on outcomes of the marginalized group.

marginalized individual (female). Similarly, an adult (female) from a marginalized caste, on average, worked 0.08 (0.25) months more in the past year than an individual (female) from a non-marginalized caste. A 50 percent higher birth year monsoon rainfall than the district norm, is associated with approximately 0.02 (0.01) additional months of employment for a marginalized adult (male) but with approximately 0.05 (0.09) fewer months of employment for a non-marginalized individual (male). This result could partially explain the unanticipated negative relationship between birth year rainfall and months of employment implied by Table 4. Among all the adults born between 1950 and 1976, higher birth year monsoon rainfall is associated with foregone education and more work for those from marginalized backgrounds, perhaps in low-paying, labor-intensive jobs, but with increased years of education and fewer months of work for the ones from non-marginalized backgrounds. Finally, the asset index for individuals in the marginalized group is 0.96 lower than that for individuals in the non-marginalized group. While birth year monsoon rainfall does not significantly affect asset index for people in the non-marginalized group, a 50 percent higher birth year monsoon rainfall than the district norm, is associated with approximately a reduction of 0.05 (0.07) for a marginalized adult (male).

Youth Outcomes

Having observed consequential impact of birth year monsoon rainfall on adult education outcomes, I also conduct a similar analysis for Nepalese youth to determine whether such impact is evident earlier in life. First, Table 5 lists the coefficients on the deviation of log rainfall from the log of mean district rainfall) obtained from model (1) for children and adolescents of ages 10 to 20 born in the 1981-1991 period. For the full youth sample and separately for males and females, the first three columns give the OLS estimates and the second three columns show the instrumental variable estimates. Robust standard errors with clustering by district of birth are presented in parentheses. Birth district and birth year fixed effects, as well as district-specific linear time trends are included in the specification but coefficients on these variables are not reported for brevity. Individual's medium run status is segregated from the mean status in the individual's locality as well as the mean outcomes of the individual's birth cohort. As before, the discussion focuses on the impact of a 0.5 log point change in the rainfall variable when interpreting the magnitude of the estimated coefficients of rainfall.[3] Unlike with adults (Table 2), both

[3] All estimated regression coefficients of birth year rainfall represent the effect of a 1% change in the independent variable, which is a 100% higher rainfall than the district norm. Since doubling the rainfall is a huge unit change, the effect of a 0.5% change is used instead.

OLS and IV estimates in Table 5 show that birth year rainfall has insignificant effects on medium term socioeconomic outcomes for Nepalese youths.

Table 5: Effect of birth year monsoon rainfall on youth outcomes: women and men born in 1981–1991, OLS and IV estimates

	OLS			*IV*		
Outcome	Total	Male	Female	Total	Male	Female
	-0.011	-0.033	0.007	-0.044	-0.067	-0.031
Literacy	(0.03)	(0.03)	(0.03)	(0.04)	(0.06)	(0.05)
	518648	264067	254581	518648	264067	254581
	0.092	0.004	0.092	0.069	0.066	0.101
Years of Schooling	(0.10)	(0.08)	(0.10)	(0.12)	(0.13)	(0.17)
	253090	262897	253090	515987	262897	253090
	0.061	-0.021	0.188	0.053	-0.218	0.347
Months Worked	(0.08)	(0.08)	(0.10)	(0.16)	(0.15)	(0.22)
	518696	264084	254612	518696	264084	254612
	-0.035	-0.054	-0.019	0.005	-0.050	0.059
Asset Index	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)	(0.07)
	518696	264084	254612	518696	264084	254612

Cluster robust standard errors in parentheses

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Notes: Sample is Nepalese individuals born outside of urban areas between 1981 and 1991 inclusive, observed in year 2001. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. Each coefficient (standard error) is from a separate regression of the outcome or dependent variable on birth year monsoon rainfall (deviation of log rainfall in birth district from log of 1948–2010 district mean rainfall). Standard errors clustered by district of birth. All regressions include fixed effects for birth year, birth district, and birth district–specific linear time trends. Asset index is sum of indicators for ownership of eight assets (house, radio, TV, modern toilet with flush, electricity as main source of light, LP Gas or kerosene as main source of cooking, access to tap water and sewage facility). See Table 1 for notes on sample composition and variable definitions.

Second, according to Table 6, this result does not change even when controlling for rainfall in the years around birth. However, I find some evidence that rainfall in the years after birth is significantly and positively associated with completed years of schooling and asset index. In particular, a 0.5 log point increase in rainfall two years after the birth year leads a young Nepalese individual (female) to attain approximately 0.12 (0.18) more completed years of schooling. Similarly, a 0.5 log point increase in rainfall in the year after the birth year is associated with approximately 0.06 (0.08) increase in asset index for a young Nepalese individual (male). No significant effect of rainfall in and around birth year is observed on the number of months worked in the past year. The OLS result for the same is shown in Table A3 in the Appendix. Overall, deficiencies in socioeconomic outcomes due to shocks in birth year monsoon rainfall seem to manifest relatively later in life (during adulthood).

Third, coefficient plots in Figure 3 depict the average marginal effect (with 95% confidence interval) - obtained from the instrumental variable regressions of the modified specification of model (1) discussed in Section 5 (see Table A4 in the Appendix) - of birth year monsoon rainfall on literacy status, years of education, months of employment and asset index for Nepalese youths from marginalized and non-marginalized backgrounds. On average, the probability of a young individual (female) from a marginalized caste being literate is 0.56 (0.63) percentage points lower than that of an individual (female) from a non-marginalized caste. The disparity in likelihood of literacy between the marginalized and non-marginalized youths is noticeably smaller than that for the adults. No statistical difference exists in how birth year monsoon rainfall affects the likelihood of literacy for young individuals from both groups. A young individual (female) from a marginalized caste, on average, completed 1.7 (1.8) fewer years of education than an individual (female) from a non-marginalized caste. A 50 percent higher birth year monsoon rainfall than the district norm, is associated with approximately 0.53 (0.32) fewer years of education for marginalized youths (females) but with no effect on years of education for the non-marginalized youths. Similarly, a young individual (female) from a marginalized caste, on average, worked 0.93 (0.71) months more in the past year than an individual (female) from a non-marginalized caste. Though, the effect of birth year monsoon rainfall is statistically insignificant for youths of both marginalized and non-marginalized backgrounds. Finally, the asset index for an individual (female) in the marginalized group is 0.84 (0.83) lower than that for an individual (female) in the non-marginalized group. While birth year monsoon rainfall does not significantly affect asset index for youths in the non-marginalized group, a 50 percent higher birth year monsoon rainfall than the district norm, is associated with approximately a reduction of 0.27 for the asset index of a marginalized young person.

