Conservation Farming in Zambia: Understanding the Impact of Property Rights on Adoption

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In partial fulfillment of the requirements for the degree of

Master of Science in Economics

Tufts University

May 2012

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Abstract:

According to the Food and Agriculture Organization of the United Nations, agriculture accounts for about 72% of employment in Zambia, making agricultural production techniques an issue of great economic importance to the country. Unfortunately, soil quality has deteriorated due to historic use of the plough and burned crop residues. As a result, a large percentage of Zambian farmers currently struggle to produce enough maize to maintain subsistence. Conservation agriculture, or zero till farming, has become an important focus for the Zambian farming industry, as farmers hope to improve their soil quality and increase yields by using an uncomplicated technology that has been around for over 50 years.

Using data collected on farmers over the years 2007-2010, this paper models the adoption decision of conservation farming and examines patterns and characteristics of adopters versus non-adopters. Also, implementing an instrumental variables approach to induce exogenous variation in property rights, the empirical results show that having a title deed increases the probability of adoption for the average household from between .55 and .66 percentage points. While these estimates only provide insight into households induced to obtain property rights by the lower costs of being close to the district capital, they are an important initial examination of conservation farming adoption in Zambia.

Acknowledgments:

I would like to thank the Conservation Farming Unit in Zambia for allowing me to use their data they collected on farm households. I especially want to thank Peter, Sinya, Gibson, Dutch, Collins and the rest of the staff at CFU for providing me guidance on Zambia and conservation farming. I also want to thank my thesis committee, Jeffrey Zabel, Kelsey Jack and David Garman for their support and guidance. Finally, I want to thank Monica Harber for all of her support.

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1. Introduction

1.1 Conservation Farming

Modern zero-till farming was a technique developed after the great Dust Bowl in the United States during the 1930's. Edward Faulkner wrote a revolutionary book that challenged the use of the plough, an agricultural instrument that has been used for centuries, and proposed zero-till, a more sustainable type of farming.[1] This agricultural technique, or technology, however, did not truly become popular until products such as fertilizer and herbicides developed after the Second World War. These new farming materials made zero-till farming more productive and farmers began to adopt these techniques, especially in the United States and Brazil.[2]

A large portion of farmers in Africa, and in particular farmers in Zambia, did not adopt zero-till techniques, but rather continued to use the plough and degraded the soil to the point that large portions of land are no longer arable (the word arable actually comes from the Latin word for "to plough"). The Zambian government has become aware of the fact that the historic farming techniques used by farmers in Zambia are not sustainable and they have been working with the Conservation Farming Unit (CFU), a Non-Governmental Organization (NGO), since 1999 to introduce a set of soil conservation practices called conservation farming, which includes zero-till techniques, to farmers all over the country. Similar NGOs and programs have been introduced in a number of other African countries including Tanzania, Senegal, and Malawi.

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[1] Faulkner, Edward H. *Plowmans Folly*. University of Oklahoma Press, 2013.
[2] Derpsch R., Historical review of no-tillage cultivation on crops, JIRCAS working report (2000) 1–18.

1.2 Motivation

During the summer of 2011, I was tasked with producing a report for CFU to help them reorganize their monitoring and evaluation strategy moving forward into the next step of the Conservation Agriculture Program (CAP II). The project sparked my interest in conservation farming and produced a number of questions related to the adoption of zero till techniques in Zambia.

CFU has been successful over the past 25 years in introducing conservation agriculture to over one hundred thousand farmers. They have accomplished their initial goal of informing farmers of the advantages of zero till techniques as opposed to the use of a plough, but non-conservation techniques are still being used on the majority of fields.[3] In order to help CFU better understand the adoption decision, this paper will use a household technology adoption model to analyze household characteristic patterns in the adoption of conservation farming in Zambia. Using data collected by CFU for the harvest and preparation seasons between 2007 and 2010, as well as latitude and longitude data for farms and district capitals, the empirical analysis will examine the relationships between farm characteristics and adoption. Furthermore, an estimate of the casual impact of property rights on the household adoption decision using distance as an instrumental variable will be presented. This estimate of the impact of property rights will provide CFU and policy makers with a better understanding of how conservation farming adoption would change as a result of land reforms that increase tenure security.

[3] Haggblade and Tembo (2003a).

