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ABSTRACT

Drought is Africa's most prevalent natural disaster and is becoming an increasingly common source of income shocks around the world. This paper presents new evidence from Africa that droughts are an important component of long run variation in health human capital. I use Census data to estimate the effects of early childhood exposure to drought on later-life disabilities among South Africans confined to homelands during apartheid. By exploiting almost forty years of quasi-random variation in local droughts experienced by different cohorts in different districts, I find that drought exposure in infancy raises later-life disability rates by 3.5 to 5.2%, with effects concentrated in physical and mental disabilities, and largest for males. An exploration of spatial heterogeneity in drought effects suggests that limits to mobility imposed on homelands may have contributed to these negative effects. My findings are relevant for low-income settings where households have limited access to formal and informal coping mechanisms and face high costs of avoiding droughts through migration.

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Drought is Africa's primary natural disaster and an important source of short run income risk for rural households. In the last thirty years, droughts in Africa have affected three times more people than all other natural disasters combined.[1] Yet, although good evidence exists on how droughts affect child nutrition and health (e.g. Hoddinott and Kinsey 2001, Alderman, Hoddinott and Kinsey 2006), evidence on the long run repercussions of drought for population health in Africa is much more limited (Stanke et al 2013). Currie and Vogl (2013) comprehensively review the recent literature linking early life shocks to health and adult outcomes in developing countries and find only three papers that focus on drought or rainfall shocks as the source of early life nutritional shocks (Alderman, Hoddinott and Kinsey 2006, Pathania 2007, Maccini and Yang 2009). Only the first of these presents evidence for effects on medium run health outcomes in an African setting. Given the central role of health human capital in development, and the fact that drought is expected to become an increasingly common source of income shocks in low-income countries (IPCC 2014), this relative neglect of long run health impacts of drought represents an important gap in the literature.

In this paper, I extend the broader economics literature on income shocks by presenting new evidence that early life exposure to local droughts has negative consequences for health in later life using the unique context of South Africans confined to homelands during *apartheid*. During this period, the majority of Africans were sent to live in rural, spatially isolated pockets of land characterized by poor land quality, almost no government services and strict legal limits on mobility. My analysis focuses on measuring how individuals from these homelands experienced the long run health effects of childhood drought exposure. While the setting is historical, the context is highly relevant for modern rural populations that lack resources to cope with natural disasters and that face substantial infrastructural, physical, and institutional constraints to avoiding drought through migration.

To estimate the long run health impacts of childhood drought exposure, I require convincingly exogenous measures of local drought. My research design exploits quasi-random variation in exposure to many local droughts experienced by different birth cohorts in different districts. I focus on one important and understudied set of health markers: the prevalence of disability. Specifically, I compare later-life disability rates among cohorts with more and less drought exposure, controlling for birth year and district fixed effects. The strength of this identification strategy is that I use many separate natural experiments for local economic shocks identified by multiple drought events across years and districts. This minimizes concerns that results are driven by confounding shocks to health that could be correlated with single

[1] EM-DAT (http://www.emdat.be/) compiles data on number of people in each region affected by disaster type (e.g. drought, floods, epidemics, storms, earthquakes, extreme temperatures, insect infestations, large accidents, wildfires, volcanoes and other complex disasters).

drought events. My research design is closest in spirit to Maccini and Yang (2009) who use the Indonesian Family Life Survey to study the longer run health effects (not including disabilities) of early life exposure to positive and negative rainfall shocks among women in Indonesia. My focus on localized drought is appropriate in an African setting where maize crop yields are more sensitive to rainfall deficits than excesses (Le Roux 2009, Akpalu, Hassan and Ringler 2009).

Implementing this strategy with Census data, I estimate large effects of cumulative drought exposure in the critical period of early childhood. Disability rates at the mean level of drought exposure are higher by 3.5 to 5.2%. Cumulative drought exposure from the *in utero* period up to age four raises disability rates for Africans in all homelands by 0.18 percentage points (3.5%), with larger effects for males (0.26 percentage points, or 5.2%) and largest relative effects for physical and mental disabilities. Male drought cohorts are smaller (by 1.1%) although these estimates are not always statistically significant. The large, precisely estimated negative impacts of drought on disabilities are particularly striking given the relative youthfulness of the sample: ages 10 to 48. They implicate persistent environmental shocks as an important component of variation in health human capital in low-income communities.

My results contribute to a growing literature on the persistent effects of early-life income shocks on later life health outcomes (see Almond and Currie 2011a, 2011b and Currie and Vogl 2013 for comprehensive reviews of this research in developed and developing countries).[2] This literature has shown that environmental conditions – notably the nutrition and disease environment – *in utero* and during early childhood matter for various dimensions of health in later life. My work is distinguished from this prior research in three main ways.

First, I use exogenous variation in localized droughts derived from a climatologically-appropriate measure of drought: the Spatial Precipitation Index (SPI). Since rainfall is not normally distributed, the SPI calls for fitting a gamma distribution to rainfall data before creating standardized measures of the deviation of rainfall from historical rainfall patterns in a district. Because maize is the staple crop in the South African setting, and in much of Africa, and because the production function of maize yields with respect to rainfall is non-linear (Akpalu et al 2009), I focus only on extreme negative values of the SPI that define drought conditions. While many studies capture local environmental shocks (both positive and

[2] Barker (1992) famously put forward the hypothesis that conditions during the *in utero* period have large effects on later-life health outcomes. Martorell et al (1994) and Martorell (1999) provide an early general discussion of the link between childhood nutrition and disease and adult health. Recent studies that have measured the longer run health impacts of early-life exposure to various types of shocks include Almond (2006) on the Spanish flu, Chen and Zhou (2007), Meng and Qian (2009) Lindeboom et al (2010) and van den Berg (2011) on the Chinese and Dutch famines, Maccini and Yang (2009) and Aguilar and Vicarelli (2012) on rainfall shocks in Indonesia and in Mexico, and Banerjee, Duflo, Postel-Vinay and Watts (2010) on insect infestations of agricultural crops.

negative) using the log of rainfall shocks, these measures are not always appropriate in all settings. Couttenier and Soubeyran (2013) have argued that several alternative measures of water stress are more efficient than the linear rainfall measure, and the SPI is one version of these measures.

Second, I focus on estimating impacts on disability outcomes not typically studied in the early-life shocks literature (Almond et al 2010 and Almond and Mazumdar 2011 are exceptions). The prevalence of disabilities in developing countries makes these important outcomes in their own right: approximately one in five of the world's poorest have some type of disability.[3] Since many of these populations live in environments subject to substantial local income risk, my results highlight a potentially relevant factor contributing to this disability prevalence. The effect sizes I estimate for long run impacts of cumulative drought exposure are consistent with, although somewhat smaller than, the long run effects of exposure to Ramadan fasting among Muslim pregnant women in Uganda (Almond and Mazumdar 2011). These similarities suggest that the mechanism through which drought affects disability rates is through nutritional deprivation in early years.[4]

Third, the results of my analysis suggest that local environmental shocks in different parts of the world have different implications depending on gender. While both males and females in South Africa are negatively affected by drought, males experience larger negative disability and cohort size effects: on the order of 40 to 100% larger than females. This finding echoes results from the fetal and childhood origins of health literature that male fetuses and babies are generally more fragile and sensitive to nutritional insults (Kraemer 2000, Cameron 2004, Almond and Mazumdar 2011). However, my results contrast with much work from Asian settings suggesting that local shocks to the environment that affect resource availability have more negative effects on females relative to males. For example, Maccini and Yang (2009) find that positive rainfall shocks in Indonesia significantly improve health outcomes among females with no significant impacts for men. Pathania (2007) finds that drought exposure reduces height among women in India. While I cannot investigate the reasons behind why local droughts in Africa have different health effects by gender than local rainfall shocks in Asia, it seems likely that differences in son preference across these continents could contribute to these differences (Jayachandran and Pande 2013). The effects of local income shocks by gender are highly context-specific.

In the final part of the paper, I explore spatial heterogeneities in the long run disability effects of drought. I estimate the differential impacts of early childhood drought exposure across early and late-established

[3] WHO Factsheet: http://www.un.org/disabilities/default.asp?id=18

[4] Almond and Mazumdar (2011) study the effects of Ramadan fasting among pregnant women for specific months during the *in utero* period. I do not have the ability to measure drought at this fine a level, since I only know year of birth for respondents from the Census.

homelands, controlling for birth year and district fixed effects. Drought raises the probability of disability on average for males and females across the entire sample. However, effect sizes for males are almost doubled among residents of the earliest established homelands (the so-called TBVC states of Transkei, Boputhatswana, Venda and Ciskei). Male disability effects are twice as large (0.3 to 0.6 percentage points higher) and cohort size is smaller by 2 to 3%. I show that these differential effects across homelands disappear in cohorts born after 1986, the year in which all homelands were reintegrated into South Africa. I offer one possible interpretation of these results as reflecting the impacts of differences in labor mobility restrictions in place across different homelands. These migration restrictions differed in intensity and duration across early and late-established homelands in the *apartheid* years, making it differentially easy for families to cope with local droughts by relying on resources from household migrants.

The paper begins with a brief description of the historical context of the South African homelands. I describe data and key variables in Section 2 and outline the research design used to identify the long run health impacts of drought in Section 3. Section 4 presents the main results for disability outcomes and examines the extent of selection through cohort and total fertility outcomes. Section 5 discusses my approach to estimating spatial heterogeneity in drought effects and presents results, and section 6 concludes.

1. Background: The South African homelands

To understand the relevance of conditions in South African homelands for current rural populations in low-income countries and to provide a framework for interpreting my empirical work, it is necessary to describe briefly the motivation for and functioning of these homelands. A central pillar of the South African government's project of *apartheid* (1948-1994) involved controlling African mobility into urban areas. A key component of this system of control involved the formalization of existing Native Reserve areas into ten homeland "states" within the state, or Bantustans, during the 1950s, 1960s and 1970s. The purpose of these homelands was to confine excess adult male labor and non-labor resources (women, children and the aged) on marginal agricultural land in rural areas.[5] By the 1960s, several million Africans had been forcefully settled in these homelands according to ethnic status (Simkins, 1983).

My empirical analysis focuses on measuring how local drought affected residents of these homelands. Figure 1 illustrates the location of these ten homelands across the country. I use maps like Figure 1 and

[5] Native Reserve Areas were demarcated as early as 1913 and expanded in 1936. Evans (1997) describes how fear of massive demographic shifts in white urban areas was the primary motivation for the establishment of these reserves to house the majority black population even before 1948. Their legal status as self-governing homelands was formalized starting in 1959 with the Bantu Authorities Act. See Wolpe (1988), Simkins (1983), Lemon (1984), Savage (1986) and Maylam (1990) for more on the policies of population control under *apartheid.*

ArcGIS software to identify spatially which modern district boundaries cover a "majority homeland area". The Data Appendix describes this assignment of districts to homelands in more detail. Note that homelands are scattered across the country, and so cover a range of different climate conditions and variation in drought events.

