



Income Shocks and Poverty Traps: Asset Smoothing in Rural Ethiopia

by

Douglas Scott

Abstract

Evidence is found of two distinct patterns of response to the onset of the recent drought in rural Ethiopia. Agricultural Households with pre-shock cattle holdings of three or more animals effectively used these assets as a buffer against the fall in agricultural income. In contrast, households with smaller herds preserved their current herd size, at the expense of reduced consumption. These results are consistent with the existence of a poverty trap in household cattle holdings, and highlight the stark choices faced by some groups during this period, to either reduce consumption today or potentially undermine productivity in the future.

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1 Introduction

The dynamics of poverty in developing countries has attracted increased attention in recent years. A small, but growing, literature has sought to identify mechanisms which serve to trap specific groups in a state of persistent deprivation, while others transition to a higher standard of living (Carter and May, 2001; Jalan and Ravallion, 2004; Lokshin and Ravallion, 2004; Lybbert et al., 2004; Adato et al., 2006; Barrett et al., 2006; Carter et al., 2007). The notion of a dynamic system separating those who will move out of poverty, given time, from those who are trapped indefinitely, is of clear interest from a policy perspective. For example, identifying such a process *ex-ante* would allow for tailored insurance instruments or safety nets to be targeted directly towards those most at risk, while also making it possible to identify where a relatively small intervention would be capable of pushing borderline individuals onto a higher trajectory.

This paper employs an innovative approach to detecting such poverty traps, through heterogeneity in the coping strategies used by households in response to an income shock. Applying this methodology to a nationally representative dataset of rural households in Ethiopia, evidence is found of two distinct patterns of response to the onset of a period of severe drought. Households with initial cattle holdings of three or more animals effectively used these assets to insulate consumption expenditure against the drought-induced fall in income. In contrast, those households with smaller herds often elected to preserve their cattle stocks, at the expense of lower levels of consumption. These findings are consistent with the hypothesis of an asset-based poverty trap, defined by the pre-shock level of household cattle holdings.

1.1 Asset-based Poverty Traps

The theoretical literature has suggested a wide variety of economic relationships which have the potential to generate some form of poverty trap.¹ However, the specific focus of this study is a bifurcation in the accumulation of asset wealth, whereby a household's convergence to either a high or low equilibrium is determined by initial asset holdings (Lybbert et al., 2004; Carter and Barrett, 2006; Adato et al., 2006; Carter et al., 2007; Quisumbing and Baulch, 2013). This type of separation could potentially occur through a variety of channels, such as a correlation between wealth and attitudes to risk, differential access to credit, or even selective exclusion from informal risk-sharing and lending networks (Banerjee, 2004; Carter, 1988; Santos and Barrett, 2011). Indeed, the theoretical literature has suggested a number of mechanisms which have the potential to generate such a growth path. However, the empirical evidence in support of the

¹Some notable examples include, Eswaran and Kotwal (1986) on credit market imperfections and land efficiency, Dasgupta and Ray (1986) on the links between nutrition, wages and productivity, and Mookherjee, Napel and Ray (2010) on poverty traps induced by a complementarity between aspirations and educational attainment.

poverty trap hypothesis is often restricted to specific populations or groups of assets. In addition, the most appropriate strategy for identifying such mechanisms also remains unclear.

This paper will proceed as follows. Section 1.2 presents a review of the current literature on asset-based poverty traps, with a particular focus on those studies relating to Ethiopia. Section 2 demonstrates how shock-responses may be influenced by the presence of a poverty trap threshold. An overview of the data used in this analysis can be found in Section 3, while Section 4 discusses the empirical strategy used to estimate the impact of the drought. The main results of the analysis can be found in Section 5, with a brief summary and concluding remarks presented in Section 6.

1.2 The Analysis of Poverty Traps

Until recently, studies which have set out to identify asset-based poverty traps have focused on modelling the dynamic relationship between current and lagged asset holdings, over time (Carter and May, 2001; Lybbert et al., 2004; Adato et al., 2006; Barrett et al., 2006). Due to the need to model a potentially complex growth path, containing multiple equilibria, estimating this relationship often relies on non-parametric techniques. Lybbert et al. (2004) employ such an approach in studying a small group of pastoralist households living on the Borana Plateau in southern Ethiopia. The authors find that, where a household's herd size exceeds 15 cattle, in any given period, the future growth path of this asset will tend towards a stable, high equilibrium of 75. In contrast, those households falling below this threshold level (either in the initial period or as a result of a shock to their livestock holdings) will instead converge to a lower equilibrium. Following a similar methodology, Barrett et al. (2006) find comparable results among a group of pastoralist households in northern Kenya, although a lower threshold of 5-6 cattle was found in the Kenyan sample. A study of households in KwaZulu-Natal, South Africa, conducted by Adato, Carter and May (2006), avoids the need to focus attention on one specific asset by constructing a livelihood-weighted asset index, based on the value of assets required to attain a level of consumption equal to the national poverty line. The study concludes that households with sufficient assets to generate a consumption level of approximately twice the poverty line would converge to a higher level of wealth over time, while those below this threshold would instead collapse to a lower, long-run equilibrium.

Although the non-parametric approach used in these studies provides the necessary degree of flexibility to estimate a complex, non-linear relationship, it relies on the as-

sumption that a population's asset dynamics can be accurately represented using only a bivariate, sample relationship (between current and lagged assets). Within such models all heterogeneity in the units of analysis is necessarily disregarded, as are external factors potentially influencing changes in herd size over time. This brings into question the policy value of conclusions based solely on this approach. Nevertheless, to enable comparison with the main results of the paper, the Ethiopian data employed in this study is analysed using a similar non-parametric method to Lybbert et al. (2004). The estimated growth path can be found in the preliminary results section of this paper.

Following the work of Jalan and Ravallion (2004) and Lokshin and Ravallion (2004), recent contributions to the literature have employed more parametric methods to attempt to identify multiple equilibria in the evolution of asset stocks. These studies have the advantage, over the papers mentioned previously, in that they permit the inclusion of covariates within the analysis. In the most commonly applied method the current level of the asset stock is regressed on its lagged value, where the lagged value is expressed as a number of polynomial terms, to allow for both a concave and convex relationship over the range of asset wealth. Quisumbing and Baulch (2009) use this approach, alongside the non-parametric methods previously discussed, in their large-scale study of rural households in Bangladesh. Within this sample, they identify only a single low-level equilibrium in both the parametric and non-parametric estimations. The authors suggest the presence of relatively well-functioning factor markets as the reason for the contrasting results to the African studies. However, using a similar methodology, Giesbert and Schindler (2012) find evidence of only a single low-level equilibrium, using a nationally representative panel of households in rural Mozambique. The presence of only a single equilibrium in these studies mirrors the results obtained by applying the lagged polynomial approach to the data used in this analysis (see Section 5.1).

Two important studies, from the perspective of this paper, come from Van Campenhout and Dercon (2012) and Naschold (2013). Both papers analyse the asset accumulation path in a sample drawn from 15 Ethiopian villages, between 1993 and 2004. Unlike the previous studies mentioned, Van Campenhout and Dercon (2012) employ a piecewise linear specification, in an attempt to identify a poverty trap in tropical livestock units. They find evidence of a discontinuity at approximately 7 units (around 7-10 cattle). However, when applying a number of non-parametric and lagged polynomial approaches to the same dataset, Naschold (2013) finds no evidence of the multiple equilibria growth path, suggested in the first paper. Contradictory findings, such as these, highlight the degree to which parametric results may be highly dependent on the functional form assumptions imposed upon the data. In addition, accurately estimating a

continuous asset growth path, using a parametric model, requires a sample containing observations at every level of the asset. This is of particular concern, as the dynamic system implied by a poverty trap would see all households converge to one of two extremes. The data must, therefore, contain sufficient exogenous shocks to ensure that the area around the threshold remains populated (Naschold, 2013). This final comment suggests an alternative approach to potentially identifying a level at which asset growth paths bifurcate.

In an environment where households have limited access to credit, Deaton (1991, 1992) demonstrates that households can effectively protect vital consumption, from all but the worst shocks to income, through the sale and accumulation of asset stocks. His seminal buffer stock model is particularly applicable to low-income, rural communities, who have little or no access to formal credit or savings. There exists a well-established literature testing the implications of the buffer stock theory.² However, it is often observed that it is the rich, rather than the poor, who employ such strategies to smooth consumption (Kazianga and Udry, 2006; Carter et al., 2007; Verpoorten, 2009). A potential explanation for such heterogeneity can be found in Hoddinott (2006), whose research on resettled household in rural Zimbabwe found that consumption smoothing through cattle stocks was more likely amongst households with a minimum of three cattle. In an attempt to explain this result, Hoddinott speculates that, in electing to sell some of their herd, households with a higher number of cattle would still be left with sufficient animals to plough their fields in the following season. If this hypothesis were accurate, such a non-linear relationship between herd size and agricultural productivity could plausibly generate the type of separation in asset wealth described in the previous section.

Observable changes in behaviour in response to an income shock open-up the possibility of identifying a poverty trap threshold indirectly, through changes in the shock-responses of households close to this level of assets. This concept is closely related to the work of Carter and Lybbert (2012), who assume the existence of a threshold in asset wealth to identify two separate consumption smoothing regimes, using a sample of households from an earlier study on rural Burkina Faso. While the original analysis found only weak evidence in support of the conventional buffer stock theory Kazianga and Udry (2006), Carter and Lybbert concluded that the behaviour of households above the threshold conformed closely to the predictions of the model. Those with smaller herd sizes however, did not appear to smooth consumption in this manner, in spite of

²See, for example, Rosenzweig and Wolpin (1993), Fafchamps et al. (1998), Kinsey et al. (1998).

having sufficient animals to do so.³

This study makes two key contributions to the literature. Firstly, the discovery of heterogeneity in the evolution of livestock holdings, in different Ethiopian populations and time-periods, provides sufficient motivation for a larger, more representative analysis of rural livestock dynamics in Ethiopia. This paper provides such an analysis. The second contribution is methodological. As discussed, the majority of previous attempts to detect multiple equilibria in asset growth, are either limited by an inability to control for the influence of covariates, or are overly dependent on the initial assumptions regarding functional form. Carter and Lybbert's finding, that a desire to protect assets may override consumption smoothing motives in the vicinity of a poverty trap threshold, suggests an alternative. This paper seeks to build on this result, by using systematic differences in rainfall shock responses as an indirect approach to detecting the presence of a poverty trap threshold in the accumulation of asset wealth.

2 Theoretical Framework

Angus Deaton's (1991, 1992a) seminal buffer stock model is the most widely applied theory of household consumption smoothing through asset stock adjustment. The model shares many characteristics with Friedman's (1957) Permanent Income Hypothesis (PIH), while diverging from the standard intertemporal choice model in the underlying assumptions regarding access to credit. Deaton's theory considers risk-averse households, who seek to smooth consumption, given a stochastic stream of income. However, in contrast to the PIH, agents are not presented with an unlimited capacity to borrow and save. Instead, the model considers the case where households are only able to insulate consumption from negative income shocks through the sale and accumulation of a buffer stock of assets. At each point in time, households will attempt to bring their consumption paths as close to the PIH benchmark as the borrowing constraint permits. However, where a household experiences a negative shock to income, with insufficient assets to fully offset the shortfall, all current income and the value of any available buffer assets will be consumed, with nothing carried forward to the next period.

