Inheritance Customs and Agricultural Investment*

Working paper draft for discussion. Comments welcome.

Brian Dillon† Alessandra Voena‡

October 23, 2015

Abstract

This paper examines the connection between women's land inheritance rights and investments in land productivity in Zambia. We study whether the threat of land expropriation upon widowhood deters households from fallowing, applying fertilizer, and employing labor-intensive tillage techniques. The primary source of policy varation comes from village customary norms governing the transfer of land after the death of a head of household, which we observe in a survey of village leaders and match to a 2008 household agricultural survey. Controlling for a large number of factors, including geographic location, household composition, and tribe, we find consistent evidence of reduced land investment by married couples in villages where widows are less likely to inherit land. For some outcomes the relationship is strongest in areas with higher rates of HIV mortality. These findings suggest that concerns over prospective loss of land by the wives crowds out investment in land productivity by the whole household.

*We thank Anthony Chapoto, Thom Jayne and the Food Security Research Project in Lusaka for sharing their data. We thank Dingiswayo Banda, Lorenzo Casaburi, William Clark, Rachel Heath, Kelsey Jack, Simone Lenzu, Salla Rantala, and seminar participants at IFPRI, UChicago, UW, and IHME for helpful comments. Michael Mulford, Holly Hickling, Sarojini Rao and Noemi Nocera provided excellent research assistance. This work was partially conducted while the authors were Giorgio Ruffolo Post-doctoral Fellows in the Sustainability Science Program at Harvard University. Support from Italy's Ministry for Environment, Land and Sea is gratefully acknowledged.

†University of Washington. Email: bdillon2@uw.edu.

‡University of Chicago and NBER. Email: avoena@uchicago.edu.

1 Introduction

Land productivity in Sub-Saharan Africa (SSA) is far lower than in other regions of the world. Intensive farming coupled with insufficient investment in restoring land quality has led to a gradual decline in soil productivity across the region. This has severe implications for agricultural output and food security. Agriculture provides the majority of employment and accounts for the largest share of GDP in most countries in SSA, so any impediment to agricultural productivity has important, negative consequences for welfare.

Why is land investment so low in SSA? One critical factor is the shifting and fragmented system of land tenure systems in the region. In many countries, the modern concept of deeded land ownership is in conflict with traditional systems of communal control over land. These traditional systems may involve allocation or revocation of land use rights by community leaders, restrictions on the sale of land, restrictions on the rental of land, land inheritance along strictly matrilineal or strictly patrilineal lines, or various other departures from the Western concept of property rights. Policymakers, researchers, and outside observers have long been concerned that limited or opaque rights to land use may be a deterrent to investment.[1]

In this paper, we examine the link between an important feature of land tenure in Zambia – land inheritance rules – and farmers' investments in long-run soil fertility. The large majority of agricultural land in Zambia is still governed by local custom. We focus on a widow's right to maintain control over the household land after her husband dies, a policy variable determined at the village level. Concern over land expropriation upon widowhood is serious: recent work shows that on average the death of a male household head leads to a one-third reduction in the the land area cultivated by the widow's household, after accounting for the reduction in household labor supply (Chapoto, Jayne and Mason, 2011). This aspect of land governance is of particular importance in modern-day Zambia, where the HIV crisis has contributed to relatively high mortality among prime age males.

Our empirical work is motivated by a simple dynamic model of agricultural investment that allows for localized heterogeneity in inheritance norms. Investment – think of fertilizer application, for now – can raise both current and future land productivity. So long as the wife has positive weight in the household planning problem, preventing her from inheriting land lowers investment relative to a situation in which the household expects that she will inherit. The distortion is exacerbated by higher mortality risk. If, on the contrary, the wife

[1] Over the last few decades, governments and international organizations have in many countries attempted to replace traditional regimes with formal systems of land tenure. These efforts are motivated in part by the concern that customary land tenure systems inadequately protect the interests of women, the poor, and other disadvantaged groups (Feder and Feeny, 1991; Leonard and Toulmin, 2000; Whitehead and Tsikata, 2003). Nevertheless, these reform efforts have encountered substantial resistance from both local leaders and outside observers (Platteau, 1995; Deininger, 2003; Sikor and Müller, 2009). This resistance is based partly on the observation that top-down efforts at formalization rarely succeed without local commitment to institutional change, and partly on the concern that without a more complete understanding of the complex nature of property rights regimes in many African states, the welfare effects of formalization are ambiguous.

has no weight in household decision, due either to lack of empowerment or to lack of altruism on the part of the household head, we show that a policy of widow non-inheritance has no impact on farming choices.

Using a large micro data set we test whether couple-headed households – those for whom widow inheritance policies are potentially relevant – invest less in land quality when they live in a non-inheritance area. We estimate policy impacts on three different types of land investment: fertilizer application, fallowing, and the use of labor-intensive tillage practices aimed at reducing erosion and run-off. Across a variety of specifications we find strong evidence of reduced land investment in areas where widows do not inherit. Couples in non-inheritance villages apply 38 to 55% less fertilizer, fallow 13 to 19% less land area, and use intensive tillage techniques on 7.5 to 17.5% fewer acres. These findings are robust to detailed wealth, geography, and ethnicity controls, and to the use of instrumental variables to correct for possible endogoneity. Placebo tests show that a policy of widow non-inheritance only impacts investment by couple-headed households, suggesting that the effect is not driven by general variation in the strength of property rights. We also find evidence for some types of land investment that the deterrent effect of widow non-inheritance is greater in areas with higher rates of HIV mortality.

We do not find significant effects of the widow inheritance policy on revenues. This is not especially surprising, as it reflects both the econometric challenge of modeling variation in this outcome in a cross section, and the likely presence of multiple market failures in which an observed impact on one set of input choices may not manifest as a detectable effect on stochastic outcomes that are functions of multiple choice variables as well as factors outside of farmers' control. What this does suggest is that as a policy to raise both investment *and* agricultural earnings, increasing tenure security for widows may be most effective when combined with policies to address imperfections in other input markets, e.g., those for insurance or credit.

The data for this paper are from a 2008 nationally representative agricultural household survey in Zambia. The data set includes a wide variety of standard agricultural, economic, and demographic information at the plot, household, and community level. Data on the widow inheritance policy comes from a survey of village leaders conducted concurrently with the household survey and designed specifically to measure land allocation and inheritance norms, among other topics. Over a third of households in the data live in an area where widows do not inherit their deceased husband's lands.

The findings here contribute to three strands of literature. The first is the substantial body of work on the link between land investment and land tenure security in developing countries (see Place (2009) and Fenske (2011) for recent reviews). Not surprisingly given the diversity of tenure regimes across SSA, the existing evidence on this link is mixed. While a number of studies have found, like this paper, a positive relationship between tenure security and land investment (Besley, 1995; Gavian and Fafchamps, 1996; Otsuka and Place, 2001; Benin, 2006; Deininger and Jin, 2006; Goldstein and Udry, 2008), others have not (Place and Hazell, 1993; Brasselle, Gaspart and Platteau, 2002; Place and Otsuka, 2002; Pender et al., 2004; Amsalu and De Graaff, 2007). Thanks largely to the richness of the Zambia data set, our approach combines many of the strengths of the best papers on this topic (see Fenske 2011). First, we have a relatively large and nationally representative data set – almost 6,000 households for our main specifications. Second, we test impacts on multiple, continuous measures of investment, rather than on binary outcomes. And third, our measure of tenure security is not a *de jure* legal statute or a self-reported plot characteristic, but is a community level policy variable that reflects the *de facto* prevailing norms. Finally, we also contribute to this literature by focusing on tenure security as it relates to inheritance rights. To our knowledge there is no previous work on the interaction between widowhood, land ownership transfer, and agricultural investment.