Table 6: Effect of monsoon rainfall in years before and after birth: women and men born in 1981–1991, IV estimates

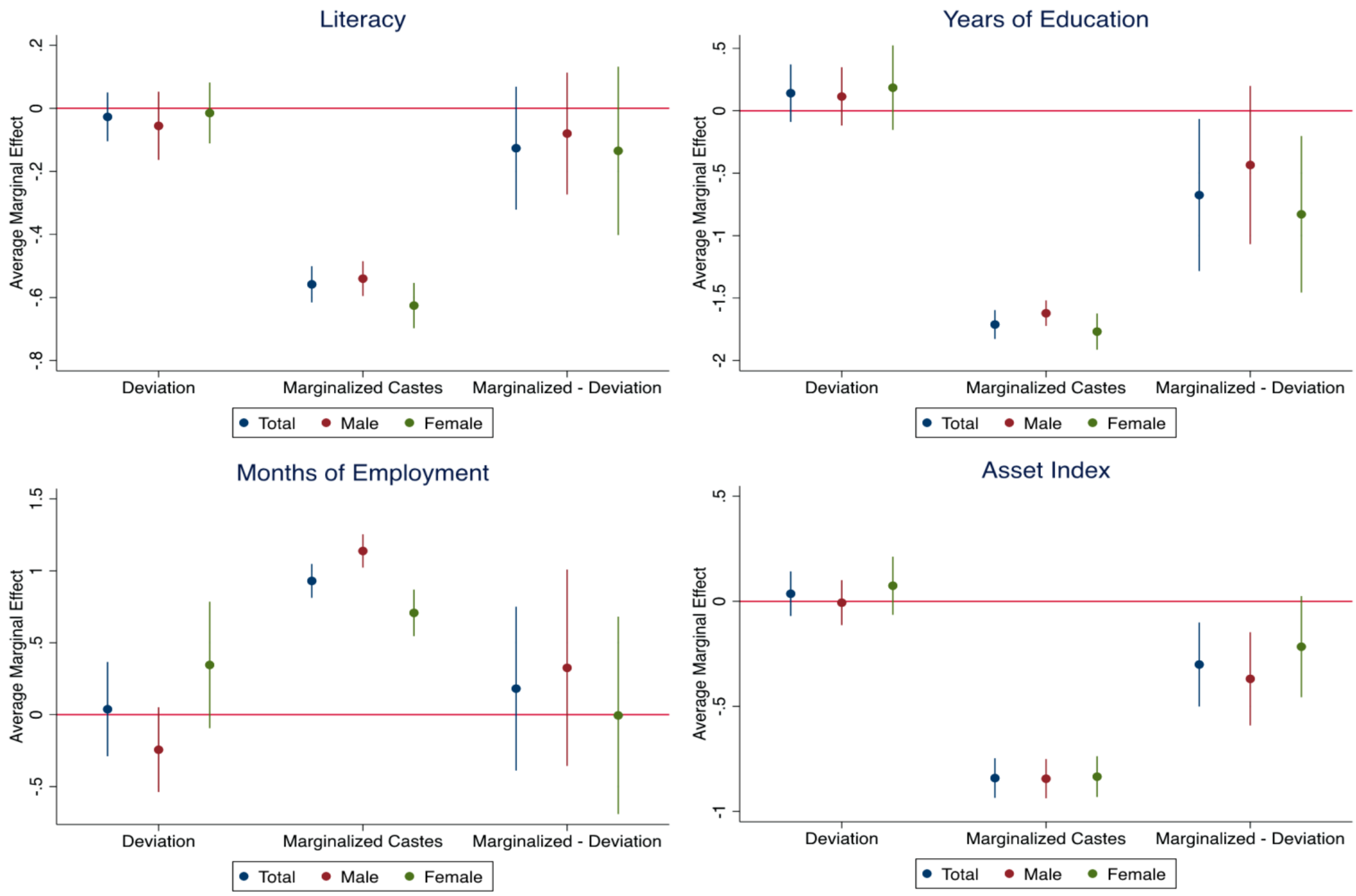
Outcome	Literacy			Years of School			Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
t - 3	0.074*	-0.045	0.170**	0.029	-0.158	0.253	0.136	0.191	0.067	0.070	0.077	0.067
	(0.04)	(0.05)	(0.05)	(0.13)	(0.14)	(0.15)	(0.12)	(0.15)	(0.18)	(0.08)	(0.10)	(0.09)
t - 2	-0.029	-0.061	0.004	-0.117	-0.051	-0.219	0.233	0.204	0.275	0.070	0.063	0.084
	(0.05)	(0.06)	(0.05)	(0.11)	(0.14)	(0.12)	(0.14)	(0.15)	(0.22)	(0.05)	(0.06)	(0.07)
t - 1	0.090	0.041	0.118	0.101	0.074	0.056	0.222	0.094	0.307	0.165	0.213**	0.122
	(0.06)	(0.08)	(0.07)	(0.15)	(0.18)	(0.17)	(0.22)	(0.26)	(0.32)	(0.08)	(0.08)	(0.11)
t = 0	-0.041	-0.103	0.003	0.121	0.166	0.097	0.173	-0.135	0.468	0.082	0.047	0.121
	(0.05)	(0.07)	(0.07)	(0.17)	(0.18)	(0.23)	(0.26)	(0.23)	(0.35)	(0.07)	(0.07)	(0.09)
t + 1	0.005	-0.097	0.083	0.246*	0.205	0.322	-0.069	0.029	-0.197	0.118*	0.174**	0.063
	(0.05)	(0.05)	(0.06)	(0.12)	(0.11)	(0.19)	(0.21)	(0.19)	(0.27)	(0.06)	(0.06)	(0.09)
t + 2	0.007	-0.038	0.040	0.233*	0.199	0.360**	-0.179	-0.124	-0.342	-0.003	-0.018	0.019
	(0.04)	(0.05)	(0.05)	(0.09)	(0.13)	(0.13)	(0.13)	(0.16)	(0.18)	(0.06)	(0.07)	(0.07)
t + 3	0.007	-0.105*	0.074	0.132	-0.046	0.331	-0.095	0.117	-0.333	-0.027	-0.035	-0.014
	(0.05)	(0.05)	(0.06)	(0.13)	(0.13)	(0.17)	(0.17)	(0.18)	(0.25)	(0.07)	(0.07)	(0.08)
N	516850	263181	253669	514204	262023	252181	516898	263198	253700	516898	263198	253700

Cluster robust standard errors in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Notes: Sample is Nepalese individuals born outside of urban areas between 1981 and 1991 inclusive, observed in year 2001. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. Each column presents coefficients (standard errors) from a separate regression of the dependent variable on various years' rainfall (deviation of log rainfall from log of 1948–2010 district mean rainfall). Year 0 is birth year, year -1 is year prior to birth year, year +1 is year after birth year, and so on. All regressions include fixed effects for birth year, birth district, and birth district-specific linear time trends. See Table 1 for notes on sample composition and variable definitions.