If there exists a threshold level in the accumulation of asset wealth, the use of assets to fully offset the impact of a negative income shock, could have potentially serious,

³The value of livestock sales was sufficient to offset between 80-90% of the shock to income in households above the threshold. Below this threshold however, only 25-30% of the income shock was smoothed using this strategy (Carter and Lybbert, 2012).

long-run implications for households close to this level. As noted in Carter and Zimmerman (2003), if a negative shock is substantial enough that fully smoothing consumption would require a household to reduce its asset stock to a level below the poverty trap threshold, the drastic consequences of such an action may instead lead households to consider allowing consumption to fall in the short-run (at least to some degree), in order to protect a level of asset wealth above the threshold. If the capacity exists to withstand a fall in consumption, or households value the long-run accumulation of assets, over the short-run stability of consumption, this strategy of asset smoothing will represent the optimal shock response.⁴

It is possible to simulate this form of heterogeneity in shock responses using an adaptation of the dual-technology model proposed by Carter and Lybbert (2012). In model (1), risk-averse households seek to maximise expected utility, over an infinite horizon, through choosing how to allocate current resources between consumption and the accumulation of a productive asset A .

$$\max_{c, A} E_0 \left[\sum_{t=0}^{\infty} \beta^t u(c_t) \right] \quad (1)$$

Subject to:

$$y_t(A_t \theta_t) = \max [f^\ell(A_t \theta_t), f^h(A_t \theta_t)]$$

$$x_t = y_t(A_t \theta_t) + (1 - \delta)A_t$$

$$A_{t+1} = x_t - c_t$$

$$c_t \leq x_t \quad \forall t$$

$$A_t \geq 0 \quad \forall t$$

The first constraint defines income as dependent on a household's choice of a low or high technology $f^\ell(A_t \theta_t)$ or $f^h(A_t \theta_t)$, where the realised income from either choice is a function of the current level of assets A_t and the realisation of a stochastic variable θ . Expected marginal returns are greater under the high technology at all levels of the asset stock, but adoption entails an initial fixed cost. The term x_t , in the second constraint, refers to 'cash-on-hand', a measure of the total resources available to the household in the current period (Deaton, 1991, 1992). This is comprised of current income and the

⁴It is important to recognise however, that if consumption levels also lie close to the type of nutritional threshold suggested in Dasgupta and Ray (1986), or reducing consumption leaves vulnerable members at risk of the long-term consequences of malnutrition (Alderman et al., 2006; Dercon and Porter, 2014), a household may simply be side-stepping one poverty trap, only to fall into another.

value of any assets held, subject to a depreciation rate δ . The equation for the evolution of the asset stock, simply imposes the condition that assets in the following period equate to current period cash-on-hand, less current consumption. The condition $c_t \leq x_t$ indicates that cash-on-hand places an upper limit on consumption, given no access to credit, while the final constraint implies that the value of the asset stock is non-negative in all periods. A set of optimal choices, for different initial asset stocks, can be obtained through expressing model (1) in Bellman equation form and solving numerically.⁵ The functional form and parameter assumptions used to generate the following growth paths can be found in Appendix 1.

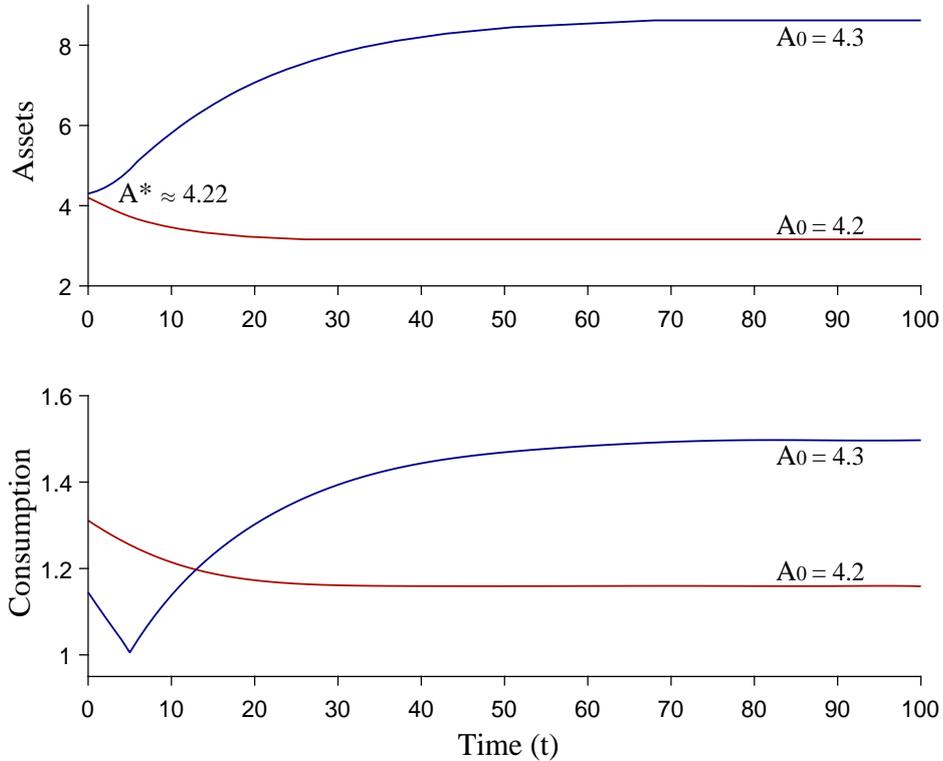


Figure 1: Time-paths of assets and consumption

Model (1) generates the type of bifurcation in asset growth described in section 1.2. The uppermost panel of Figure 1 illustrates the movement towards a high and low asset equilibrium, for households with initial asset stocks immediately above and below a

⁵The Bellman equation relating to model (1) is $V(A_t) = \max_{c \leq x} [u(c_t) + \beta \int V(x_t - c_t) d\Omega\theta]$, where Ω = the cdf of $[\theta]$.

separating threshold of $A^* \approx 4.22$. While $A_0 = 4.3$ implies adoption of the high return technology, $A_0 = 4.2$ does not. In the example shown, however, $A_0 = 4.3$ is still not sufficient to allow immediate adoption of the high technology. Instead, it comes at the initial cost of foregone consumption in the early time periods, shown in the lower panel of Figure 1.

The presence of the bifurcating threshold A^* also generates heterogeneity in income shock responses. The clearest illustration of this comes through analysing optimising behaviour, based on the first-order condition from the Bellman equation. This condition implies that households should consume available resources until the marginal utility of consumption equals the (discounted) expected value of carrying assets forward into the next period, $u'(c_t) = \beta E(V')$. Following Carter and Lybbert (2012), Figure 2 provides a graphical representation of this relationship, as a function of A_{t+1} .

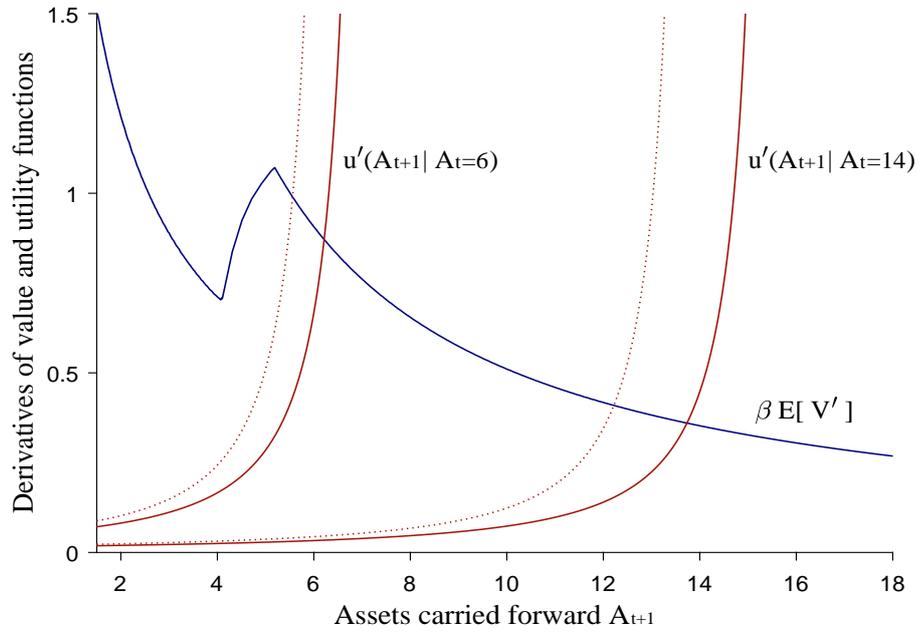


Figure 2: The response of assets and consumption to an income shock

The key feature of Figure 2 is that the marginal value curve $\beta E(V')$ is not strictly decreasing in assets. Over the optimal range of choices of A_{t-1} , defined by the threshold $A^* \approx 4.22$ and the level of assets required to adopt the high technology (≈ 5.08) the value of holding additional assets increases rapidly. Over this range, households will be willing to sacrifice consumption to accumulate sufficient assets to optimally choose the high return technology (see Figure 1). Having achieved this minimum asset level, however, households faced with having to return to the low technology, in the

event of an unexpected shock to income, will also be willing to sacrifice higher level of consumption to ensure they remain in this position (relative to those at higher levels of the asset distribution).