This paper also contributes to the important literature on gender-related differences in agricultural outcomes (Besley, 1995; Udry, 1996; Yngstrom, 2002; Allendorf, 2007; Goldstein and Udry, 2008; Ubink and Quan, 2008; Kumar and Quisumbing, 2012; Ali, Deininger and Goldstein, 2014; Doss et al., 2015), and more generally on the effect of women's rights on development (Doepke, Tertilt and Voena, 2011; Duflo, 2012; Fernández, 2013). In one sense, our empirical tests can be interpreted as joint tests of the importance of women in the household planning problem and of the effect of non-inheritance on investment. Our results suggest that women do matter in household decisions, and that depriving them of secure access to land in the future can distort present-day investments.

Lastly, because our estimates of the relationship between inheritance norms and some types of land investment are stronger in areas with higher HIV rates, i.e. areas where the risk of widowhood is higher, the findings here connect to other work on the impact of AIDS or AIDS treatment on resource allocation and forward-looking economic behavior (Ainsworth, Beegle and Koda, 2005; Delavande and Kohler, 2009; Graff Zivin, Thirumurthy and Goldstein, 2009; Thornton, 2012; Baranov and Kohler, 2014; Baranov, Bennett and Kholer, 2015).

The paper proceeds as follows. In the following section we develop a theoretical framework for the analysis. Section 3 describes the data and setting. Section 4 contains results, which we then discuss in Section 5. Section 6 concludes.

2 Theory and empirical framework

To capture the impact of women's inheritance rules on agricultural investment, we develop a simple non-separable discrete time model of a farming household making agricultural production choices related to land quality. We abstract from numerous complicating factors in order to focus on the most relevant features of the problem.

2.1 The model

Consider a household composed of two agents, a husband (H) and wife (W). Each person derives utility from consumption c_t^{si} according to the spot utility function $\ln(c_t^{si})$, where t is the period, s is the state of the world (in period t, unless otherwise specified), and $i \in \{H, W\}$. The couple solves an intertemporal collective household planning problem, making Pareto efficient decisions about resource allocation using the Pareto weights μ^i for each person i. The presence of children can easily be accommodated by allowing for an equivalence scale.

The household faces uncertainty about the survival of its members, who have respective probabilities π_t^i of being alive in period t. The states of the world are $s \in \{B, H, W\}$ to indicate who is still living: "both", "husband only", or "wife only." The household farms a fixed amount of land A, with land quality defined by the state variable Q_t^s. In every period t and state s of the world, the household divides its resources between consumption by living members, c_t^{si}, and agricultural investment, q_t^s. For the moment, q_t^s is a generic investment. The farm production function is $F(A, Q_t^s, q_t^s)$, with output increasing in all three arguments. Investment raises both current output and output in the next period, through the equation of motion for land quality: $Q_{t+1}^{s^t} = q_t^s + (1-\delta)Q_t^{s^{t-1}}$, where δ is the rate of land quality depreciation. The productivity of each unit of land is increasing in both land quality and investment:

$$F_{AQ}(A, Q_t^s, q_t^s) = \frac{\partial^2 F(A, Q_t^s, q_t^s)}{\partial A \partial Q_t^s} > 0$$
$$F_{Aq}(A, Q_t^s, q_t^s) = \frac{\partial^2 F(A, Q_t^s, q_t^s)}{\partial A \partial q_t^s} > 0$$

We further suppose that $F(0, Q_t) = 0 \ \ \forall Q_t$ and that widows who lose their land enjoy a fixed, positive consumption floor $\underline{c} > 0$.

The local inheritance policies are given by the variables ϕ^i, which take a value of 1 if spouse i can inherit the land in the event that the other spouse dies, and 0 otherwise. In keeping with the prevailing norms in Zambia, we allow ϕ^W to be a function of the local context, but we always assume $\phi^H = 1$.

A household with both spouses alive in period 0 solves the following problem:

$$max_{c,q\geq 0} \sum_{i \in H,W} \mu^i \sum_{t=0}^{T} \beta^t \cdot \left\{ \pi_t^i \pi_t^{-i} ln(c_t^i) + \pi_t^i (1-\pi_t^{-i})[\phi^i ln(c_t^{si}) + (1-\phi^i) ln(\underline{c})] \right\} \quad (1)$$

$$
\begin{aligned}
&s.t., \qquad \forall \text{ period } t, \text{ states } s^t \\
&c_t^{BH} + c_t^{BW} + dq_t^B \leq F(A, Q_t^{s^{t-1}}, q_t^B) && \text{if both alive at time} t \\
&c_t^{HH} + dq_t^H \leq F(A, Q_t^{s^{t-1}}, q_t^H) && \text{if } H \text{ is a widower at time } t \\
&c_t^{WW} + dq_t^W \leq F(A^{WS}, Q_t^{s^{t-1}}, q_t^W) && \text{if } W \text{ is a widow at time } t \\
&q_t^B = Q_{t+1}^B - (1-\delta)Q_t^{s^{t-1}} && \text{if both alive at time } t \\
&q_t^H = Q_{t+1}^H - (1-\delta)Q_t^{s^{t-1}} && \text{if } H \text{ is a widower at time } t \\
&q_t^W = Q_{t+1}^W - (1-\delta)Q_t^{s^{t-1}} && \text{if } W \text{ is a widow at time } t
\end{aligned}
$$

where d is the price of land investment.

2.2 Intertemporal choice and agricultural investment

Consider a household with both spouses alive at time t. Define $p_{t+1}^B = \frac{\pi_{t+1}^H}{\pi_t^H}\frac{\pi_{t+1}^W}{\pi_t^W}$ (probability both spouses survive till $t+1$ having survived till t), $p_{t+1}^H = \frac{\pi_{t+1}^H}{\pi_t^H}\frac{(1-\pi_{t+1}^W)}{\pi_t^W}$ (probability that the wife dies at the end of period t) and $p_{t+1}^W = \frac{(1-\pi_{t+1}^H)}{\pi_t^H}\frac{\pi_{t+1}^W}{\pi_t^W}$ (probability that the husband dies at the end of period t).

From the first order conditions of the problem above with respect to q_t^B we have that:

$$
\begin{aligned}
\frac{d}{c_t^{BH}} &= \frac{F_q(A, Q_t^B, q_t^B)}{c_t^{BH}} + \\
&\beta \left\{ p_{t+1}^B \frac{F_Q(A, Q_{t+1}^B, q_{t+1}^B)}{c_{t+1}^{BH}} + p_{t+1}^H \frac{F_Q(A, Q_{t+1}^B, q_{t+1}^H)}{c_{t+1}^{HH}} + \phi^W \frac{\mu^W}{\mu^H} p_{t+1}^W \frac{F_Q(A, Q_{t+1}^B, q_{t+1}^W)}{c_{t+1}^{WW}} \right\}
\end{aligned} \tag{2}
$$

The marginal cost of land investment is equal to the sum of the marginal benefit in the present period (the first term on the right hand side) and the expected value of the marginal benefit in the next period (the second term on the right hand side). Equation (3) further implies the following:

(i) if $\mu^W = 0$, the widow inheritance policy ϕ^W does not affect land investment

(ii) if $\mu^W > 0$, a household facing $\phi^W = 0$ will choose lower investment and higher present consumption than a household facing $\phi^W = 1$

Point (i) states that the inheritance rule only affects investment if the wife has positive weight in household decision making. This may be the result of altruism on the part of the husband, or of efficient intrahousehold bargaining. Point (ii) states that as long as the wife has some weight in the planning problem, the household will undertake less investment, and hence land quality will be lower, if she loses access to the household land upon the death of the husband.