Two features of these homelands are important to understand. First, because these homelands were regarded as self-sufficient entities, central government funding for education, health, and welfare was severely limited (De Beer 1984). For example, although the homelands housed 32% of the South Africa population by the mid-1970s, health services to these homelands absorbed only 0.23% of South African GDP (Price 1986). Average annual health spending per capita was ZAR1.70 (about USD1.22) in 1970 (Horrell 1971), there was one doctor for every 15,000 patients in the homelands at this time (Coovadia et al 2009) and high user fees made it difficult to access even these limited health care services (Tanaka 2014). Chronic underfunding of public health services contributed to high baseline levels of malnutrition in all homelands and a high prevalence of kwashiorkor and marasmus, respiratory infractions, gastroenteritis, and measles among children (De Beer 1984; Horrell 1971). These underlying high rates of disease along with poor access to good farmland and no social safety nets may have made homeland populations more susceptible to negative impacts of shocks to agricultural production and clean water access entailed by frequent drought shocks.[6]

Second, although the homelands functioned as labor reserves, in practice homeland residents were severely limited in their access to labor markets outside the homelands. People were assigned to homelands based on ethnicity and had extremely limited rights to live and look for work outside of this area. Free migration between and out of homelands was prohibited. Neither children nor families could move. An entire *apartheid* bureaucracy developed to control legal migration and restrict illegal migration from these areas. District-level labor bureaux were the official gatekeepers for legal labor migration out of the homelands.[7] Requests for labor permits allowing circular labor migration had to be made through these offices, located within one's assigned district (Greenberg and Giliomee 1983). Jobseekers were required to register with their assigned bureau, job requisitions from South African companies were sent

[6] As late as the 1990s over half of rural African adults consumed under 2,100 calories per day (Wilson 1996). Using data from the South African National Income Dynamics Panel, Mariotti (2015) shows that a particular acute positive income shock in some of the homelands in the mid-1970s led to height improvements among African boys.

[7] In Secretary for Bantu Administration and Development General Circular No. 25 (1967), "1. It is accepted Government policy that the Bantu are only temporarily resident in the European areas of the Republic, for as long as they offer their labour there. As soon as they become, for some reason or other, no longer fit for work or superfluous in the labour market, they are expected to return to their country of origin or the territory of the national unit where they fit in ethnically if they were not born and bred in the homeland." Much of the organized, legal migration was of unskilled labor into mining, commercial agricultural, or low-level manufacturing jobs. Unauthorized migration (often with forged documents) would have been concentrated in the difficult-to-monitor household sector and into other low-skilled informal sector jobs.

to specific offices, and all job contracts had to be certified through this bureaucracy. Legal restrictions on migration, together with the expansive *apartheid* bureaucracy of the labor bureaux substantially raised the costs of free internal migration for all Africans living in homelands. In section 5, I further discuss how these costs of internal migration varied between the early and late-established homelands.

The rest of the paper uses this context of extreme poverty and deprivation coupled with high costs of migration to provide quantitative evidence on the long run health impacts of drought.

2. Data and measurement of key variables

i. Measuring disability, cohort size and fertility with Census data

I construct the main analysis sample using the 10% individual record data from the 1996 South African Census. The main advantage of using Census data rather than household survey data to look at how long run health outcomes are affected by spatially-specific local drought shocks is that it provides information on individuals living in all parts of the country. This allows me to focus the analysis on homeland residents while retaining sufficient sample size in each birth cohort and birth district.

The Census provides basic demographic information, total completed fertility (live births) reports for all women, and asks household heads to report whether each person on the roster has any serious disability and the type of disability: vision, hearing or speech, mental or physical disability. I restrict the sample to Africans born between 1948 and 1986 (age 10-48 at the time we see them in 1996) whose current district (for never movers) or prior district (for movers) is in a rural homeland.[8] Since the Census does not ask for district of birth, I use information from the following questions to construct an imputed birth district: "Where do you live now? Where did you live before this?" For anyone who has never moved, or has moved across district boundaries only once, these two variables provide complete migration histories and correct information about birth district. Although birth district is mismeasured for multiple movers, recent household survey data from South Africa suggests that the share of people who have moved across district boundaries more than once is relatively low. As late as 1997 and 2008, the share of multiple movers was only 5% (or 12% conditional on ever moving).[9]

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[8] I exclude Africans born in urban areas, and those born in rural non-homeland areas that were dominated by white farmers, since neither of these areas are easily comparable to other poor, rural, agricultural settings in other parts of Africa.

[9] Further discussion of sample selection issues and coding of key variables is provided in the Data Appendix.

Disabilities represent an important set of health markers that drought shocks in early childhood could affect.[10] The economics literature has recently provided much evidence for the fetal origins of disease (Currie and Almond 2011b reviews this literature; Almond and Mazumdar 2011 discuss biological mechanisms for the fetal origins hypothesis). Even beyond the *in utero* period though, infants and children continue to be vulnerable to malnutrition and infection for some years, with potential long-run effects on health. For example, even mild malnutrition and associated micronutrient deficiencies (in vitamin A, folic acid, zinc, iodine, and iron) during the early years contribute to a syndrome of "developmental impairment" that includes growth failure (e.g. stunting and wasting, nutritional blindness), delays in cognitive, motor and behavioral development, lower levels of resistance to disease, and increased morbidity and mortality (Martorell 1999).[11] Absence of sufficient clean water and related poor sanitation may also affect the development of some systems. For example, trachoma, a potentially disabling disease of the eye and the second leading cause of blindness in Africa (Lewallan and Courtright 2001), often starts in early childhood and is related to poor access to clean water.[12] Reduced nutritional intake of mothers and infants, and severely limited access to clean water resulting from drought shocks could plausibly affect long run health by affecting childhood development during critical growth windows in the first few years of life.

I use the Census data to create several measures of health. I construct indicators for "Any serious disability?" and for individual disability types and measure the "Number of serious disabilities" reported for each person. I measure log cohort size (overall and separately by gender) in each district in each year between 1948 and 1986 and create a crude measure of total fertility among women likely to have completed fertility by 1996: the total number of children ever born to women aged 40 to 60 in 1996.

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[10] Self-reported disability variables capture meaningful variation in health status across individuals. For a similarly aged sample in a high quality household survey, the South African National Income Dynamics Study (2008), each additional self-reported disability raises a person's score on an index of difficulties with activities of daily living by 0.75 of a standard deviation. This highly significant correlation is conditional on age, gender and age-gender interactions.

[11] While nutritional deprivation is known to affect many markers of health (Strauss and Thomas 1998), different systems have different critical windows for development, only some of which are well understood. For example, binocular vision develops between 3 and 8 months of age, while neuronal development of the vestibular system which affects motor skill development has a critical period in the first three weeks of life (Rice 2000). Nutritional blindness results from micronutrient deficiencies such as vitamin A in the first two years of life (Steinkuller 1983; Lewallen and Courtright 2001). In the well-known INCAP study in Guatemala, a randomized nutritional intervention for pregnant women and infants led to taller, heavier adults with greater strength and work capacity, and higher wages (Martorell 1999, Hoddinott et al 2008). Schroeder et al (1995) show that nutritional intervention before three years of age had the largest impacts on health outcomes for children. Case and Paxson (2008) use data from several surveys to show that height deficiencies in childhood are strongly correlated with significantly higher rates of disabilities and poorer health in later life. Almond and Mazumdar (2011) show that exposure to nutritional deprivation *in utero* as a result of Ramadan fasting practices results in 20% more disability among Muslims in Uganda and Iraq.

[12] WHO http://www.who.int/water_sanitation_health/diseases/trachoma/en/ and Kok (1983).

ii. Measuring drought

To measure drought, I use rainfall data from over 1,000 local weather station locations across South Africa. I construct a district-year specific drought measure using the Standardized Precipitation Index (SPI) (McKee, Doesken and Kleist 1993).[13] The SPI measures the probability of observing a recent rainfall event based on the distribution of all rainfall events for a given time scale and place, and characterizes South African droughts well (Roualt and Richard 2003). Since rainfall is not normally distributed, the SPI procedure calls for a gamma distribution to be fit to the empirical data distributions for each district before generating the probability of a given rainfall event (see more details in the Data Appendix). Following the climatological literature, I define $DROUGHT_{dt}$ in each district d and year t to be 1 for values of the SPI below -1.5 and 0 otherwise (McKee et al 1993). The spatial specificity of this measure is important because the same quantitative rainfall deficit may indicate inadequate precipitation in historically wetter districts but not in historically drier districts.

Figure 2 shows the distribution of these drought events across homelands during *apartheid*. This is the main source of variation used to identify the long-term effects on disability rates and cohort size. Each bar represents the fraction of homeland districts experiencing a local drought in a given year. The figure shows substantial variation over time: some years are entirely drought-free (e.g. 1975) while in other years (the early 1980s) over 40% of districts experience drought. In most years, a smaller, positive fraction of districts experience drought.

Droughts are important for agricultural output in South Africa. Maize, the country's staple crop, is rain-fed and limited water availability reduces maize output by interrupting growth at several points in the growing season (Le Roux 2009). Insufficient rainfall over an extended period has particularly negative consequences for yields. Data Appendix Figure 1 shows that maize yields appear more sensitive to rainfall deficiencies than to rainfall excesses. This is in contrast to rice output that increases linearly with in total rainfall (Levine and Yang, 2006). Drought is therefore the relevant measure of an important local environmental shock in South Africa. For comparison, I present results using the more commonly used linear rainfall shock measure in appendix tables.

I merge drought prevalence data with the Census sample using district and year of birth data. I create two key measures of early childhood drought exposure for each person: an indicator for whether there was a

[13] There is no consensus on how the onset, duration or completion of a drought should be marked (Wilhite, 2001; World Meteorological Organization 2006), however, the climatological literature has shown the robustness of the SPI in capturing precipitation deficiencies that extend over time (Roualt and Richard 2003). Couttenier and Soubeyran (2013) discuss two other related measures that are more efficient at capturing water stress than linear rainfall measures.

drought in the year of birth, and a fractional measure of the share of years exposed to any drought between the *in utero* period up to and including age four ($DROUGHT_{jdt}$). This latter measure is the main treatment variable.

iii. Summary statistics

Table 1 shows summary statistics for key variables at individual and district levels. Drought exposure measures, and basic demographics and disability prevalence for the sample appear in Panel A; geographic and baseline historical district-level covariates are shown in Panel B.