To illustrate this final point, the marginal utility curves for two representative levels of the initial asset stocks ($A_t = 6$ and $A_t = 14$), are indicated by the solid u' curves in Figure 2. The optimal choice of assets carried forward in each case is found at the intersection with the marginal value curve $\beta E(V')$. The dashed lines represent the marginal utility of consumption, for the same initial asset levels, after a severe, unexpected shock to income (introduced via a 0.4 downward shift in the entire distribution of the stochastic term θ in model (1)). The two new points of intersection with $\beta E(V')$ imply that a higher proportion of the shock will be absorbed through a reduction in assets by the household with $A_t = 14$. while, the household closer to the high technology adoption level will respond with a relatively larger reduction in consumption.⁶

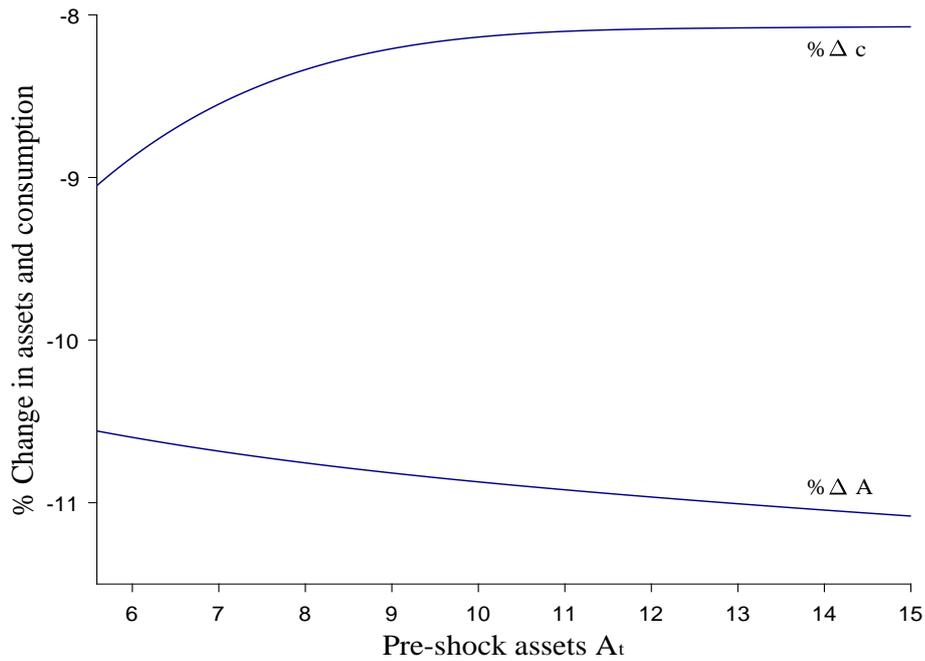


Figure 3: Heterogeneous Shock Responses

Figure 3 illustrates the percentage change in both the asset and consumption variables, induced by the shock to income. The figure clearly illustrates how the model

⁶This can be seen in the relative increases in the marginal utility of consumption (the vertical change between the pre-shock and post-shock points of intersection).

generates heterogeneity in the extent to which households favour asset or consumption smoothing, dependent on pre-shock asset holdings A_t .

The model described in this section leads to a number of testable predicatons. If an asset threshold A^* does exists, it should be possible to define an initial level of assets, henceforth denoted γ , as the point at which proximity to the threshold induces households to switch from a strategy which prioritises smoothing consumption to a strategy which also (only) values asset protection. The level $\gamma > A^*$ would serve to separate households into two distinct shock response regimes.

Proposition 1: For those households who's pre-shock assets exceed γ , a marginal decrease in transient income should induce a smaller reduction in consumption, relative to those below γ . Instead, asset wealth should be drawn down as a buffer against the shock.

Proposition 2: For those households below γ , an income shock will induce an asset smoothing response and any asset reduction will be of a smaller magnitude than that observed for households in the higher asset regime. As a consequence, consumption in the low asset group will be permitted to fall to a relatively greater degree.

3 Data and descriptive statistics

The specific years considered in this analysis mark the onset of a period of extreme drought in Ethiopia. Weak or failed rains were reported in some regions as early as mid-2014, and throughout the following year the situation became progressively worse (FAO, 2015). Driven by the unpredictable El Niño weather patterns, the country experienced the initial failure of the early *belg* rains in 2015, followed by low or erratic rainfall in the main *meher* season.⁷ The resultant poor harvests, particularly in the North and East of the country, prompted the need for emergency food assistance to be distributed to an estimated 10.2 million people, in addition to the 7.9 million already protected by the government's Productive Safety Net Programme (HRD, 2015). Although the drought was considered to be one of the worst the country has experienced, improvements in Ethiopia's capacity to respond to such events prevented the type of widespread famine experienced in the 1970s and 80s. Nonetheless, the loss of agricultural income

⁷Ethiopia typically experiences two rainy seasons, the relatively smaller *belg* rains, between March and May, before the main *meher* rains, between June and September. 90% of cereal production is derived from the larger *meher* season (Taffesse et al., 2012).

suffered by small-scale farmers during the period was extremely high, with the fall in grain output ranging from between 10 and 30%, in the Tigray, Somalie and Gambela region, to between 45 and 66% in Afar and Dire Dawa (CSA, 2016).

The data used in this study comes from two waves of the Ethiopian Socioeconomic Survey (ESS), representing the pre-shock period 2013-14 and the height of the drought in 2015-16. The initial sample was selected to be representative of all households in rural Ethiopia. In accordance with the previous literature, the natural choice for the asset stock variable (over which the sample splitting point γ is defined) is household livestock holdings (Lybbert et al., 2004; Carter et al., 2007; Van Campenhout and Dercon, 2012; Naschold, 2013). Furthermore, as the sale of cattle was found to be the most common coping response in the severe drought periods of 1984-85 and 1990-92 (Webb et al., 1992), this paper focuses specifically on cattle as the potential buffer stock asset.⁸

The two sample waves employed come from an earlier ESS survey of 3466 rural households conducted in 2011.⁹ Attrition between this initial data collection and the first panel wave is minimal (approximately 4%), leaving a potential sample of 3323 households in the 2013-14 survey. Although the majority of rural households in Ethiopia are involved in both crop and livestock agriculture, a relatively small proportion are not involved in one or other of these activities. As the population of interest is small-scale agriculturalists, households who owned no cattle in any of the three waves of the ESS survey (including the initial 2011 wave) are omitted, as are households with no cultivated land in any period. In addition, to avoid the inclusion of large-scale, commercial agriculture, households with more than 30 cattle or 5 hectares of cultivated land, in any survey wave, are also omitted from the analysis.¹⁰ The level of attrition between the 2013-14 and 2015-16 wave is, again, minimal (approximately 1.9%). However, it is not possible to generate key variables for all observations in the selected sample. In particular, measurement of land areas and food consumption are commonly reported in local units, for a small number of which there exists no plausible method of conversion.¹¹ Subsequently, the usable sample of observations falls to 2572 in 2013-14 and 2494 in 2015-16.

⁸Livestock is arguably the most important asset in rural Ethiopia (Dercon, 2004) and cattle are present in more than 90% of livestock owning households (Van Campenhout and Dercon, 2012).

⁹Substantial differences within the agricultural survey instrument prevents the use of the 2011 wave in this analysis.

¹⁰The sensitivity of key finding to alternative cut-off levels is considered in Section 5.5.

¹¹This particular source of attrition appears largely random, however. A comparison of mean household characteristics between observations included in the sample and those with missing values (including attrition between waves) can be found in Appendix table A1.

3.1 Variable summary

Table 1

	Sample		Wave 1 (2013-14)		Wave 2 (2015-16)	
	mean	sd	mean	sd	mean	sd
<i>Demographics and education</i>						
Household size	5.54	2.15	5.53	2.12	5.54	2.18
Age of head	46.62	14.39	45.79	14.30	47.47	14.44
% of members (15 ≤ age ≤ 60) with no education	65.35	33.98	64.86	33.89	65.86	34.08
<i>Income and consumption (000)[†]</i>						
Total farm income	4.83	11.80	5.89	12.75	3.75	10.62
Total consumption	4.82	7.18	5.52	7.69	4.11	6.54
Food consumption	3.96	7.07	4.42	7.59	3.48	6.45
<i>Agriculture and rainfall</i>						
Number of cattle	4.09	4.16	4.40	4.23	3.77	4.06
Land cultivated (ha)	0.98	0.92	1.05	0.93	0.92	0.91
Land irrigated (ha)	0.13	0.47	0.14	0.49	0.12	0.45
Land rented (ha)	0.13	0.40	0.18	0.45	0.08	0.32
Plot TWI	12.73	1.58	12.76	1.61	12.70	1.55
Rainfall deviation (cm)	-5.30	35.56	9.90	28.00	-20.96	35.74
<i>Location and social protection</i>						
Distance to bank (kms)	17.50	12.00	18.22	12.78	16.76	11.09
Distance to MFI [‡] (kms)	12.97	11.98	12.92	12.00	13.03	11.96
Distance to market (kms)	24.50	5.70	24.06	5.76	24.95	5.61
PSNP [‡] in kebele ^{††}	0.42	0.49	0.40	0.49	0.43	0.50
Observations	5067		2572		2495	

MFI = Micro-finance Institute, PSNP = Productive Safety Net Programme

[†] All income and consumption figures reported in 1000 Ethiopian Birr, per adult equivalent

[‡] TWI = Topographical Wetness Index. MFI = Micro-finance Institute.

PSNP = Productive Safety Net Programme.

^{††} A *kebele* is the smallest administrative area in Ethiopia (e.g. a group of villages)

Table 1 summarises the key variables used in the following analysis. The section on *Demographics and education* indicates that households are composed of 5-6 members, on average, with a household head who is most likely to be illiterate and aged between 45 and 50 years old. The remarkably poor levels of education in rural Ethiopia are reflected by the proportion of working age household members within the sample, who have received no formal schooling.

Total farm income reports farm revenue, minus farm expenditure, for the previous 12 months, where the measure of revenue is comprised of income from land rental and the rental of agricultural tools, combined with the (imputed) value of all crops produced. Deducted from this is a measure of expenditure, comprising of the cost of hired factors of production (land and labour), as well as the imputed value of crops paid to these factors as non-financial reimbursement. The nominal value of farm income is deflated spatially and temporally, following Deaton and Zaidi (2002), and reported in table 1 in (1000) Ethiopian Birr, per adult-equivalent.¹²

The measure of total consumption in table 1 is the value of household food and non-food consumption over the previous 12 months. Food consumption is comprised of purchased, gifted and own-produced food items, from a list of 26 commonly consumed foodstuffs.¹³ Non-food consumption includes everyday items, such as candles, soap, fuel and transportation, but also expenses such as clothing, education and informal funeral insurance (IDDIRs). Expenditures on taxes and levies are excluded, as are ceremonial expenses (such as weddings and funerals), which would represent one-off purchases, rather than the general pattern of household expenditure. Expenditure on durable asset purchases is also omitted. Nominal consumption values are again deflated spatially and temporally, and expressed in 1000 Ethiopian Birr, per adult equivalent.

The average number of cattle reported in table 1 is seen to decline from a mean herd size of 4.4 animals in the 2013-14 wave, to 3.77 at the height of the drought in 2015. Although some of this decline may capture direct livestock mortality (FAO, 2015), it will also reflect the use of cattle sales as a buffer against the subsequent income shock. Figure 4 provides a frequency distribution of the herd size in the two survey waves. As would be expected in this sample of small-scale, agricultural households, this distribution is heavily weighted towards cattle holdings of less than 5 animals.¹⁴

The remainder of the *Agriculture and rainfall* section of table 1 reports the characteristics of cultivated land, such as the area which is irrigated or rented by the sample households. In addition, the topographical wetness index (TWI), provides a measure

¹²Adult-equivalency scales are reported in Appendix table A2.

¹³See CSA (2017) for the full list of food and non-food items included in the final calculated value of total consumption.

¹⁴The distribution does not appear obviously bimodal, which would perhaps have provided early evidence of the presence of a high and low equilibrium in general asset wealth. However, the observed distribution may simply reflect the influence of shocks to cattle holdings disrupting movement towards either extreme.

of the soil saturation and the topographical control of hydrological processes (Sørensen et al., 2006). In the following analysis this variable is separated into three groups, representing low, medium and high TWI.¹⁵ The rainfall deviation variable records one-year deviations from the average annual rainfall between 2001 and 2015. The effects of the drought are clearly visible in the second wave of the survey, where the sample households experienced an average rainfall deficit of approximately 21cm, relative to the expected long-run level. Unsurprisingly, the deviation from rainfall is highly correlated with farm income in the two survey waves ($\rho = 0.4239$).

