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Drought, Livestock Holding, and Milk Production

A Difference-in-Differences Analysis

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Drought, Livestock Holding, and Milk Production: A Difference-in-Differences Analysis*

Meseret B. Abebe and Yonas Alem

Abstract

We identify the effects of the 2015-16 El-Niño-induced large-scale drought on smallholder farmers' livestock holding and milk production. The drought reduced milk production and livestock holding by 28.5% and 8.7%, respectively. Heterogenous impact analysis suggests that asset-rich households sold livestock and financed feed purchases, likely insulating milk production from the drought. In contrast, asset-poor households kept their livestock at all costs and absorbed all the decline in milk production. Our findings have important implications for formulating safety net and adaptation programs targeting smallholder farmers and the livestock sector in a rapidly changing climate.

Keywords: Drought, diff-in-diff, climate change, livestock holding, Ethiopia.

JEL Codes: D13, O13, O44, Q18, Q54

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1. Introduction

Households in developing countries are vulnerable to considerable risk and shocks that may have long-term consequences. The most notable risk in rural settings is unpredictable rainfall (Townsend, 1994; Bellemare and Christopher, 2013), which has been exacerbating in the past few decades due to climate change (IPCC, 2014, 2021). Households cannot access formal financial institutions to mitigate risk and cope with shocks. While some idiosyncratic shocks are insured through informal risk-sharing arrangements, albeit partially (Bardhan and Udry, 1999; Dercon, 2004; Dercon et al., 2005), covariate shocks, such as drought, are not insured and often have a long-term impact on household outcomes (Bardhan and Udry, 1999; Dercon, 2004; Dercon et al., 2005; Manccini and Yang, 2009; Carrillo, 2020). Previous studies document that drought negatively affects crop choice and yield (Huang et al., 2015; Wang et al., 2022; Agamile et al., 2021) consumption (Dercon et al., 2005; Dercon, 2002), the growth and school attendance of children (Hoddinott and Kinsey, 2001; de Janvry et al., 2006), and technology adoption (Alem et al., 2010; Alem and Broussard, 2017; Dercon and Christiaensen, 2011). In this paper, we focus on the impact of a large-scale drought on livestock holding - the key productive asset of poor smallholder farm households - and milk production.

We identify the impact of the 2015/16 El-Niño-induced drought[1] on livestock holding and milk production using panel data from Ethiopia collected before and after the drought, which we matched with high-resolution weather data. The 2015 El-Niño was notable in its strength and devastating effects. It resulted in severe drought in Eastern Africa, Southern Africa, and Latin America, cyclones, and frost in Asia, affecting over 60 million people (FAO, 2016b). The drought failed two consecutive rainy seasons in large parts of Ethiopia. As a result, it was reported to be the worst drought the country experienced in decades, leaving over 10 million people emergency food dependent (NDRMC, 2016). The availability of rich household panel data documenting detailed information before and after the drought allows us to control for household unobserved heterogeneity and identify the impact of the drought on the key outcome variables of interest using the difference-in-differences estimator.

The drought reduced farm households' livestock holding and milk production by 8.7% and 28.5%, respectively. The key pathway through which the drought affected livestock holding is the sale of cattle, the key input in crop and milk production in smallholder setup. We also find that asset-rich households account for all the livestock sales, whereas asset-poor households account for all the reduction in milk production. By selling livestock, asset-rich households financed the purchase of improved feed, which likely insulated their milk production from the drought. Asset-rich households paid about 48.3% more for the purchase of livestock feed. On the other hand, asset-poor households kept their livestock at all costs in the face of the harsh drought but absorbed a substantial decline in milk production, likely due to wa-

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[1] El-Niño is the unusual warming of sea surface temperatures in the tropical Pacific occurring every 2 - 7 years and causing heavy rain, flooding, and drought (FAO, 2016b).

ter stress and feed shortage. The responses of asset-rich and asset-poor households are consistent with the asset-smoothing theory Carter and Lybbert (2012), showing that at times of shock, only households above a certain threshold level of wealth sell livestock to smooth consumption. Our results are robust to various robustness checks.

This paper contributes to the rapidly evolving literature on the impact of climate change on smallholder farmers. Smallholder farmers in Africa and other developing regions contributed little to the problem of climate change, but they are being affected more proportionately than industrialized countries (Wei et al., 2012; Althor et al., 2016; IPCC, 2014, 2021). Climate change is expected to increase the frequency of extreme weather events, such as drought and flooding (IPCC, 2014, 2021). Wang et al. (2019) show that climate change is making El-Niños more frequent and intense. Important research in both developed countries (Deschênes and Greenstone, 2007; Mendelsohn et al., 1994; Schlenker and Roberts, 2009; Lobell and Asner, 2003; McCarl et al., 2008; Ortiz-Bobea, 2012) and developing countries (Maddison et al., 2007; Di Falco et al., 2011; Chen et al., 2016; Zhang et al., 2017; Sesmero et al., 2018) investigates the impact of climate change on crop yield. The livestock sector plays an important role in global food security by providing 17% of global kilocalorie consumption and 33% of global protein consumption (Rosegrant et al., 2009). The sector also offers livelihood for over 1.1 billion people in the developing world (Hurst et al., 2005) and is forecasted to grow rapidly as the demand for livestock products increases exponentially in the developing world (Wright et al., 2012). Climate change is expected to affect the livestock sector significantly through reduced feed crop and forage (IFAD, 2010; Chapman et al., 2012), water scarcity (Henry et al., 2012; Nardone et al., 2010), reduced animal growth, reproduction, and milk production (Henry et al., 2012) and frequent outbreak of disease (Nardone et al., 2010; Thornton et al., 2009).[2]

The effects of extreme climatic shocks on the livestock sector in general and in developing countries in particular is under-investigated likely because of lack of micro data (Pica-Ciamarra et al., 2015). Key and Sneeringer (2014) use operation-level economic data from the United States matched with high-resolution data climate data and show that modest heat-stress reduces meat and milk production significantly. In the context of developing countries, Abay and Jensen (2020) find that unpredictable weather induces households to keep livestock for precautionary savings and insurance purposes, while market access promotes livestock production for sales. Our paper sheds light on the additional impacts of extreme climatic events on livestock holding and milk production of vulnerable smallholder farm households using rich micro data and a credible identification strategy. Ethiopia offers important setup to explore the impact of the drought on the livestock sector managed by smallholder farmers. With a population of 99 million at the time of the follow-up survey (2015-16), 70% of whom depended on rain-fed smallholder agriculture for their livelihood, Ethiopia ranks the

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[2] See Rojas-Downing et al. (2017) for a recent review of the literature on the impact of climate change on the livestock sector.

second most populous country in Africa and one of the most vulnerable countries to recurrent weather-related shocks. According to the emergency events database (Guha-Sapir et al., 2016), Ethiopia experienced more than 15 drought events since the 1960s, including the large-scale El-Niño induced drought of 2015. With around 57 million cattle in 2014, Ethiopia also ranks as the richest country in Africa, and the fifth richest country in the world in terms of cattle holding. However, the sector is characterized by traditional management which limits its contributions to the economy of the country (UNIDO, 2017). Understanding the possible impact of climatic shocks on the sector is important for designing effective adaptation and coping strategies.