2.3 Changes in survival probability

Consider a decrease in survival probability due to the HIV epidemic. Suppose that this lowers the probability of survival in period $t+1$ of each spouse by a factor $\alpha < 1$, such that $\pi'^{j}_{t+1} = \alpha\pi^{j}_{t+1}$. The intertemporal condition then becomes:

$$\begin{aligned} \frac{d}{c_t^{BH}} &= \frac{F_q(A, Q_t^B, q_t^B)}{c_t^{BH}} + \alpha\beta\Bigg\{ \frac{\alpha\pi^H_{t+1}\pi^W_{t+1}}{\pi^H_t\pi^W_t}\frac{F_Q(A, Q^B_{t+1}, q^B_{t+1})}{c^{BH}_{t+1}} + \\ &\quad \frac{\pi^H_{t+1}(1-\alpha\pi^W_{t+1})}{\pi^H_t\pi^W_t}\frac{F_Q(A, Q^B_{t+1}, q^H_{t+1})}{c^{HH}_{t+1}} + \phi^W\frac{\mu^W}{\mu^H}\frac{(1-\alpha\pi^H_{t+1})\pi^W_{t+1}}{\pi^H_t\pi^W_t}\frac{F_Q(A, Q^B_{t+1}, q^W_{t+1})}{c^{WW}_{t+1}}\Bigg\} \end{aligned} \quad (3)$$

The higher mortality rate has two effects. First, it decreases the expected marginal utility of land quality in the following period, which lowers investment and increases consumption in period t (a discount rate effect). Second, the probability of widowhood unambiguously increases relative to the probability of the "both survive" state, which can further exacerbate the impact of the inheritance policy.[2]

2.4 Empirical framework

For the purposes of this study, the key predictions of the above model are captured by regressions of the following form:

$$q_{dsh} = \beta\, NoInheritance_{ds} + \gamma' X_{dsh} + \nu_d + \epsilon_{dsh} \quad (4)$$

where q_{dsh} is the land investment choice of household h in SEA s in district d, $NoInheritance_{ds}$ is a dummy variable that takes a value of 1 if widows do not inherit in the SEA, X is a vector of household and SEA controls, ν is a vector of district fixed effects to control for prices and fixed district characteristics, and ϵ_{dsh} is an error term clustered at the SEA level.

[2]The condition is $\frac{\alpha\pi^W_{t+1}(1-\alpha\pi^H_{t+1})/\pi^W_t\pi^H_t}{\alpha^2\pi^W_{t+1}\pi^H_{t+1}/\pi^W_t\pi^H_t} > \frac{\pi^W_{t+1}(1-\pi^H_{t+1})/\pi^W_t\pi^H_t}{\pi^W_{t+1}\pi^H_{t+1}/\pi^W_t\pi^H_t} \iff \alpha < 1$. Note that if $\pi^H_{t+1} > \frac{1}{1+\alpha}$, a condition that will be satisfied for many households, the raw probability of the widowhood state also increases.

The hypothesis that insecure tenure rights for widows reduces land investment takes the form $H_0 : \beta < 0$.

We also explore the link between inheritance norms, land investment and the probability of widowhood as proxied by district-level HIV rates. To this end we estimate regressions of the following form:

$$\begin{aligned} q_{dsh} &= \beta\, NoInheritance_{ds} + \delta_1 HIV_d + \delta_2 HIV_d^2 \\ &\quad +\delta_3\, NoInheritance_{ds} HIV_d + \delta_4\, NoInheritance_{ds} HIV_d^2 + \gamma' X_{dsh} + \nu_d + \epsilon_{dsh} \end{aligned} \tag{5}$$

where HIV_d is the district-level HIV rate, and all other variables are as above. By plotting linear combinations of $\hat{\beta} + \hat{\delta}_3 HIV + \hat{\delta}_4 HIV^2$ for counterfactual HIV rates HIV_d we can examine whether the disincentive effect of widow non-inheritance is greater in magnitude when the probability of widowhood is higher.

3 Data and setting

The data for this paper come from the 2008 wave of the Rural Income and Livelihoods Survey, undertaken by the Food Security Research Project of Michigan State University (MSU) and the Central Statistical Office (CSO) of Zambia. This is the third round of a panel survey conducted in 2001, 2004, and 2008, which build on a sequence of post harvest surveys from the 1990s. We use only the 2008 cross section because the survey of village headmen was conducted in 2008, so our key policy variable can be reliably matched to only this wave of the data. We also use district-level HIV rates for 2007 (Central Statistical Office, 2005).

The original 2001 sample was drawn in order to be nationally representative, and replacement households were randomly drawn in 2004 and 2008 in order to maintain representativeness. The 2008 wave contains data for 8,094 households: 4,570 panel households and 3,524 replacements. After dropping households with no agricultural activities, and a small number of additional households that are missing key variables, we have a data set of 7,770 households.

We limit our analysis to investment on plots governed by the customary system. This is not very restrictive: of the 27,134 plots in the data set, 94.5% (25,629) are described by households as owned, but without a title deed. These are primarily lands that were allocated to households by the village headman or by other family members. Also, for most specifications we focus on the 5,803 households that are led by a married couple, because the widow inheritance policy can only be expected to impact these households.

In 2008 a separate survey was conducted with 1,043 village chiefs ("headmen") in the study area. This survey covered a range of village characteristics, including norms regarding inheritance, distances to trading centers, business activities, access to government extension and input subsidization programs, trends in community well-being, and others. For this paper, the key question in the headmen survey is: "If a male head of household dies and there are only young children and a wife, who gets the right to the homestead and crop land?" The options are "Spouse (wife)", other family members such as "Wife's brother" or "Brothers of deceased", and "Goes back to the village for headman to re-allocate". We encode these responses by forming a widow non-inheritance variable that takes a value of 0 if the spouse inherits and 1 if the response is anything other than "Spouse (wife)". This widow non-inheritance variable is the key source of policy variation in the paper.

Each headman represents a village, so the widow tenure security variable is measured at the village level. Unfortunately, because of how the data were recorded it is not possible to match the household and headmen survey data at the village level.[3] However, we are able to match households to headmen at the standard enumeration area (SEA) level, one geographical level above the village (but still highly localized). On average, 3.3 headmen were surveyed in each SEA. We assign each household the modal response from all headmen interviewed in the SEA.[4]

Table 1 shows summary statistics for inheritance norms at the provincial level. Figure 3 maps the same data. The lack of correlation with agro-climatic zone or crop areas is clear: inheritance norms vary within every province of Zambia.

[3] In both surveys "village" is recorded as a text variable with no corresponding numeric code. Our attempts to match villages by text name were not successful, with less than 40% matched even after correcting for spelling variations.

[4] As a robustness check we construct an alternate version of the policy variable using the share of headmen in the SEA who report that widows do not inherit. This has no major effect on findings (see Section 4.4).

Table 1: Variation in survey coverage and inheritance norms, by province

Province	Number of SEAs	Number of households	Number of couples	Widow non-inheritance (%)
Central	37	745	561	33.3
Copperbelt	21	427	330	5.0
Eastern	72	1521	1153	37.4
Luapula	46	986	743	18.5
Lusaka	9	188	139	40.7
Northern	76	1525	1153	22.9
Northwestern	27	546	398	31.3
Southern	49	1017	789	42.2
Western	41	815	537	22.4
Overall	378	7770	5803	27.9

Notes: Percent widow non-inheritance calculated by first averaging responses across headmen within an SEA, then averaging across SEAs within a province. Response variable takes a value of 1 if widows inherit, and 0 otherwise.

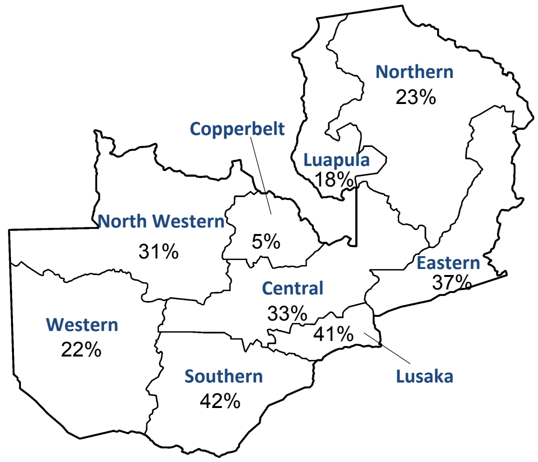


Figure 1: Percent of villages where widows do not inherit land
Source: Headmen Survey.