1.3 Property Rights in Zambia

Property rights in Zambia have historically been connected to customary rules and laws. Under customary land rules, each village head/chief makes decisions with regards to property disputes. Prior to 1995, around 95% of all land in Zambia was still under customary title. The Zambian government, however, passed a land reform bill in 1995 (1995 Land Act), which allowed the conversion of customary land into state land with private leaseholds. Since the bill's enactment, more than 10% of land held under customary tenure has been converted to private land through the Ministry of Lands in Zambia. This conversion of land has led to a number of benefits in certain regions, including increased access to credit, as well as improved infrastructure and social services. Privatizing of land also has its disadvantages, as some large scale farmers have obtained land that was traditionally a common pooled resource, resulting in some small scale farmers losing access to water and/or forest products.[4]

While land privatization has varying direct costs and benefits for different stakeholders, the majority of farmers in Zambia are subsistence farmers that may not be able to, or willing to, bear the cost of obtaining property rights. These costs include transportation to the capital as well as fees associated with completing the necessary paperwork required by the Ministry of Lands. Furthermore, households that have strong family ties or connections to land and communities may feel that land security is not an issue and therefore they would not benefit from the conversion to formal property rights. However, households that have migrated or are headed by a female

[4] USAID (2010).

would greatly benefit from private property rights, because the customary system does not provide them with enough land security. Therefore, the development of institutions that can implement low-cost methods for the allocation of land rights, as well as land conflict resolution, is imperative for the success of land titling in Zambia. Overall, Africa as a whole has been moving towards strengthening land rights in order to increase productivity and security (African Union 2009), but empirical studies of the impacts of the extension of property rights in Zambia are necessary to understand the effects within Zambia's unique political and cultural history.

2. Literature Review

2.1 Conservation Farming Adoption

There have been an extensive number of published articles related to farming technology adoption, as well as conservation farming. Haggablade and Tembo have produced a number of articles that examined the benefits of conservation farming in Zambia for small scale cotton farmers. They found that yields significantly increase when conservation techniques are used compared to traditional tilling, but that adoption is costly in the first few years specifically because of the increased amount of labor needed for weeding (Haggblade and Tembo 2003a). The same authors also find that the benefits of using conservation techniques, specifically increased yields. vary across regions and occur gradually over time (Haggblade and Tembo 2003b). These variations may be one possible reason why farmers are unwilling to adopt conservation techniques on their land. Ashraf, Jack and Reed (2010) also analyzed data from Zambia gathered by CFU that contained information on CFU farm coordinators and contact farmers and found that there seemed to be no correlation between education, adoption levels and purchases of subsidized CF inputs, while age, gender and peer effects were correlated with adoption. This paper will reexamine these relationships using a random sample of all CFU farms, not just farm coordinators and contact farmers.

Another important area of research that will provide some insight into the analysis in this paper is the impact of property rights on the adoption of conservation farming. The literature on this topic is mixed. Neef (2001) found that increasing land security did not lead to increases in conservation farming. Pieri et. al. (2002) suggest that increased land security provides the incentive for farmers to invest in conservation techniques. Using an instrumental variables approach allows for the identification of causal effects of land title on adoption to compare the case of Zambia and conservation farming to the previous literature.

Knowler and Bradshaw (2007) reviewed and synthesized a large portion of the empirical studies of conservation agriculture adoption and other farming techniques globally. Their findings show that only a few key variables impacted the adoption decision over all studies and that once they controlled for background factors, such as location and model specification, that there were not any universal variables that effectively predicted adoption. They concluded that the promotion of conservation agriculture must be examined on a case by case basis as previous studies had measured adoption and control variables in different ways. This paper hopes to build on the existing literature by looking within the context of Zambia as well as taking advantage of an extensive dataset that has yet to be closely analyzed. Table 1 below is taken directly from Knowler and Bradshaw (2007) and summarizes the methods and results of the existing literature on conservation farming adoption.

Table 1.

Details of the 31 technology analyses from 23 studies of conservation agriculture adoption reviewed