This paper also speaks to the microeconomics literature on the impact of shocks on household welfare. Previous research documents that covariate shocks, such as drought affect crop choice and yield (Huang et al., 2015; Wang et al., 2022; Agamile et al., 2021), household consumption (Dercon et al., 2005; Dercon, 2002), child development and child labor (Hoddinott and Kinsey, 2001; de Janvry et al., 2006), and technology adoption (Alem et al., 2010; Alem and Broussard, 2017; Dercon and Christiaensen, 2011). Research also shows that some of the effects of shocks, especially on children, could be long-term, e.g., human capital formation and earning (Bardhan and Udry, 1999; Dercon, 2004; Dercon et al., 2005; Manccini and Yang, 2009; Carrillo, 2020). Focusing specifically on the 2015 El Nino-induced drought, Hirvonen et al. (2020) shows that the drought led to chronic undernutrition in drought-exposed areas that had limited network. We add to the literature by investigating the impact of the drought on livestock holding and milk production. Understanding the impact of drought on livestock assets of farm households is important for several reasons. Livestock is the key capital input used for farming (Gilligan and Hoddinott, 2007), for investment as a buffer stock for consumption smoothing, especially in semi-arid tropical areas (Rosenzweig and Wolpin, 1993; Carter and Lybbert, 2012), and as a source of income and own consumption through the production and sale of animal products (FAO, 2019). Losing a productive asset during drought can therefore have a long-term negative impact on the welfare of farm households. Our paper sheds light on the mechanisms through which drought affects livestock holding and milk production and the scope for adaptation and safety net measures targeting the livestock sector.

The rest of the paper is structured as follows. Section 2 presents country context. Section 3 describes the data, sample construction and descriptive statistics. Section 4 discusses the empirical strategy. Section 5 presents results from alternative difference-in-differences estimators. This section also discusses the mechanisms through which drought affects livestock holding and milk production and some key robustness checks. Section 6 concludes.

2. Country Context

Ethiopia is located in the Northeastern part of the Horn of Africa, bordering Kenya in the south, Djibouti and Somalia to the east, Eritrea to the north, and Sudan and South Sudan to the West. It has a total area of 1.1 million km^2 and a total population of 99 million, out of which 81 percent lived in rural areas in 2016 when the follow-up data was collected (WorldBank, 2022). Ethiopia has a tropical monsoon climate with wide topographic-induced variation, which is classified into three climatic zones; a cool zone (Dega) 2400 m above sea level consisting of the central parts of the western and eastern section of the high plateaus, where the temperature ranges from close to freezing to 16 dc; a temperate zone (Woina Dega) between 1500 m and 2400 m above sea level, where the temperature ranges between 16 -30 dc; and the hot zone (Qola) in the lowlands below 1500 m which encompasses both tropical and arid areas, and has temperatures ranging from 27 dc to 50 dc (USAID, 2016). Annual rainfall varies from about 2000 mm in some pocket areas in southwest Ethiopia to less than 100 mm in the Afar Lowlands in the northeast, with the average being 848 mm (FAO, 2016a).

Agriculture plays a significant role in the Ethiopian economy, contributing about 35 percent of the GDP, 68.2 percent of employment, and 90 percent of export earnings (FDRE, 2016). The livestock sub-sector contributes about 45 percent to agricultural GDP (FAO, 2019), 19 percent to the overall GDP, and 16–19 percent to the foreign exchange earnings of the country (MoA, 2012). Livestock serves multiple functions in the rural household economy. In the context of rural Ethiopia, not only is livestock a source of livelihood and important input in agricultural production, but it is also a source of income to meet daily needs, protein for own consumption, manure for crop production and cooking fuel, means of transport, and store of wealth (ILRI, 2011). Around 14 million Ethiopian households (70 percent of the population) keep livestock (FAO, 2019). Consequently, the livestock sector has great potential to improve the population's livelihood and reduce poverty.

Ethiopia is believed to have the largest livestock population in Africa and the tenth largest in the world (UNIDO, 2017).[3] In 2015, the country was estimated to own about 57 million cattle, 30 million sheep, 23 million goats, and 57 million chickens, and it produced over 5.6 billion liters of milk, 1.1 million tons of beef, and 419 million eggs (FAO, 2019). Endowed with a large number of livestock, favorable climate, and a relatively disease-free environment for livestock, Ethiopia has a great potential to develop the sector (Ahmed et al., 2004). However, despite the large livestock population and favorable weather conditions, livestock output and productivity are poor due to technical, economic, and institutional constraints (FAO, 2019). Livestock production takes place through two systems: the mixed crop-livestock, which combines both crop and livestock production and is based on limited communal or private grazing areas and crop residue or stubble, and the nomadic pastoral system,

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[3] Considering only the cattle population, Ethiopia ranks first in Africa and fifth in the World (UNIDO, 2017).

which is based on extensive communal grazing (Negassa et al., 2011). Both systems are managed through inefficient and traditional methods, and as a result, the livestock sector offers low and unreliable returns, leaving many livestock-dependent households in poverty (Rettberg et al., 2017).

Ethiopia is a highly drought-prone country. As its rain-dependent agriculture, the livestock sector is also significantly vulnerable to climatic shocks such as drought. Since the 1960s, Ethiopia experienced more than 15 drought events (Guha-Sapir et al., 2016), significantly impacting the country's poor population. The impact of climate change is visible with the average temperature in the country increasing by $1^{o}C$ resulting in a 37.5 percent increase in the average number of hot nights between 1960-2003 (McSweeney et al., 2009). The temperature increase has led to accelerated evapotranspiration and reduced soil moisture, particularly in the central and highland areas of the country (Ministry of Environment and Forest - MoEF, 2015). Ethiopia also experienced significant variability in long-term precipitation with an overall decline in the last three decades, with some areas such as the south-central region experiencing a 20% reduction in rainfall since 1960 (Ministry of Environment and Forest - MoEF, 2015). The timing and duration of rainfall seasons will be significantly affected in the future due to the surface temperature rise in the Indian Ocean, causing more frequent droughts (USAID, 2012). Given the above, analyzing the impact of drought on the livestock sector is vital to understand the cost of climatic shocks and designing effective coping and adaptation strategies.