Figure 3: Effect of birth year monsoon rainfall on various socioeconomic outcomes for non-marginalized and marginalized Nepalese youths of ages 10 to 20 born in 1981-1991



Notes: The coefficient plots show the average marginal effects (with 95% confidence interval) of birth year monsoon rainfall and the interaction between rainfall and an indicator for whether individuals belonged to marginalized group of castes on various socioeconomic outcomes for Nepalese adults of ages 10 to 20 born in 1981-1991. The estimates are obtained from a modified version of model (1) that additionally includes an indicator for whether households belonged to a government-categorized group of marginalized castes and an interaction between that indicator and birth year monsoon rainfall. The coefficient on deviation represents the marginal effect of rainfall on outcomes of the non-marginalized group and the sum of coefficients on deviation and the interaction term represents that on outcomes of the marginalized group.

7. Robustness Check

Given the primary linear specification evaluates divergences in birth year rainfall from historical trends, time-invariant differences between regions are not a source of bias, but time-variant differences could be confounding. In particular, the possibility that sample selection bias from mortality or migration over time might affect the results is important to consider. If drought has a negative impact on socioeconomic status, one would expect negative deviations in birth year monsoon rainfall to increase mortality or out-migration, and positive to decrease it. As a selection check, I separately test whether rainfall shocks affect the size of the birth district and year cohort and the likelihood of out-migration, controlling for district-fixed and year-fixed effects as well as for district-specific linear time trends. As shown in Table 7 below, the coefficients on birth year rainfall for both cohort population size and propensity to out-migrate from the district of birth are not statistically significant for total, male and female samples, indicating that birth year rainfall shocks do not affect the likelihood of inclusion in the study.

Table 7: Impact of Rainfall Shocks on Survival and Migration

	Survival			Migration		
	Total	Male	Female	Total	Male	Female
Deviation	-16.260	-19.716	-12.942	0.004	-0.002	0.009
	(22.30)	(23.47)	(21.23)	(0.01)	(0.01)	(0.01)
Constant	738.924***	-172.539***	-326.020***	-1.242***	-1.383***	-1.129***
	(38.46)	(22.02)	(32.77)	(0.01)	(0.01)	(0.01)
N	726480	363151	363329	726480	363151	363329

Cluster robust standard errors in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Another potential issue that could weaken the validity of the results discussed in the paper is whether schools are preferentially established in better off, fertile areas that perhaps receive higher rainfall. Due to the lack of historical information on school infrastructure, I separately model the percentage of adults with formal education and their mean years of schooling as a function of their current district's mean monsoon season rainfall and other socio-graphic characteristics. Endogenous association between rainfall and access to schools would likely have led districts that receive higher average rainfall between 1948-2010 to have better educational outcomes. However, I observe no such relationship as shown in Table 8 below.

Table 8: Current rainfall shocks and adult education outcomes

	Percentage with formal education			*Years of schooling*		
	Total	Male	Female	Total	Male	Female
Mean Rainfall (1000 cm)	0.026	0.018	0.033	0.193	0.159	0.244
	(0.02)	(0.03)	(0.02)	(0.18)	(0.27)	(0.13)
Population (1000s)	0.001	0.001	0.000	0.002	0.006	-0.001
	(0.00)	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
Age	0.004	-0.014	0.023	-0.070	-0.152	0.050
	(0.02)	(0.02)	(0.01)	(0.13)	(0.20)	(0.10)
Male	-0.614**	-1.375***	-0.528**	-4.950**	-11.284***	-4.198**
	(0.22)	(0.30)	(0.18)	(1.64)	(2.45)	(1.22)
Asset Index	0.047***	0.053**	0.041***	0.422***	0.531***	0.324***
	(0.01)	(0.02)	(0.01)	(0.10)	(0.14)	(0.07)
Oparting Agricultural Land	0.356***	0.319**	0.400***	3.964***	4.464***	3.490***
	(0.07)	(0.10)	(0.06)	(0.53)	(0.78)	(0.39)
Marginalized	-0.156	-0.066	-0.206	-1.499	-0.806	-1.823*
	(0.14)	(0.19)	(0.11)	(1.06)	(1.58)	(0.79)
Constant	-0.098	1.097	-1.028	1.365	7.854	-3.799
	(0.71)	(1.00)	(0.58)	(5.43)	(8.09)	(4.03)
N	75	75	75	75	75	75
R-squared	0.780	0.675	0.837	0.868	0.801	0.889

Standard errors in parentheses
* p<0.05 ** p<0.01 *** p<0.001

8. Conclusion

Subsistence households in Nepal mainly depend on fluctuating natural rainfall for agricultural production due to the lack of irrigation infrastructure. Without appropriate crop insurance and credit schemes, unreliable farm output compels rural families to adopt sub-optimal measures, such as trading livestock, crop-switching, etc., to mitigate the onerous consequences of extreme weather events. During strenuous times, they may even have to forego investments necessary for the development of their children in the critical years of early life.

Considering such predicaments, this paper estimates the effects of shocks in birth year monsoon rainfall on future socioeconomic status of youths and adults of rural Nepal. The cross-sectional measures of adult and youth socio-economic outcomes are obtained from the 2001 Nepal Census data. Each individual in the sample is matched with the historical rainfall information for his or her birth district and year. The historical rainfall data shows that rainfall varied considerably over time and across districts of Nepal. I use this spatial and temporal variation in rainfall patterns throughout the 1951-1991 period to identify the causal effect. Birth year rainfall measurement is defined as the total rainfall in the monsoon season of the calendar year of birth and is taken from the grid point that is closest to the birth district's centroid. To address the consequent measurement error in the early-life rainfall variable, I use an instrumental variables strategy using data from second and third closest grid point as instruments for rainfall measured at the nearest point. The instruments used for rainfall measured at the closest station are strong based on the conventional F-tests.