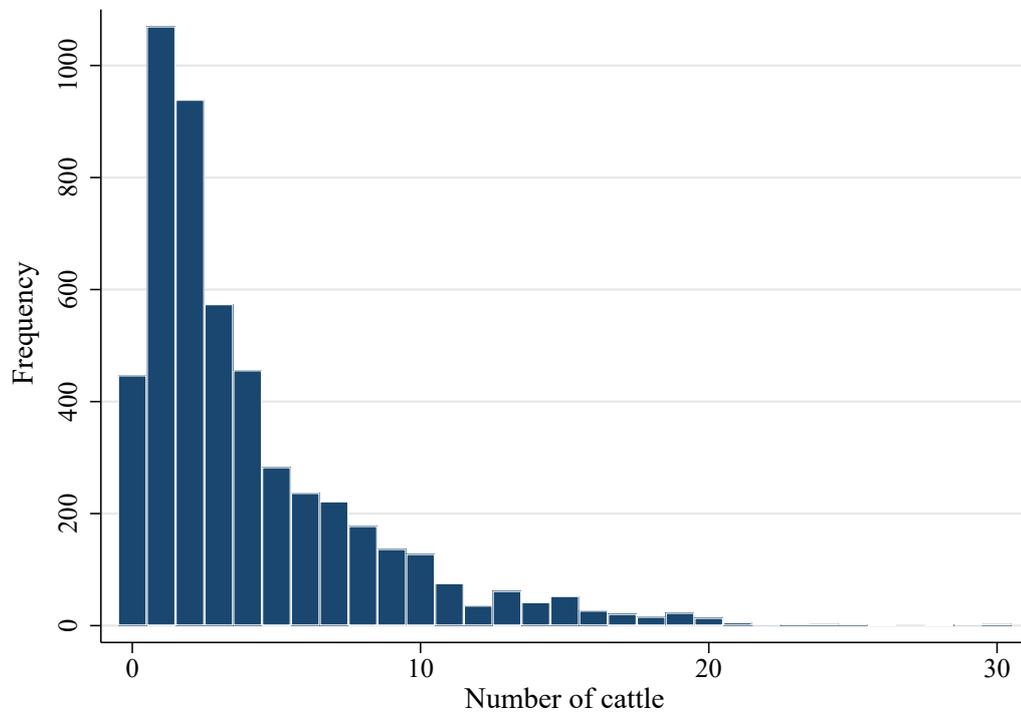


Figure 4: Distribution of herd size

The final set of variables reported in table 1 indicate the relative location of the households and their access to the Productive Safety Net Programme (PSNP). The dis-

¹⁵A plot of land classified as low TWI will have an index score ≤ 11 , while a plot classified as high TWI will have an index score ≥ 14 . Any area of land with a score between these values is classified as medium TWI.

tance to a bank and micro-finance organisation (MFI) are intended to control for variation in access to formal savings and credit facilities, which could provide an alternative to the use of asset sales as a potential coping strategy. Proximity to a large weekly market is a measure of remoteness, which would be a characteristic of both differential access to asset markets, and a strong indication of household poverty status (World Bank, 2016). As a further control, the PSNP variable indicates whether or not the safety net programme was operating in the local area during the period in which the survey took place.

4 Empirical Strategy

4.1 The consumption response to an income shock

The first prediction of the theory presented in Section 2 is that the consumption response to the drought-induced, income shock will differ, dependent on the level of pre-shock cattle holdings, relative to γ (see Proposition 1). Model (2) uses the deviation from long-run rainfall R as an exogenous measure of the transient shock to agricultural income. The dependent variable is the value of household consumption (per adult equivalent), for household i , at time t . The term H_{it} represents a vector of characteristics, specific to the household, while τ_t and ψ_i represent a common time effect and household fixed-effect. μ_{it} denotes the error term.

$$c_{it} = \theta_1 R_{it} + \beta' H_{it} + \tau_t + \psi_i + \mu_{it} \quad (2)$$

Although the ability to smooth consumption in the sample of households overall is clearly of interest, Section 2 puts forward the hypothesis that consumption smoothing behaviour will be more pronounced amongst households with initial cattle stocks above an asset level γ . This level of cattle holdings should mark the point at which proximity to a hypothesised poverty trap induces a switch from consumption smoothing to asset smoothing behaviour. Testing this prediction requires separating the sample into households with a pre-shock herd size $A_{pre} > \gamma$ from those with cattle holdings $A_{pre} \leq \gamma$.¹⁶ This separation is illustrated in equation (3), which includes the h and ℓ

¹⁶The pre-shock period refers to the 2013/14 survey wave.

terms on the rainfall coefficient, to make clear the distinction between the high and low cattle regimes.¹⁷

$$c_{it} = \begin{cases} \theta_1^h R_{it} + \beta' H_{it} + \tau_t + \psi_i + \mu_{it}, & \text{if } A_{it} > \gamma \\ \theta_1^\ell R_{it} + \beta' H_{it} + \tau_t + \psi_i + \mu_{it}, & \text{if } A_{it} \leq \gamma \end{cases} \quad (3)$$

If the level of cattle holdings γ were known *a priori* estimation of equation (3) would be relatively straightforward. As this is not the case however, it is necessary to utilise the sample splitting approach devised by Hansen (1996, 1999). This method relies on minimising the residual sum of squares across a range of candidate values. Therefore, allowing the data itself to determine the most likely value of γ . A detailed description of this approach is provided in Appendix 3.

4.2 The cattle response to an income shock

If a poverty trap threshold does exist in asset wealth, Section 2 suggests that a household's proximity to this threshold will influence the extent to which asset sales are used to offset a negative shock to income. According to Proposition 2, behaviour above γ should broadly conform with the buffer stock theory, whereby cattle stocks will be drawn upon to achieve a level of consumption which is as close to smooth as the availability of the buffer stock permits. In contrast, those households below γ may employ a strategy of asset smoothing, when faced with a similar shock to income.

$$A_{it} = \begin{cases} \alpha_1^h R_{it} + \beta' H_{it} + \tau_t + \psi_i + v_{it}, & \text{if } A_{pre} > \gamma \\ \alpha_1^\ell R_{it} + \beta' H_{it} + \tau_t + \psi_i + v_{it}, & \text{if } A_{pre} \leq \gamma \end{cases} \quad (4)$$

The estimation strategy for determining the effect of the rainfall shocks, on cattle holdings, is similar to the approach used to assess the extent of consumption smoothing in section 4.1. In model (4), the dependent variable is replaced with the number of cattle A_{it} , while α_1^h and α_1^ℓ measure the impact of the rainfall shock in the high and

¹⁷To ease notation, no *h* or *ℓ* script is applied to the other terms in (3), although all coefficients are permitted to vary between the two regimes.

low cattle regimes, respectively. Again, the hypothesis of separate response regimes implies that all coefficients in the model may assume different values above and below γ . This separation is modelled below, where all independent variables in (4) have the same interpretation as previously. As in the consumption model (3), the value of the sample splitting level of cattle γ will be replaced with an estimated value $\hat{\gamma}$, representing the herd size which minimises the residual sum of squares from a single-equation estimation of (3).

Versions of models (3) and (4) are also estimated using ordinary least squares, where the model includes a regional fixed-effect (in place of ψ_i) and the variables indicating distance (kms) to i) a market ii) a bank iii) a microfinance organisation, and the presence of the PSNP in the local area, are added to the H vector of controls. The OLS estimates also include variables intended to capture heterogeneity in the agricultural land available to households in the 2013/14 survey. This includes the area of cultivated land (ha) classified by irrigation and rental status, as well as high, medium and low TWI (see section 3).

5 Results

5.1 Preliminary results

This section provides an initial investigation of the possibility of multiple equilibria in the time-path of cattle stocks, using the more commonly applied methods discussed in Section 1.2. Section 5.1.1 uses a similar non-parametric approach to Lybbert et al. (2004) and Adato et al. (2006), while Section 5.1.2 employs the lagged polynomial method of Jalan and Ravallion (2004), Barrett et al. (2006) and Giesbert and Schindler (2012).

Before comparing these preliminary results with the main findings of the paper, however, it is important to recognise that the methods used below do not necessarily provide answers to precisely the same questions. Directly modeling the evolution of asset stocks has the potential to identify a poverty trap which generates measurable changes in asset stocks. However, if agents engage in avoidance behaviour, through asset smoothing, multiple equilibria in the underlying growth path may not be detected. In contrast, it is the detection of precisely this type of avoidance behaviour which motivates the main results of this analysis.

5.1.1 Non-parametric estimation of the asset growth-path

Figure 5 maps the relationship between current and lagged cattle holdings using the Locally Weighted Scatter-plot Smoothing (LOWESS) method of Lybbert et al. (2004) and Adato et al. (2006), whereby local regressions are estimated for each of the n data-points within the sample. In generating Figure 5, each regression uses only those observations within a 8% bandwidth of the data-point in question. Unlike more parametric methods, this approach makes no assumptions regarding the functional form underlying the relationship $A_t = f(A_{t-1})$.

It is clear from Figure 5 that estimating the evolution of the asset using this approach implies a relationship which does not generate multiple equilibria in the accumulation of cattle stocks. Instead, the figure indicates the presence of only a single (low-level) equilibrium. This can be found at approximately 3 cattle, and represents a point of convergence, as opposed to bifurcation.