3. Data

3.1. Sampling and Data Collection

The analysis conducted in this paper uses household survey data from rural Ethiopia. To identify the impact of the El-Nino-induced drought on livestock holding and milk production, we use the two rounds of a panel data set - the Ethiopian Socioeconomic Survey (ESS) - that represents rural Ethiopian households. ESS was conducted as part of the World Bank Living Standards Measurement Study – Integrated Surveys on Agriculture (LSMS-ISA), in collaboration between the Ethiopian Central Statistics Agency (CSA) and the World Bank (WB). The key objective of the survey was to understand agriculture and its role in household wellbeing. The first round was conducted as a rural survey in 2011/12 covering only rural and small-town areas with a total sample of 333 enumeration areas (EAs) constituting 3,776 households and called the Ethiopian Rural Socioeconomic Survey (ERSS). In the subsequent two rounds conducted in 2013/14 and 2015/16, the survey was expanded to include urban areas to ensure that the data could provide nationally representative samples with a total of 433 EAs and 5,262 households, forming (ESS) the Ethiopian Socioeconomic Survey. [4]

ERSS was designed to represent Ethiopia's rural and small town population in the

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[4] See https://microdata.worldbank.org/index.php/catalog/2053 for a detailed description of ESS.

four major regions: Amhara, Oromia, Southern Nations, Nationalities and People (SNNP), and Tigray, using a two-stage probability sampling. In the first stage, primary sampling units of 290 rural and 43 small-town EAs were selected from EAs used by the Ethiopian Central Statistics Agency in proportion to the populations of the regions. In the second stage, 12 sample households from each rural sample EAs and ten households from each of the small town EAs were randomly selected. We use the survey's first round to test the difference-in-differences estimator's parallel trend assumption.

The second round was conducted in 2013/14 as the ESS with additional 1500 households living in 100 EAs in large urban towns, including the capital, Addis Ababa, using the two-stage sampling referred to above. Fifteen households were randomly selected from each urban EA. Including urban households in the second wave increased the total sample to 433 EAs and 5469 households. Since the 2015 El-Nino-induced drought happened after the second round, we use the second round as the baseline round in our difference-in-differences analysis. The third round, which we treat as the post-drought round - was conducted in 2015/2016 after the El-Niño induced drought from the same sample of EAs and households established during the second round. Attrition in the rural sample is negligible ($< 2\%$).

Data collection began in September in all rounds to avoid the effect of seasonality. The survey collects detailed socioeconomic information through five questionnaires: a household questionnaire documenting information on demographics, education, consumption, labor market activities, etc.; a community questionnaire addressed to a group of community members about EA-level resource management initiatives, community needs, actions, and achievements; two agriculture questionnaires consisting of questions about post-planting and post-harvest agricultural activities including input use, crop harvest, and utilization; and a livestock questionnaire documenting information on the number and type of livestock, change in livestock, animal health and feed, milk and egg production. ESS is the richest and nationally representative panel data set for Ethiopia - the second most populous country in Africa. Descriptive statistics of key household variables of the sample households at baseline are presented in Table 1.

3.2. Weather Data

In addition to the household survey data, we constructed rainfall data from the Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS). Most previous studies investigating the impact of drought on household welfare in Ethiopia used either self-reported measures (Dercon et al., 2005; Porter, 2012) or meteorological data (Dercon, 2004; Yamano et al., 2005; Thiede, 2014) provided by the Ethiopian meteorological agency. Self-reported data suffer from reporting bias; metrological data suffers from many missing observations and measurement errors due to a large spatial coverage. There has been a decline in the number of weather stations in Africa during the past decade. According to (Lorenz and Kunstmann, 2012), the number of reporting weather stations in Africa has fallen from around 3500 to around 500 since 1990. Moreover, (Alem and Colmer, 2021) show that Ethiopia has, on average, 0.03 stations per woreda (district), which are likely placed in more surplus agricultural producer areas, likely resulting in estimates using weather stations systematically biased upward.

CHIRPS is a 35+ year quasi-global rainfall data set. The data contains monthly, pentadal, and daily rainfall data from 1981 to the present day with 0.05-degree (5×5 km) spatial resolution satellite imagery. CHIRPS creates gridded time-series rainfall data with fine resolution through in-house climatology, CHPclim, and in-situ station data usable for trend analysis and seasonal drought monitoring (Funk et al., 2015). For this study, we used CHIRPS data for a spatial resolution of around 5 km (at the equator) and a temporal resolution of one month. The CHIRPS data has been used extensively in previous research which investigates the effects of weather shocks (Hirvonen et al., 2020; Tambet and Stopnitzky, 2019; Aragón et al., 2018).

3.3. Sample Construction

We use the household latitude and longitude coordinates from the Ethiopian Socioeconomic Survey (ESS) to match the CHIRPS data using an inverse-distance weighted average of the four nearest satellite observations. After matching the two data sets, we followed Shah and Steinberg (2017) and Mahajan (2017) and defined drought, our primary explanatory variable of interest, as a binary variable if rainfall in 2015 was below the 20^{th} percentile within the enumeration area over the long-term period (i.e., 1981–2015). In the “Results” section, we check for the robustness of the results to alternative definitions of drought.

Our outcome variables of interest are livestock holding measured in Tropical Livestock Unit (TLU) and the average daily milk produced per cow. We converted livestock holding of households using the conversion factors provided by FAO (2011). The final sample comprised 2661 households for the livestock holding sample and 2641 for the milk production sample. The difference is that we dropped 20 households with unrealistically high values for milk production.

Figure 1 shows the map of Ethiopia, the distribution of the ESS enumeration areas, and the distribution of rainfall in the El-Nino-induced drought year 2015.

4. Identification Strategy

We employ a difference-in-differences estimator to identify the impact of the 2015 El Nino-induced drought on livestock holding and milk production. The combination of rich household data in the ESS panel and reliable fine-resolution weather data enables us to identify the impact of the drought by controlling for both observable and unobservable time-invariant characteristics. By comparing the quantity of livestock and milk production of drought-affected and non-drought-affected households before and after the 2015 drought, we can capture the effect of the drought. One estimates the standard difference-in-differences estimator from the following regression:

$$\Delta Y_i = \beta_0 + \beta_1 D_i + \epsilon_i \tag{1}$$

where ΔY_i is the change in the outcome variable of interest between 2013/14 and 2015/16 for household i, and D is an indicator variable equal to 1 if the household was affected by the drought, and 0 otherwise. Our measure of drought is constructed from the rainfall data discussed in the preceding section. The parameter estimate of β_1 captures the mean difference in the relevant outcome variable between drought-affected and non-drought-affected households.

Comparing the simple differences between drought-affected and non-drought-affected households could lead to biased estimates of the true impact of the drought households living in the two areas have different characteristics before the drought. Baseline characteristics of households may vary systematically with drought exposure due to differences in the choice of risk mitigation and shock coping mechanisms of households. Additionally, the difference-in-differences estimator relies on the strong assumption that average outcomes for the treated and comparison households would have followed parallel trends over time in the absence of the treatment. Let X be a vector of observable baseline control variables which differ between the two groups and are correlated with the outcome variables. Regressing ΔY on D and X would allow us to identify the effect of drought on the outcome variable. This is the unconfoundedness assumption or the selection-on-observables assumption, which states that treatment (exposure to drought) is independent of potential outcomes conditional on the observed covariates. This means that conditional on covariates, treated and non-treated households would, on average, be expected to experience the same changes in outcomes following the drought in the absence of treatment. Thus, conditioning on the propensity score, where the propensity score is $Pr(D = 1|x)$, also achieves identification as shown by Rosenbaum and Rubin (1983).