The key outcome variables in this paper are the farmer choices that measure investment in land. The three that we consider are the amount of inorganic fertilizer applied (kg), the share of land fallowed, and the share of cultivated land that is prepared using intensive tillage techniques. These are all of the major measures of land investment in the data – there is insufficient variation in tree crops, and no information on fencing, security measures, or other forms of investment.

Fallowing is an unambiguously multi-year investment, because fallow lands yield no return in the present period. Share fallow is defined as the proportion of land under the household's control that is described as "fallow" or "improved fallow" during the current cultivation period (of which "improved fallow" represents only a very small share). Fertilizer application and intensive tillage can have immediate returns by increasing yields in the present period, as well as long-run returns by maintaining soil nutrition and structure for future years. Total fertilizer application is defined as the sum of all fertilizer applied as either basal or top-dressing to cultivated plots. The share of intensive tillage is the percentage of cultivated land that is tilled using planting basins, ridges, or bunds. These techniques are designed to prevent erosion, absorb water, and improve yields. The most common alternative tillage techniques, accounting for over 85% of tillage that we term "non-intensive", are conventional hand hoeing and plowing.[5]

Table 2 shows summary statistics at the household level. Households are large, with nearly 6 members on average. 75% of households are headed by a married couple. 15% of households are headed by a widow, underscoring the importance of policies related to widowhood. The asset index is a standardized wealth measure formed from the first principal component

[5]See Ngoma, Mulenga and Jayne (2014) for an analysis of the use of conservation tillage methods in the same setting.

of a vector of assets and dwelling characteristics (Sahn and Stifel (2003)). Slightly less than half of households are self-described as matrilineal, i.e., tracing lineage through female ancestors and descendants. The mean HIV prevalence rate is 11.4%. Approximately a third of households live in a village where widows do not customarily inherit land.

In Table 3 we report household descriptive and agricultural statistics by inheritance regime, for couple-headed households only. Although there are a number of statistically significant differences between the two groups, most of the magnitudes are small enough to be of little economic interest. Households in non-inheritance areas are slightly larger and less educated, plant a higher share of maize, and live in communities with slightly higher HIV rates and greater access to government fertilizer subsidies. Importantly, households in the two groups are not statistically different in terms of average wealth, land owned, or number of plots. When relevant, we control for some or all of these differences in the regressions below. The "Female agriculture" binary variable is from a different data set, the *Ethnographic Atlas* of Murdock (1967). This variable takes a value of 1 if the tribe of the household head is traditionally associated with female participation in agriculture.[6] There is correlation in gender-related norms, as households in non-inheritance areas are less likely to be matrilineal. Finally, the unconditional mean levels of fallowing, fertilizer and intensive tillage - the key outcome variables in the data set - are all lower in the non-inheritance areas than in areas where widows can inherit. This is consistent with the central hypothesis of the paper and previews the results to follow.

[6]This variable is only available for two thirds of households.

Table 2: Household and community summary statistics, household level (2008)

	N	Mean	s.d.
Size of household	7770	5.93	2.98
Adult equivalents	7770	4.94	2.51
Head education (yrs)	7766	5.52	3.82
Couples (=1)	7770	0.75	0.43
Head is widowed (=1)	7770	0.15	0.36
Asset index value	7770	-0.03	0.82
Matrilineal household (=1)	7765	0.43	0.50
HIV prevalence (%)	7670	11.40	5.11
No inheritance (=1)	7770	0.34	0.47

Table 3: Household summary stats by inheritance regime, couples only

	Widow can inherit	Widow cannot inherit	Difference
<u>Household characteristics</u>			
Size of household	6.44	6.64	-0.20*
Adult equivalents	5.36	5.52	-0.16*
Head education (yrs)	6.23	5.88	0.35***
Asset index value	0.03	0.03	0.00
Matrilineal household (=1)	0.43	0.40	0.04**
HIV prevalence (%)	11.00	12.20	-1.20***
<u>Agricultural variables</u>			
Number of plots	3.76	3.73	0.04
Total land area (Ha)	3.86	4.36	-0.50
Share maize	0.39	0.45	-0.07***
Fertilizer subsidy available (=1)	0.63	0.71	-0.08***
Female agriculture (=1)	0.80	0.90	-0.10***
Total fertilizer applied (kgs)	174.15	151.38	22.77
Share fallow	0.12	0.09	0.02***
Intensive tillage (share)	0.34	0.29	0.05***
N	3825	1978	

Notes: Entries are mean values. *** p <0.01; ** p <0.05; * p <0.10.

4 Results

In this section we present regression results based on equations (4) and (5). We report results separately for three land investment decisions: fertilizer application, fallowing, and intensive tillage.

4.1 Fertilizer

Table 4 shows the main coefficient of interest from estimates of equation (4) with fertilizer application (kg) as the dependent variable. All regressions include district fixed effects and controls for landholdings, household size, and presence of a government fertilizer subsidy program in the SEA. Column 1 includes all farming households, and columns 2-5 show results for couple-headed households with various sets of controls. The key coefficient of interest is remarkably stable across specifications, highly statistically significant, and of significant economic magnitude. Farming households apply 62-91 fewer kilograms of fertilizer in SEAs where widows do not inherit, equivalent to 38-55% of the mean rate of fertilizer application for couple-headed households. The result is robust to the addition of controls for wealth (column 3), for wealth and tribe fixed effects (column 5), and for a dummy variable indicating a tribe traditionally associated with female participation in agriculture (column 4).

To test the predictions of equation (5) we estimate the same set of regressions with the addition of interactions between the district HIV rate and the inheritance regime. Here the HIV rate is a proxy for the household's uncertainty about the survival of the male head. The question is whether households in communities with higher rates of HIV are even less likely to invest in land when widows do not inherit than are households in communities with lower rates of HIV. We find strong evidence to this effect. Because it is difficult to interpret the combined results of the regression coefficients, coefficients are only reported in Appendix Table A2 and Figure 2 shows the combined effect on fertilizer application of increasing HIV prevalence. Figure 2 uses the coefficient estimates from column 5 of Table A2 and the delta method to calculate standard errors. The solid line in the lower panel shows the effect of the rising HIV rate on fertilizer usage in areas with no widow inheritance, relative to areas with widow inheritance. To aid interpretation, a kernel density approximation of the HIV distribution is shown in the upper panel. Fertilizer usage declines steadily through the first 70% of the HIV distribution, then effectively levels off over the relevant support. The magnitude of the effect is again substantial. The underlying regression includes controls for wealth, landholdings, district fixed effects, household size, and tribe effects, suggesting that this result is not driven by any significant omitted variable. Furthermore, the analysis is limited to couple-headed households, so that identification is from the perceived probability of a death rather than the actual loss of the household head.