About 6.7% of the sample experienced a drought in the year of birth, and people spend on average 6.2% of their lives up to age four in a drought. This is the equivalent of one third of a year across the entire sample. Just over one in twenty individuals (5.2%) report any serious disability, and the average number of disabilities in the sample is 0.057. Almost half of these disabilities are related to vision: 2.3% of people report a serious vision disability, with 1.4% reporting a physical disability and 1.1% reporting a serious speech or hearing disability. A lower fraction of mental disabilities (0.7%) are reported. Because the Census sample includes people aged 10 to 48 years (mean age is 23 years), the disability rates seen here do not merely reflect diseases of old age. As a point of comparison, this South African sample has very similar overall levels of disability (around 5%) compared with Census data from non-Muslims in Uganda (Almond and Mazumdar, 2011). However, the Ugandan sample is much older on average than the South African sample (20 to 80 years). The distribution of disability types also differs, with vision disabilities in the South African homeland sample more than double the rates in Uganda.

While the Census contains no direct measures of disability severity, other datasets provide evidence that disabled South Africans face poorer health conditions and lower living standards than those without disabilities. In a large, cross-sectional household survey (the 2007 South African Community Survey of around 1 million individuals) with the same overall rates of self-reported disability, 59% of disabled women and 63% of disabled men report that their disability is severe. This means that, for example, someone with a severe physical disability requires a wheelchair or crutches while someone with a severe vision disability is blind or has "severe visual impairment".[14] These rates of severe disability are even higher when the sample is restricted to those whose birth provinces contain rural ex-homelands: KwaZulu-Natal and the Eastern Cape. Further corroborating evidence on the severity of self-reported disabilities comes from the South African National Income Dynamics Study (2008). In a similarly aged African sample born in rural areas, one additional self-reported disability raises a person's score on an

[14] The specific question asked in this survey is "Does the disability seriously prevent the person from full participation in life activities e.g. education, work and social life?"

index of difficulties with activities of daily living (ADLs) by a highly significant 0.75 of a standard deviation, conditional on age, gender and age-gender interactions. It is therefore likely that the broader measures of disability captured in Census 1996 describe meaningful variation in health status across individuals.

The summary statistics in Table 1 indicate relatively high total fertility rates among the sample of older women (ages 40 to 60). Among cohorts of women who have completed childbearing by 1996, total fertility rates are about 4.7 children per woman. These women have spent about 7.1% of their childbearing years in a drought.[15] Finally, districts are fairly remote (33 kilometers away from the nearest large city), have moderate historical population density in 1946 (48 people per square kilometer) and are relatively unsuitable for maize production on an index of maize suitability. These three baseline characteristics of homeland areas interacted with drought measures will be important in robustness checks below.

3. Identifying the impacts of drought on later-life health: Empirical strategy

To identify the main effect of early life drought exposure on health outcomes in later life, I exploit quasi-random variation in drought events over space and time. I compare health outcomes across drought and non-drought cohorts, controlling for average differences in these outcomes across birth years and across districts. To fix ideas, consider the following estimating equation for individual-level disability outcomes *Y* of person *j* born in district *d* in year *t*:

$$Y_{jdt}=\beta_0+\beta_1 DROUGHT_{jdt}+\mu_d+\phi_t+\omega_{jdt} \qquad (1)$$

where $DROUGHT_{jdt}$ is a measure of cumulative drought exposure in early life, μ_d are birth district fixed effects and ϕ_t are birth year fixed effects. I estimate this specification first using the full sample and then separately for men and women, following prior research showing the particular sensitivity of males to early-life nutritional insults (e.g. Almond and Mazumdar 2011, Almond 2006; Almond and Currie 2011a). Because droughts are empirically uncorrelated within a district over time, I present robust standard errors clustered on year of birth to adjust for within-year spatial correlations between health outcomes and drought (Bertrand, Duflo and Mullainathan 2004).[16] For completeness, I also present two-way clustered standard errors, clustered on year and district of birth (Cameron, Gelbach and Miller 2008)

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[15] For each woman in the fertility sample, I compute the fraction of her childbearing years (1951-1996) exposed to drought. I use the prior district designation as the relevant location for each woman's drought exposure.

[16] After controlling for year and district fixed effects there is no first order serial correlation in errors for the drought indicator. The coefficient from the lagged residual regressions for drought is .025 (*p* value = .36).

Because I do not have data on month or season of birth, and know only a person's age (and therefore their approximate year of birth), I measure drought exposure ($DROUGHT_{dt}$) as the fraction of years from *in utero* up to four years of age that a person was exposed to drought in their birth district using the climatological measure of district-year specific drought described in Section 2. This measure therefore includes any drought shocks that may have occurred at generally accepted critical periods for biological growth and development, without taking a stand on whether these shocks are more or less critical *in utero* or otherwise. Depending on their year and place of birth, individuals could be exposed to between zero and six drought events in early childhood. Mean exposure is 0.062, or about one third of a year. I also construct and use two alternative measures of treatment: an indicator of any drought in the birth year and district, and the log rainfall shock in the birth year and district. The latter is measured as the difference between log rainfall in a given district and birth year and the log of mean district rainfall over the entire period.

For some in my sample, $DROUGHT_{jdt}$ is potentially measured with error. The Census only asks for current and previous district of residence, and I define birth district as a person's prior district of residence for someone who has ever moved, and current district of residence for someone who has never moved. For those who have moved more than once (i.e. for whom district of prior residence is not district of birth), drought exposure in early life may be mis-measured. There are two reasons why this measurement error is unlikely to drive results. First, prior to 1986, the share of people who move across homeland district boundaries more than once is likely to have been very small. Only 5% of the homeland-born sample of Africans report multiple cross-district moves as late as 2008; conditional on moving at all, only 12% of movers have moved more than once.[17] Second, what measurement error exists is likely to bias estimates of β_1 towards zero, since healthier adults are more likely to be multiple movers and therefore have their drought status mis-measured. To check this intuition, I restrict the sample to those who have never moved. While this sample of non-movers is a selected group of individuals, I still estimate large negative impacts of more early childhood drought exposure among these never movers from homeland districts. Results are shown in appendix Table 3.

Since drought may be severe enough to affect total population through adjustments in total mortality and total fertility, I consider two additional population health outcomes: log cohort size at the district level (Y_{dt}) for the full sample and for men and women separately; and total completed fertility among women

[17] These estimates are from a high quality household survey dataset, the South African National Income Dynamics Study. According to these data, 44 out of every 100 homeland-born individuals report ever moving out of their birth district by 2008, with half of these moves occurring before 1986. Among these 44 movers, just over 5 of them would have moved more than once before 2008 (fewer even before 1986), and hence their early childhood drought exposure would be measured with error.

aged 40 to 60 in 1996. For cohort size outcomes, I estimate district-year level regressions using the same set of controls as in (1). For total fertility impacts, I estimate the effects of drought exposure during childbearing years, ages 15 to 40 (rather than childhood exposure), spent in homeland areas.

For all outcomes, the main effect of drought exposure is captured by β_1. Within-district variation in birth timing relative to drought identifies β_1. Birth year fixed effects account for age effects in health outcomes and as well as contemporaneous national shocks affecting these outcomes. District fixed effects control for constant unobservable differences between districts that may affect health. The key identification assumption for this research design is that there are no contemporaneous shocks to health occurring in each drought year: local droughts are as good as random. An attractive feature of my research design is that because there are multiple drought events in different districts across many different years, I exploit many separate natural experiments to identify the effects of drought, rather than rely on a single drought event. This feature protects against many possible threats to validity, for example: fluctuations in government policy towards the homelands (e.g. Pass Laws were more heavily enforced in later years of the analysis period) are highly unlikely to be correlated with every drought event.

4. Main Results

i. Disability outcomes

Table 2 presents the main effects from estimating the regression in equation (1) for the aggregate disability outcomes. For each outcome, I present results using the full sample in column (1) and for male and female samples separately in columns (2) and (3). To ease interpretation, I evaluate coefficients on the main variable of interest, the fraction of early childhood spent in drought conditions, using the mean fraction of early life exposed to drought (0.062). This is about two thirds of a standard deviation of the drought exposure measure. Beneath each coefficient, I show robust standard errors clustered on year of birth in parentheses and show alternative two-way clustered robust standard errors, clustered on year and district of birth in square brackets.[18]

The main empirical result of the paper is that greater cumulative exposure to drought in early childhood significantly raises the chances of having a serious disability. At the mean level of drought exposure, an individual is 0.186 percentage points more likely to report any disability (Table 2, Panel A), and has 0.0022 more disabilities on average (Table 2, Panel B). Relative to sample averages, greater exposure to

[18] I show both sets of standard errors to deal with any concerns that drought may be spatially correlated across districts within a given year and additionally serially correlated within a district over time. The two-way clustering is not clearly more conservative than clustering on birth year alone; in some cases, two-way clustering raises the standard errors and while in other cases, it reduces standard errors.

drought in early childhood raises the chances of reporting a disability by 3.5% (0.186/5.25) and raises the number of disabilities by 3.8%, controlling for district and birth year fixed effects. Effects are even larger in the male subsample. Males exposed to the mean level of drought are 5.2% more likely to report any disability (0.268/5.13) and have 5% more disabilities. Impacts are smaller for females at 2.4% and 2.7% respectively. In each regression, the drought coefficients are statistically significantly different from zero at least the 10% level, regardless of whether standard errors are clustered on only year of birth or on year and district of birth.

Results in Appendix Tables 1, 2, 3 and 4 indicate that these results are robust to using an alternative measure of drought exposure, to alternative subsamples, and to including birth district linear trends. Using an indicator of drought in the birth year rather than a cumulative drought measure produces quantitatively similar results, with larger impacts for males than for females (Appendix Table 1). The impacts of a drought in the birth year are larger: a drought in the birth year raises the chances of having any disability by 0.3 percentage points. These results are not always significant given the smaller share of individuals who were ever exposed to drought in their birth year. In Appendix Table 2, I replace drought in the year of birth with the more commonly used rainfall shock in the birth year and district that captures both positive and negative variation in rainfall. Coefficients in this table are evaluated using a one standard deviation (0.21 log point) rainfall shock. None of the coefficients in these regressions is close to being precisely estimated. Note that, if instead of using the standard deviation of rainfall shock to evaluate coefficients, I use the mean rainfall shock in the data (which is negative, -0.14), all of the signs in the table are consistent with results using either of the drought exposure measures. Restricting the sample to never movers in Appendix Table 3 produces even larger effects of drought exposure on disability rates, with male cohorts again experiencing the worst impacts of drought. Finally, including a set of birth district specific linear trend controls does not wipe out the effects of drought exposure in early life, although because these controls absorb some of the cumulative impacts of drought, some of the point estimates are smaller (Appendix Table 4). Taken together, these four results show that cumulative early life exposure to drought and to the average rainfall shock increases later-life disability, especially for males, regardless of the measure of drought exposure, sample or set of controls used.

Table 3 disaggregates these disability effects into impacts on specific disabilities for males and females. Drought exposure raises the prevalence of all types of disabilities. Males with the average level of drought exposure are 0.075 percentage points more likely to report a vision disability, 0.124 percentage points more likely to report a physical disability, and 0.056 (0.037) percentage points more likely to report a hearing/speech (mental) disability. For females, the coefficients on drought exposure in early childhood are positive for each outcome, but always smaller than the male effect sizes. In percent terms, the average level of drought exposure raises the prevalence of each component disability for males by between 3.2 and 8.2%. For women, the corresponding impacts are positive, and always less than 3.9%.