The main empirical result from this research indicates that higher birth year rainfall has statistically significant and positive effects on adult educational outcomes of females, but not for males, possibly reflecting the gender bias in domestic resource allocation in dire conditions. Females with higher birth year rainfall are more likely to be literate and to attain more completed years of formal schooling. This result is reinforced by the empirical results from specification using indicators for quintiles of rainfall with respect to district-specific trend as an independent variable instead of approximated deviation from the norm. For both males and females, being in the highest quintile of rainfall is associated with greater years of schooling relative to being in the bottom quintile. However, higher birth year rainfall is significantly and negatively associated with months of economic employment in the past year. This unanticipated result could be reconciled by the fact that higher birth year monsoon rainfall is associated with foregone education and more work for adults from marginalized backgrounds, but with increased years of education and fewer months of work for those from non-marginalized backgrounds.

The results from this paper have important policy implications in favor of agricultural insurance and safety net programs, the likely benefits of which should be considered when structuring antipoverty government interventions, targeted in particular for females and individuals from marginalized backgrounds. Such programs could not only protect infants, who otherwise would have suffered from food insecurity and poor nutrition from immediate consequences of negative rainfall shocks, but also compensate for their lost future productivity and earnings from education associated with drought in and around the years of birth. Much needed efforts to plan private or public drought insurance programs in developing countries like Nepal in order to aid the poor in coping with external weather shocks and in investing in proper upbringing of their children ought to motivate further research in this topic.

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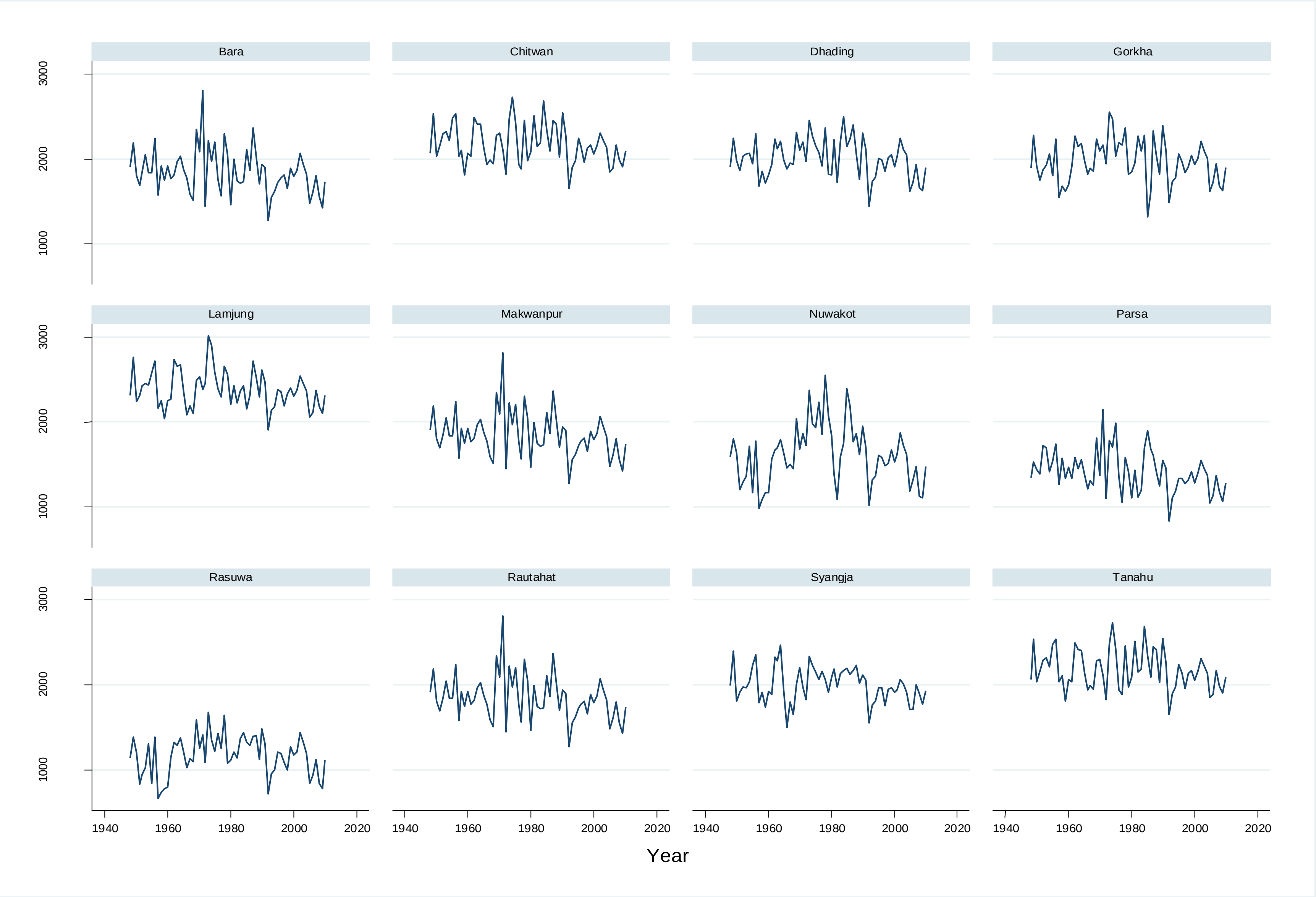
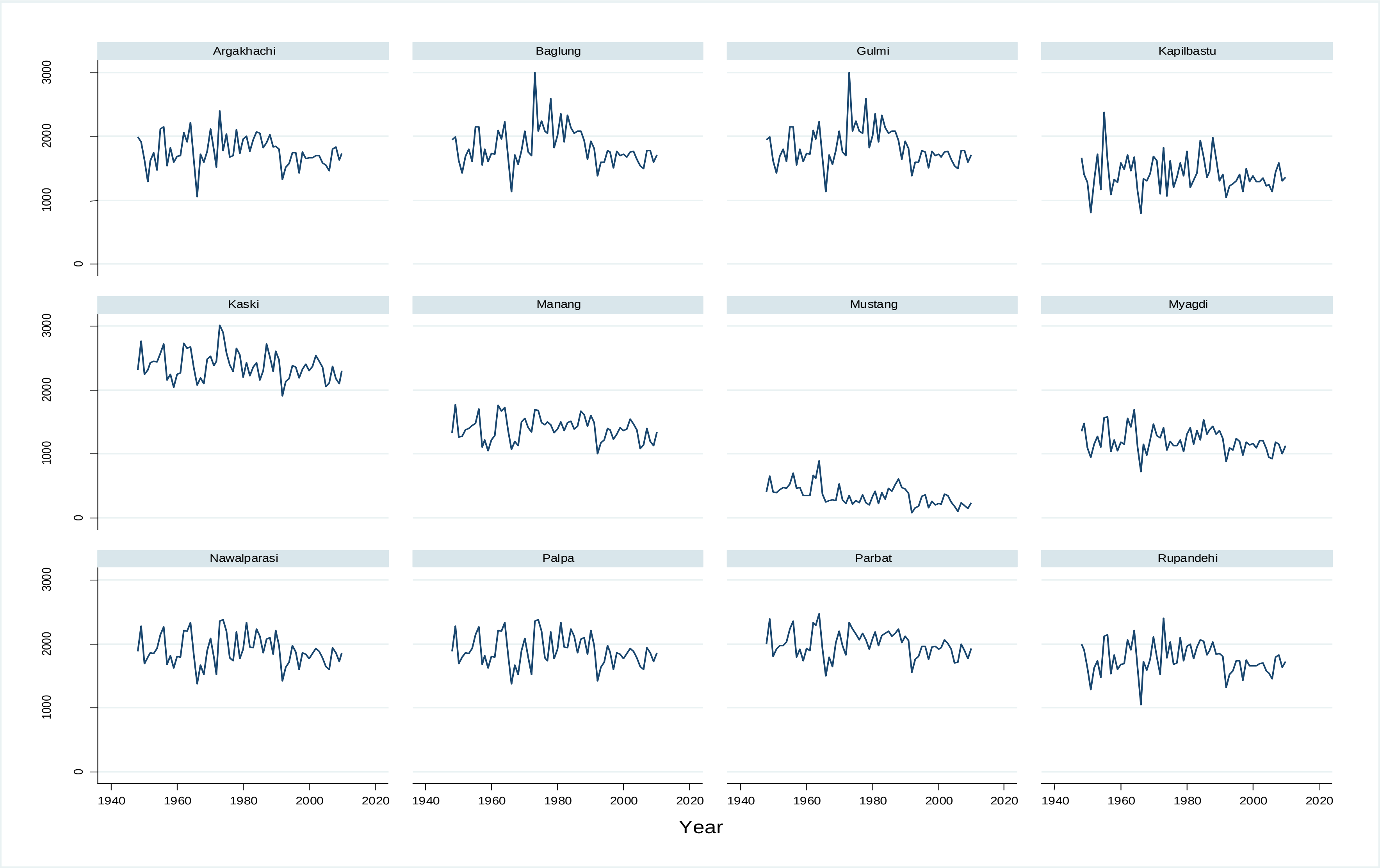
Appendix