We use the propensity score for weighting to estimate the average treatment effect on the treated (ATT). The inverse propensity score weighting efficiently estimates the ATT (Hirano et al., 2003). It also exhibits minimal bias when the propensity score model is correctly specified and performs just as well as most matching estimators when there is reasonable overlap (Busso et al., 2013a). Subsequently, the semiparametric difference-in-differences estimator, a panel data version of the estimator, was proposed by Abadie (2005).

Inverse-propensity score weighting constructs two counterfactual means and takes their difference to obtain the average treatment effect (DiNardo, 2002). One computes the treatment and control mean for the population by a weighted mean of outcomes in the treatment and control groups, respectively. The data is reweighted to balance the distribution of covariates across treated and control households. Recent studies (Alem and Broussard, 2018; Bitler et al., 2006; Busso et al., 2013b) used this method to estimate the average treatment effects of development programs in different contexts. DiNardo (2002) and Hirano et al. (2003) offer informative discussion on using propensity score reweighting to estimate the average treatment effect on the treated. We calculate the ATT by applying weights to comparison households such that the outcomes for the comparison households represent the counterfactual outcomes of drought-affected households.

Let the estimated propensity score for household i be $\hat{p}_i$. Thus, the estimated inverse-propensity score weight for household i is:

$$\hat{w}_i = D_i + (1 - D_i)\frac{\hat{p}_i}{1 - \hat{p}_i} \tag{2}$$

and the estimated average treatment effect on the treated is:

$$A\hat{T}T = \frac{1}{N_T}\sum_{i \in T} \hat{w}_i y_i - \frac{1}{N_C}\sum_{i \in C} \hat{w}_i y_i \tag{3}$$

where N_T is the number of treated observations and N_C is the number of comparison observations. The ATT is calculated by comparing the treatment mean to the reweighted comparison group mean.

The richness of the ESS data allows us to ensure that the variables used to construct the propensity scores are related to selection into drought-affected areas and outcomes, that drought-affected and non-drought-affected households have access to the same markets, and that the dependent variable is measured in the same way for both groups (Heckman et al., 1997). We control for many of the control variables believed to be associated with the probability of living in drought-prone areas, including age, gender, maximum education in the household; household size; owning a non-farm enterprise by the head; the size of total land holding measured in hectares; access to credit by at least one member of the household; and owning a mobile phone by at least one member.

Balancing the distribution of these covariates between treatment and control group households would allow us to construct a valid counterfactual. We weight the regression by the inverse propensity score presented above to identify the average treatment effect of the drought on the outcome variables of interest, livestock holding, and milk production. We compute the standard errors through clustering at the enumeration area level. As a robustness check, we also estimate the treatment effects using an alternative propensity score matching estimator - the kernel matching.

5. Results

5.1. Validating the Parallel Trend Assumption

The key identifying assumption of the difference-in-differences estimator is that the *trend* in the outcome variables of interest must be similar for both treatment and control groups pre-intervention (Angrist and Pischke, 2009). To test this assumption, we report livestock holding and milk production trends for two rounds (2011/12 and 2013/14) before the El Nino-induced drought. If the parallel trend assumption holds before the drought, then the two groups can be compared using difference-in-differences estimation.

Table 2 presents ATT estimates on the impact of the 2015/16 drought on livestock holding and milk production in 2011/12, when no household experienced drought. Regression results from difference-in-differences estimators implemented with alternative matching methods (columns 1-3) indicate that the El-Niño-induced drought did not affect both outcome variables of interest - livestock holding and milk production in 2011/12. This suggests that the parallel trend assumption holds and that the difference-in-differences estimation is a valid method to identify the impact of the drought.

Table 2 about here

5.2. Impact on Livestock Holding and Milk Production

We present descriptive statistics of key variables at baseline in Table 1. About 76% of the households are male-headed, the maximum level of education in the average household is about 4.5 years of schooling, and households, on average, have five members. Rural Ethiopia exhibits one of the lowest land holdings in Sub-Saharan Africa (Deininger et al., 2017) with the average holding per household being 1.6 ha land and 0.33 ha on a per capita basis. Table 1 also shows that about one-third of households have access to credit, and 27% own a non-farm enterprise. Livestock is the most important asset in the context of rural Ethiopia, with an average holding of 2.48 livestock in Tropical Livestock Units.[5] At baseline, households, on average, produced 0.64 liters of milk/cattle.

Table 1 about here

Figures 2 and 3 present mean comparison results of the key outcome variables of interest (livestock holding and milk production) before and after the drought. At baseline, there is no statistically significant difference in both variables between households in the drought-affected and non-drought-affected villages (Figure 2). At follow-up (after the drought), the mean difference in both variables for the treatment and control groups is statistically significant (Figure 3). Households in the treated villages have 14.5% and 33.9% less livestock holding and milk production/cattle than households in the control villages, respectively. This provides preliminary evidence that the drought significantly affected livestock holding and milk production.

Figure 2 about here

Figure 3 about here

Table A.1 in the appendix presents the mean values of baseline covariates for the treatment and control groups and the corresponding statistical tests of the differences in means before and after covariate adjustment. Column 3 reports mean differences between treated and control group households before covariate adjustment. Relative to the control group, households in drought-affected areas tend to be

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[5] FAO (2011) proposes the following units to convert household livestock holding to standard Tropical Livestock Units: Cattle=0.5, Goat and Sheep=0.1, Horse = 0.5, Mule=0.6, Donkey = 0.3, Camel=0.7 and Chicken=0.01.

headed by females, older and more educated individuals. Treated households also have a lower household size, a lower likelihood of owning a non-farm enterprise, and a higher likelihood of having credit access and a mobile phone. Columns 4-5 present baseline mean difference in covariates between the treated and control group sample households after covariate adjustment through inverse propensity score weighting and kernel matching, respectively. The results suggest that the mean differences in covariates between drought-affected and unaffected sample households are no longer statistically significant.

We use a probit estimator to estimate the propensity scores for all the matching methods used in computing the ATT of the El Nino-induced drought on livestock holding and milk production. The baseline household characteristics we control for include the age and gender of the household head, the maximum number of years of schooling in the household, household size, ownership of a non-farm enterprise, access to credit, ownership of a mobile phone by at least one member of the household, and the size of household land holding measured in hectares. Balancing the distribution of these covariates between treatment and control group households would allow us to construct a valid counterfactual.

Table 3 shows the results on the impact of the 2015/16 El-Niño-induced drought on livestock holding and milk production from a difference-in-differences estimator with alternative matching methods. All regressions consistently suggest that the drought reduced livestock holding significantly. The most conservative estimates from column 2 (DID with propensity score weighting) show that the drought reduced livestock holding of the treatment group by 0.207 units. Given the mean livestock holding of the control group at baseline is 2.39 in tropical livestock units, the effect of the drought is equivalent to about 8.7% reduction in livestock.