The results in Tables 2 and 3 suggest that drought shocks up to age 4 have large effects on health human capital as measured by later-life disabilities. They are consistent with drought exposure affecting the health of infants through shocks to the availability of nutrition and sufficient clean water during critical windows of growth and development. Comparing these estimates to the literature is tricky, since few fetal origins and early life health shocks papers measure impacts on disability in later life. The one notable exception is Almond and Mazumdar (2010) who estimate large negative impacts of Ramadan fasting during the *in utero* period on disability rates in Ugandan and Iraqi Muslim populations.[19] Ramadan fasting is an example of a relatively mild, highly prevalent shock to the nutritional environment of some mothers during pregnancy, and in this way, is more closely related to a local drought shock in intensity than to famines. In their well-identified study, adults exposed to Ramadan during the early *in utero* period (month 1) are roughly 20% more likely to be disabled, with the largest increase in disability rates for cognitive disabilities. My results for drought exposure are consistent with although smaller than their results: on the order of 5% rather than 20%. There are several possible reasons for this: first, instead of restricting the drought shock to the *in utero* period, I cumulate drought shocks over the first 4 years of life. This means that some individuals who are treated do not have any drought exposure *in utero*, which may attenuate my effects relative to the Ugandan study. Second, their Ugandan sample of Muslims is older (ages 20-80) and so cognitive disabilities may have had more time to emerge than in the South African sample. And third, mean rates of disability in the Ugandan sample are lower than in the South African sample, meaning that impacts of the same type of shock could have a larger relative impact on the chances of having any disability.

A notable feature of my results is that across outcomes, measures of drought exposure, and samples, impacts are uniformly larger among males and more precisely estimated. These gender differences are consistent with the literature that shows greater vulnerability of male babies to the negative effects of early life health shocks (Barker, 1995; Kraemer 2000; Almond and Mazumdar 2010). They differ from a large literature that shows gender biased allocation of resources to girls and boys in Asian settings (e.g. Maccini and Yang 2009). In contrast, in the present African setting, it appears there is no evidence that females are more negatively affected by drought than males. The gender differences across these studies strongly suggest that context matters for understanding the long run effects of early life health shocks.

[19] Although they analyze a disease (rather than nutrition) shock related to Spanish flu exposure, Almond and Mazumdar (2005) and Almond (2006) also find significantly higher rates of difficulty with activities of daily living (17% or more) and higher rates of disability (1-2% higher) among adults whose mothers were exposed during their *in utero* period.

ii) Assessing the extent of selection: Cohort size and total fertility

The disability impacts of drought shocks presented in Tables 2 and 3 may be underestimates if drought significantly increases infant mortality rates and/or reduces fertility rates. To explore this possibility, Table 4 presents results for log cohort size and fertility rates. Indeed, mean levels of drought exposure in the first few years of life result in a 0.7 percent smaller cohort at the district level, although this effect is not significantly different from zero (Table 4, column 1). The effect for male cohorts is again larger than for female cohorts and statistically different from zero at the 10% level, although not significant using standard errors clustered on year and district of birth (see Table 4, columns 2 and 3).

In Table 4 column 4, I estimate a regression of completed fertility among women aged 40 to 60 in 1996 on the fraction of their childbearing years (age 15 to 40) in which they were exposed to drought. This regression allows us to show whether women who spent more of their childbearing years exposed to local droughts also report fewer children ever born, although it is an admittedly crude approach to getting at fertility impacts. I assume each woman bears her children in the same district as her first district of residence.[20] All regressions include district fixed effects and birth year of the mother to capture age effects and the coefficient on fraction of years in drought is evaluated at the mean fraction exposure for this sample (0.071). If anything, the results in column (4) of Table 4 indicate that total fertility rates look somewhat higher among women with more total drought exposure. This impact, however, is not statistically different than zero; nor is the magnitude large relative to average total fertility for this sample.

Taking the cohort size and fertility results together it appears that drought may have only moderately affected cohort size and composition. This is not surprising, since these local droughts did not induce large-scale famine along the lines of the Chinese or Dutch famines. These South African results are consistent with estimates from other settings (e.g. Indonesia and Uganda) that find moderate or no impacts on cohort size of restricted nutrition in early life. Rather than being significant underestimates, the overall disability impacts shown in Tables 2 and 3 seem to reasonably reflect the scarring impact of early childhood exposure to droughts on health as measured by later life disability rates (Bozzoli, Deaton and Quintana-Domeque 2009).

5. Exploring heterogeneity in effects of early childhood drought exposure

The main results of the paper indicate that families in homelands could not adequately smooth consumption in the wake of drought shocks and that this had long run repercussions for important

[20] This assumption generates a noisy assignment of first district for the (likely small) fraction of women who moved multiple times during *apartheid*.

population health outcomes. As discussed in the background section, homeland residents faced two related disadvantages that likely contributed to these drought impacts. First, residents were crowded into pockets of poverty: they were forced to live on low quality agricultural land, and denied access to even the most basic forms of public health infrastructure. All of these disadvantages may have increased susceptibility to the negative impacts of drought. Second, homeland residents could not easily escape these conditions, because of the very high barriers to mobility created by the myriad of labor and migration controls of the *apartheid* government.[21] To explore how these two features may have contributed to the negative long term impacts of drought, I analyze heterogeneity in the impacts of drought within the homeland areas.

i. Spatial heterogeneity in the impacts of drought within homelands

The primary and most salient distinction between homeland areas that I exploit in this section is the political distinction between homelands that were established very early in the period, and those homelands established later in the period. The four earliest homelands –Transkei, Boputhatswana, Venda and Ciskei, the so-called TBVC areas – were established between 1959 and 1962. Starting at the end of the 1970s, these TBVC areas additionally received political independence from South Africa (Savage 1986), implying that international passports were required to leave these homelands. In contrast, the remaining non-TBVC homelands – QwaQwa, KwaZulu, Gazankulu, Lebowa, Kangwane and KwaNdebele – were established in a later wave between 1969 and 1977. None of these later homelands were ever granted full independence.[22] Reasons for this staggered formalization of homelands were primarily political. To ensure continued control of homeland administrations, the *apartheid* government needed time to establish bureaucratic structures in these rural areas and ensure that local chiefs would be sufficiently compliant (Evans 1997). Even though all homelands started out as labor reserves, differences in the timing of when TBVC and non-TBVC areas gained official homeland status or become independent states implied differences in how long and how intensely formal homeland structures were in place in each district.

To explore how these differences across homelands may have affected the long reach of drought exposure in childhood, I interact the drought measure in equation (1) with an indicator for whether the district

[21] Lemon (1984) writes "Probably no avowedly capitalist country controls its labor market to the same degree as South Africa….State restrictions on freedom of movement continue to hinder Africans in particular from selling their labor freely."

[22] Transkei, Boputhatswana, Venda and the Ciskei were established in 1959, 1961, 1962 and 1961 respectively and legally granted independent status in (order) October 1976, December 1977, September 1979 and 1981. The remaining homelands were established: QwaQwa (1969), KwaZulu (1970), Lebowa and Gazankulu (1971), KaNgwane (1976) and KwaNdebele (1977).

contained a TBVC homeland or not ($TBVC_d$). I continue to control for district and year fixed effects, thereby eliminating all time-invariant differences between TBVC and non-TBVC districts as well as national differences in health outcomes across years. As before, within-district variation in birth timing relative to drought events identifies the main drought parameters while the interaction term allows us to see whether the long run impacts of drought were worse in TBVC or in non-TBVC districts. Figure 3 shows that both types of homelands experienced a great deal of variation in drought prevalence across the period. Individual-level drought exposure in the birth year and cumulative early childhood exposure to drought are balanced across the two types of districts (results not shown, *p* values of these differences are larger than 0.2).

Table 5 presents results from this heterogeneity analysis for male and female samples separately. The first point to note is that for both samples, drought negatively impacts disability rates in all homelands, with largest effects for males. Echoing the message in Table 2, mean drought exposure raises male disability rates by 0.17 percentage points (column 1) and raises the number of disabilities by 0.002 (column 3). More striking is the result that these impacts are substantially and significantly larger for male residents of TBVC districts, compared with male residents in non-TBVC districts. Controlling for differences across districts and across cohorts, males with the mean level of cumulative drought exposure in TBVC are an *additional* 0.15 percentage points more likely to have any disability, and have double the number of disabilities. Relative to males born into non-TBVC districts during a drought, males in TBVC districts and drought cohorts are over 80% more likely to have a serious disability (0.15/0.17). These males have a 0.32 percentage point higher prevalence of any disability. Relative to the average level of disability in the male sample, mean drought exposure over the first four years of life for males from TBVC districts raises disability rates by over 6% (0.32/5.1) and raises the total number of disabilities by over 7% (.004/.055).[23]

For the female sample (columns 2 and 4), the coefficients on the $DROUGHT_{dt}*TBVC_d$ interaction terms are substantially smaller than the main drought effect and not statistically different from zero. While drought exposure in early life is bad for females disability outcomes -- female disability is higher by 0.12 percentage points -- it is not apparently different across TBVC and non-TBVC homelands.

The cohort size results in the final two columns of Table 5 suggest similar patterns of spatial heterogeneity for males. Male cohorts exposed to the mean rate of drought before age four are somewhat smaller in all areas. In TBVC areas, male drought cohorts are about 2 percentage points smaller while female cohorts are 1.4 percentage points smaller. Although large, neither cohort size effects are

[23] Appendix Tables 5 and 6 present similar results for main disability outcomes and component disabilities using drought in the year of birth as an alternative measure of exposure. Drought in the birth year in TBVC districts continues to have even larger impacts among males.

significantly different than zero using two-way clustering. The point estimates alone imply that drought exposure within the subset of TBVC homelands may have affected the health of surviving cohorts through a combination of selection (higher male infant mortality or fewer male fetuses conceived) and scarring.

ii. Do pre-existing differences between homelands explain heterogeneous drought impacts?

One set of explanations for these differences across TBVC and non-TBVC districts relates to how resilient each type of area might have been to droughts. For example, since TBVC districts were the earliest homelands to be established, they may have been situated in districts with the worst quality of farmland, and had worse access to social services and public infrastructure for a longer period of time. Indeed, TBVC areas are more remote (mean distance to the nearest large city is 36kms rather than 31kms in non-TBVC areas) and less suitable for growing maize, but they are also less dense historically (38 people per square km compared with 54 people per square km in non-TBVC areas). These pre-existing characteristics across TBVC and non-TBVC areas may have influenced how well residents were able to cope with the immediate effects of drought, with implications for long run outcomes.