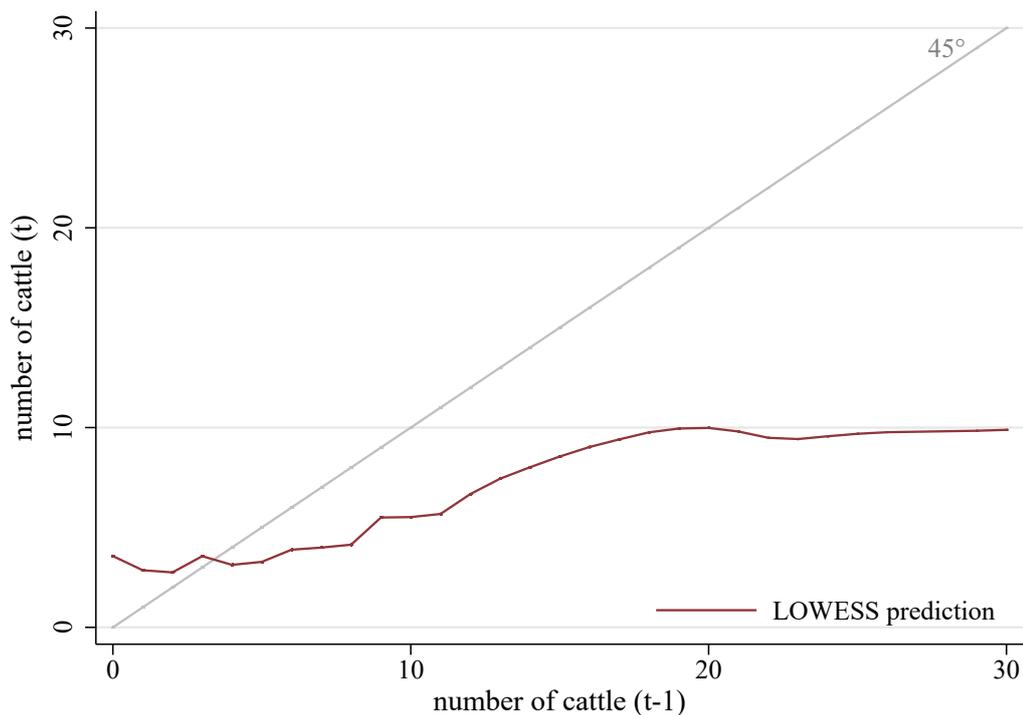


Figure 5: Non-parametric estimation of herd size dynamics

5.1.2 Parametric estimation of the asset growth-path

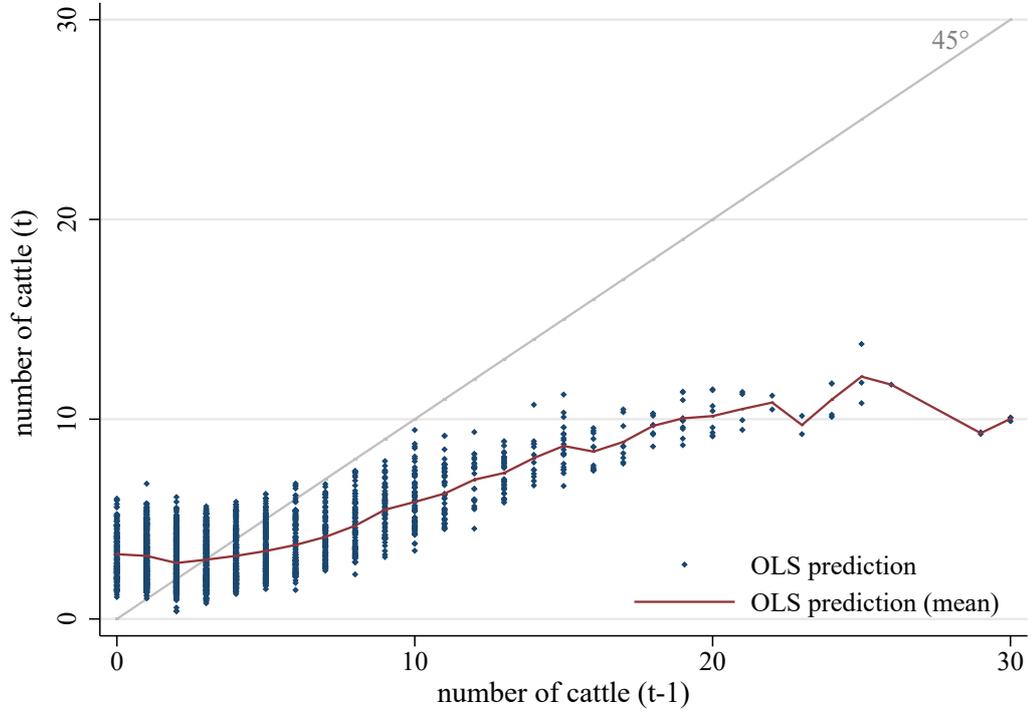


Figure 6: Parametric estimation of herd size dynamics

Turning now to the lagged polynomial approach of Jalan and Ravallion (2004), Barrett et al. (2006) and Giesbert and Schindler (2012). Figure 6 graphs the predicted values of current cattle holdings against lagged herd size, with the predicted value of A_t obtained from an estimation of model (5). This equation is similar to that employed by Barrett et al. (2006), whereby polynomials of the lagged herd size (up to the fourth-order) are included as regressors, allowing the relationship $A_t = f(A_{t-1})$ to generate the hypothesised non-linearities.

$$A_{it} = \sum_{p=0}^4 \beta_p A_{it-1}^p + \beta' G_i + \beta' T_i + \tau_t + \xi_i + \varepsilon_{it} \quad (5)$$

The first term on the right-hand side of (5) represents the polynomials of lagged herd size (and a constant β_0). G is a vector of control variables, measured in the 2013/14 wave, including demographic and education characteristics, as well as the general location characteristics of the household. T_i represents the variables which measure the

characteristics of cultivated land in the initial wave, while ξ_t and τ_t indicate a region fixed effect and common time effect. The full regression results are reported in Appendix table A3.

Figure 6 summarises the relationship between current and lagged herd size, estimated using the lagged polynomial approach described above. As the lagged herd size variable is discrete, each value on the x axis corresponds to a number of predictions at any given level of A_{t-1} . Figure 6 reports these predicted values, but also fits a line through the mean prediction at each level of lagged cattle holdings.¹⁸ Although few observations make for an imprecise estimation of the time-path at larger herd sizes, the results of the parametric approach appear to mirror those of the non-parametric estimation. Again, the 45 degree line is intercepted only once, and from above, indicating a pattern of converge rather than bifurcation.

5.2 Estimation of γ

The main findings of this paper begin by reporting the results of the estimation used to determine the sample splitting value γ . Having found the herd size most likely to represent this value, sections 5.3 and 5.4 report the effect of the drought-induced income shock on consumption and cattle holdings for households above or below (equal to) this level.

Using the methodology described in Appendix 3, the most likely candidate value for γ is found through comparison of the residual sum of squares (RSS), from a single-equation estimation of model (3), across the range of pre-shock (2013/14) cattle holdings A_{pre} . If two distinct consumption smoothing regimes exist, this implies that households can be separated into either regime, dependent on whether their pre-shock cattle holdings lie above or below the predicted level. Figure 7 graphs the residual sum of squares obtained from splitting the sample at all potential values of γ , between $1 \geq A_{pre} \geq 30$. The graph is minimised at a value of 2, indicating that this herd size is the level of cattle holdings, around which the coefficients in the model are most likely to assume different values.

¹⁸If instead, the median predicted value at each lagged herd size is used, this does little to alter the relationship in Figure 6.

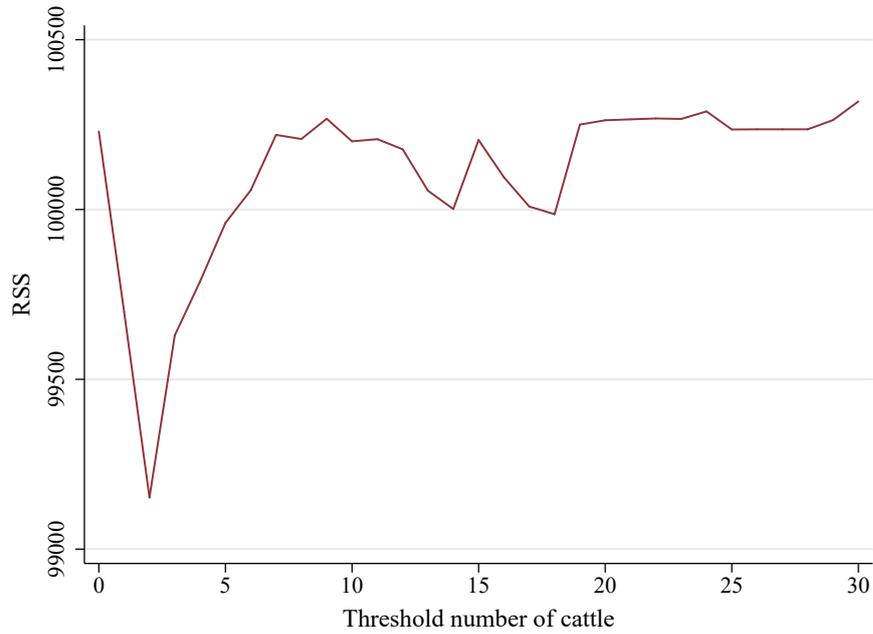


Figure 7: Residual sum of squares at potential levels of γ

Having estimated the most likely value, at which to split the sample, it is also necessary to determine whether being above or below $\hat{\gamma} = 2$ alters the impact of the rainfall shock in a statistically significant manner. Based on Hansen’s (1999) approach, the p -value of 0.008 in Table 2 provides strong evidence against the null hypothesis of no difference between coefficients in the two regimes. Therefore, as section 2 suggests, splitting the sample at $\hat{\gamma} = 2$, is required to accurately model household’s behaviour, in response to the drought-induced, income shock.

Table 2: Significance of difference between regime coefficients

Threshold estimate	RSS	MSE	Bootstrap repetitions	p -value
$\hat{\gamma} = 2$	99175	19.77	1000	0.0080

Table 3 reports the mean values and standard deviations for key variables above and below (equal to) $\hat{\gamma} = 2$. F -test 1 reports a standard test of the significance of inclusion in either regime, in predicting the values of the listed variables, while F -test 2 conducts the same test, with the inclusion of regional fixed-effects. This second test is necessary when assessing the similarity of rainfall deviations experienced by the two regimes, as both cattle holdings and the impact of the drought are likely to vary between different

regions. Although the impact of the drought may not be equivalent at the national level, at the regional level, households should have experienced similar rainfall deficits.

Table 3: Characteristics of households in high and low cattle regimes

	$A_{pre} > 2$		$A_{pre} \leq 2$		F -test 1	F -test 2
	mean	sd	mean	sd	p -value	p -value
Household size	5.78	2.10	5.20	2.18	0.0000	0.0000
Age of head	46.82	14.03	46.35	14.87	0.2564	0.1996
Head is female	0.17	0.38	0.19	0.40	0.0700	0.0511
Total farm income	4.90	8.93	4.75	14.81	0.6554	0.3638
Total consumption	4.75	6.85	4.93	7.60	0.3735	0.3545
Food consumption	3.93	6.84	4.00	7.38	0.7246	0.7203
Land cultivated (ha)	1.00	0.93	0.96	0.91	0.1289	0.0838
Rainfall deviation (cm)	-4.98	37.10	-5.65	33.40	0.5039	0.1217
Distance to bank (kms)	18.11	12.08	16.66	11.84	0.0000	0.0000
Distance to MFI (kms)	13.19	11.99	12.71	11.97	0.1588	0.0501
Distance to market (kms)	23.79	5.58	25.44	5.71	0.0000	0.0000
PSNP in kebele	0.40	0.49	0.43	0.50	0.0603	0.1616
Observations	2899		2161			

All income and consumption figures reported in 1000 Ethiopian Birr, per adult equivalent
 F test 1: Significance of high or low regime in determining the value of the listed variable
 F test 2: Includes the addition of controls for region-specific fixed-effects

The table indicates significant differences in demographics between the two regimes. Those households in the small herd group have fewer member, on average, and appear more likely to have a female household head. The rainfall deviations experienced during the survey do not appears to be more negative in the small herd group, even before partialing out the regional fixed-effect. Therefore, there is no evidence that either regime was significantly worse affected by the drought.