Study	Country	Conservation Agriculture Technology	Study Details		
			Sample Size	Method of Analysis	Goodness of Fit
Okoye (1998)	Nigeria	Soil Erosion Control	125	OLS	R^2=0.125
Clay et al. (1998)	Rwanda	Organic Inputs	1240	Random Effects GLS	R^2=0.35
Westra and Olsen (1997)	US	Conservation Tillage	585	Logit	LR=234.9
Rahm and Huffman (1984)	US	Conservation Tillage	869	Probit	χ^2=166.8
Nowak (1987)	US	Conservation Tillage	89	Stepwise Regression	Adj. R^2=0.33
Agbamu (1995)	Nigeria	Conservation Tillage	160	OLS	R^2=0.82
Shortle and Miranowski (1986)	US	Conservation Tillage	48	Linear Probability Model	R^2=0.11
Gould et al. (1989)	US	Conservation Tillage	--	Probit	χ^2=31.9
Marra and Ssali (1990)	US	Conservation Tillage	43	Probit and OLS	OLS R^2=0.11
Warriner and Moul (1992)	Canada	Conservation Tillage	314	Logit	χ^2=122.52
de Harrera and Sain (1999)	Panama	Conservation Tillage	60	Multinomial Logit	Correct Prediction=65%
Uri (1997)	US	Conservation Tillage	825	Cragg Model	--
Soule et al. (2000)	US	Conservation Tillage	941	Logit	Correct Prediction=68.5%
Traoré et al. (1998)	Canada	Conservation Tillage	82	Probit	Correct Prediction=66%
Swinton (2000)	Peru	Soil Erosion Control	178	Random Effects GLS	χ^2=314.1
Neill and Lee (1999)	Honduras	Cover Crops	370	Probit	LR=67.03
Saltiel et al. (1994)	US	Sustainable Practices	437	OLS	Adj. R^2=0.435
Napier and Camboni (1993)	US	Conservation Tillage	1305	OLS	Adj. R^2=0.07
Fuglie (1999)	US	Conservation Tillage	1425	Multinomial Logit	Correct Prediction=81.5%
Somda et al. (2002)	Burkina Faso	Compost Adoption	116	Logit	Correct Prediction=93.6%
Pautsch et al. (2001)	US	Conservation Tillage	221	Logit	Correct Prediction=67%
Smit and Smithers (1992)	Canada	Conservation Tillage	246	Non-Parametric Chi-Square Test	--
Carlson et al. (1994)	US	Soil Erosion Control	80	Multiple Classification Analysis	R^2=0.17 and 0.24

Note: Above Table is Table 3 in Knowler and Bradshaw (2007).

Ali, Deininger and Goldstein (2011) wrote a more recent paper that examines the environmental and gender impacts of land tenure in Rwanda. Using a geographic discontinuity empirical approach with spatial fixed effects, the authors are able to identify the short term impact of land tenure on land access, investment and soil conservation techniques. The authors find that land tenure led to a significant increase in the amount of land households put under conservation techniques. Furthermore, the authors showed that land market activity declined, allowing them to reject the hypothesis that land tenure would lead to distressed sales. Finally, the authors examined impact by gender and they found that woman benefited more than men, suggesting that woman experienced higher levels of land insecurity. This study hopes to expand on the findings of Ali, Deininger and Goldstein (2011) by focusing on conservation farming adoption in Zambia.

Theoretically modeling the household's or farm's decision of which type of agriculture practices to use has been heavily studied in the agricultural economics literature. McConnell (1983) used production theory at the farm level with individual farmers maximizing profits subject to farm constraints. More recent papers dealing with conservation adoption have used an approach similar to Rahm and Huffman (1984), in which individual farms maximize household utility by choosing the level of adoption to undertake subject to farm level constraints (see Swinton and Quiroz (2003a; 2003b) Marra et al. (2001), and Norris and Batie (1987)). This paper will also use a household or farm level utility maximization approach very similar to Rahm and Huffman (1984). Using the household as the unit of observation is important, given that the data is organized at the household level. This model will allow for an empirical specification that coincides with the CFU data.

2.2 Instrumental Variables

The empirical analysis section of this paper will not only examine correlations between household characteristics and adoption, but will also attempt to estimate causal effects of property rights on adoption. An instrumental variables approach will be used to try to identify a causal estimate of this key input into the adoption decision. The literature on the application of instrumental variables has grown immensely in the past ten years. This paper will use similar methods as those found in Anderson and Matsa (2008) and Card (1995), which both used distance as an instrumental variable. Anderson and Matsa (2008) exploit household distance to the nearest highway to induce an exogenous source of variation in access to fast food restaurants. Card (1995) used distance to a four year college as an exogenous instrument of schooling to estimate causal impacts of education on wages. Card (2005) and Anderson and Matsa (2008) were able to exploit the randomness of straight line distance to produced unbiased estimates of their coefficients of interest, because straight line distance serves as an excellent proxy for travel costs. In a similar vein, Duflo and Udry (2004) use rainfall measures as a source of exogenous variation to income to examine whether income from all sources are pooled within a household. This study will use distance calculations as instruments to identify the causal impact on conservation farming adoption related to exogenous variation in property rights.

3. Model

3.1 Theoretical Model of Adoption

The theoretical model used in this paper is taken directly from Marra, Hubbell and Carlson (2001) and Rahm and Huffman (1984), with a few modifications to make it applicable to conservation farming adoption in Zambia. The CFU data is collected at the household level and therefore the model assumes a unitary household with men and women, where preferences are combined into a single decision making process.