Table 3 about here

Table 3 also reports results on the impact of the drought on milk production from the same estimators. Similarly, all the regression results suggest that the drought significantly reduced milk production in the drought-affected areas. DID propensity weighting results reported in column 2 suggest that milk production was reduced by 0.177 litters (28.5%)/day/cow in the drought-affected group compared to the non-drought-affected group.

Households keep different types of livestock for different purposes. Cattle (more importantly oxen) are the key capital inputs used for farming (Gilligan and Hoddinott, 2007), and investment as a buffer stock for consumption smoothing, especially in semi-arid tropical areas (Rosenzweig and Wolpin, 1993). Cows are kept to produce milk and milk products for own consumption and the market (FAO, 2019), and smaller livestock, such as sheep, goats, and chicken, are kept for own consumption and sales to meet emergency cash needs (Pica-Ciamarra et al., 2015). From social protection and public policy point of view, it is therefore important to understand the impact of the drought on livestock holding by livestock type.

In Table 4, we divide livestock ownership into cattle, small animals, and other animals and present the impact of the drought by livestock type. Results from all versions of the DID estimators suggest that the impact of drought on livestock holding is driven primarily by its effect on cattle and small animal holding. Comparing the ATT effects on cattle holding reported in column 2 of Table 4 (-0.151) with the ATT impacts reported in the same column in Table 3 (-0.207), we note that about 73% of the impact of the drought on livestock is through its effect on cattle holding. Given the importance of cattle for draft power in rural Ethiopia, the reported significant impact has important implications for the long-term wellbeing of small-holder farmers.

Table 4 about here

5.3. Heterogenous Impacts

We check for heterogenous effects of the 2015/16 drought based on two important socioeconomic variables - the gender of the head and household wealth status. There is strong existing evidence indicating that female-headed households are more vulnerable to shocks, less likely to have access to modern technologies, and often face constraints in navigating through input and product markets (Bardhan and Udry, 1999; Dercon, 2002; Alem et al., 2010). In Tables 5 and 6, we report regression results on the effects of the drought by the gender of the head of the household on livestock holding and milk production, respectively. Contrary to the expectation, we note in Table 5 that livestock holding of both male-headed and female-headed households have been affected negatively, but the effects are statistically significant for male-headed households only. The reason is likely because 76% of the households are male-headed (Table 1) and that they already had a larger number of livestock holding (2.73 units) than female-headed households (1.66 units) at baseline, with a statistically significant difference in mean values (p-value = 0.000). Male-headed households had more livestock and lost more because of the drought. We also note in Table 6 that the effect of the drought on milk production is statistically significant for male-headed households only.

Table 5 about here

Table 6 about here

To check for heterogenous effects of the drought-based wealth, we classified households as asset-rich and asset-poor based on ownership of two cattle and above at baseline. Cattle ownership in rural Africa is important not only as a source of draft power but also as a store of wealth (Hoddinott, 2006). Owning two cattle, the key capital input for farming is the threshold used by previous studies to define rural small-holder farm households. Scott (2019) uses several iterative estimations using the same data set from rural Ethiopia and shows that two cattle can be used as the benchmark to classify rural households as asset rich and poor. Based on this criteria, about 57% of the sample are asset-rich at baseline.

We report regression results on the heterogeneous impact of the drought on livestock holding and milk production by livestock asset in Tables 7 and 8, respectively. The results suggest that the drought affected asset-rich and asset-poor households' livestock holdings. Still, the effect is statistically significant for asset-rich households only for livestock holding and asset-poor households only for milk production. Column 2 of Table 7 suggests that the drought reduced livestock holding of asset-rich households by about 0.32 tropical livestock units or by 13.4%. This finding is unsurprising given that we used livestock to measure wealth, and livestock-rich households lost more livestock than livestock-poor households. However, we note from Table 8 that the drought reduced milk production of livestock-poor households more proportionately than livestock-rich households. Column 2 suggests that the drought reduced milk production of livestock-poor households by 0.20 liters/cattle/day or by 32.3%. This corresponds to a 13% increase in the ATT effects of the drought compared to what we reported in the main regressions in Table 3. In the next section, we use livestock feed data to shed light on the possible mechanisms that explain these heterogenous effects.

Table 7 about here

Table 8 about here

5.4. Mechanisms

From an adaptation and social protection point of view, it is important to tease out the mechanisms through which the El-Niño-induced drought reduced smallholder farmers' livestock holding and milk production. We begin by differentiating the source of livestock loss by death, sales, and own consumption and report the ATT effects in Table 9. The results suggest that the drought affected both livestock death and livestock sales. Still, the effect is statistically and economically significant in all DID regressions on livestock sales. For example, the regressions with the propensity score weighting reported in column 2 of panel B suggest that treatment households, on average, sold 0.09 units of livestock following the drought.

Table 9 about here

Next, we investigate the source of livestock loss (livestock death, sales, and own consumption) for livestock-rich and livestock-poor households using similar regressions and report the results in Table 10. We note that livestock-rich households sold more livestock than livestock-poor households. The ATT effects of livestock sales for livestock-rich households reported in Table 10 are very similar to the ATT effects for livestock sales of the whole sample reported in Table 9, which suggests that livestock sales by asset-rich households account for all livestock sales post-drought.

To shed light on why livestock-rich households sold livestock in our sample, we use information on livestock feed purchase collected in the post-drought wave (2015/16) of the Ethiopian Socioeconomic Survey.[6] We estimated three regressions: whether a household used improved feed or not, whether the household purchased improved feed or not, and the log of expenditure on feed. The results reported in Table 11 suggest that the drought did not affect all three outcome variables when we

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[6] We use data on feed purchase and use from the post-drought survey (2015/16) only due to inconsistency in the feed data collection between the two waves.

consider the entire sample. However, by dividing the sample into livestock-rich and livestock-poor, we find that the drought has a statistically significant effect (at 10%) on the probability of feed purchase and the log of purchased feed cost by livestock-rich. Specifically, livestock-rich households paid 48.3% more for feed purchases. This provides suggestive evidence that livestock-rich households sold livestock at least in part to generate cash to finance the cost of purchased feed, and this may have insulated their milk production from the drought.

Table 11 about here

Our finding that livestock-rich households sold more livestock during drought is consistent with previous studies (Rosenzweig and Wolpin, 1993; Fafchamps et al., 1998; Carter and Lybbert, 2012). Rosenzweig and Wolpin (1993) uses data from rural India and shows that farmers invest in bullocks for productive use and sell them to smooth consumption when weather outcomes are poor. Fafchamps et al. (1998) offer limited evidence that households in the West African semi-arid tropics use livestock sales and purchases as consumption smoothing strategies during rainfall shocks. More recently, Carter and Lybbert (2012) used a poverty trap model and showed that only households above a certain threshold level of wealth sell livestock to smooth consumption during shocks. Using household panel data from Burkina Faso, these authors show that households above the threshold level of wealth almost fully protect their consumption from weather shocks by selling livestock. In contrast, households below the threshold level of wealth guard their livestock even when they face a significant decline in income. Our results are consistent with the predictions of the asset-poverty trap model of Carter and Lybbert (2012). Livestock-rich households sold livestock to finance the cost of feed to insulate their milk production and possibly to smooth consumption, but livestock-poor households kept their livestock at all costs.