Figure A1: Annual Rainfall by District





Argakhachi
Baglung
Gulmi
Kapilbastu
Kaski
Manang
Mustang
Myagdi
Nawalparasi
Palpa
Parbat
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1000
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1980
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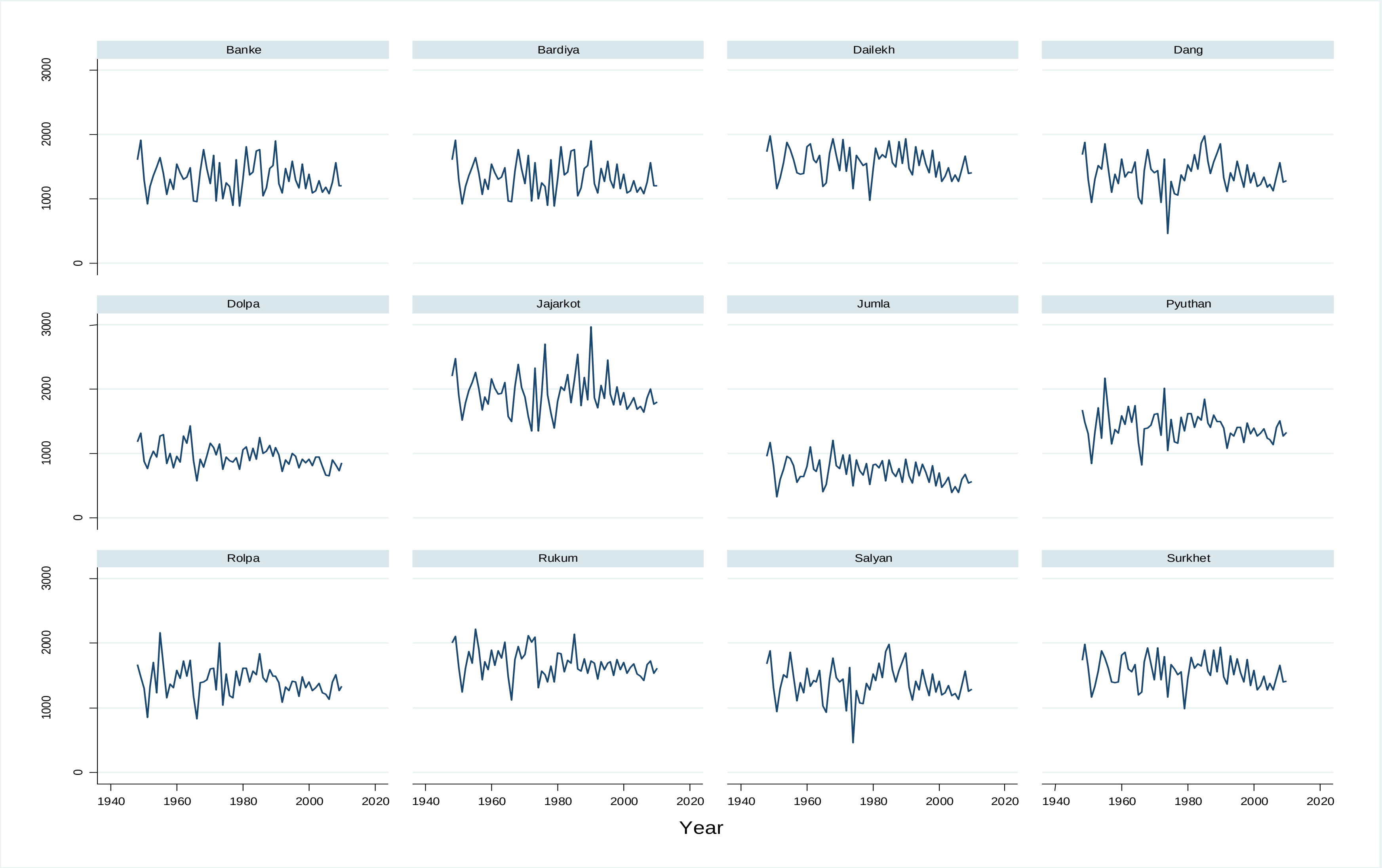
Year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Bardiya
Dailekh
Dang
Dolpa
Jajarkot