Table 6 provides some evidence that important pre-existing differences between homelands cannot account for the spatially heterogeneous effects on disability. In this table, I show regression output from specifications that include interactions of $DROUGHT_{dt}$ with the three district-specific baseline controls (log population density in 1946, the distance to the nearest large city and an index of suitability for growing maize, the staple crop). To maximize power in this and all remaining regressions, I restrict the sample to males, for whom the heterogeneous effects of drought in Table 5 and Appendix Tables 5 and 6 are largest and most precisely estimated. The results in Table 6 indicate that the main impacts of drought on male disabilities as well as the differential impacts on males born into TBVC areas survive the inclusion of these baseline interaction controls and grow even larger. Controlling for these baseline characteristics interacted with drought, males at the mean drought exposure are 0.32 percentage points more likely to have any disability, while males in TBVC areas are 0.6 percentage points more likely to have a disability. This is a 12% higher chance of having any disability among drought-exposed male cohorts. For cohort size, we see that drought exposed TBVC cohorts are 2.6 percentage points smaller after controlling for the interactions of drought with baseline homeland characteristics. If anything, pre-existing differences between early and late-established homelands that were not controlled for Table 5 mitigate the negative impacts of drought.

iii. Do drought impacts disappear after homeland re-integration?

How important were the institutions of homeland bureaucracies for generating the impacts of drought, and exacerbating these impacts in TBVC areas? To investigate this question, I ask whether drought exposure in childhood continues to negatively impact the health of males born after South Africa reintegrated the homelands but before the legal end of *apartheid* and the advent of democracy. The homelands were legally reintegrated into South Africa in 1986 and all legal restrictions on migration – most notoriously, the Group Areas Act, as well as the Pass Laws– fell away. This change meant that residents were legally able to move out of the homelands for work or other purposes, although the anticipated mass outmigration did not materialize in the aftermath of this reintegration (Reed 2012). No other important legal changes occurred in the homelands until the transition to democracy, in 1994. I exploit this change by estimating the main health equation (1) for males born between 1987 and 1993, the last year of formal *apartheid*.

Table 7 presents results from this placebo regression for the sample of boys ages 3 to 9 years in 1996. All regressions control for birth year and district fixed effects, and for the interaction of the drought measure with baseline district controls. For this youth sample, mean drought exposure in early life still has large negative consequences for disability rates, implying that re-integration of homelands did not completely eliminate the negative impacts of drought. Mean exposure to drought in early life raises disability rates by 0.97 percentage points (significant at the 5% or 1% level) and raises the number of disabilities by a significant 0.011. These main effects of drought are actually larger than the effects of exposure for cohorts born during 1948-1986 period. The likely reason for this is because the post-1986 period experienced more total drought exposure than the earlier period (mean exposure in this later period is 0.139 or about 10 months). What is really noticeable in this table is that the differential disability effects of drought across TBVC and non-TBVC areas have disappeared. Not only are the interaction term coefficients not significant, they are also much smaller than the main effects. Results for the cohort size regressions are similar (not significant using two way clustering). I can reject a large negative effect of drought exposure in early life on cohort size in TBVC areas for the post-1986 cohorts.

The removal of legal barriers to mobility in 1986 was a discrete change in one of the key constraints to coping with drought. Although these barriers fell across all homelands, reintegration would have reduced the costs of migration to a greater extent for TBVC residents, since these homelands faced the highest legal constraints on mobility for the longest time. Some basic migration statistics bear out this interpretation. By 1986, only 9 percent of residents from TBVC areas had permanently migrated away from their district, compared with 11 percent of non-TBVC residents (p value of the difference is 0.002). By 1993, these shares had risen and equalized, to about 14 percent (p value of the difference is 0.718, results not shown).[24] The disappearance of the spatial heterogeneity in the negative impacts of drought in the post-1986 period is consistent with the legal changes in 1986 giving TBVC districts expanded access to external labor markets, and related remittance income from labor migrants.

Anecdotal evidence as well as empirical research suggest that remittances flowing through migrant networks were key to surviving droughts and other local shocks in all of the homelands. For example, discussing newspaper reports from the 1970s, Horrell (1971) writes about a tour of homelands in the Pietersburg district that *"The crops planted had yielded little or nothing because of the drought… people were living almost exclusively on mealiemeal and the wild spinach-like plant called morogo…. Meat was a rare luxury for many, and milk practically never available….Almost every family interviewed relied on remittances…sent by breadwinners working outside the area*." In the same volume, Horrell reports that total documented remittances into homeland areas in 1970 were equal to the entire health budget allocated to these areas. De Beer (1984: 57) describes migrants as "the most privileged people in the reserves", estimating that an average worker from the Ciskei, working illegally in a large city for three quarters of the year and spending the remaining months in jail for pass law violations would still increase their standard of living by 700%. Using the limited household survey and Census data on migration and remittances that exist for South Africa, Casale and Posel (2006) show that significant fractions of African households used to and still do rely on migrant remittances for survival. All of this suggests that when migration restrictions loosened in 1986, improved access to outside labor markets would have made it easier for families – and especially easier for families in TBVC areas – to access remittance resources to cope with local income shocks.

The placebo results in Table 7 are consistent with changes in migration restrictions contributing to the disappearance of the spatial heterogeneity in drought impacts on health. One caveat, however, is that TBVC and non-TBVC homelands may have differed in other unobserved ways that might have contributed to differential effects of drought. For example, access to additional informal methods of smoothing (e.g. participation in informal savings associations, use of self-insurance methods like grain storage or holding buffer stocks) and access to formal credit (banks or moneylenders).[25] While it is

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[24] I compute outmigration rates as the fraction of adults living in a given district in a given year that permanently migrate away from a district using last-move data in the 1996 Census, details in the Data Appendix. I cumulate up to the share of ever movers by aggregating the annual rates of migration. For comparison, 11.6% of US individuals are categorized as movers in 2011 data (US Census Bureau, 2011). Differences in permanent outmigration rates capture meaningful differences in access to migrant networks across TBVC and non-TBVC areas since permanent migrants continue to be associated with their rural homes and be listed on the household roster as absent household members for long periods of time (Posel 2011).

[25] As late as 2001, over three quarters of Africans were unbanked, with a much higher fraction in rural areas. In the lowest income quintile, only 8% of households had a bank account (Ardington et al 2011). In the mid-1990s, whole homeland districts had no banks, and no post offices (Ardington1999). There are also documented

unlikely that the prevalence and use of these alternative coping mechanisms would have changed discretely after 1986, it is not possible without more data to rule out these other potential channels that might have contributed to the spatial heterogeneity in drought impacts prior to 1986.

6. Conclusion

This paper extends the broader economics literature on the effects of income shocks in poor countries by analyzing the long run effects of early-life exposure to local droughts on later-life health human capital. I study the unique context of South Africans confined to homelands during *apartheid*, where limited access to formal and informal coping mechanisms and high costs of migration would have made it particularly difficult to cope with or avoid recurrent and local environmental shocks. My identification strategy exploits multiple drought events within districts over time, and controls for interactions of key district-level variables with drought measures. Unlike studies of single drought events, this design controls for many potential confounders to isolate the causal and long run health effects of early life drought exposure.

Using Census data and a measure of drought exposure appropriate to the South African setting, I find results consistent with the early-life health shocks literature. Drought in early-life has significant negative impacts on the prevalence of disabilities of Africans from former homeland areas, with larger and more precise estimates for males. Drought exposure accounts for an even larger share of total disability for African males born into TBVC districts that were formal homelands for the longest period, although after reintegration, this spatial heterogeneity in the effects of drought across homelands disappears.

Taken together, these results have several implications for future work on the long-term impacts of early-life health shocks. By providing new evidence on the long run impacts of drought on disability, my findings suggest that local environmental shocks, which are expected to grow more prevalent over time, play an important role in accounting for variation in population health outcomes in low-income settings. Quantifying the economic consequences of these environmentally-driven increases in disability in low-income setting is an important avenue for future research.[26] Second, the fact that I find larger and more precisely estimated negative impacts for males further indicates that context is an important mediator of

complementarities between informal and formal mechanisms of risk-sharing. Even even among the poorest households, only 7% of adults participated in informal group insurance (*stokvels*) as late as 2002 (Ardington 2011).

[26] While not the focus of this paper, the economic consequences of being disabled in South Africa, and in other African countries, are likely severe. Data from the Census and from other household surveys indicate that disability is associated with a much lower likelihood of working. In recent years, the South African government has recognized the economic difficulties faced by the disabled and has extended access to a disability grant equivalent to the value of the well-known state old age pension (Case and Deaton 1998). However, such social safety nets for the disabled are unlikely to exist in most current African settings.

how local environmental shocks play out by gender. Societies with strong son preference may exhibit very different long run health impacts of local income shocks, making it more challenging to generalize from these settings to other cultural contexts. Finally, the spatial heterogeneity in drought effects across homelands opens the way for more research to understand the exact role that spatial mobility could play in helping families to at least partially mitigate long run health effects of local droughts.

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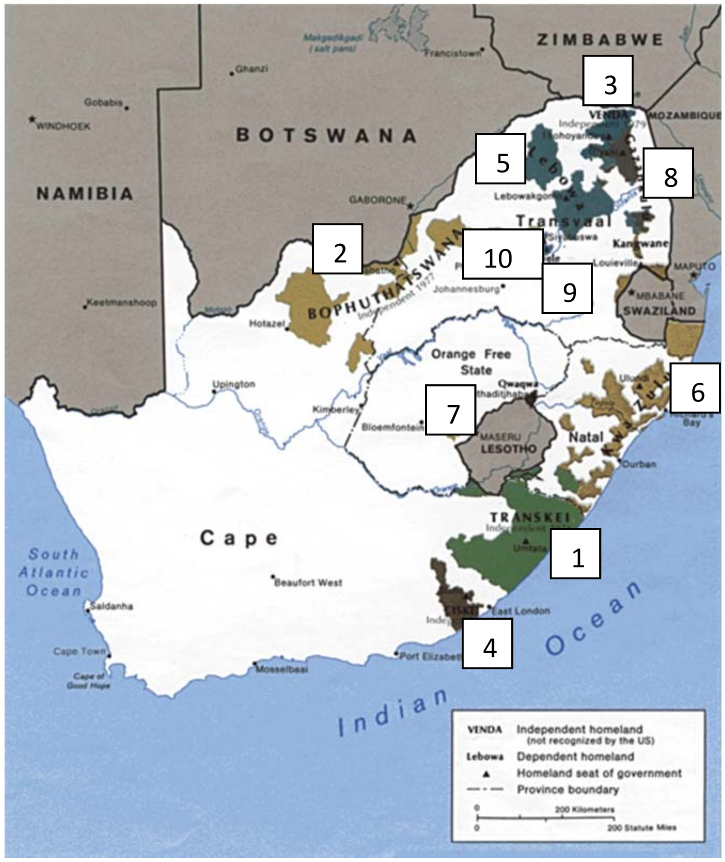
FIGURE 1