Table 4: Fertilizer application and female inheritance, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	-62.47***	-81.01***	-64.68***	-90.78***	-63.75***
	(19.2)	(22.6)	(18.5)	(25.1)	(19.1)
Couples only	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
Female agriculture	No	No	No	Yes	No
Tribe fixed effects	No	No	No	No	Yes
Observations	7825	5843	5831	3866	5828
R-squared	0.25	0.25	0.32	0.33	0.33
Mean of dep. variable	141.18	165.76	166.05	177.50	166.03

Notes: Regressions restricted to household headed by a male and female member, except column 1. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

Figure 2: Relationship between HIV rates and fertilizer use

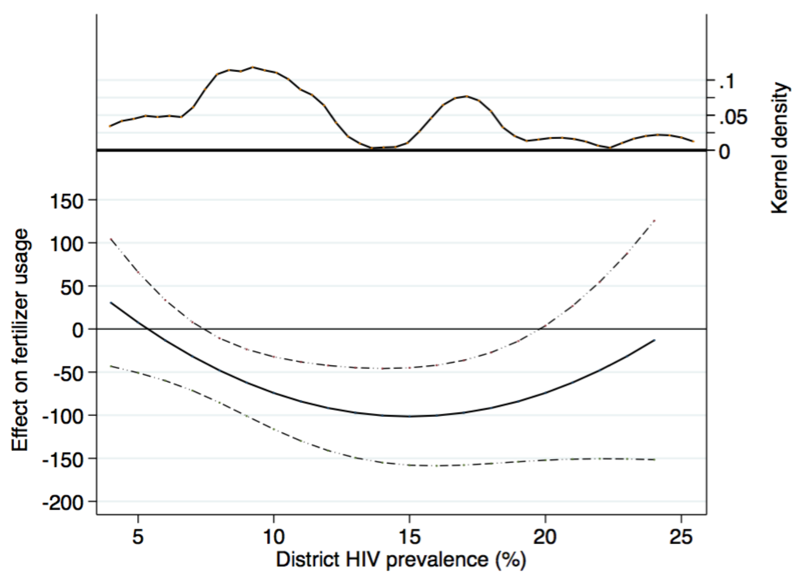


Table 5: Share of land fallowed and female inheritance, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	-0.012	-0.013*	-0.015**	-0.016*	-0.013*
	(0.007)	(0.007)	(0.007)	(0.010)	(0.007)
Couples only	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
Female agriculture	No	No	No	Yes	No
Tribe fixed effects	No	No	No	No	Yes
Observations	7389	5529	5518	3622	5515
R-squared	0.16	0.17	0.18	0.17	0.19
Mean of dep. variable	0.112	0.107	0.107	0.102	0.107

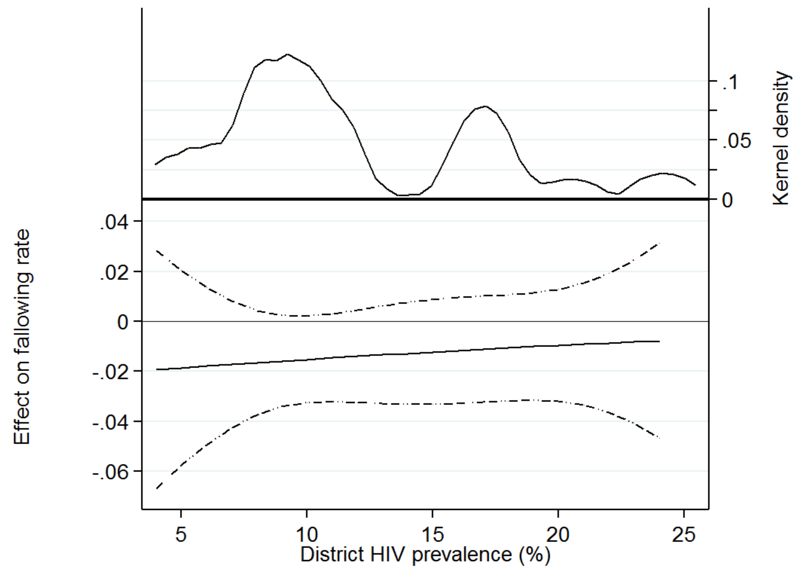
Notes: Dependent variable is share of land fallowed. Regressions restricted to household headed by a male and female member, except column 1. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

4.2 Fallowing

Table 5 shows the main coefficient of interest from estimates of equation 4 with the share of land fallowed as the dependent variable. As before, all regressions include district fixed effects and controls for landholdings, household size, and presence of a government fertilizer subsidy program in the SEA. The effect of non-inheritance is statistically significant at 5 or 10% in all regressions limited to couple-headed households (columns 2-5). The effect is again of substantial economic magnitude and stable across specifications. A policy of widow non-inheritance reduces fallowing rates by 0.014-0.02 percentage points, representing 13-19% of the mean fallowing rate. The result is robust to the various extended sets of controls in columns 2-5.

In Table A3 and Figure 3 we explore the interaction between the community HIV rate and the household fallowing share. Unlike with fertilizer application, we find no statistically significant heterogeneity in the effect of widow non-inheritance based on the HIV rate.

Figure 3: Relationship between HIV rates and fallowing rate



4.3 Intensive Tillage

Table 6 shows results using intensive tillage as the dependent variable. We limit all tillage regressions to couple-headed households, and all regressions include controls for landholdings, household size, and presence of a government fertilizer subsidy program in the SEA. Additional controls are cumulatively added, moving left from column 1 to column 5, and beginning with cattle ownership which is a potentially important complement to intensive tillage practices. The signs of the estimated inheritance policy coefficients are consistent with the fertilizer and fallowing results, in that investment is lower in areas where widows do not inherit. Conditional intensive tillage rates are lower by 0.024-0.056 percentage points, or 7.5-17.5%, in non-inheritance communities. The key coefficient is statistically significant at 10% in all specifications other than the last, which includes both district effects and controls for tribe of the household head. Overall, the effect of widow non-inheritance on intensive tillage practices is slightly weaker in magnitude and statistical significance than on fallowing rates or fertilizer use, but remains important and in the hypothesized direction.

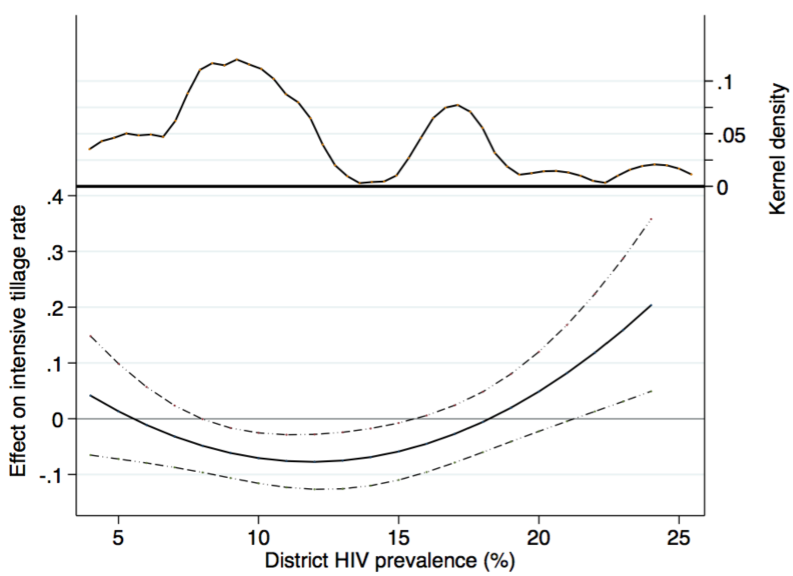
In Table A4 we report tillage results from regressions that include interactions between the HIV rate and the non-inheritance policy variable, and in Figure 4 we plot the effect of increasing HIV rates on intensive tillage in areas with a policy of widow non-inheritance (relative to areas where widows inherit). Although the average effect is statistically significant across the HIV levels that constitute the majority of the support, the relationship is not as clear as it was in the case of fertilizer. The disincentive to invest in land is increasing in the HIV rate at lower levels and increasing at higher levels, though always negative on net over the majority of the support.

Table 6: Share of land under intensive tillage and female inheritance, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	-0.056*	-0.052*	-0.052*	-0.035*	-0.024
	(0.031)	(0.030)	(0.030)	(0.021)	(0.019)
Cattle owned	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
District controls	No	No	No	Yes	Yes
Tribe controls	No	No	No	No	Yes
Observations	5476	5475	5464	5464	5461
R-squared	0.02	0.04	0.04	0.37	0.38
Mean of dep. variable	0.32	0.32	0.32	0.32	0.32

Notes: Regressions restricted to households headed by a couple. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. Intensive tillage defined as construction of planting basins, bunding, mounding, and ridging. *** p <0.01; ** p <0.05; * p <0.10

Figure 4: Relationship between HIV rates and use of intensive tillage



So far in this section we have examined the effect of widow non-inheritance on the three land investment variables in the data. Despite some variation in the magnitude of the impacts, the results present a consistent story: couple-headed household invest less in their land in areas where widows do not inherit. What might explain the variation in the magnitude of the effects across the three types of investment? A reasonable hypothesis is that the full costs of each type of investment vary substantially, but in a manner that we cannot measure and that lies beyond the scope of this paper.