Proximity to a formal bank, weekly market or microfinance organisation also varies between the groups, with households in the low cattle regime more likely to be found further from these facilities. In summary, table 3 indicates that variables generally considered to be good predictors of overall poverty status increase the probability of inclusion in the lower cattle regime.¹⁹

¹⁹The possibility that γ may actually be detecting heterogeneity, due to more general patterns of household wealth, is considered in section 5.5.

5.3 Smoothing consumption

Table 4 present the results from the consumption smoothing model shown in equation (3), with OLS and household-level fixed-effects estimations reported for each group. The dependent variable in table 4 is the total value of household consumption, measured in 1000 Ethiopian Birr, per adult equivalent. The reported standard errors are clustered at the level of the household and the common time effect (τ_t) is included, but not reported.

Focusing on the coefficients on the rainfall deviation in Table 4, it is not possible to reject the hypothesis of full consumption smoothing, amongst the large herd group, in either the household fixed-effects or OLS estimations (at any common level of significance). For those households with smaller numbers of cattle, however, the coefficients on rainfall, shown in columns 2 and 4, indicate that the shock has a highly significant impact on consumption expenditure in this group. A test of the equality of the rainfall coefficients between the two regimes (test $\theta_1^l = \theta_1^h$ in table 4) indicates the two effects are statistically different from each other, in both sets of estimations, lending early support to the poverty trap hypothesis discussed in Section 2.

5.4 Smoothing assets

Establishing that households with a higher level of cattle holdings are more capable of smoothing consumption is not sufficient evidence to conclude the existence of an asset-based poverty trap. Similar results could indicate a variety of different underlying mechanisms (see section 1.2). It is, therefore, necessary to determine whether the extent to which cattle are used as a buffer against the shock also depends on a household's level of pre-shock cattle holdings. Table 5 reports the results of an estimation of the asset model (4), where the dependent variable in all estimations is the herd size A_{it} .

The coefficient on the rainfall shock, again, indicates a large degree of heterogeneity between the two regimes. For those households with a pre-shock herd size of three or more animals, the positive coefficients in columns 1 and 3 imply that a fall in rainfall is associated with a decline in cattle holdings. In contrast, column 2 and 4 indicates that the shock has no significant impact on the herd size of households below (equal to) $\gamma = 2$. Testing whether the effect of the rainfall shock differs between the estimations in models (1) and (2), and models (3) and (4) (see test $\alpha_1^l = \alpha_1^h$), again, leads to a strong rejection of the null of homogeneity in shock responses within the two regimes.

Table 4: The effect of rainfall shocks on household consumption

	(1)	(2)	(3)	(4)
	$A_{pre} > 2$	$A_{pre} \leq 2$	$A_{pre} > 2$	$A_{pre} \leq 2$
	OLS	OLS	FE	FE
Rainfall deviation (cm)	0.0075 (0.0049)	0.0592*** (0.0067)	0.0012 (0.0051)	0.0415*** (0.0146)
Household size	-0.5891*** (0.0720)	-0.6470*** (0.0721)	-0.3432*** (0.1063)	-0.5415*** (0.1463)
Age of head	0.1062* (0.0593)	0.0639 (0.0711)	0.1935 (0.1266)	0.0811 (0.1641)
Age of head squared	-0.0011* (0.0005)	-0.0007 (0.0007)	-0.0018 (0.0012)	-0.0011 (0.0018)
% No education	-0.0120*** (0.0043)	-0.0199*** (0.0063)	-0.0100 (0.0071)	-0.0325* (0.0174)
Distance to market (kms)	-0.0363* (0.0208)	-0.0176 (0.0264)	-	-
Distance to bank (kms)	-0.0176 (0.0119)	-0.0066 (0.0117)	-	-
Distance to MFI (kms)	0.0127 (0.0125)	-0.0036 (0.0146)	-	-
PSNP in kebele	-0.1289 (0.3638)	-0.0717 (0.3195)	-	-
Land low TWI (ha)	0.2406 (0.3335)	-0.3616 (0.3339)	-	-
Land medium TWI (ha)	0.8080*** (0.2428)	0.4969 (0.3106)	-	-
Land high TWI (ha)	1.0529*** (0.2829)	0.8930** (0.3738)	-	-
Land irrigated (ha)	0.0915 (0.2962)	0.3060 (0.3375)	-	-
Land rented (ha)	-0.7164** (0.2938)	-0.2947 (0.3991)	-	-
Household fixed-effects	No	No	Yes	Yes
Region fixed-effects	Yes	Yes	No	No
Observations	2899	2166	2899	2166
R^2	0.0853	0.1485	0.0337	0.1110
R^2 within	-	-	0.0251	0.0900
R^2 between	-	-	0.0406	0.1233
Test: $\theta_1 = 0$ p -value	0.1204	0.0000	0.8133	0.0045
	OLS models (1) and (2)		FE models (3) and (4)	
Test: $\theta_1^l = \theta_1^h$ p -value	0.0000		0.0091	

Clustered standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Cultivated land characteristics are based on the 2013/14 wave only

Table 5: The effect of rainfall shocks on household cattle holdings

	(1)	(2)	(3)	(4)
	$A_{pre} > 2$ OLS	$A_{pre} \leq 2$ OLS	$A_{pre} > 2$ FE	$A_{pre} \leq 2$ FE
Rainfall deviation (cm)	0.0376*** (0.0026)	0.0028 (0.0023)	0.0407*** (0.0028)	0.0019 (0.0030)
Household size	0.3205*** (0.0432)	0.0233 (0.0314)	0.0430 (0.0733)	0.0012 (0.0497)
Age of head	0.0748** (0.0340)	-0.0048 (0.0241)	0.0544 (0.0707)	0.0507 (0.0508)
Age of head squared	-0.0008** (0.0003)	0.0000 (0.0002)	-0.0002 (0.0006)	-0.0005 (0.0005)
% No education	-0.0045* (0.0026)	-0.0037*** (0.0013)	0.0026 (0.0034)	-0.0094*** (0.0025)
Distance to market (kms)	-0.0294* (0.0160)	-0.0071 (0.0089)	-	-
Distance to bank (kms)	0.0053 (0.0072)	-0.0015 (0.0045)	-	-
Distance to MFI (kms)	0.0012 (0.0074)	-0.0097** (0.0044)	-	-
PSNP in kebele	-0.7709*** (0.1705)	0.0532 (0.0980)	-	-
Land low TWI (ha)	0.2119 (0.1936)	-0.0475 (0.1171)	-	-
Land medium TWI (ha)	0.2025 (0.1622)	0.0502 (0.0945)	-	-
Land high TWI (ha)	0.2615 (0.2093)	0.1779 (0.1471)	-	-
Land irrigated (ha)	-0.0914 (0.2200)	0.0834 (0.1244)	-	-
Land rented (ha)	-0.1173 (0.2163)	0.2048 (0.1687)	-	-
Household fixed-effects	No	No	Yes	Yes
Region fixed-effects	Yes	Yes	No	No
Observations	2899	2166	2899	2166
R^2	0.1999	0.1602	0.1448	0.1177
R^2 within	-	-	0.2971	0.2117
R^2 between	-	-	0.0621	0.0090
Test: $\alpha_1 = 0$ p -value	0.0000	0.2178	0.0000	0.5278
	OLS models (1) and (2)		FE models (3) and (4)	
Test: $\alpha_1^{\ell} = \alpha_1^h$ p -value	0.0000		0.0000	

Clustered standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Cultivated land characteristics are based on the 2013/14 wave only

To summarise the key findings of the previous sections, those observations coming from households with pre-shock cattle holdings of three or more animals experience a reduction in herd size, as a result of the drought. For this group, it is also impossible to reject the hypothesis that consumption is fully insulated from the shock. In the case of households with two or fewer cattle, however, there is no evidence of any adjustments to herd size, yet the rainfall shock is associated with a significant decline in household consumption. This heterogeneity in coping strategies is consistent with the existence of the type of asset-based poverty trap described in Section 2.

5.5 Robustness

5.5.1 Choice of sample splitting variable

In using cattle herd size as the variable defining γ , it is possible that the estimation procedure may actually be detecting heterogeneity defined by more general patterns of household wealth. For example, Table 3 suggests there exists a possible correlation between cattle holdings and measures such as area of land cultivated and remoteness. To test this hypothesis, the sample splitting procedure is repeated, using the variables measuring land ownership and distance to a weekly market.²⁰

Table 6: Test for threshold effect in other variables

	$\hat{\gamma}$	RSS	MSE	Bootstrap repetitions	p -value
Owned land (ha)	0.36	99083	19.92	1000	0.2320
Distance to market (kms)	16.00	98947	19.89	1000	0.1490

The table indicates that the most likely candidate for γ in cultivated land is at approximately 3600m². However, splitting the sample around this value does not generate significant differences in the high and low regime coefficients (p -value = 0.2320). Similarly, splitting the sample, based on the distance of a household from a weekly market also fails to generate a significant difference in the coefficients either side of the respective candidate γ value (16kms). These findings suggest that it is household cattle holdings specifically, which generate the heterogeneity in shock responses.

²⁰A household's distance from a weekly market should be a strong indicator of poverty status. In rural Ethiopia, the proportion of those falling below the national poverty line is found to increase by 7% for every 10kms travelled from a market town (World Bank, 2016).

5.5.2 Availability of cattle

Although rural households with no involvement in cattle rearing are omitted from the sample (see sample description in section 3), the dataset still contains observations where a household owns no cattle in one of the two survey waves. The estimations in table 7 are intended to test whether the non-significant effect, in the small herd group, is a result of some households entering the period of the drought with no cattle available to sell (whether they would otherwise, choose to or not). Table 7 reports that it is still not possible to reject the hypothesis of no effect in this adjusted sample, at any of the significance levels reported.

Table 7: Omitting observations with no cattle

Rainfall coefficients and standard errors reported				
	(1)	(2)	(3)	(4)
Dependent variable:	Total consumption		Change in herd size	
	$A_{pre} > 2$	$0 < A_{pre} \leq 2$	$A_{pre} > 2$	$0 < A_{pre} \leq 2$
	FE	FE	FE	FE
	0.0033	0.0436**	0.0396***	0.0010
	(0.0053)	(0.0202)	(0.0028)	(0.0032)

Clustered standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5.5.3 Uniqueness of $\gamma=2$

When assessing the residual sum of squares (RSS) generated by splitting the sample at possible values of γ , a value of $\hat{\gamma} = 3$ provided the second lowest RSS above $\hat{\gamma} = 2$ (see Figure 7). It is therefore, worth considering the implications of splitting the sample at the alternative herd size of 3.

Table 8 reports the coefficients on the rainfall shock for households with pre-shock cattle holdings in a high and low asset regime, separated by $\hat{\gamma} = 3$. Columns 1 and 2 indicate that the consumption response follows the same pattern as Table 4. Again, only the coefficient in the high cattle regime is significantly different from zero.

The coefficients representing the effect of the rainfall shock on herd size (columns 3 and 4) indicate a significant response in cattle holdings, for households in the lower cattle regime, where none was present when splitting the sample at $\hat{\gamma} = 2$ (see Table 5). This is evidence that at least some households with a pre-shock herd size of 3 animals

were willing to use these assets to protect consumption. Testing the null hypothesis that the effect of the drought shock is equivalent in both regimes, however, generates a strong rejection (test $H0 : \alpha_1^h = \alpha_1^l$ yields p -value = 0.0000).