Finally, livestock sales, feed shortage, and water stress are likely to explain the 29% reduction in milk production by drought-affected households. There is notable scientific evidence linking the decline in milk production to drought. Andrade et al. (2017) use long time series data from Brazil, showing strong links between drought indices obtained through remote sensory devices and milk production. (Abbas et al., 2019) show that Pakistan's drought threatens every aspect of dairy production, including milk. More recently, USFAS (2022) shows that the EU-wide drought in 2022 significantly reduced EU27 dairy herd and milk production.

5.5. Robustness Checks

We check for the robustness of our results using two robustness checks. First, we reconstruct the drought variable using subjective responses by households to the question of whether they experienced drought or not. About 26% of the respondents of the rural version of the Ethiopian Socioeconomic Survey reported that they experienced drought. Reassuringly, the results remained the same. ATT estimates of drought reported in column 2 of Table B.1 in the appendix (-0.211) are very similar to the main ATT estimates reported in column 2 of Table 3 (-0.207).

Second, we re-estimate the main ATT effects, including the sample of households from the nomadic regions. The results reported in Table B.2 in the online appendix are higher than those reported in Table 3. This result is expected because the livelihood of these households depends almost exclusively on livestock keeping. The more livestock the household has, the more likely it will be affected.

6. Conclusion

The 2015/2016 El-Niño-induced drought negatively affected the livelihood of over 60 million people globally FAO (2016b). We use the exogenous variation in the prevalence of the drought to investigate its effects on livestock holding and milk production in rural Ethiopia, one of the most severely affected countries. The availability of nationally representative household panel data - the Ethiopian Socioeconomic Survey - collected before and after the drought gave us the ideal setup to implement difference-in-differences estimation using alternative matching methods.

We find that the drought reduced livestock holding of smallholder farmers by about 8.7% and milk production by about 28.5%. We also show that the main livestock affected by the drought are cattle, the key assets that serve as a source of draft power in smallholder agriculture. Consistent with the predictions of the asset poverty trap model (Carter and Lybbert, 2012), we find that livestock sales by livestock-rich households drive the impact of the drought on livestock holding. Livestock-rich households sold livestock and financed the purchase of improved feed, which likely insulated their milk production from the drought. However, livestock-poor households kept their livestock despite the large-scale drought. The results remain robust to using different matching methods, livestock measures, and sample size.

Our findings are important for formulating safety net programs and adaptation strategies targeting the livestock sector and smallholder farmers. Disaster and relief agencies and NGOs often respond to drought by providing emergency food assistance (such as free food distribution and food-for-work programs) to save lives. Research suggests these interventions have been effective (Gilligan and Hoddinott, 2007; Alem and Broussard, 2017). However, given the predicted frequent drought, specific adaptation plans that address livestock holding of households are urgently needed. To this end, improving the livestock feed value chain and establishing livestock feeding stations, which some research has proved to be effective, is important (Bekele and Abera, 2008). These adaptation strategies will protect household consumption and asset from shocks and help improve the productivity and economic contribution of the livestock sector in Sub-Saharan Africa, which appears to be very low currently.

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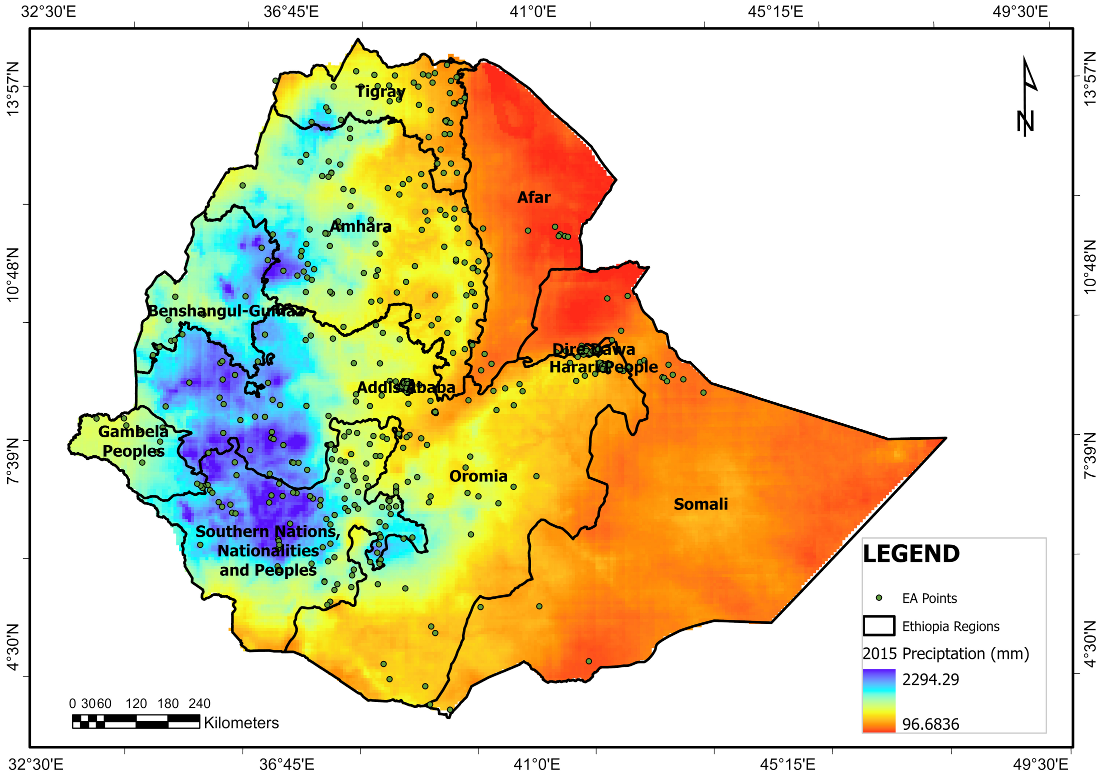
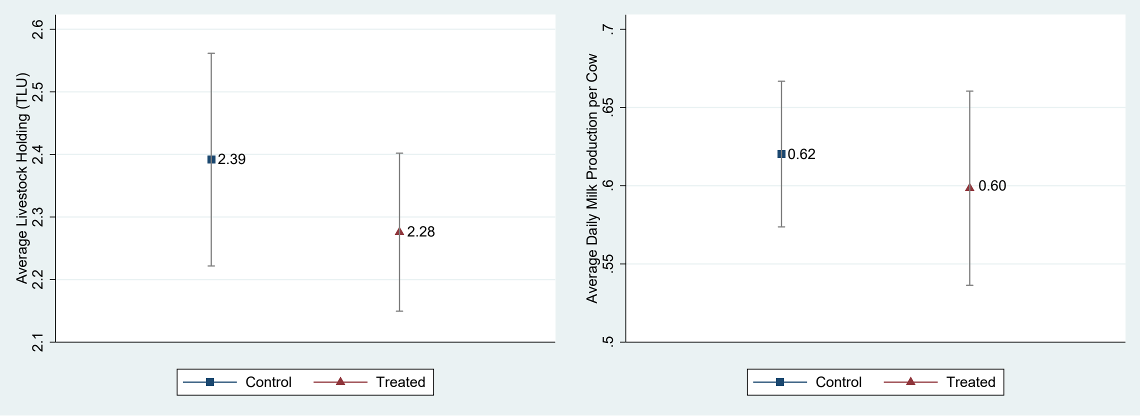
Figure 1: ESS Sample Enumeration Areas and Rainfall Distribution, 2015