4.4 Robustness

We have implemented a number of robustness checks to confirm the strength of our central findings. Two of these checks involve variations in variable definitions. First, because multiple headmen were interview in each SEA, an alternative way to specify the policy variable is to use the share of headmen in the SEA who report that non-inheritance by widows (this changes the variable definition in only a minority of SEAs). Defining the policy variable this way does not change the central results: the signs of the main coefficients are unchanged in all regressions, the fertilizer and tillage results are somewhat stronger in terms of magnitude and statistical significance, and the fallowing results are slightly weaker. Second, we have also varied the definition of intensive tillage, to ensure that our findings are not sensitive to the borderline decisions we made in categorizing certain tillage techniques as long-run / intensive. If we include "mounding" as an intensive tillage technique, or exclude "ridging", we can slightly change the pattern of statistically significant results. But there is no clear ordering to the changes, and the sign of the policy variable is always negative.

A second set of robustness checks involves varying our chosen estimator. To this end we have used Tobit regression to deal with truncation at zero in the fertilizer models, and the Papke-Wooldridge fractional response estimator (Papke and Wooldridge (1996)) for the models with fallowing share or intensive tillage share as the dependent variable. These models uniformly support the conclusions of the linear models, and in most cases the average marginal effect of non-inheritance is greater than that reported above. This is especially true of the Tobit results which show a disincentive effect nearly double that of the linear model – not surprising since the interpretation of the Tobit result is restricted to those households that used fertilizer in the first place.

5 Discussion

The empirical results of the previous section show a consistently negative association between land investment and widow tenure security. This relationship is economically and statistically significant for the large majority of productivity measures considered in our study. In this section we delve deeper into these results by considering the possibility of policy endogeneity, placebo tests to better understand the mechanism, the welfare implications of the findings, and the robustness of the main specifications to a variety of alternatives.

5.1 Concerns about policy endogeneity

We have assumed so far that inheritance norms are exogenous to land investment. How confident can we be in that assumption? It is difficult to imagine inheritance norms reversing course dramatically because of localized, village-level changes in land productivity. Widows' rights are an expression of community values that likely supersede patterns of fertilizer application, fallowing, or tillage. Thus we are skeptical that land distribution policies related to widowhood and gender rights would react to the investment variables that we study.

Furthermore, if inheritance norms *have* changed because of land investments, then the natural concern would be that widows have lost inheritance rights in areas where land investment and land quality are particularly high. This would create a positive correlation between non-inheritance and land investment – but that is the opposite of what we find. For these two reasons we do not consider reverse causality to be likely in this context.

However, even with our extensive controls it remains possible that some unobserved factors affect both local land policies and the investment choices of farmers. To account for this possibility we estimate IV regressions using as instruments SEA-level tribal representation shares and dummy variables for other gender norms not directly related to agriculture. Details and results are in Appendix Section A. With the caveat that IV regression is not efficient when there is no endogoneity, the IV findings are broadly supportive of the OLS results.

5.2 Placebo tests to isolate the mechanism

How sure can we be that the effect we are measuring relates specifically to widow non-inheritance, and not to some generalized differences in the security of property rights across communities? If the effect we document were due to the latter rather than to the mechanism proposed, it would have a negative impact on the land investment choices of all types of households, not just those headed by couples. To test this, we conduct placebo tests of the widow non-inheritance variable on the land investment choices of households headed by a single man or woman. These households were excluded from the results shown above.

Table 7 shows the results. The specifications match those from column 5 of Tables 4, 5, and 6. For both fertilizer and fallowing the estimated effect is only a fraction of the analogous effect for couple-headed households, and is not statistically different from zero. The effect on long-run tillage is similar in magnitude to that for couple-headed households, but again it is not statistically different from zero. These tests are not perfect, because the placebo groups

Table 7: Placebo tests, non-couple headed households, OLS

	Fertilizer	Fallowing	Tillage
No inheritance (=1)	-5.983	-0.003	-0.023
	(12.350)	(0.012)	(0.023)
Cattle owned	No	No	Yes
Asset index	Yes	Yes	Yes
Tribe controls	Yes	Yes	Yes
Observations	1978	1856	1819
R-squared	0.48	0.25	0.43
Mean of dep. variable	68.82	0.13	0.31

Notes: Regressions restricted to households not headed by a couple. All regressions contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

include a substantial number of widows who might be impacted by other policies related to widowhood. But if anything, we would expect such policies to co-move with the widow non-inheritance policy, so that the expected direction of bias would be to exaggerate rather than attenuate the effects in Table 7. Taken collectively we interpret Table 7 as strong evidence that the effects we measure are indeed functioning through a perceived lack of future tenure security on the part of couple-headed households.

5.3 Implications for welfare

If widow non-inheritance reduces investment in land quality, is there a corresponding effect on output? A strength of the empirical approach in the previous section is that it deals exclusively with input demand equations, not with highly stochastic outcomes such as revenues or profits. Nevertheless, soil degradation threatens food security largely by reducing land productivity, so it would reasonable to hypothesize that average revenue may be lower in areas with lower land investment. To test this proposition we test for effects of widow non-inheritance on agricultural revenues at the household level. Table 8 shows the results of a series of household level regressions similar to those from the previous section, with the log of total agricultural revenue as the dependent variable. There is no significant relationship between widow non-inheritance and agricultural earnings. While it remains possible that *profits* are lower in non-inheritance areas – something we cannot test because we cannot properly measure farm costs in these data – total revenues are unaffected.

These findings cannot be interpreted as a direct measure of a policy impact in the same manner as the core results for land investment, because we know from above that input choices are at least partly endogenous to widow inheritance. Also, cross-sectional agricul-

Table 8: Log of total agricultural revenue and female inheritance, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	-0.065	-0.094*	-0.062	-0.047	-0.054
	(0.055)	(0.056)	(0.053)	(0.063)	(0.053)
Couples only	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
Female agriculture	No	No	No	Yes	No
Tribe fixed effects	No	No	No	No	Yes
Observations	6902	5231	5220	3496	5218
R-squared	0.40	0.42	0.46	0.47	0.47
Mean of dep. variable	0.105	0.101	0.101	0.098	0.101

Notes: Regressions restricted to household headed by a male and female member, except column 1. All regressions contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** $p < 0.01$; ** $p < 0.05$; * $p < 0.10$

tural productivity regressions must always be interpreted cautiously because of substantial unobserved spatial variation in weather and agro-climatic factors. However, a reasonable interpretation of these results may be that farmers in non-inheritance areas make adjustments that compensate for lower land quality, possibly in a manner that raises costs. This is consistent with other evidence on agriculture in Africa. When farmers are constrained on multiple dimensions because of excessive uninsured risk, input market failures, or patchy credit markets, the relaxation or imposition of a single constraint may not have detectable effects (Dillon and Barrett (2014); Karlan et al. (2014)). We know from the main results in Section 4 that widow non-inheritance contributes to low land investment and thereby soil degradation, so that strengthening of tenure security would be an important component of any package of reforms intended to increase productivity in African agriculture.

6 Concluding remarks

In this paper we examined the connection between the security of women's land inheritance rights and investments in land productivity in rural Zambia. We presented a simple, dynamic model of land investment that highlighted the link between the widow inheritance policy and the place of the wife in the household planning problem. We then tested whether the threat of land expropriation upon widowhood, which is a driver of land ownership transfer in the same setting, deters households from fallowing, applying fertilizer, and employing labor-intensive tillage techniques even while the male head of the household is alive. We exploited variation in tenure security driven by village customary laws that govern the inheritance of land after the death of a head of household, which we observe in detailed survey data from chiefs and headmen. Controlling for a large number of factors, including geographic location, household composition, and tribe, we found consistent evidence of reduced land investment by married couples in villages where widows are less likely to inherit land. For some investment measures, relationship is strongest in areas with higher rates of HIV mortality. These findings suggest that concerns over prospective loss of land by the wives crowds out investment in land productivity by the whole household.