Table 8: Splitting the sample at $\gamma = 3$

Rainfall coefficients and standard errors reported				
	(1)	(2)	(3)	(4)
Dependent variable:	Total consumption		Change in herd size	
	$A_{pre} > 3$	$A_{pre} \leq 3$	$A_{pre} > 3$	$A_{pre} \leq 3$
	FE	FE	FE	FE
	0.0019	0.0289***	0.0356***	0.0122***
	(0.0057)	(0.0109)	(0.0032)	(0.0026)

Clustered standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In light of both sets of results, therefore, it is possible to conclude that splitting the sample at a pre-shock herd size of $\hat{\gamma} = 3$ would also generate significant heterogeneity in coping strategies between the high and low cattle groups. Although, the difference in shock-responses appears more pronounced under the condition that $\hat{\gamma} = 2$.

5.5.4 Choice of inclusion within the sample

To avoid the inclusion of large-scale, commercial farms in the analysis, it was necessary to set upper-bounds on cattle holdings and cultivated land (see section 3). The initial cut-off points were at 5 hectares of land or 30 head of cattle. The uppermost section of table 9 tests the sensitivity of key findings to alternative cut-off levels. As previously, only the effect of the rainfall variable, on total consumption (columns 1 and 2) and the change in cattle holdings (columns 3 and 4), is reported in each case.

Omitting households who possess more than 4 hectares of land or 25 cattle, in any wave, reduces the sample from 5067 to 4875. However, table 9 indicates this does little to alter the interpretation of the results. Similarly, increasing the cut-off for sample inclusion to 6 hectares of land or 35 cattle, increases the sample to 5076 households, but again, does not alter the overall pattern of results.

Table 9: Robustness of results to alternative choice of sample

Rainfall coefficients and standard errors reported				
Dependent variable:	(1)	(2)	(3)	(4)
	Total consumption $A_{pre} > 2$ FE	$A_{pre} \leq 2$ FE	Change in herd size $A_{pre} > 2$ FE	$A_{pre} \leq 2$ FE
<i>Alternative cut-off for sample inclusion</i>				
Land<4 ha and cattle<25	0.0039 (0.0053)	0.0547*** (0.0085)	0.0404*** (0.0027)	0.0029 (0.0031)
Land<6 ha and cattle<35	0.0013 (0.0051)	0.0414*** (0.0146)	0.0407*** (0.0027)	0.0020 (0.0030)
<i>Omission of regions</i>				
Tigray omitted	0.0039 (0.0053)	0.0366** (0.0159)	0.0436*** (0.0028)	0.0028 (0.0033)
Amhara omitted	-0.0023 (0.0062)	0.0408** (0.0177)	0.0318*** (0.0031)	-0.0001 (0.0032)
Oromia omitted	0.0005 (0.0050)	0.0473*** (0.0084)	0.0360*** (0.0031)	0.0041 (0.0033)
SNNP omitted	0.0005 (0.0059)	0.0377** (0.0185)	0.0390*** (0.0031)	0.0008 (0.0036)
Other regions omitted [†]	0.0034 (0.0061)	0.0446** (0.0201)	0.0521*** (0.0032)	0.0005 (0.0036)

Clustered standard errors in parentheses

* p<0.1, ** p<0.05, *** p<0.01

[†] Afar, Somalie, Benishagul Gumuz, Gambela, Harari, Dire Dawa

As the type of farming practised in Ethiopia varies substantially between different agro-climatic zones, it is important to determine whether any specific region is responsible for driving the main results of the analysis. The lower section of table 9 tests the robustness of key results to the omission of observations from the four most populous rural regions.²¹ Table 9 also reports tests from a sample which omits all observations from the remaining six regions (listed below table 9). Any changes in the coefficients are not sufficient to warrant any new interpretation of the results (although, the significance of the coefficients does vary to a small degree in some cases). It is therefore, possible to conclude that no specific, single region is driving the main results of the analysis.

²¹Tigray, Amhara, Oromia and SNNP, representing approximately 10.2%, 21.6%, 20.4% and 27.3% of the sample, respectively.

5.6 Heterogeneity within regimes

Significant differences in smoothing behaviour, amongst households with two or fewer cattle, mirrors the findings of Hoddinott (2006), in a study conducted in rural Zimbabwe. The key reason suggested for this effect was the need to provide sufficient animal traction to ensure fields could be ploughed in the following season. The wide variety of crops and farming practices found in Ethiopia provides an opportunity to test this hypothesis.

In the Ethiopian case, the traditional plough (*maresha*) requires oxen to operate. If the household does not possess these animals they must either obtain them by other means (short-term hire, for example) or cultivate the land without animal traction. Either option is likely to have a negative impact on the following season's net farm profits. In turn, lower profits in future harvests would be expected to hinder a household's efforts to bring its herd size back to the minimum number of animals required. It is therefore, highly plausible that such a non-linear relationship between cattle stocks and productivity could generate the type of bifurcating growth path illustrated in Figure 1.

Formulating a suitable test of this hypothesis, requires utilising the wide variety of crops and farming methods employed in Ethiopia. Approximately three-quarters of the total cultivated land in Ethiopia is dedicated to the production of cereal crops, such as teff, wheat and maize (Taffesse et al., 2012). In almost all areas, this form of agriculture is highly dependent on the traditional ploughing methods described above. In contrast, farmers who specialise in the cultivation of non-cereal crops are far less reliant on cattle for the purpose of ploughing and preparing land. For example, in the South-West of the country, households rely heavily on the enset palm as a principle source of food, a crop which is cultivated using a wooden hoe, and requires no animal traction (Westphal and Stevels, 1975). Similarly, many farmers dedicate significant proportions of their land to tree crops or vegetables (Taffesse et al., 2012). As a result, if the need for animal traction determines γ , the requirement to retain a minimum number of cattle should be more evident amongst those households growing predominantly cereal crops.

$$A_{it} = \begin{cases} \alpha_1^h R_{it} + \alpha_2^h (R_{it} * C_{pre}) + \beta' H_{it} + \tau_t + \psi_i + v_{it}, & \text{if } A_{pre} > \gamma \\ \alpha_1^\ell R_{it} + \alpha_2^\ell (R_{it} * C_{pre}) + \beta' H_{it} + \tau_t + \psi_i + v_{it}, & \text{if } A_{pre} \leq \gamma \end{cases} \quad (6)$$

Model (6) modifies the original asset equation, by interacting the rainfall shock R_{it} with a continuous variable, indicating the share of a household's cultivated land

dedicated to cereal crops in the pre-shock period C_{pre} (taking values between 0 and 1). Based on this model, a significant interaction effect in the coefficient α_2 would indicate that the response of cattle holdings to the shock is dependent on the share of cultivated land dedicated to cereal crops.²²

Table 10: Heterogeneous effects of rainfall shocks on household cattle holdings

	(1)	(2)	(3)	(4)
	$A_{pre} > 2$	$A_{pre} \leq 2$	$A_{pre} > 2$	$A_{pre} \leq 2$
	OLS	OLS	FE	FE
Rinfall deviation (cm)	0.0373*** (0.0035)	0.0094*** (0.0034)	0.0424*** (0.0035)	0.0127*** (0.0048)
% Cereal crop	0.0631 (0.2355)	0.0508 (0.1256)	-	-
Rainfall dev * % Cereal	0.0007 (0.0051)	-0.0102*** (0.0038)	-0.0037 (0.0049)	-0.0164*** (0.0051)
Household fixed-effects	No	No	Yes	Yes
Region fixed-effects	Yes	Yes	No	No
Observations	2899	2166	2899	2166
R^2	0.1999	0.1676	0.1441	0.1262
R^2 within	-	-	0.3001	0.2274
R^2 between	-	-	0.0601	0.0142
Test: $\alpha_1 = 0$ p -value	0.0000	0.0003	0.0000	0.0004
Test: $\alpha_2 = 0$ p -value	0.8966	0.0001	0.0117	0.0000

Clustered standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All variables in table 5 included, but not reported

Cereal crop share is based on the 2013/14 wave only

Table 10 reports the results of an estimation of model (6), where all control variables in Table 5 are included (but not reported). The results of both the OLS and household fixed-effects estimations indicate the interaction term is significant in the low cattle regime, only. The coefficient on the main effect of the shock now also represents a significant effect in this group, where none was present in the initial estimations (see Table 5), implying that cattle holdings will respond to a rainfall shock in the small herd sub-sample, but *only* when the share of cereal crops approaches zero. The coefficient on the interaction term indicates that the strength of this correlation decreases, the greater

²²The cereal crops considered are teff, wheat, maize, barley, millet, sorghum and oats.

the share of land these households dedicate to cereal crops. Overall, these findings lend strong support to the hypothesis that heterogeneity in the degree to which cattle are used to smooth consumption exists due to the need to protect a minimum number of animals to allow for efficient land preparation in the following season.

6 Summary and concluding remarks

Using a nationally representative dataset of agricultural households in rural Ethiopia, this paper finds evidence of two distinct methods of response to the income shock caused by the onset of a period of severe drought. A threshold estimation approach is used to separate the sample into two groups, according to each household's pre-shock level of cattle holdings. Analysis of these sub-samples concludes that households with an initial herd size of 3 or more animals effectively used these assets as a means of protecting consumption from the impact of the shock. In contrast, those households with 2 or less cattle did not reduce their holdings in response to the drought, instead choosing to protect their current herd size, at the cost of lower consumption. These results are consistent with the hypothesis of a poverty trap threshold, defined by household cattle ownership.

The key findings of this analysis contradict results obtained from direct estimations of the asset growth path (see section 5.1). Modelling the relationship between current and lagged herd size directly produces no evidence of the type of multiple equilibria, which would characterise a poverty trap. The likely explanation for this disparity lies in this paper's use of behavioural changes to indirectly identify the existence of an asset threshold. With this approach, it is possible to identify such a threshold, even where no household's asset stock ever falls below it. Modelling the asset path directly however, will only identify a threshold which is observed to have measurable consequences for a household's asset wealth.

Extending the main results uncovers further heterogeneity within the small herd group. The degree to which cattle are used as a buffer stock within this group is shown to depend on the extent to which these households dedicate land to the cultivation of cereal crops. As cattle are an essential source of animal traction in cereal cultivation, this result suggests that a change in smoothing behaviour, between a herd size of 3 and a herd size of 2, is a response to the need to retain sufficient animals to allow for the preparation of land for the following season.

This analysis is not without its limitations however. In particular, the treatment

of consumption shortfalls as uniform to all household members. While convenient, this approach does not attempt to ascertain how the negative cost of protecting cattle stocks impacts on vulnerable members. If such costs are borne disproportionately by younger generations within the households, short term drops in consumption may have very long term consequences (see Dercon and Porter, 2014). Determining the extent to which asset smoothing strategies influence the outcomes of future generations will be a topic considered in future research.