Consider a farming household that each year has to decide what farming practices to use on their field. The model allows for the use of two practices: conservation or traditional.[5] Allowing for non-neutral risk attitudes, adoption of conservation agriculture will occur when the expected household utility of adoption is greater than the expected utility of not adopting. Utility is a function of profits, π_{ij}, where $i = 1$ if the household j uses conservation techniques and $i = 0$ if they use traditional framing practices. Utility is not only a function of profits but also of other attributes associated with the technology, such as aesthetic preferences, social acceptance, and sustainability which are defined by $\boldsymbol{x}_i$. These attributes, along with profits, impact a household's preference about the expected utility obtained through the adoption of conservation practices or continuing use of conservation practices versus the use of traditional farming. Therefore, we can write the household j's adoption decision rule as the following:

(1) $$E\left[U\left(\pi_{1j}, \boldsymbol{x}_{1j}\right)\right] > E\left[U\left(\pi_{0j}, \boldsymbol{x}_{0j}\right)\right].$$

[5] Expanding the model to include other farming techniques doesn't change the result.

That is, the expected utility of adoption is greater than the expected utility of using traditional farming techniques.[6] The variables π_{1j} and $\boldsymbol{x}_{1j}$ are not observed or available, but a linear relationship can be hypothesized for the jth household's utility derived from the adoption of conservation farming and a vector of observed household characteristics $\boldsymbol{z}_j$, as well as a zero mean random error term e_i.

The household characteristics vector is composed of farm level information including property rights, gender, education, farm size, household size, etc. Thus, we can write the linear relationship between utility of adoption and observable characteristics as the following:

(2) $$U_{ij} = \boldsymbol{z}_j \alpha_i + e_{ij}; \quad i = 0{,}1; \;\; j = 1, \dots, n.$$

Each farm household is assumed to choose the land preparation technology that provides the overall household with the most utility. Utility should be thought of as the summation of total lifetime utility. Moreover, a household can change techniques from year to year. The jth household thus adopts conservation farming in a given year if U_{1j} is greater than U_{0j}. Letting a qualitative variable D_j index the adoption decision by each household we arrive at:

(3) $$D_j = \begin{cases} 1 \;\; if \; U_{0j} < U_{1j}, & Conservation\ farming\ is\ Used \\ 0 \; if \; U_{0j} > U_{1j}, & Traditional\ farming\ is\ Used \end{cases}$$

Using (2) and (3) above, the associated probability of D_j being equal to one can be expressed as a function of observable household characteristics:

[6] It is also possible to view π as a vector of moments of profits associated with adoption and traditional farming. Higher moments may impact the adoption decision, especially yield variance.

(4) $$P_j = P_r(D_j = 1) = P_r(U_{0j} < U_{1j}) = P_r(\mathbf{z}_j\alpha_0 + e_{0j} < \mathbf{z}_j\alpha_1 + e_{1j})$$

$$= P_r[e_{1j} - e_{0j} > \mathbf{z}_j(\alpha_0 - \alpha_1)] = P_r(\mu_j < \mathbf{z}_j\beta) = F(\mathbf{z}_j\beta),$$

where $P_r(\cdot)$ is a probability function, $\mu_j = e_{0j} - e_{1j}$ is a random error term, $\beta = \alpha_1 - \alpha_0$ is a coefficient vector associated with correlations between household characteristics and adoption. Also, $F(\mathbf{z}_j\beta)$ is the cumulative distribution function for μ_j evaluated at the value $\mathbf{z}_j\beta$. Therefore, the probability of household j adopting conservation farming is the probability that the expected lifetime utility gained from using traditional farming techniques is less than the expected lifetime utility gained from using conservation farming techniques during a given year, or the cumulative distribution F defined at $\mathbf{z}_j\beta$. The precise distribution of F depends on the distribution of the random error term defined above, $\mu_j = e_{0j} - e_{1j}$. If e_{ij} is normally distributed, then μ_j is normally distributed and F is simply a cumulative normal distribution. If e_{ij} is uniform, then μ_j is uniform and F is a triangular distribution.

Examining the marginal effect of a variable, z_k in the household characteristics vector $\mathbf{z}_j$ on the probability of adopting conservation farming, we can write the following:

(5) $$\frac{\partial P_j}{\partial \mathbf{z}_{jk}} = f(\mathbf{z}_j\beta) \cdot \beta_k,$$

where $f(\cdot)$ is the marginal probability density function of μ_j. The direction of the marginal effect is determined by the sign of β_k. Returning to equation (4), we can write that $\beta_k = \alpha_{1k} - \alpha_{0k}$, or the direction of the marginal effect depends on the difference between the coefficients for adoption and non-adoption associated with the household characteristic variable z_k. Therefore, β_k is positive if $\alpha_{1k} > \alpha_{0k}$, zero if $\alpha_{1k} = \alpha_{0k}$, and negative if $\alpha_{1k} < \alpha_{0k}$.