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Pyuthan
Rolpa
Rukum
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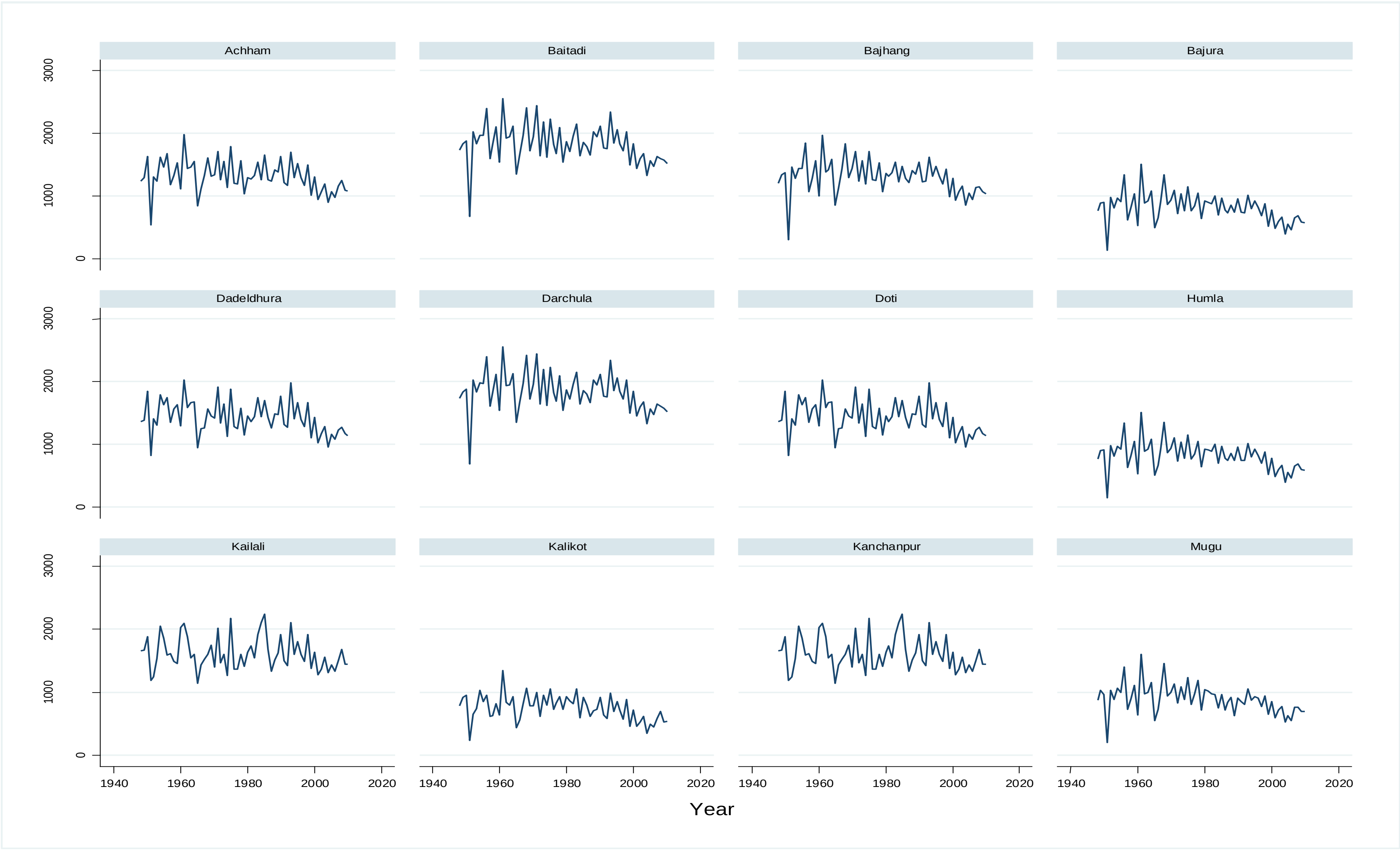
Achham
Baitadi
Bajhang
Bajura
Dadeldhura
Darchula
Doti
Humla
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Kalikot
Kanchanpur
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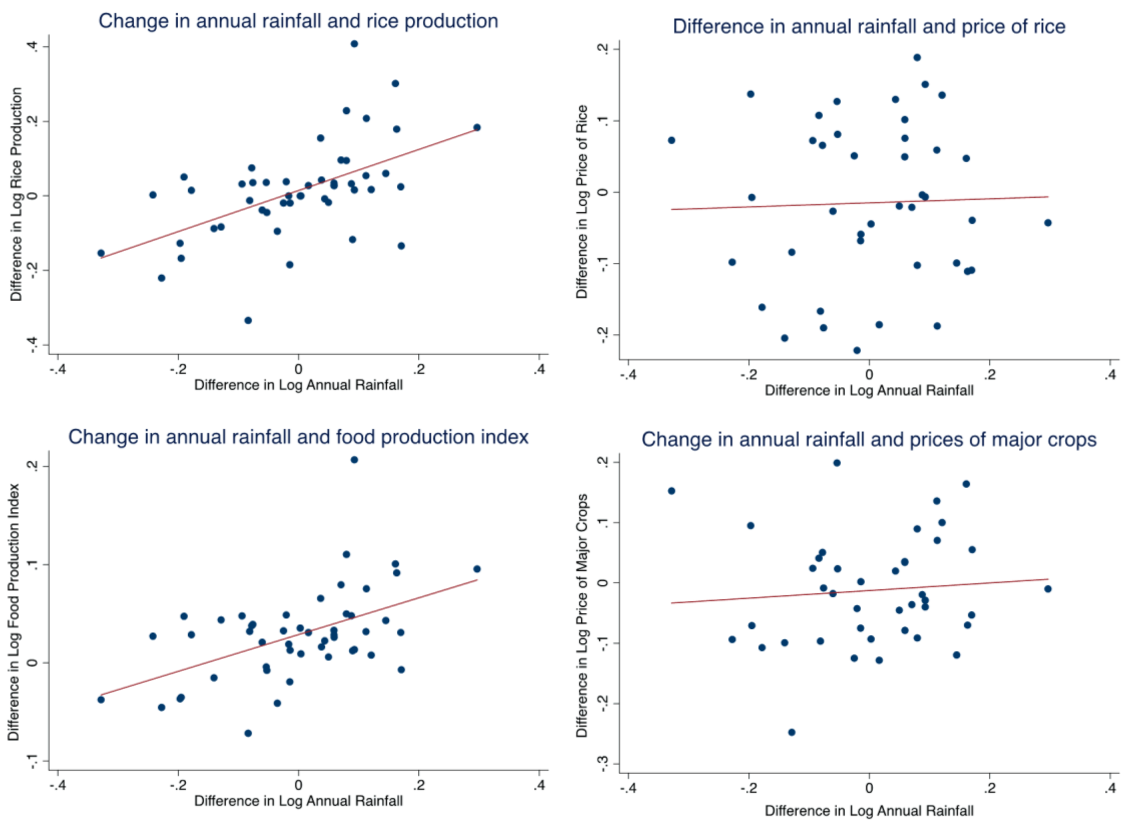
Note A1: Rainfall Variation and Agricultural Production in Nepal