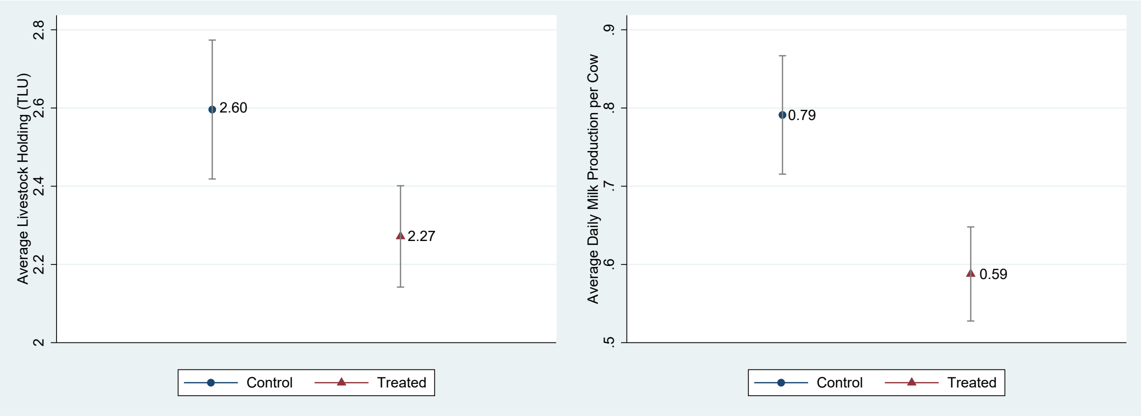
Map1.jpg

Figure 2: Mean comparisons of outcome variables before drought



Notes: This figure presents livestock holding and milk production for the drought-unaffected and drought-affected groups before the drought and the corresponding mean comparison test results.

Figure 3: Mean comparisons of outcome variables after drought



Notes: This figure presents livestock holding and milk production for the drought-unaffected and drought-affected groups after the drought and the corresponding mean comparison test results.

Table 1: Descriptive statistics at baseline

Male head	0.753 (0.432)
Head's age	46.49 (15.29)
Maximum education in the household	4.885 (3.816)
Household size	5.047 (2.287)
Land holding	1.575 (4.537)
Access to credit	0.307 (0.462)
Owns a non-farm enterprise	0.311 (0.463)
Owns a mobile phone	0.383 (0.486)
Tigray	0.124 (0.329)
Amhara	0.277 (0.448)
Oromia	0.260 (0.439)
SNNP	0.339 (0.474)
Livestock in TLU	2.332 (2.766)
Average daily milk/cattle(litters)	0.609 (1.027)
Experienced drought	0.512 (0.500)
Observations	2661
Clusters (Enumeration Areas)	251

Notes: This table presents summary statistics of variables at baseline (pre-drought) for the pooled sample (treatment and control group combined).

Table 2: Validating Parallel Trend Assumption

VARIABLES	(1) DID	(2) DID-IPSW	(3) DID-Kernel
Difference in average outcomes (ATT): Livestock holding	0.00788	0.0126	0.0168
	(0.0973)	(0.101)	(0.100)
Observations	1,978	1,973	1,963
Difference in average outcomes (ATT): Milk Production	0.0334	0.0298	0.0486
	(0.0730)	(0.0713)	(0.0723)
Observations	1974	1,969	1,959

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding and milk production in 2011/12 to test for the parallel trend assumption. Column 1 reports ATT estimates from the standard difference-in-differences estimator. Columns 2 - 3 present ATT estimates from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 3: The Impact of Drought on Livestock Holding and Milk Production

VARIABLES	(1) DID	(2) DID-IPSW	(3) DID-Kernel
Difference in average outcomes (ATT): Livestock holding	-0.195**	-0.207**	-0.212**
	(0.0886)	(0.0932)	(0.0912)
Observations	2,661	2,648	2,655
Difference in average outcomes (ATT): Milk Production	-0.160**	-0.177**	-0.175**
	(0.0737)	(0.0733)	(0.0729)
Observations	2,641	2,628	2,635
Control mean - livestock	2.392		
	(3.123)		
Control mean - milk	0.620		
	(0.854)		

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding and milk production. Column 1 reports ATT estimates from the standard difference-in-differences estimator. Columns 2 - 3 present ATT estimates from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 4: The Impact of Drought by Livestock Type

VARIABLES	(1) DID	(2) DID-IPSW	(3) DID-Kernel
Difference in average outcomes (ATT): Cattle	-0.139**	-0.151**	-0.153**
	(0.0656)	(0.0704)	(0.0681)
Difference in average outcomes (ATT): Small Animals	-0.0742**	-0.0762**	-0.0756**
	(0.0295)	(0.0297)	(0.0304)
Difference in average outcomes (ATT): Other Animals	0.0176	0.0201	0.0161
	(0.0209)	(0.0198)	(0.0197)
Observations	2,661	2,648	2,655

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding by livestock type. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT effects from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 5: Heterogenous Impact by Gender of Head - Livestock Holding

VARIABLES	(1) DID	(2) DID-IPSW	(3) DID-Kernel
Panel A: Male Headed Households			
Difference in average outcomes (ATT): Livestock Holding	-0.229**	-0.266**	-0.269**
	(0.102)	(0.109)	(0.108)
Observations	2,003	1,991	2,002
Panel B: Female Headed Households			
Difference in average outcomes (ATT): Livestock Holding	-0.106	-0.0848	-0.101
	(0.136)	(0.136)	(0.138)
Observations	658	650	651

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding by the gender of the household head. Column 1 reports ATT estimates from the standard difference-in-differences estimator. Columns 2 - 3 present ATT estimates from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 6: Heterogenous Impact by Gender of Head - Milk Production

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Panel A: Male Headed Households			
Difference in average outcomes (ATT): Milk Production	-0.180**	-0.198**	-0.194**
	(0.0802)	(0.0821)	(0.0816)
Observations	1,987	1,975	1,986
Panel B: Female Headed Households			
Difference in average outcomes (ATT): Milk Production	-0.107	-0.0579	-0.0710
	(0.109)	(0.122)	(0.116)
Observations	654	647	647