The probability of adopting conservation farming can be estimated using equation (4) and the correlations between household characteristics and adoption are shown in the estimates of β. While most of these correlations should not be interpreted as causal relationships, they still provide insight into what type of farmers are adopting conservation farming techniques.[7]

3.2 Empirical Model

Using the above proposed theoretical model of adoption we can write the adoption decision as a linear function of household characteristics:

(6) $$D_j = \boldsymbol{z}_j\beta + e_j.$$

Again, D_j is a binary variable indicating a household has adopted some type of conservation farming, $\boldsymbol{z}_j$ is a vector of household j's characteristics, and e_j is a well behaved error term. Ordinary least squares estimates will produce consistent estimates of the causal effects of the variables encompassed by $\boldsymbol{z}_j$ as long as certain conditions are met. The key assumption necessary for the model to estimate casual impacts is strict exogeneity, $E(\boldsymbol{z}|e) = 0$. This assumption implies that there is no correlation between the independent variables and the error term. Again, $\boldsymbol{z}_j$ is a vector of household j's characteristics that influence the adoption decision of a household j, which our

[7] The theoretical model of adoption should also be indexed by t, or year, but this is suppressed to avoid additional notation.

theoretical models suggest are variables that impact the costs and benefits associated with traditional farming and conservation farming. The literature summarized in Knowler and Bradshaw (2007) tells us that the possible significant variables that should be included in $\boldsymbol{z}_j$ are education, household size, land tenure, gender, land area, cattle, input and output prices, soil quality and other important agrological factors. A number of these variables pose an empirical predicament because of endogeneity issues which arise when an independent variable is correlated with the error term.

An example of a variable that suffers from such endogeneity and that is the focus of this paper's analysis is property rights, or title deed. As discussed previously property rights are of particular interest in Zambia and may provide a possible mechanism to increase the number of farmers adopting conservation techniques. Property rights are seen as endogenous because certain households have chosen to obtain property rights and other households have not. This choice regarding property rights is not a problem unless the households that obtain property rights are fundamentally different, either observably or unobservably, than households that do not.

In Zambia, wealthier households are more likely to obtain property rights because of the associated costs, but are also less likely to adopt conservation techniques. The reason for this relationship is that the main input costs of traditional farming, such as access to cattle to plough, as well as the opportunity cost of waiting for cattle to become available, are much lower for wealthier households. This relationship creates endogeneity by causing the strict exogeneity assumption to fail, resulting in the ordinary least squares estimates to be inconsistent and negatively bias of the causal impact of property rights.

Strict exogeneity often fails when examining variables of interest such as school choices (Card (1993)) or eating choices (Anderson and Matsa (2008)) because, similar to the above example, more intelligent people will pursue more education and overweight people will eat at fast food restaurants more often. There are a few ways to overcome the property rights endogeneity problem, most notably instrumental variables. Starting with a model specified above in equation (6), we can examine the estimates associated with property rights.

(7) $$D_j = \mathbf{z}_j\beta + \theta Title\_Deed_j + e_j.$$

The above equation will provide inconsistent and negatively biased results for θ because property rights are endogenous and correlated with the error term, because of the their relationship with wealth. To arrive at consistent estimates we need to find a variable that is correlated with property rights, uncorrelated with the error term and should not be included in the model specification above. Finding such a variable is not a trivial task. In this case of property rights in Zambia, we can exploit the institutional process a household needs to undertake to obtain a title deed for their land. This process involves going to the district capital, where one must fill out paperwork and pay a fee to obtain a title deed. While this process may seem unrelated to the theoretical model above, it allows for the use of distance as an instrument for property rights, exploiting the difference in travel cost for households that want to obtain title deed. Using a 2SLS approach, the first stage is run to establish the regression of title deed on distance, which is a dummy variable that takes on the value 1 if a household is located near a district capital and 0 otherwise, and other exogenous variables in $\boldsymbol{z}_j$.

(8) $$Title\_Deed_j = \boldsymbol{z}_j\varphi + \gamma Distance_j + u_j.$$

Obtaining the predicted values of title deed from this first stage regression, $\widehat{Title\_Deed}_j$, we can then plug this value into the second stage regression, which resembles the original model in equation (7):

(9) $$D_j = \boldsymbol{z}_j\beta + \delta \widehat{Title\_Deed}_j + e_j.$$

By doing this our 2SLS coefficient δ will provide a consistent estimate of the casual impact of property rights on the household's adoption decision.

Theoretically, in order for distance to be a legitimate candidate for an instrumental variable, it needs to be excluded from the original regression model, correlated with the endogenous variable of interest as well as be random, or uncorrelated with the error term in equation (7). The validity of the instrument will be discussed in the results and conclusion section.