Source: Political map of South Africa 1986, Perry-Castañeda Library Map Collection, http://www.lib.utexas.edu/maps/south_africa.html, accessed July 2011. Homelands are (in order of establishment dates): TBVC areas: Transkei (1), Boputhatswana (2), Venda (3), Ciskei (4) and non-TBVC areas: Lebowa (5), KwaZulu (6), Qwaqwa (7), Gazankulu (8), Kangwane (9), KwaNdebele (10)

FIGURE 2

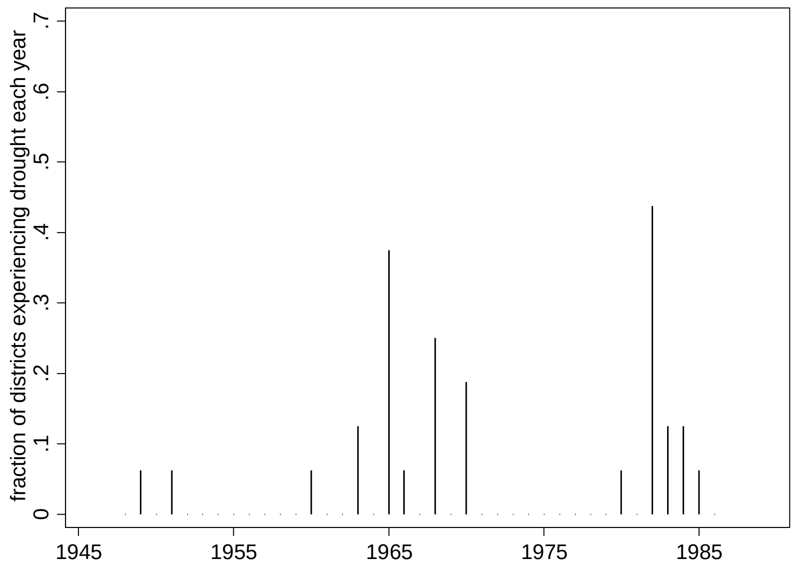


Figure 2 shows the fraction of South African homeland districts experiencing a drought annually between 1948 and 1986. The data appendix describes how the drought indicator is derived from the Standardized Precipitation Index (SPI).

FIGURE 3

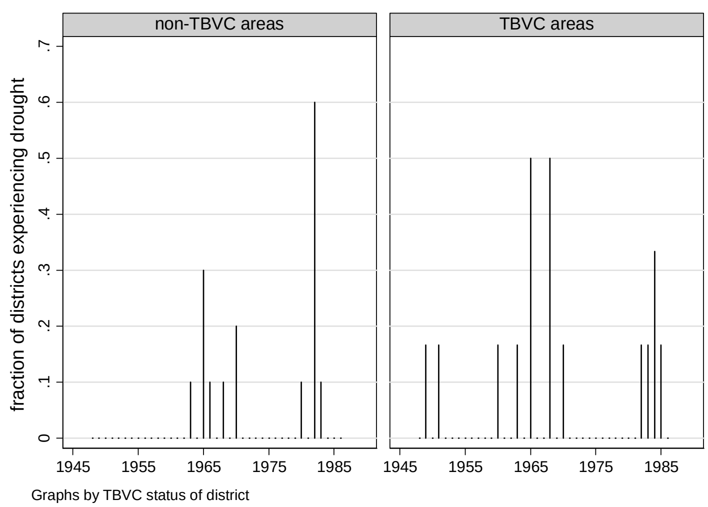


Figure 3 shows the fraction of South African homeland districts experiencing a drought annually between 1948 and 1986. The left hand panel shows drought in non-TBVC areas, the right hand panel for TBVC areas. The data appendix describes how the drought indicator is derived from the Standardized Precipitation Index (SPI).

Appendix 1: DATA - For Online Publication

1. Homeland Boundary Data

GIS data on sub-national boundaries for the 1996 and 2001 Census were obtained from Statistics South Africa (www.statssa.gov.za*)*. I use the 2001 district council Census boundaries as the main geographic unit of observation since these areas are large enough to treat as distinct local labor markets and contain sufficient population in each year to make aggregation feasible.[27]

To define which of these districts belong to former homeland areas, I obtained online maps of the ten homelands with the predominant map dated 1986 (see Figure 1 in the main text). I overlaid these homeland maps onto Census boundaries and, where there was overlap, assigned districts to homelands. I created an indicator $TBVC_d$ that takes a value of 1 if a district overlapped with any of the TBVC homelands, and is 0 for those districts overlapping the remaining six homelands.[28] Of the 53 district councils in South Africa, 16 of them (30%) fall into prior rural homeland areas. Of these 16 areas, six fall in the former TBVC areas and the remaining 10 fall in the non-TBVC areas.

2. 1996 Census Data: Sample and key variables

The 10% sample of individual records from the 1996 South African Census was obtained from Statistics South Africa (www.statssa.gov.za*).*

The sample is restricted to African adults born after 1948 into a homeland district. I therefore exclude Africans born in urban areas, and those born in rural non-homeland areas that were dominated by white farmers, since neither of these areas are easily comparable to other poor, rural, agricultural settings in other parts of Africa.

Since the Census does not ask for district of birth, I use information from the following questions to construct an imputed birth district: "Where do you live now? Where did you live before this?" For anyone who has never moved, or has moved across district boundaries only once, these two variables provide complete migration histories and correct information about birth district. However, birth district is miscoded for those who have moved across district boundaries more than once.

One implication of mismeasured birth district among multiple movers is that the sample mistakenly excludes multiple movers who were from a homeland but whose last place of residence was not a homeland and includes multiple movers who were not originally from a homeland district, but whose last place of residence was a homeland. Recent household survey data from South Africa suggests that the share of people who have moved across district boundaries more than once is relatively low: even in recent times, since the end of *apartheid*, multiple migration rates are only around 5% (or 12% conditional on ever moving).[29]

[27] Magisterial districts are too small to contain sufficient population and rainfall measurements for my analysis.
[28] TBVC stands for Transkei, Boputhatswana, Venda and the Ciskei.
[29] Corroborating evidence of these low rates of multiple migrations exists in other data. The 2007 South African Community Survey (a sample of 300,000 adults) and the 2007 Cape Area Panel Study (a sample of young adults living in Cape Town) indicate that the percent of Africans who move more than once in the past five years is between 1% and 13% respectively. Older data from the 1997 October Household Survey shows that among African

For the disability analysis, and for the analysis of cohort size and sex composition, I use this sample of African adults from ex-homeland districts born between 1948 and 1986. I match cross-sectional data on outcomes at the individual level to drought data on year of birth and prior district. For the analysis of fertility and child mortality outcomes, I restrict the sample to African women aged 40 to 60 in 1996 who have completed childbearing. I create a variable that represents the fraction of their childbearing years (ages 15-40) that they experienced drought. I assign drought exposure at the district level using the prior district reported by these women.

I also use a variable capturing the cumulative outmigration rate across homeland districts before 1986. I construct the cumulative outmigration rate at the district level data by combining current and prior district of residence information with the year in which a person moved from their former to their current district (the Census asks: "What year did you move here?"). I construct a pseudo-panel dataset of individual-year observations capturing where each person lived in each year. This dataset indicates whether a person moved out of a given district in any given year, based on their "last move" information and allows me to observe the total number of adults (ages 18 and over) in each district in each year between 1948 and 1986 and the number who move away from each district in each year. I collapse the data to district-year level and generate the percent of adults living in each district that migrated away in each year, the outmigration rate.

3. Baseline District-level control variables

I control for key district level variables that could contribute to differential responses of disability rates to drought events. These variables include:

- District-level population density data from the 1946 South African Census digitized from hardcopies of Census aggregate reports and matched to later district boundaries
- Straight-line distance (in kilometers) from the midpoint of each district polygon to the nearest large city calculated using 1996 Census maps in ArcGIS version 10
- A district's median score on the FAO's maize suitability index. This index captures how suitability land is for maize production at a fine grid level. I use these values to create the median value of the suitability index across all points in given district in ArcGIS. Low values of this number represent greater suitability of the soil for maize production

4. Rainfall Data and Drought

The South African Weather Service http://www.weathersa.co.za/web/ provided raw historical rainfall data. These data contain monthly rainfall measures at the weather station level for over 1,600 weather stations across South Africa from 1920 to 2009. I spatially match GIS locations of rainfall stations to district boundaries and aggregate rainfall totals to district-year level.

To create a measure of drought, I construct the Standardized Precipitation Index (SPI) at the district and year level (McKee, Doesken and Kleist 1993). The SPI measures the probability of observing a recent rainfall event based on the distribution of all rainfall events for a given time scale and place. Since rainfall

adults aged 15 and older in 1986, only about 4% of them report moving at all across magisterial districts in any year prior to 1986. Less than 1% report multiple cross-district moves during the *apartheid* period.

is not normally distributed, the SPI procedure calls for a gamma distribution to be fit to the empirical data distributions. I fit a gamma distribution to the annual total rainfall of each district and generate estimates of the scale and location parameters for district-specific rainfall patterns. For each year in the data, and the district-specific gamma distribution, I compute the probability of observing the total rainfall that was measured in each year and translate this into a normally distributed random variable using the normal CDF. This number is the district-year-specific SPI, where positive numbers reflect above-average rainfall and negative values reflect below-average rainfall. The positive relationship between log rainfall and the SPI measure across all districts is shown in Appendix Figure 2.

Following the climatological literature (e.g. McKee et al 1993) I define an indicator $DROUGHT_{dt}$ for each district (d) and year (t) that takes a value of 1 when the SPI is less than -1.5, and 0 otherwise. Appendix Figure 3 shows lowess-smoothed graphs of the district level mean SPI values across TBVC and non-TBVC areas for the years 1948 to 1986.

There is a tight link between the SPI measure and South African maize production. Using province-level data from the South African Maize Board for the period 1964 to 1984 and for the commercial maize-growing provinces (Transvaal and the Orange Free State), I estimate the relationship between the SPI measure and maize yields. Appendix Figure 1 shows the lowess-smoothed relationship between the log of South Africa's annual maize output (in tons) against the Spatial Precipitation Index using an Epanechnikov kernel with a 0.5 bandwidth. This positive relationship is asymmetric. Output appears more sensitive to low values of the SPI than it is to higher, positive values of the SPI. Figure 1 suggests that drought in particular captures an important negative productivity shock in agriculture.