A Instrumental variables

In looking for policy instruments we considered SEA-level variables that relate to gender and women's empowerment but that are not directly related to land use. The best performing instrument is a dummy variable from the headman survey that takes a value of 1 if the community is virilocal, i.e., if upon marriage women usually move into their husbands' households. Approximately 75% of couple-headed households live in virilocal communities. Virilocality is generally a strong predictor of widow non-inheritance and is included in all IV regressions. In some specifications we also include the SEA-level percentage of households that report matrilineal family lineage, as calculated from the household survey. The mean of this variable among couple-headed households is 44%. Finally, to capture broader attitudes toward gender that are correlated with ethnicity we also use in some IV specifications the share of respondents in each SEA from different tribes.

One might be concerned that tribe controls directly affect land investment through channels other than gender norms, most notably location and agro-ecology. In this regard it is important that tribes do not perfectly co-move with geography in Zambia – the average SEA has 4.1 different tribes in the data – and all regressions include district fixed effects, so that identification is based on highly localized variation in tribe shares. Nevertheless, to minimize the over-identification challenges from having a very large set of tribal shares as instruments we include only tribes with an average share that surpasses a minimum threshold.

The main IV results are shown in Table A1. The signs of the coefficient estimates are uniformly in line with the OLS results, in that land investment is always decreasing in widow non-inheritance. In the case of fertilizer, this result is only statistically significant when we estimate a Tobit IV to account for the large number of households that do not use any fertilizer. For fallowing the instrumented policy variable is highly statistically significant and of larger magnitude than the OLS results, but the instruments only pass the over-identification test if we restrict the tribal shares to the largest tribes. In the case of intensive tillage the estimated coefficient is again of significant magnitude and is statistically significant if we use the tribal share variables as instruments, though in this case the instruments fail over-identification. We have been unable to find other plausible instruments that pass the over-identification test for intensive tillage.

Taken together the IV results are broadly supportive of the core OLS results: weak inheritance rights for widows are a deterrent to land investment. That we are able to find plausible and statistically significant instruments despite our belief that the OLS results are not biased is a testament to the strength of the disincentive effect.

Table A1: Instrumental variables results

	Fertilizer		Fallowing		Tillage	
	2SLS	Tobit	2SLS	2SLS	2SLS	2SLS
	(1)	(2)	(3)	(4)	(5)	(6)
No inheritance (=1)	-217.09	-261.04*	-0.09***	-0.07**	-0.29	-0.54***
	(376.82)	(149.82)	(0.03)	(0.03)	(0.44)	(0.17)
Instrument set	A	B	B	C	A	C
Observations	5831	5831	5518	5518	5465	5465
R-squared	0.30		0.15	0.17	0.31	0.14
First stage F-stat	0.63		1.84	1.64	0.65	1.66
Over ID (p-val)	0.20		0.02	0.25	0.00	0.00

Notes: Instrument set A includes an SEA-level dummy variable for virilocality and SEA-level matrilineality rate. Instrument set B includes the SEA-level virilocality dummy and SEA-level tribal membership percentages for all tribes with at least 1% average population share. Instrument set C includes the SEA-level virilocality dummy and SEA-level tribal membership percentages for all tribes with at least 3% average population share. Regressions restricted to household headed by a male and female member. All regression contain district fixed effects, controls for a 4th-degree polynomial in landholding size, household size (adult equivalent), a household wealth index, and presence of fertilizer subsidy program in the sampling unit. Robust standard errors in parentheses. *** p <0.01; ** p <0.05; * p <0.10

B Appendix Tables

Table A2: Fertilizer application, female inheritance, and HIV, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	180.82**	185.24**	150.67*	60.49	143.87*
	(77.3)	(93.1)	(83.9)	(96.4)	(83.3)
HIV rate	179.56***	136.16***	94.44***	112.95***	55.66**
	(29.2)	(28.1)	(27.3)	(34.1)	(23.1)
No inher * HIV rate	-37.18***	-40.70**	-33.00**	-17.85	-32.73**
	(13.2)	(16.2)	(14.8)	(19.4)	(14.5)
HIV rate sq.	-5.77***	-4.62***	-3.36***	-3.93***	-2.16***
	(0.9)	(0.9)	(0.8)	(1.1)	(0.7)
No inher * HIV rate sq.	1.19**	1.31**	1.07*	0.42	1.09**
	(0.5)	(0.6)	(0.6)	(0.8)	(0.5)
Couples only	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
Female agriculture	No	No	No	Yes	No
Tribe fixed effects	No	No	No	No	Yes
Observations	7725	5777	5765	3808	5762
R-squared	0.26	0.25	0.32	0.33	0.33
Mean of dep. variable	142.35	167.06	167.35	179.44	167.33

Notes: Regressions restricted to household headed by a male and female member, except column 1. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

Table A3: Share of land fallowed, female inheritance, and HIV, OLS

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	-0.035	-0.022	-0.019	0.040	-0.008
	(0.043)	(0.045)	(0.045)	(0.061)	(0.046)
HIV rate	-0.034***	-0.043***	-0.037***	0.005	-0.032
	(0.008)	(0.009)	(0.010)	(0.012)	(0.023)
No inher * HIV rate	0.003	0.001	-0.000	-0.011	-0.001
	(0.006)	(0.007)	(0.007)	(0.009)	(0.007)
HIV rate sq.	0.001***	0.002***	0.001***	0.000	0.001*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)
No inher * HIV rate sq.	-0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Couples only	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
Female agriculture	No	No	No	Yes	No
Tribe fixed effects	No	No	No	No	Yes
Observations	7301	5470	5459	3571	5456
R-squared	0.16	0.17	0.18	0.17	0.19
Mean of dep. variable	0.11	0.11	0.11	0.10	0.11

Notes: Regressions restricted to household headed by a male and female member, except column 1. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

Table A4: Share of land under intensive tillage, female inheritance, and HIV

	(1)	(2)	(3)	(4)	(5)
No inheritance (=1)	0.091	0.114	0.118	0.179	0.193*
	(0.177)	(0.173)	(0.173)	(0.119)	(0.115)
HIV rate	-0.072***	-0.069***	-0.068***	0.093	0.176
	(0.014)	(0.014)	(0.014)	(0.115)	(0.126)
No inher * HIV rate	-0.035	-0.038	-0.038	-0.046**	-0.045**
	(0.028)	(0.027)	(0.027)	(0.019)	(0.019)
HIV rate sq.	0.002***	0.002***	0.002***	-0.004	-0.007
	(0.000)	(0.000)	(0.000)	(0.005)	(0.005)
No inher * HIV rate sq.	0.002*	0.002*	0.002*	0.002***	0.002***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Cattle owned	No	Yes	Yes	Yes	Yes
Asset index	No	No	Yes	Yes	Yes
District controls	No	No	No	Yes	Yes
Tribe controls	No	No	No	No	Yes
Observations	5420	5419	5408	5408	5405
R-squared	0.09	0.10	0.10	0.37	0.39
Mean of dep. variable	0.32	0.32	0.32	0.32	0.32

Notes: Regressions restricted to household headed by a male and female member, except column 1. All regression contain district fixed effects, control for the a 4th-degree polynomial in landholding size, household size (adult equivalent), and presence of fertilizer subsidy program in the sampling unit. Standard errors in parentheses, clustered at the SEA level. *** p <0.01; ** p <0.05; * p <0.10

References

Ainsworth, Martha, Kathleen Beegle, and Godlike Koda. 2005. "The Impact of Adult Mortality and Parental Deaths on Primary Schooling in North-Western Tanzania." *The Journal of Development Studies*, 41(3).