4. Data

4.1 Conservation Farming Unit Data

The data used for this study comes from the Conservation Farming Unit's monitoring and evaluating surveys completed between the harvest and land preparation seasons for a panel of farmers over the years 2007 through 2010. Beginning in 2007 annual data for farmers within the Conservation Agriculture Program (CAP) regions was collected. An independent consulting firm was hired by CFU to develop a survey instrument and the firm interviewed 4,512 farmers. The initial goal was to interview 5,000 farmers, but a number of issues occurred and CFU fell short of that goal. The random sampling was done at the CFU farm coordinator level as well as the individual CFU farmer level. Going into the next year, CFU again made an attempt to increase the panel in order to reach the original goal of 5,000 farmers, but fell short. They added an additional 1,586 farmers, but, because of attrition (32% attrition between 2007 and 2008), the total number of unique farmers in 2008 was 4,650.

CFU continued to try to follow these farmers for the following two years creating a panel dataset of four years for households that entered in 2007 or three years for households that entered in 2008. However, the panel decreased each year and only 2,429 farmers were interviewed in the 2010 (68% of all households attrite by 2010). The attrition rate is rather high and may pose some issues with the empirical analysis within this paper. Table 2 shows the results of running a regression of a dummy variable indicating whether or not a farm remained in the dataset for the duration on key characteristics. Standard errors are clustered by region. There are significant differences in observable variables between the attriters and the households that stay in the survey such as education, number of female headed households and total farm area. This is an indication that attrition is non-random and will lead to bias estimates. The empirical analysis will use both the full survey, as well as the original 2007 cross section to deal with possible non-random attrition.

Table 2.		
Balance Table By Attrition		
	Remain in Panel Dataset (s.d)	Attrit from Dataset – Remain in Panel (s.e.)
Total Area of Farm (Limas)	15.079	5.341*
	(23.267)	(1.084)
Female Headed Houshold	0.394	-0.043*
	(0.489)	(0.008)
Housing Structure has Cement Walls	0.009	0.005
	(0.094)	(0.003)
Total Cattle	2.792	0.198
	(7.918)	(0.152)
Secondary School	0.263	0.045*
	(0.440)	(0.008)
Primary School	0.607	-0.001
	(0.488)	(0.012)
No School	0.116	-0.044
	(0.320)	(0.022)
Number of Working Household Members	8.505	-3.554
	(197.981)	(2.671)
Purchased Fertilizer	0.453	0.079*
	(0.498)	(0.018)
* p<0.05		

Note: First column represents the mean and standard deviation of variables of households that remain in the dataset throughout. The second column represents the coefficient estimates of regressing each variable on a panel dummy variable indicating an household stays in the dataset. Standard errors of the coefficient estimates are clustered by region and reported in the second column.

Utilizing the full dataset would result in a panel that is extremely useful for empirical analysis because it allows for the controlling of unobserved heterogeneous time invariant effects, which can help reduce or eliminate omitted variables bias. However, there are key variables such as education and title deed that were not part of the 2010 survey instrument. Therefore, the final full CFU dataset used in the analysis contains only three years of data, which makes it difficult to obtain fixed effect estimates.

The dataset is not perfect, but it is still a large micro dataset that is unique in the conservation farming literature and will provide insight into the adoption decision of a large set of farmers in Southern Africa.

4.2 Latitude and Longitude Data

The last data set that is used for this paper was created using Google Earth and contains the latitude and longitude coordinates for villages within the CFU dataset. This data was collected manually by the author and varies slightly depending on how precise the enumerator was when recording the farm's village. Using the village coordinates, a straight line distance measurement to the nearest city where property rights or title deed can be obtained in Zambia is calculated. These distances are merged on to each village and will be used as instruments in the empirical analysis. Table 3 below provides summary statistics for the key variables in both the CFU and latitude and longitude datasets.

Table 3. Summary Statistics		
Variable Name	**Mean**	**Standard Deviation**
Conservation Farmer	0.465	0.499
Female	0.370	0.483
Married	0.819	0.385
Title Deed Ownership	0.101	0.301
Eastern Region	0.159	0.366
Southern Region	0.280	0.449
Western Region	0.272	0.445
College	0.008	0.088
Secondary School	0.284	0.451
Housing Structure has Brick Walls	0.366	0.482
Housing Structure has a Stone Roof	0.235	0.424
Primary School	0.615	0.487
Total Cattle	2.608	9.152
Number of Working Household Members	4.148	2.582
Total Area of Farm (Limas)	1.592	2.355
Distance to District Capital (Miles)	25.149	21.292
Source: Conservation Farming Database 2007		

5. Empirical Analysis

5.1 Conservation Farming and Household Characteristics

The first part of the empirical analysis examines patterns between household characteristics and their adopting of conservation farming techniques. Using the CFU data and estimating equation (6) using a probit regression, we can determine correlations between household characteristics and the probability of adoption.