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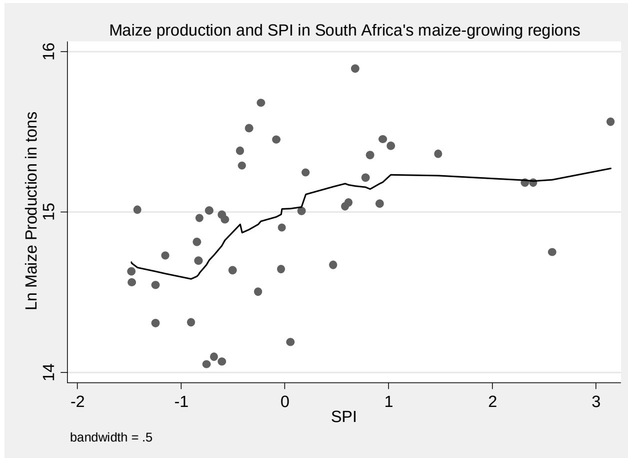
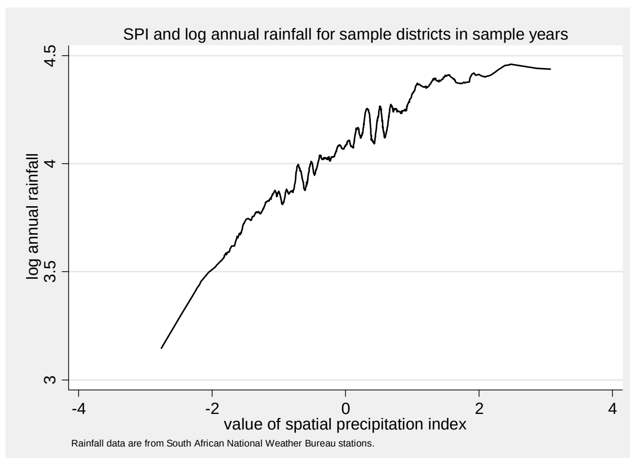
McKee, T. B., N. Doesken and J. Kleist 1993 "The relationship of drought frequency and duration to time scales", Preprints, 8th Conference on Applied Climatology, pp. 179–184. January 17–22, Anaheim, California

Appendix Figure 1



Appendix Figure 2



Appendix Figure 3

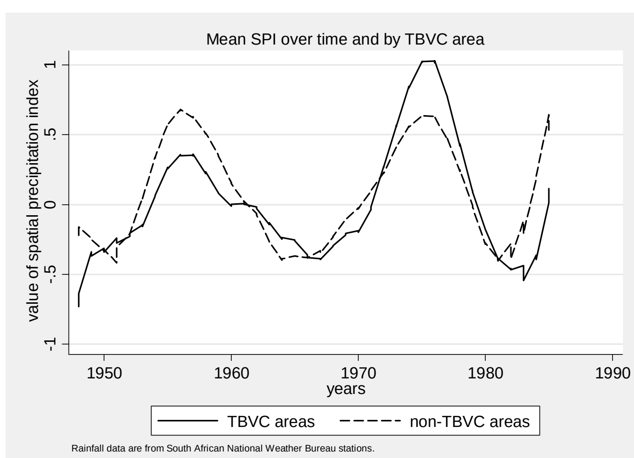


Table 1: Summary statistics

	Mean	sd	N	Min.	Max.
Panel A: Individual-level Census data					
Cohorts born 1948-1986					
Drought in year of birth	0.067	0.251	655,532	0	1
Fraction of infancy (*in utero* to age 4) in drought	0.062	0.099	655,532	0	0.33
Age	23.742	10.582	655,532	10	48
Female	0.545	0.498	655,532	0	1
Number of serious disabilities	0.057	0.257	655,532	0	4
% with Any serious disability	5.247	22.30	655,532	0	100
% with Sight disability	2.335	15.10	655,532	0	100
% with Speech/hearing disability	1.129	10.57	655,532	0	100
% with Physical disability	1.448	11.95	655,532	0	100
% with Mental disability	0.743	8.59	655,532	0	100
Female cohorts age 40-60 in 1996					
Number of children ever born	4.793	3.024	79,532	0	23
Fraction of child-bearing years in drought	0.071	0.044	79,532	0	0.4
Panel B: District-level data					
Population density in 1946 (per km^2)	48.237	38.081	16	15	137
Remoteness: Distance to nearest large city (kms)	33.247	18.954	16	7	77
Agricultural potential: maize suitability index (median)	6.563	0.964	16	5	9
Number of districts	16				
Number of birth years	39				

Individual and district-level means for African respondents in the 1996 Census, 10% sample. Individual-level data includes people born 1948-1986 (age 10-48 in 1996) who are currently or previously living in any districts formerly part of a homeland. Fertility data is reported for females who have completed childbearing in 1996, i.e. cohorts born 1936-1956. District controls include: population density measured in the 1946 national Census, distance to the nearest large city calculated using 1996 Census maps, and the median value of the maize suitability index calculated from FAO data (higher values imply lower suitability).

Table 2: Effects of Drought Exposure in Early Childhood on Disabilities Later in Life, 1948-1986

	Full sample	***Male sample***	***Female sample***
	(1)	(2)	(3)
	Panel A: % with Any Disability		
Fraction early childhood in drought	0.186***	0.267***	0.13***
	(0.050)	(0.068)	(0.043)
	[0.078]**	[0.096]***	[0.066]*
Birth year, district FE	Y	Y	Y
Mean of outcome (%)	5.25%	5.13%	5.34%
	Panel B: Number of disabilities		
Fraction early childhood in drought	0.0022***	0.0029**	0.0016**
	(0.001)	(0.001)	(0.001)
	[0.001]**	[0.001]**	[0.001]*
Birth year, district FE	Y	Y	Y
Mean of outcome	0.057	0.055	0.058
N	655,532	298,475	357,057

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* period to age 4 that the drought indicator equals one. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. Coefficient on fraction early childhood in drought evaluated at the mean of the drought exposure variable (0.062). All regressions contain a full set of birth year and district fixed effects.

Table 3: Effects of Drought Exposure in Early Childhood on Components of Disability in Later Life

	Male sample [N=298,475]		***Female sample [N=357,057]***	
	(1)	(2)	(3)	(4)
Disability outcome (%)	***Sight***	***Physical***	***Sight***	***Physical***
Fraction early childhood in drought	0.075**	0.124***	0.043	0.05**
	(0.031)	(0.031)	(0.031)	(0.019)
	[0.043]*	[0.062]***	[0.043]	[0.031]*
Birth year, district FE	Y	Y	Y	Y
Mean of outcome (%)	2.30%	1.50%	2.60%	1.40%
Disability outcome (%)	***Hearing/speech***	***Mental***	***Hearing/speech***	***Mental***
Fraction early childhood in drought	0.056***	0.037**	0.043**	0.025**
	(0.019)	(0.019)	(0.019)	(0.012)
	[0.025]**	[0.019]*	[0.025]*	[0.012]**
Birth year, district FE	Y	Y	Y	Y
Mean of outcome (%)	1.10%	0.50%	1.10%	0.90%

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* to age 4 that the drought indicator equals one. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. Coefficient on fraction early childhood in drought evaluated at the mean of the drought exposure variable (0.062). All regressions contain a full set of birth year and district fixed effects.

Table 4: Effects of Drought Exposure on Cohort Size and Fertility

	Log cohort size at year-district level			*Num. kids born*
	Full Sample	*Male sample*	*Female sample*	
	(1)	(2)	(3)	(4)
Fraction early childhood in drought	-0.007	-0.011*	-0.004	
	(0.005)	(0.006)	(0.005)	
	[0.007]	[0.009]	[0.006]	
Fraction childbearing years in drought				0.168
				(0.288)
				[0.437]
Birth year, district FE	Y	Y	Y	Y
Mean of outcome	6.766	5.943	6.180	4.793
N	624	624	624	79,532

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Sample in column 4 restricted to women who have completed childbearing in 1996 (ages 40-60). The fraction of years exposed to drought during childbearing years is constructed using drought prevalence in the first district during the years in which the woman is between age 15 and 40 inclusive. Coefficients are evaluated at the mean fraction of years in drought: 0.05.

Table 5: Heterogeneous Effects of Drought Exposure in Early Childhood on Disabilities and Cohort Size Later in Life, 1948-1986

	Males [N=298,475]	***Females [N=357,057]***	***Males [N=298,475]***	***Females [N=357,057]***	***Males [N=624]***	***Females [N=624]***
Dependent variable:	***% with Any disability***		***Num. disabilities***		***Ln cohort size***	
	(1)	(2)	(3)	(4)	(5)	(6)
Fraction early childhood in drought	0.174**	0.118*	0.002**	0.001*	-0.002	0.003
	(0.074)	(0.062)	(0.001)	(0.001)	(0.004)	(0.004)
	[0.07]**	[0.055]*	[0.001]*	[0.001]***	[0.002]	[0.004]
Fraction early childhood in drought*TBVC	0.155***	0.012	0.002**	0.001	-0.02**	-0.014**
	(0.056)	(0.062)	(0.001)	(0.001)	(0.007)	(0.005)
	[0.08]	[0.08]	[0.001]	[0.001]	[0.016]	[0.008]
Birth year, district FE	Y	Y	Y	Y	Y	Y
p-values for F-tests						
All drought parameters jointly =0	0.000	0.021	0.000	0.013	0.07	0.03
Sum of Drought and Drought*TBVC=0	0.000	0.010	0.000	0.004	0.04	0.11
Mean of outcome	5.10%	5.30%	0.055	0.057	5.94	6.18

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* period to age 4 that the drought indicator equals one; TBVC indicates whether an individual reports a prior district is TBVC or not. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. In columns 5 and 6, data are collapsed to district-year of birth level. Coefficient on fraction early childhood in drought evaluated at the mean of this variable (0.0502).

Table 6: Testing Robustness of Heterogeneous Effects for Male Sample, 1948-1986

Dependent variable:	***% with Any disability [N=298,475]***	***Num. disabilities [N=298,475]***	***Ln cohort size [N=624]***
	(1)	(2)	(3)
Fraction early childhood in drought	0.322**	0.005***	-0.040
	(0.174)	(0.002)	(0.031)
	[0.081]***	[0.001]***	[0.032]
Fraction early childhood in drought*TBVC	0.285***	0.003***	-0.026
	(0.062)	(0.001)	(0.01)**
	[0.056]***	[0.001]***	[0.015]**
Birth year, district FE	Y	Y	Y
District controls*Drought	Y	Y	Y
p-values for F-tests			
All drought parameters jointly =0	0.000	0.000	0.03
Sum of Drought and Drought*TBVC=0	0.002	0.000	0.10
Mean of outcome	5.10%	0.055	5.94

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* period to age 4 that the drought indicator equals one ; TBVC indicates whether an individual reports a prior district is TBVC or not. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. In column 3, data are collapsed to district and year of birth level. Coefficient on fraction early childhood in drought evaluated at the mean of this variable (0.062). District*Drought controls are: drought measure*population density in 1946, drought measure*distance to nearest city, and drought measure*median value on maize suitability index.