The scatter plots below show that food supply is reduced in times when rainfall decrease but food price is not affected. A simple time series analysis of the possible relationship between change in log annual rainfall and change in log quantity of rice produced as well as in log Agricultural Production Index of Nepal for the years 1967 – 2007 also supports this graphical evidence.[4] There is a statistically significant positive relationship between log-change in annual rainfall and log change in quantity of rice produced and log change in overall agriculture production. Approximately, a one percent increase in annual rainfall is associated with a 0.6 percent increase in quantity of rice produced and with a 0.2 percent increase in the Agriculture Production Index. The standard errors for the two estimates are 0.12 and 0.04 respectively. On the other hand, there is no significant relationship between change in log rainfall and change in log food price for any major food crop. This is plausible given food crops are traded in a global market and changes in rainfall might have a limited effect on price.



[4] Rice production is used, as it is the staple food crop of the country (Joshi et al. 2011). The FAO Agricultural Production Index shows the relative level of the aggregate volume of agricultural production for each year in comparison with the base period 2004-2006. They are based on the sum of price-weighted quantities of different agricultural commodities produced after deductions of quantities used as seed and feed weighted in a similar manner. The resulting aggregate represents, therefore, disposable production for any use except as seed and feed.

Table A1: Effect of monsoon rainfall in years before and after birth: women and men born in 1951–1976, OLS estimates

Outcome	Literacy			Years of School			Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
t - 3	-0.013	-0.008	0.012	-0.006	-0.014	0.069	-0.024	-0.016	-0.007	-0.014	-0.024	0.001
	(0.01)	(0.01)	(0.02)	(0.04)	(0.04)	(0.04)	(0.03)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)
t - 2	0.006	0.013	0.005	0.054	0.041	0.093**	-0.038	-0.042	-0.026	-0.002	0.003	-0.009
	(0.01)	(0.01)	(0.01)	(0.03)	(0.05)	(0.03)	(0.03)	(0.03)	(0.04)	(0.01)	(0.02)	(0.02)
t - 1	0.024*	0.009	0.023	0.022	-0.010	-0.028	0.033	-0.003	-0.026	0.005	-0.016	0.025
	(0.01)	(0.01)	(0.02)	(0.03)	(0.04)	(0.03)	(0.02)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
t = 0	0.038**	0.024	0.053*	0.103*	0.069	0.146***	-0.059	-0.125***	0.003	0.013	0.014	0.012
	(0.01)	(0.02)	(0.02)	(0.04)	(0.06)	(0.03)	(0.03)	(0.03)	(0.04)	(0.02)	(0.02)	(0.02)
t + 1	0.014	0.013	0.027	0.046	0.034	0.099*	-0.009	0.011	-0.007	0.007	0.013	0.003
	(0.01)	(0.02)	(0.02)	(0.04)	(0.06)	(0.04)	(0.05)	(0.05)	(0.04)	(0.02)	(0.03)	(0.02)
t + 2	-0.016	-0.009	-0.024	-0.042	-0.034	-0.025	-0.035	0.027	-0.042	0.002	-0.005	0.011
	(0.02)	(0.02)	(0.02)	(0.05)	(0.08)	(0.05)	(0.03)	(0.04)	(0.06)	(0.02)	(0.03)	(0.03)
t + 3	-0.008	-0.015	0.001	-0.037	-0.080	0.004	-0.023	-0.085*	0.006	-0.019	-0.013	-0.023
	(0.01)	(0.02)	(0.02)	(0.04)	(0.07)	(0.04)	(0.04)	(0.04)	(0.04)	(0.02)	(0.02)	(0.02)
N	717945	359310	358635	716939	357673	359266	725834	362838	362996	725834	362838	362996

Cluster robust standard errors in parentheses

* $p<0.05$ ** $p<0.01$ *** $p<0.001$

Notes: Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. Each column presents coefficients (standard errors) from a separate regression of the dependent variable on various years' rainfall (deviation of log rainfall from log of 1948–2010 district mean rainfall). Year 0 is birth year, year -1 is year prior to birth year, year +1 is year after birth year, and so on. All regressions include fixed effects for birth year, birth district, and birth district-specific linear time trends. See Table 1 for notes on sample composition and variable definitions.