The findings of this study highlight some of the complexities of assessing vulnerability to drought in rural populations. Even with the availability of social protection and safety nets, it is inevitable that some households will still be faced with a choices of either reducing consumption now or undermining productivity in the future. Such stark choices draw attention to the need for improvements in the coverage and design of agricultural insurance programmes, particularly in more drought-prone rural areas. Encouraging, the implementation and uptake of insurance products, where financial literacy and monitoring capacity are low, may require some degree of public sector involvement. Yet, if the country is able to effectively manage the substantial weather risk to small-scale agricultural, the removal of such a binding constraint may see Ethiopia turn recent investments in rural development into long-term, sustained economic growth.

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Appendices

Appendix 1. Model (1) parameterisation

Low technology: $f^l(A_t\theta_t) = \theta_t A_t^{0.3}$

High technology: $f^h(A_t\theta_t) = \theta_t A_t^{0.45} - 0.45$

Depreciation rate: $\delta = 0.08$

Discount factor: $\beta = 0.95$

$u(c_t) = \frac{c_t^{1-\sigma}-1}{1-\sigma}$, with: $\sigma = 1.5$

Probability distribution of θ approximated as:

$$\theta = \begin{cases} 0.05 & \text{if } \theta_t = 0.8 \\ 0.10 & \text{if } \theta_t = 0.9 \\ 0.70 & \text{if } \theta_t = 1 \\ 0.10 & \text{if } \theta_t = 1.1 \\ 0.05 & \text{if } \theta_t = 1.2 \end{cases}$$

Probability distribution of θ (post-shock) approximated as:

$$\theta = \begin{cases} 0.05 & \text{if } \theta_t = 0.4 \\ 0.10 & \text{if } \theta_t = 0.5 \\ 0.70 & \text{if } \theta_t = 0.6 \\ 0.10 & \text{if } \theta_t = 0.7 \\ 0.05 & \text{if } \theta_t = 0.8 \end{cases}$$

A_t and A_{t+1} approximated using a grid of discrete values $A_t = \{0.1, 0.2 \dots 45\}$

Appendix 2. Test of attrition bias

The upper panel of table A1 indicates the mean and standard deviation of important household characteristics. These are reported for observations included in the sample and those which were omitted due to missing values (see Section 3). The F -test in the right-hand column of the table indicates that omission from the sample is not a significant predictor of any of the variables listed.

Table A1: Tests for non-random attrition due to missing variables

	Sample		Omitted		F -test
	mean	sd	mean	sd	p -value
Household size	5.54	2.15	5.42	2.28	0.2549
Age of head	46.62	14.39	46.67	14.80	0.9332
Head is literate	0.40	0.49	0.39	0.49	0.8745
Number of cattle	4.09	4.16	4.39	3.88	0.1114
Land cultivated (ha)	0.98	0.92	1.01	0.93	0.5739
Total consumption	4.82	7.18	5.14	4.22	0.1503
Food consumption	3.96	7.07	4.03	3.23	0.7047
Total farm income	4.83	11.80	5.77	22.33	0.4773
Rainfall deviation (cm)	-5.30	35.56	-5.68	27.52	0.7581
<i>Regions</i>					
Tigray	0.10	0.29	0.09	0.29	0.8582
Afar	0.01	0.10	0.01	0.12	0.5355
Amhara	0.22	0.41	0.20	0.40	0.3989
Oromia	0.20	0.40	0.21	0.41	0.7367
Somalia	0.07	0.26	0.09	0.28	0.2734
Benishagul-Gumuaz	0.03	0.16	0.02	0.15	0.6359
SNNP	0.27	0.44	0.27	0.44	0.8991
Gambela	0.03	0.17	0.04	0.19	0.5528
Harari	0.04	0.19	0.03	0.17	0.3052
Dire Dawa	0.04	0.19	0.04	0.20	0.7159
Observations	5067		591		

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All income and consumption figures measured in 1000 Ethiopian Birr, per adult equivalent

Similarly, the lower panel of table A1 reports that inclusion within the sample is not significantly more likely for any of the 10 survey regions. This implies the sample used should still be considered as nationally representative of the population of agricultural households in rural Ethiopia.

Appendix 3. Estimation of γ

The following describes the procedure used to estimate γ . It is useful to follow Hansen (1999) and represent the two parts of (3) in a single equation. Collecting the right-hand side variable $\{R_{it}, H_{it}, \tau_t\}$ in a vector X_{it} , and representing all associated coefficients for the low and high asset regimes as β_ℓ and β_h , respectively, the empirical model (3) can be written as follows.

$$c_{it} = \beta'_\ell X_{it} I(A_{it} \leq \gamma) + \beta'_h X_{it} I(A_{it} > \gamma) + \psi_i + e_{it} \quad (\text{a1})$$

In equation (a1) the bracketed terms indicates the position of the household, relative to γ , where $I(\cdot)$ is an indicator function. A further simplification combines the coefficient vectors for the high and low regimes, and represent the separation of the data as follows.

$$c_{it} = \beta' X_{it}(\gamma) + \psi_i + e_{it} \quad (\text{a2})$$

where

$$\beta = (\beta'_\ell, \beta'_h)'$$

$$X_{it}(\gamma) = \begin{Bmatrix} X_{it} I(A_{it} \leq \gamma) \\ X_{it} I(A_{it} > \gamma) \end{Bmatrix}$$

Subtracting the mean, over the time-index t , for each household i , yield the transformed, fixed-effects model, where * denotes the transformed variables, and the fixed-effect ψ_i is eliminated.

$$c_{it}^* = \beta' X_{it}^*(\gamma) + e_{it}^* \quad (\text{a3})$$

For a given γ , equation (a3) can be estimated via ordinary least squares (OLS), yielding both the vector of regression residuals $\hat{e}_{it}^*(\gamma)$ and the residual sum of squares $S(\gamma)$.

$$\hat{e}_{it}^*(\gamma) = c_{it}^* - \hat{\beta}'(\gamma) X_{it}^*(\gamma) \quad (\text{a4})$$

$$S(\gamma) = \hat{e}_{it}^*(\gamma)' \hat{e}_{it}^*(\gamma) \quad (\text{a5})$$

The most likely candidate for a possible splitting point is found through a process of searching over the range of values of the pre-shock herd size variable A_{pre} . The candidate value $\hat{\gamma}$ is the herd size which minimises the residual sum of squares from an OLS estimation of (a3) (Hansen, 1999).

$$\hat{\gamma} = \min_{\gamma} S(\gamma) \quad (\text{a6})$$

Testing for the significance of differences in the high and low regime coefficients is a test of the null hypothesis, $H_0 : \beta_h = \beta_\ell$ in equation (a1), with γ replaced by $\hat{\gamma}$. However, under the null hypothesis, the indicator function $I(\cdot)$ has no place in the estimation and the pooled model (2) is the appropriate choice. Similarly to equation (a3), under the null hypothesis, model (2) can be written as follows, where the subscript p indicates the vector of coefficients relate to the pooled model.

$$c_{it}^* = \beta_p' X_{it}^* + \eta_{it}^* \quad (\text{a7})$$

Estimation of (a7) again generates the predicted standard errors $\hat{\eta}$ and the residual sum of squares S_p .

$$\hat{\eta}_{it}^* = c_{it}^* - \hat{\beta}' X_{it}^* \quad (\text{a8})$$

$$S_p = \hat{\eta}_{it}^{*'} \hat{\eta}_{it}^* \quad (\text{a9})$$

The test statistic for determining the significance of differences in regime coefficients takes the form in (a10). However, as the sample splitting point is not identified under H_0 , the asymptotic distribution of F is non-standard and strictly dominates χ_k^2 (Hansen, 1999).

$$F = \frac{S_p - S(\hat{\gamma})}{\hat{\sigma}^2} \quad (\text{a10})$$

Hansen (1996, 1999) describe a bootstrap procedure which can be used to generate an asymptotically valid p -value for the test of the significance of differences in the regime coefficients. The procedure involves cluster re-sampling (with replacement) of the predicted errors \hat{e}^* from an estimation of (a3). These errors are then used to generate a bootstrapped dependent variable in equation (a7), by holding the values of X^* and the variable A fixed (in all bootstrap samples), while allowing the coefficients β_p' to assume any arbitrary value.²³ The generated bootstrap sample is then used to estimate the residual sum of squares, under the null and alternative hypotheses, and compute a

²³This is permitted, as F is not dependent on β_p' , under the null hypothesis (Hansen, 1999).

bootstrapped version of the F statistic (a10). In repeated samples, the proportion of draws, in which this bootstrapped statistic exceeds F , is the bootstrapped p -value for the null hypothesis of no threshold effect. Further details of this procedure can be found in Hansen (1999), pages 350-351.

Appendix 4. Adult equivalency measures

All income and consumption variables used in the analysis are expressed per adult equivalent. The weighting used to construct these variables is shown in table A2. These weights are based on the suggested construction of consumption aggregates, provided with the ESS data (2011-12).

Table A2: Adult equivalency scales

Age range	Male	Female
age \leq 1 year	0.33	0.33
1 year $<$ age \leq 2 years	0.46	0.46
2 year $<$ age \leq 3 years	0.54	0.54
3 year $<$ age \leq 5 years	0.62	0.62
5 year $<$ age \leq 7 years	0.74	0.70
7 year $<$ age \leq 10 years	0.84	0.72
10 year $<$ age \leq 12 years	0.88	0.78
12 year $<$ age \leq 14 years	0.96	0.84
14 year $<$ age \leq 16 years	1.06	0.86
16 year $<$ age \leq 18 years	1.14	0.86
18 year $<$ age \leq 30 years	1.04	0.8
30 year $<$ age \leq 60 years	1	0.82
60 year $<$ age	0.84	0.74

Appendix 5. Parametric estimation of the evolution of cattle holdings

Table A3 reports the results of an estimation of equation (5). The fitted values from this estimation are used to generate the herd size growth path, shown in Figure 6. The dependent variable in table A3 is the current number of cattle owned by each household A_{it} and the model is estimated using OLS. All control variables come from the first survey wave only.

Table A3: Lagged polynomial estimation of herd size dynamics

	(1)		
$A(t - 1)$	-0.2492 (0.1685)	Distance to bank (kms)	-0.0036 (0.0067)
$A^2(t - 1)$	0.0740** (0.0366)	Distance to MFI (kms)	-0.0107 (0.0072)
$A^3(t - 1)$	-0.0026 (0.0026)	PSNP	-0.5188*** (0.1513)
$A^4(t - 1)$	0.0000 (0.0001)	Land low TWI (ha)	0.0524 (0.1755)
Household size	0.0732* (0.0398)	Land medium TWI (ha)	0.4282*** (0.1322)
Age of head	0.0054 (0.0330)	Land high TWI (ha)	0.4203* (0.2182)
Age of head squared	-0.0000 (0.0003)	Irrigate land (ha)	0.1598 (0.1958)
% No education	0.0006 (0.0021)	Rented land (ha)	-0.1259 (0.1939)
Distance to market (kms)	0.0210 (0.0134)		
Region fixed-effects			Yes
Observations			2488
R^2			0.2295

Clustered standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

All control variables are measured from 2013/14 wave