Table 7: Heterogeneous Effects of Drought Exposure in Early Childhood on Male Health Outcomes After Homeland Reintegration, 1987-1993

Dependent variable:	***% with Any Disability***	***Num. Disabilities***	***Ln cohort size***
	(1)	(2)	(3)
Fraction early childhood in drought	0.976**	0.011**	0.052
	(0.375)	(0.004)	(0.050)
	[0.334]***	[0.004]***	[0.152]
Fraction early childhood in drought*TBVC	-0.070	0.000	0.016*
	(0.167)	(0.002)	(0.007)
	[0.139]	[0.002]	[0.016]
Birth year, district FE	Y	Y	Y
District controls*Drought measures	Y	Y	Y
p-values for F-tests			
All drought parameters jointly =0	0.091	0.091	0.14
Sum of Drought and Drought*TBVC=0	0.071	0.072	0.25
Mean of outcome	3.00%	0.03	6.83
N	111,553	112,385	112

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* period to age 4 that the drought indicator equals one ; TBVC indicates whether an individual reports a prior district is an historical TBVC area or not. Sample restricted to 1996 Census data on those born between 1987 and 1993 (ages 3-9). Coefficient on fraction early childhood in drought evaluated at the mean of this variable (.139).

APPENDIX

Table 1: Main Effects of Drought Exposure in Early Childhood on Disabilities Later in Life, 1948-1986 - Using drought in birth year as treatment

	Full sample	***Male sample***	***Female sample***
	(1)	(2)	(3)
		Panel A: % with Any disability	
Drought in birth year	0.3*	0.400	0.200
	(0.200)	(0.300)	(0.200)
	[0.2]	[0.4]	[0.2]
Birth year, district FE	Y	Y	Y
Mean of outcome (%)	5.25%	5.13%	5.34%
N	655,532	298,475	357,057
		Panel B: Number of disabilities	
Drought in birth year	0.004**	0.006*	0.003
	(0.002)	(0.003)	(0.002)
	[0.003]	[0.004]	[0.003]
Birth year, district FE	Y	Y	Y
Mean of outcome	0.057	0.055	0.058
N	655,532	298,475	357,057

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Drought exposure is a binary variable constructed using values of the Spatial Precipitation Index. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. All regressions contain a full set of birth year and district fixed effects.

APPENDIX

Table 2: Main Effects of Drought Exposure in Early Childhood on Disabilities Later in Life and Cohort Size, 1948-1986 - Using rainfall shock as treatment

	Full sample	***Male sample***	***Female sample***
	(1)	(2)	(3)
	Panel A: % with Any disability		
Rainfall shock in birth year	-0.042	-0.063	-0.042
	(0.084)	(0.105)	(0.084)
	[0.084]	[0.105]	[0.063]
Birth year, district FE	Y	Y	Y
Mean of outcome (%)	5.25%	5.13%	5.34%
N	655,532	298,475	357,057
	Panel B: Number of disabilities		
Rainfall shock in birth year	0.000	-0.001	0.000
	(0.001)	(0.001)	(0.001)
	[0.001]	[0.001]	[0.001]
Birth year, district FE	Y	Y	Y
Mean of outcome	0.057	0.055	0.058
N	655,532	298,475	357,057

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Rainfall shock is the log of the annual rainfall deviation from historical mean. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. All regressions contain a full set of birth year and district fixed effects. 0.21 is a one standard deviation rainfall shock.

APPENDIX

Table 3: Effects of Drought Exposure in Early Childhood on Disabilities Later in Life, 1948-1986

Sample restricted to never movers

	Full sample	***Male sample***	***Female sample***
	(1)	(2)	(3)
	Panel A: % with Any disability		
Fraction early childhood in drought	0.211***	0.306***	0.149***
	(0.056)	(0.075)	(0.050)
	[0.093]**	[0.106]***	[0.081]*
Birth year, district FE	Y	Y	Y
Mean drought	0.062	0.062	0.062
Mean of outcome	5.15%	5.08%	5.21%
N	587,605	265,990	321,615
	Panel B: Number of disabilities		
Fraction early childhood in drought	0.002***	0.003**	0.002**
	(0.001)	(0.001)	(0.001)
	[0.001]**	[0.001]***	[0.001]**
Birth year, district FE	Y	Y	Y
Mean of drought	0.062	0.062	0.062
Mean of outcome	0.056	0.055	0.056
N	587,605	265,990	321,615

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from *in utero* period to age 4 that the drought indicator equals one. Sample restricted to 1996 Census data on individuals born between 1948 and 1986 and who have never moved from district of birth. Coefficient on fraction early childhood in drought evaluated at the mean of the drought exposure variable (0.062). All regressions contain a full set of birth year and district fixed effects.

APPENDIX

Table 4 Robustness Check: Main Effects of Drought Exposure in Early Childhood on Disabilities Later in Life, 1948-1986 - Including district-specific linear trends

	Full sample	***Male sample***	***Female sample***
	(1)	(2)	(3)
	Panel A: % with Any disability		
Fraction early childhood in drought	0.062**	0.068*	0.056
	(0.025)	(0.031)	(0.037)
	[0.031]**	[0.05]	[0.043]
Mean drought	0.062	0.062	0.062
Mean of outcome (%)	5.25%	5.13%	5.34%
N	655,532	298,475	357,057
	Panel B: Number of disabilities		
Fraction early childhood in drought	0.001**	0.0005	0.001*
	(0.000)	(0.000)	(0.000)
	[0.0003]**	[0.001]	[0.0005]*
Mean of drought	0.062	0.062	0.062
Mean of outcome	0.057	0.055	0.058
N	655,532	298,475	357,057
	Panel C: Log cohort size		
Fraction early childhood in drought	-0.005	-0.005	-0.005
	(0.004)	(0.005)	(0.004)
	[0.004]	[0.005]	[0.005]
Mean of drought	0.050	0.050	0.050
Mean of outcome	6.766	5.943	6.180
N	624	624	624

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Fraction of infancy in drought is the fraction of years from in utero to age 4 that the drought indicator equals one. Sample restricted to 1996 Census data on individuals born between 1948 and 1986. All regressions contain a full set of birth year and district fixed effects, and district-specific linear trends.

APPENDIX

Table 5: Heterogeneous Effects of Drought Exposure in Early Childhood on Male Disabilities and Cohort Size Later in Life, 1948-1986 - Using drought in birth year as treatment

	Male sample [N=298,475]				***Male sample [N=624]***	
Dependent variable:	***% with Any disability***		***Num. disabilities***		***Ln cohort size***	
	(1)	(2)	(3)	(4)	(5)	(6)
Drought in birth year	-0.080	-0.800	0.0003	-0.011	0.013	-0.062
	(0.330)	(0.900)	(0.004)	(0.011)	(0.029)	(0.201)
	[0.4]	[0.5]*	[0.005]	[0.004]**	[0.027]	[0.061]
Drought in birth year*TBVC	0.99**	0.900*	0.0098*	0.009*	-0.063	-0.079
	(0.400)	(0.400)	(0.005)	(0.005)	(0.058)	(0.081)
	[0.4]***	[0.4]**	[0.005]*	[0.004]**	[0.066]	[0.067]
p-values for F-tests						
All drought parameters jointly =0	0.01	0.06	0.03	0.04	0.46	0.40
Sum of Drought and Drought*TBVC=0	0.01	0.79	0.02	0.59	0.48	0.61
Birth year, district FE	Y	Y	Y	Y	Y	Y
District controls*Drought	N	Y	N	Y	N	Y
Mean of outcome	5.10%	5.10%	0.055	0.055	5.97	5.97

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Drought exposure is a binary variable constructed using values of the Spatial Precipitation Index. TBVC indicates whether an individual reports a prior district is TBVC or not. Sample restricted to 1996 Census data on individuals born between 1948 and 1986.

APPENDIX

Table 6: Heterogeneous Effects of Drought Exposure in Early Childhood on Components of Male Disabilities: 1948-1986

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Disability outcome:	**Sight [Mean=2%]**				**Physical [Mean=1%]**			
Fraction early childhood in drought	0.062*		0.155		0.062**		0.217**	
	(0.031)		(0.118)		(0.031)		(0.093)	
	[0.05]		[0.105]		[0.043]		[0.062]***	
Fraction early childhood in drought*TBVC	0.02		0.056		0.105***		0.18***	
	(0.019)		(0.118)		(0.031)		(0.037)	
	[0.05]		[0.043]		[0.062]*		[0.031]***	
Drought in birth year		0.090		0.600		-0.090		-0.700
		(0.190)		(0.500)		(0.200)		(0.400)
		[0.3]		[0.4]		[0.2]		[0.3]**
Drought in birth year*TBVC		0.420*		0.500**		0.320*		0.200
		(0.240)		(0.200)		(0.180)		(0.200)
		[0.3]		[0.3]*		[0.2]*		[0.2]
p-values for F-tests								
All drought parameters jointly =0	0.05	0.04	0.24	0.08	0.00	0.11	0.00	0.04
Sum of Drought and Drought*TBVC=0	0.02	0.01	0.13	0.08	0.00	0.10	0.00	0.49
Birth year, district FE	Y	Y	Y	Y	Y	Y	Y	Y
District variables*Drought controls	N	N	Y	Y	N	N	Y	Y
Disability outcome:	**Hearing/speech [Mean=1%]**				**Mental [Mean=1%]**			
Fraction early childhood in drought	0.043		0.043		0.031		0.124	
	(0.025)		(0.093)		(0.025)		(0.099)	
	[0.025]		[0.074]		[0.031]		[0.068]*	
Fraction early childhood in drought*TBVC	0.025		0.043		0.012		0.050	
	(0.025)		(0.031)		(0.031)		(0.043)	
	[0.031]		[0.019]**		[0.031]		[0.068]	
Drought in birth year		0.020		-0.600		0.000		-0.40
		(0.070)		(0.600)		(0.120)		(0.700)
		[0.1]		[0.1]		[0.1]		[0.1]
Drought in birth year*TBVC		0.120		0.000		0.130		0.10
		(0.130)		(0.200)		(0.190)		(0.200)
		[0.1]		[0.1]		[0.1]		[0.1]
p-values for F-tests								
All drought parameters jointly =0	0.02	0.56	0.38	0.24	0.10	0.68	0.39	0.75
Sum of Drought and Drought*TBVC=0	0.01	0.29	0.39	0.45	0.05	0.38	0.18	0.75
Birth year, district FE	Y	Y	Y	Y	Y	Y	Y	Y
District variables*Drought controls	N	N	Y	Y	N	N	Y	Y

Levels of significance: p<0.01***, p<0.05**, p<0.1*. Robust standard errors clustered on the year of birth are shown in parentheses beneath each coefficient and level of significance indicated next to coefficient. Two way clustered standard errors, clustered on year and district of birth are reported in square brackets along with level of significance. Two way clustered standard errors, clustered on year and district of birth, reported in square brackets. Drought exposure is a binary variable constructed using values of the Spatial Precipitation Index. TBVC indicates whether an individual reports a prior district is TBVC or not. District*Drought controls are: drought measure*population density in 1946, drought measure*distance to nearest city, and drought measure*median value on maize suitability index. Sample restricted to 1996 Census data on males born between 1948 and 1986. Coefficient on fraction early childhood in drought evaluated at the mean of this variable (0.062). Sample size in all regressions is 298,475.