Equation (6) is estimated using binary variables that are associated with the adoption of conservation techniques as the dependent variables. The first variable of interest is conservation farming adoption, which takes on a value of 1 if a household adopts conservation farming and zero otherwise. Other important binary variables closely related to conservation farming are also used as dependent variables. These variables are: planting cassava, which is a crop that CFU is promoting in conjunction with conservation farming, planting faidherbia albida, which is highly valued in agroforestry and also supported by CFU, and ownership of important tools used by adopters of conservation farming. All of these probit regressions examine patterns between adoption and household characteristics. [8]

The estimates will provide some interesting insights into which households are adopting and suggest other possible channels through which households adopt compared to previous findings. The CFU data contains a number of key characteristics which can be used as independent variables that should be related to adoption such as: education, indicator of female headed households, proxy measures for wealth, total area of farm, title deed and the number of working household members.

5.2 Identification of the Effects of Title Deed

The empirical analysis above examines patterns and correlations between household characteristics and conservation farming adoption, but, in order to identify causal effects, a different empirically strategy is necessary. Returning to the theoretical model for instrumental variables estimation discussed previously, in order to identify a causal impact of property rights an instrument related to property rights and

[8] Both probit regressions and ordinary least squares regressions were examined, but because dependent variables are dichotomous probit results are preferred.

uncorrelated with the error term and not present in the adoption model itself is necessary. Distance from the district capital theoretically would be a possible candidate for an instrument for property rights because of institutional policies and its direct relationship with transportation costs, but, in order for distance to be a valid instrument, it needs to be exogenous so that it can provide sufficient exogenous variation in property rights.

There is no direct way to test whether distance is truly exogenous, but Table 4 shows the results of running balance regressions of distance on key variables that could possibly be correlated with distance, while also clustering standard errors by region. The table shows that there is no significant difference between farms close to district capital (within 20 miles) and farms further away. Judging from these regressions it seems that distance is uncorrelated with all of the key observables. Card (1993) used a similar binary measure of closeness, but he used the presence of a four year college as an instrument for education as opposed to a distance measurement to the district capital for property rights. The results are robust to small changes in the distance to capital variable and twenty miles was used because it provided the best balance between near and far to the capital. Furthermore, this distance provides a sufficient cutoff such that the increase in transportation costs are significantly different between the two groups.

Table 4. Balance Table By Distance to District Capital		
	Close to District Capital Means (s.d)	Far from Capital – Close to Capital (s.e.)
Total Area of Farm (Limas)	17.706	-0.023
	(94.568)	(0.265)
Female Headed Houshold	0.409	-0.075
	(0.492)	(0.041)
Housing Structure has Cement Walls	0.014	-0.005
	(0.116)	(0.003)
Total Cattle	2.974	-0.176
	(8.153)	(0.641)
Secondary School	0.280	0.001
	(0.449)	(0.014)
Primary School	0.588	0.040
	(0.492)	(0.023)
No School	0.117	-0.038
	(0.321)	(0.024)
Number of Working Household Members	4.223	-0.238
	(2.507)	(.117)
Purchased Fertilizer	0.561	-0.094
	(0.496)	(0.068)
* p<0.05		

Note: First column represents the mean and standard deviation of variables of households within 20 miles to the district capital. Second column represents the coefficient estimates of regressing each variable on a distance dummy variable indicating an observation is over 20 miles from district capital. Standard errors of the coefficient estimates are clustered by region and reported in the second column.

The next necessary condition for an instrument to be valid is that it must be correlated with the endogenous variable. In this case, being close to the distance capital should be positively correlated with property rights, meaning that, as a household moves closer to the district capital, the cost of obtaining property rights decreases and they are more likely to have a title deed. This condition can be tested directly using regression analysis, which is called the first stage. The following simple ordinary least squares regression of title deed on distance is estimated and γ needs to be significantly greater than zero.

(10) $$Title\_Deed_j = \mathbf{z}_j\beta + \gamma Distance_j + u_j.$$

The measure to see if the relationship is strong enough to provide a valid instrument is the F-statistic. The literature suggests that the F-statistic must be greater than 10 in the first stage in order to pass the relevance test (see Stock, Wright and Yogo (2002)), because at that point the estimate obtained by using an instrumental variables approach is no better than the biased ordinary least squares estimate.

Capturing the predicted values in the first stage, $\widehat{Title\_Deed}_j$, the theoretical model for instrumental variables estimation requires that we then plug the predicted values into our original model, which is called the second stage.