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein. 2014. "Environmental and gender impacts of land tenure regularization in Africa: Pilot evidence from Rwanda." *Journal of Development Economics*, 110: 262–275.

Allendorf, Keera. 2007. "Do Women's Land Rights Promote Empowerment and Child Health in Nepal?" *World Development*, 35(11): 1975–1988.

Amsalu, Aklilu, and Jan De Graaff. 2007. "Determinants of adoption and continued use of stone terraces for soil and water conservation in an Ethiopian highland watershed." *Ecological economics*, 61(2): 294–302.

Baranov, Victoria, and Hans-Peter Kohler. 2014. "The Impact of AIDS Treatment on Savings and Human Capital Investment in Malawi."

Baranov, Victoria, Daniel Bennett, and Hans-Peter Kholer. 2015. "The Indirect Impact of Antiretroviral Therapy: Mortality Risk, Mental Health, and HIV-Negative Labor Supply."

Benin, Samuel. 2006. "Policies and programs affecting land management practices, input use and productivity in the highlands of Amhara region, Ethiopia." *Strategies for sustainable land management in the East African Highlands*, 217–256.

Besley, Timothy. 1995. "Property Rights and Investment Incentives: Theory and Evidence from Ghana." *Journal of Political Economy*, 103(5): 903.

Brasselle, Anne Sophie, Frédéric Gaspart, and Jean Philippe Platteau. 2002. "Land tenure security and investment incentives: Puzzling evidence from Burkina Faso." *Journal of Development Economics*, 67(2): 373–418.

Central Statistical Office. 2005. "Zambia - HIV/AIDS Epidemiological Projections 1985-2010." Republic of Zambia.

Chapoto, Antony, T. S. Jayne, and Nicole M. Mason. 2011. "Widows' land security in the era of HIV/AIDS: panel survey evidence from Zambia." *Economic development and cultural change*, 59(3): 511–547.

Deininger, Klaus. 2003. "Land policies for growth and poverty reduction." World Bank.

Deininger, Klaus, and Songqing Jin. 2006. "Tenure security and land-related investment: Evidence from Ethiopia." *European Economic Review*, 50(5): 1245–1277.

Delavande, Adeline, and Hans-Peter Kohler. 2009. "Subjective expectations in the context of HIV/AIDS in Malawi." *Demographic Research*, 20: 817–875.

Dillon, Brian, and Christopher B. Barrett. 2014. "Agricultural factor markets in Sub-Saharan Africa : an updated view with formal tests for market failure." *World Bank Policy Research Working Paper*, WPS 7117.

Doepke, Matthias, Michèle Tertilt, and Alessandra Voena. 2011. "The Economics and Politics of Women's Rights."

Doss, Cheryl, Chiara Kovarik, Amber Peterman, Agnes Quisumbing, and Mara van den Bold. 2015. "Gender inequalities in ownership and control of land in Africa: myth and reality." *Agricultural Economics*, 46(3): 403–434.

Duflo, Esther. 2012. "Women, Empowerment, and Economic Development." *Journal of Economic Literature*, 50(4): 1051–1079.

Feder, Gershon, and David Feeny. 1991. "Land Tenure and Property Rights : Theory and Implications for Development Policy." *The World Bank Economic Review*, 5(1): 135–153.

Fenske, James. 2011. "Land tenure and investment incentives: Evidence from West Africa." *Journal of Development Economics*, 95(2): 137–156.

Fernández, Raquel. 2013. "Women's rights and development." *Journal of Economic Growth*, 19(1): 37–80.

Gavian, Sarah, and Marcel Fafchamps. 1996. "Land Tenure and Allocative Efficiency in Niger." *American Journal of Agricultural Economics*, 78(2): 460.

Goldstein, Markus, and Christopher Udry. 2008. "The Profits of Power: Land Rights and Agricultural Investment in Ghana." *Journal of Political Economy*, 116(6): 981–1022.

Graff Zivin, Joshua, Harsha Thirumurthy, and Markus Goldstein. 2009. "AIDS treatment and intrahousehold resource allocation: Children's nutrition and schooling in Kenya." *Journal of Public Economics*, 93(7-8): 1008–1015.

Karlan, Dean, Robert Osei, Isaac Osei-Akoto, and Christopher Udry. 2014. "Agricultural Decisions after Relaxing Credit and Risk Constraints." *Quarterly Journal of Economics*, 129(2): 597–652.

Kumar, Neha, and Agnes R. Quisumbing. 2012. "Gendered Impacts of the 2007-08 Food Price Crisis: Evidence Using Panel Data from Rural Ethiopia." *Food Policy*, 38: 11–22.

Leonard, R, and C Toulmin. 2000. "Women and land tenure: a review of the issues and challenges in Africa." *IIED Drylands Programme.*

Ngoma, Hambulo, Brian P. Mulenga, and T.S. Jayne. 2014. "What Explains Minimal Usage of Minimum Tillage Practices in Zambia? Evidence from District-Representative Data." *Indaba Agricultural Policy Research Institute (IAPRI) Working Papers*, 82.

Otsuka, Keijiro, and Frank M Place. 2001. *Land tenure and natural resource management: A comparative study of agrarian communities in Asia and Africa.* Intl Food Policy Res Inst.

Papke, Leslie E, and Jeffrey M Wooldridge. 1996. "Econometric Methods for Fractional Response Variables with an Application to 401 (K) Plan Participation Rates." *Journal of Applied Econometrics*, 11: 619–632.

Pender, John, Ephraim Nkonya, Pamela Jagger, Dick Sserunkuuma, and Henry Ssali. 2004. "Strategies to increase agricultural productivity and reduce land degradation: evidence from Uganda." *Agricultural economics*, 31(2): 181–195.

Place, Frank. 2009. "Land Tenure and Agricultural Productivity in Africa: A Comparative Analysis of the Economics Literature and Recent Policy Strategies and Reforms." *World Development*, 37(8): 1326–1336.

Place, Frank, and Keijiro Otsuka. 2002. "Land tenure systems and their impacts on agricultural investments and productivity in Uganda." *Journal of Development Studies*, 38(6): 105–128.

Place, Frank, and Peter Hazell. 1993. "Productivity effects of indigenous land tenure systems in sub-Saharan Africa." *American journal of agricultural economics*, 75(1): 10–19.

Platteau, Jean Philippe. 1995. "Reforming land rights in Sub-Saharan Africa: Issues of efficiency and equity." *UNRISD Discussion Paper*, 60.

Sahn, David E., and David Stifel. 2003. "Exploring Alternative Measures of Welfare in the Absence of Expenditure Data." *Review of Income and Wealth*, 49(4): 463–489.

Sikor, Thomas, and Daniel Müller. 2009. "The Limits of State-Led Land Reform: An Introduction." *World Development*, 37(8): 1307–1316.

Thornton, Rebecca L. 2012. "HIV testing, subjective beliefs and economic behavior." *Journal of development economics*, 99(2): 300–313.

Ubink, Janine M, and Julian F Quan. 2008. "How to combine tradition and modernity? Regulating customary land management in Ghana." *Land Use Policy*, 25(2): 198–213.

Udry, Christopher. 1996. "Gender, Agricultural Production, and the Theory of the Household." *Journal of Political Economy*, 104(5): 1010.

Whitehead, Ann, and Dzodzi Tsikata. 2003. "Policy Discourses on Women's Land Rights in Sub-Saharan Africa: The Implications of the Re-turn to the Customary." *Journal of Agrarian Change*, 3(1-2): 67–112.

Yngstrom, Ingrid. 2002. "Women, Wives and Land Rights in Africa: Situating Gender Beyond the Household in the Debate Over Land Policy and Changing Tenure Systems." *Oxford Development Studies*, 30(1): 21–40.