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on milk production by the gender of the household head. Column 1 reports ATT estimates from the standard difference-in-differences estimator. Columns 2 - 3 present ATT estimates from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 7: Heterogenous Impact by Livestock Wealth - Livestock Holding

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Panel A: Asset Rich			
Difference in average outcomes (ATT): Livestock Holding	-0.275*	-0.315**	-0.316**
	(0.150)	(0.160)	(0.156)
Observations	1,392	1,373	1,389
Panel B: Asset Poor			
Difference in average outcomes (ATT): Livestock Holding	-0.0517	-0.0617	-0.0640
	(0.0860)	(0.0841)	(0.0832)
Observations	1,269	1,265	1,266

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding by wealth. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT effects from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 8: Heterogenous Impact by Livestock Wealth - Milk Production

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Panel A: Asset Rich			
Difference in average outcomes (ATT): Milk Production	-0.134	-0.145	-0.145
	(0.106)	(0.109)	(0.104)
Observations	1,377	1,358	1,374
Panel B: Asset Poor			
Difference in average outcomes (ATT): Milk Production	-0.183*	-0.200**	-0.202**
	(0.0807)	(0.0806)	(0.0808)
Observations	1,264	1,260	1,261

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on milk production by wealth. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT impacts from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 9: The Impact of Drought on Livestock Holding - Mechanisms

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Panel A: Livestock Death			
Difference in average outcomes (ATT): Livestock Death	0.0377	0.0187	0.0307
	(0.0470)	(0.0505)	(0.0497)
Panel B: Livestock Sales			
Difference in average outcomes (ATT): Livestock Sales	0.0930**	0.0890**	0.0856*
	(0.0449)	(0.0434)	(0.0436)
Panel C: Livestock Slaughtering			
Difference in average outcomes (ATT): Livestock Consumption	0.0115	0.00791	0.00796
	(0.0128)	(0.0128)	(0.0129)
Observations	2,661	2,648	2,655

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock death, sales, and consumption. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT effects from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 10: The Impact of Drought on Livestock Holding by Asset Holding- Mechanisms

	1	2	3	4	5	6
	Asset Rich Households			Asset Poor Households		
	Naive DID	DID-IPSW	DID-Kernel	Naive DID	DID-IPSW	DID-Kernel
ATT: Livestock death	0.111	0.0962	0.111	-0.0423	-0.0600*	-0.0591*
	(0.0827)	(0.0918)	(0.0875)	(0.0358)	(0.0339)	(0.0338)
ATT: Livestock sales	0.0913*	0.0941*	0.0891*	0.0987	0.0818	0.0798
	(0.0550)	(0.0536)	(0.0537)	(0.0750)	(0.0665)	(0.0673)
ATT: Livestock consumption	0.00913	0.00482	0.00494	0.0149	0.0116	0.0116
	(0.0191)	(0.0197)	(0.0197)	(0.0121)	(0.0111)	(0.0113)
Observations	1389	1377	1386	1267	1263	1264

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding by household asset holding status at baseline. Columns 1-3 report ATT effects on asset-rich households from three alternative DID estimators. Columns 4 - 6 present ATT impacts on asset-poor households. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table 11: The Impact of Drought on Feed

	(1)	(2)	(3)
VARIABLES	Whole Sample	Asset Rich	Asset Poor
Impact on the Probability of Improved Feed use	0.019	0.030	0.002
	(0.017)	(0.025)	(0.012)
Impact on the Probability of Feed Purchase	0.035	0.068*	-0.008
	(0.027)	(0.038)	(0.021)
Impact on the Total log of Purchased Feed Cost	0.269	0.483*	-0.011
	(0.172)	(0.247)	(0.123)
Observations	2,661	1,392	1,269

Notes: This table reports OLS estimates of the impact of the 2015/16 drought on livestock feed use using the post-drought (2015/16) data. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Drought, Livestock Holding and Milk Production: A Difference-in-Differences Analysis (Online Appendix)

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July 7, 2023

Contents

1. Covariate Balance

Table A.1. Covariate Balance Before and After Matching

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Treated	Controlled	Unadjusted	IPSW matched	Kernel matched
Head's gender	0.719	0.788	-0.070***	0.000	-0.015
	(0.012)	(0.011)	(0.017)	(0.017)	(0.017)
Head's age	47.980	44.921	3.059***	-0.438	0.518
	(0.414)	(0.421)	(0.590)	(0.623)	(0.608)
Maximum education	5.058	4.704	0.354**	-0.068	-0.010
	(0.104)	(0.105)	(0.148)	(0.154)	(0.152)
Land holding (ha)	1.588	1.560	0.028	-0.014	-0.004
	(0.127)	(0.122)	(0.176)	(0.187)	(0.185)
Household size	4.844	5.261	-0.417***	0.030	-0.018
	(0.061)	(0.064)	(0.088)	(0.087)	(0.087)
Owns non-farm enterp.	0.283	0.339	-0.056***	0.009	0.005
	(0.012)	(0.013)	(0.018)	(0.017)	(0.017)
Credit access	0.329	0.285	0.044**	0.005	0.004
	(0.013)	(0.013)	(0.018)	(0.018)	(0.018)
Owns mobile phone	0.421	0.343	0.077***	-0.011	0.000
	(0.013)	(0.013)	(0.019)	(0.019)	(0.019)
Observations	1,362	1,299	2,661	2,648	2,655
No. of clusters	251	251	251	251	251

Notes: This table reports covariate balance test before and after matching. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

2. Robustness Checks

Table B.1. Robustness Check - Self Reported Drought

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Difference in average outcomes (ATT): Livestock Holding	-0.215**	-0.211**	-0.217**
	(0.0930)	(0.0927)	(0.0924)
Observations	2,661	2,656	2,660
Difference in average outcomes (ATT): Milk Production	-0.127**	-0.124**	-0.120*
	(0.0624)	(0.0626)	(0.0624)
Observations	2,641	2,636	2,640

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding and milk production using self-reported drought measures. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT impacts from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.

Table B.2. Robustness Checks - Adding Nomadic Regions

	(1)	(2)	(3)
VARIABLES	DID	DID-IPSW	DID-Kernel
Difference in average outcomes (ATT): Livestock Holding	-0.288**	-0.280**	-0.285**
	(0.124)	(0.120)	(0.111)
Observations	3,401	3,394	3,399
Difference in average outcomes (ATT): Milk Production	-0.122*	-0.136**	-0.135**
	(0.0644)	(0.0602)	(0.0628)
Observations	3,379	3,372	3,377

Notes: This table reports ATT estimates of the impact of the 2015/16 drought on livestock holding and milk production, including the sample of nomadic households. Column 1 reports ATT effects from the standard difference-in-differences estimator. Columns 2 - 3 present ATT effects from difference-in-differences with inverse-propensity-score-weighting and kernel matching, respectively. Standard errors reported in parentheses are clustered at the enumeration area level. ***, ** and * denote significance at the 1, 5 and 10% levels, respectively.