Table A2: Effect of birth year monsoon rainfall on adult outcomes by caste: women and men born in 1951–1976, IV estimates

Outcome	Literacy			Years of Schooling		
	Total	Male	Female	Total	Male	Female
Deviation	0.036**	0.015	0.046	0.164**	0.078	0.249***
	(0.01)	(0.02)	(0.02)	(0.05)	(0.07)	(0.05)
Marginalized	-0.723***	-0.804***	-0.874***	-2.117***	-2.981***	-1.236***
	(0.02)	(0.03)	(0.02)	(0.08)	(0.11)	(0.08)
Marginalized - Deviation	-0.049	-0.066	-0.040	-0.664***	-0.724***	-0.607***
	(0.03)	(0.04)	(0.05)	(0.08)	(0.09)	(0.11)
N	726478	363151	363327	726477	363149	363328

Outcome	Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female
Deviation	-0.103*	-0.172***	-0.047	0.008	0.006	0.009
	(0.05)	(0.03)	(0.06)	(0.02)	(0.03)	(0.02)
Marginalized	0.077*	-0.059	0.254***	-0.958***	-0.993***	-0.921***
	(0.04)	(0.04)	(0.05)	(0.04)	(0.04)	(0.04)
Marginalized - Deviation	0.140	0.194*	0.062	-0.114***	-0.126***	-0.101***
	(0.07)	(0.09)	(0.08)	(0.02)	(0.03)	(0.03)
N	726480	363151	363329	726480	363151	363329

Notes: Sample is Nepalese individuals born outside of urban areas between 1950 and 1976 inclusive, observed in year 2001. The estimates are obtained from instrumental variables estimation of a modified version of model (1) that additionally includes an indicator for whether households belonged to a government-categorized group of marginalized castes and an interaction between that indicator and birth year monsoon rainfall. The coefficient on deviation represents the marginal effect of rainfall on outcomes of the non-marginalized group and the sum of coefficients on deviation and the interaction term represents that on outcomes of the marginalized group. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. All regressions include fixed effects for birth year, birth district, and birth district-specific linear time trends. See Table 1 for notes on sample composition and variable definitions.

Table A3: Effect of monsoon rainfall in years before and after birth: women and men born in 1981–1991, OLS estimates

Outcome	Literacy			Years of School			Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female	Total	Male	Female	Total	Male	Female
t - 3	0.052*	0.025	0.078*	0.100	0.027	0.205	0.093	-0.033	0.195*	0.084	0.100	0.067
	(0.03)	(0.03)	(0.03)	(0.08)	(0.08)	(0.10)	(0.07)	(0.08)	(0.09)	(0.04)	(0.05)	(0.05)
t - 2	-0.044	-0.037	-0.043	-0.066	0.029	-0.164*	0.175*	0.123	0.235*	-0.008	0.013	-0.028
	(0.03)	(0.03)	(0.03)	(0.06)	(0.08)	(0.07)	(0.08)	(0.09)	(0.10)	(0.03)	(0.03)	(0.04)
t - 1	0.055*	0.015	0.089**	0.163**	0.103	0.238*	0.127	0.055	0.162	0.075	0.093	0.061
	(0.02)	(0.03)	(0.03)	(0.06)	(0.07)	(0.09)	(0.09)	(0.10)	(0.13)	(0.05)	(0.05)	(0.05)
t = 0	-0.022	-0.056	0.009	0.059	0.042	0.109	0.158	0.061	0.288*	-0.028	-0.029	-0.026
	(0.03)	(0.04)	(0.03)	(0.08)	(0.08)	(0.11)	(0.10)	(0.10)	(0.13)	(0.04)	(0.05)	(0.04)
t + 1	0.018	-0.030	0.062*	0.184**	0.132*	0.244**	0.082	0.076	0.086	0.078	0.079	0.084
	(0.02)	(0.03)	(0.03)	(0.06)	(0.06)	(0.08)	(0.09)	(0.10)	(0.10)	(0.04)	(0.04)	(0.05)
t + 2	0.011	-0.023	0.035	0.117*	0.078	0.203*	0.012	0.072	-0.110	-0.018	0.002	-0.035
	(0.02)	(0.04)	(0.02)	(0.05)	(0.06)	(0.08)	(0.09)	(0.10)	(0.12)	(0.04)	(0.04)	(0.04)
t + 3	0.034	0.004	0.053*	0.191**	0.131	0.242**	-0.026	-0.071	0.053	0.002	-0.003	0.009
	(0.02)	(0.03)	(0.03)	(0.06)	(0.08)	(0.08)	(0.10)	(0.10)	(0.13)	(0.04)	(0.04)	(0.05)
N	518156	263833	254323	515500	262666	252834	518204	263850	254354	518204	263850	254354

Cluster robust standard errors in parentheses

* p<0.05 ** p<0.01 *** p<0.001

Table A4: Effect of birth year monsoon rainfall on youth outcomes by caste: women and men born in 1981–1991, IV estimates

Outcome	Literacy			Years of Schooling		
	Total	Male	Female	Total	Male	Female
Deviation	-0.027	-0.055	-0.015	0.142	0.114	0.185
	(0.04)	(0.06)	(0.05)	(0.12)	(0.12)	(0.17)
Marginalized	-0.558***	-0.540***	-0.626***	-1.711***	-1.621***	-1.768***
	(0.03)	(0.03)	(0.04)	(0.06)	(0.05)	(0.07)
Marginalized - Deviation	-0.126	-0.080	-0.135	-0.675*	-0.434	-0.829**
	(0.10)	(0.10)	(0.14)	(0.31)	(0.32)	(0.32)
N	518696	264084	254612	518696	264084	254612

Outcome	Months Worked			Asset Index		
	Total	Male	Female	Total	Male	Female
Deviation	0.038	-0.244	0.346	0.036	-0.006	0.074
	(0.17)	(0.15)	(0.22)	(0.05)	(0.05)	(0.07)
Marginalized	0.930***	1.138***	0.708***	-0.841***	-0.844***	-0.834***
	(0.06)	(0.06)	(0.08)	(0.05)	(0.05)	(0.05)
Marginalized - Deviation	0.182	0.326	-0.005	-0.301**	-0.369**	-0.216
	(0.29)	(0.35)	(0.35)	(0.10)	(0.11)	(0.12)
N	518696	264084	254612	518696	264084	254612

Notes: Sample is Nepalese individuals born outside of urban areas between 1981 and 1991 inclusive, observed in year 2001. The estimates are obtained from instrumental variables estimation of a modified version of model (1) that additionally includes an indicator for whether households belonged to a government-categorized group of marginalized castes and an interaction between that indicator and birth year monsoon rainfall. The coefficient on deviation represents the marginal effect of rainfall on outcomes of the non-marginalized group and the sum of coefficients on deviation and the interaction term represents that on outcomes of the marginalized group. Instruments for birth year rainfall measurement from the grid point closest to the centroid of the respondent's birth district are rainfall measured at second-and-third-closest grid points. All regressions include fixed effects for birth year, birth district, and birth district-specific linear time trends. See Table 1 for notes on sample composition and variable definitions.