(11) $$D_j = \mathbf{z}_j\beta + \delta \widehat{Title\_Deed}_j + e_j.$$

The regression results of equation (11) will provide a causal interpretation of δ for households induced by the distance instrument. The empirical analysis uses two staged probit regression estimation, similar to Fitzgerald, Gottschalk, and Moffitt (1998), because in both stages the dependent variable is binary.

6. Results and Conclusion

6.1 Results

The first set of empirical results are shown for the cross section of 2007 data only, because of high levels of attrition and missing key variables in the 2010 data. These results, displayed in Table 5, examine the marginal effects of household characteristics and the probability of adopting conservation farming and other variables related to adoption. The first three regressions uses binary outcome variables that are assocaicted with the adoption of conservation farming, cassava planting and musangu planting respectively. The final two regressions use the number of conservation farming tools owned by a household as the dependent variables.

Table 5.

Demographic Regression Results

	(1)	(2)	(3)	(4)	(5)
VARIABLES	cf_farmer	cassava_plot	faidherbia_albida	chaka_hoes	magoye_rippers
female	0.0280	-0.0368***	-0.0133	-0.0201*	-0.0161***
married	-0.000895	-0.0105	0.0282**	0.0180	0.0179**
title_deed_ownership	0.180***	0.121***	0.00718	0.0295	0.0316**
eastern	-0.0301	-0.0565***	0.0509**	0.0199	0.0421***
southern	0.148***	0.0641***	0.0842***	0.134***	0.0235**
western	0.390***	0.0463***	0.155***	0.215***	0.0486***
college	-0.173**	0.162*	0.165*	0.264***	0.193*
secondary_school	0.142***	0.0867***	0.194***	0.242***	0.139***
primary_school	0.0494*	0.0463*	0.0761***	0.105***	0.0486***
no_workers_fam_members	0.0177***	0.00869***	0.0100***	0.0137***	0.00812***
total_cattle	-0.00398***	-0.00371***	-0.000967	0.000840	0.00196***
total_area	0.0121*	0.0143***	0.0217***	0.0124***	0.00617***
total_area2	-0.000370**	-0.000325**	-0.00148***	-0.000351**	-0.000161***
Observations	4,510	4,510	4,510	4,510	4,510

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

Source: Conservation Farming Database 2007

The first regression in Table 5 shows that there are positive and significant (at the 95% level) relationships between title deed, secondary education, and the number of working family members in a household with the adoption of conservation farming. There also is a significant (95% level) negative relationship between conservation farming and a college education, as well as the number of cattle a household owns and the farm size area squared. As a robustness check of these relationships, the remaining regressions of household characteristics and outcome variables related to adoption are presented. The correlations between title deed, secondary education and total area stay consistent when the other outcome variables are used. This suggests that these relationships, especially between adoption and title deed, are robust.

As discussed earlier, the coefficient on property rights should not be considered causal because of possible issues of endogeneity. The endogeneity problem associated with property rights is the result of wealthier households being more likely to obtain property rights, and the results in Table 5 show that within this sample wealthier households, using cattle ownership as a proxy variable, are also less likely to adopt conservation farming. This selection problem would bias the ordinary least squares estimates downward (Bekele and Mekonnen (2010)). Therefore, using instrumental variables estimation should provide a causal, unbiased estimate of property rights for the households that are induced by the distance instrument.

Table 6. Title Deed IV Regressions (2007 Data)		
	(1)	(2)
VARIABLES	cf_farmer	cf_farmer
female		0.0128
married		0.00349
title_deed_ownership	0.551***	0.660***
college		-0.212**
secondary_school		0.205***
primary_school		0.127***
no_workers_fam_members		0.0280***
total_cattle		-0.00490***
total_area		-0.0163**
total_area2		4.21e-05
Observations	4,512	4,510
First Stage F-Statistic	225.24	29.79
Source: CFU 2007 Data		
*** p<0.01, ** p<0.05, * p<0.1		

The results for the instrumental variables estimation using only 2007 data are shown in Table 6. The first thing to notice is that the F-statistic from the first stage is well above 10, signifying that the instrument passes the test for relevance. Furthermore, the first regression shows that using the binary variable for distance as an instrument for property rights results in a marginal effects estimate of .55, which corresponds to an increase in the probability of adoption when a household obtains property rights. Compared to the probit marginal effects estimate in Table 5 of .11, this is a significant increase. The second regression controls for other covariates, increasing the marginal effect estimate of the impact of property rights on conservation adoption to .66. The increase in the marginal effects estimates from .11 to .55 and .66 are rather large because the overall average probability of adoption conservation farming is .46 and the average probability of having title deed is .101. These results suggest that property rights could be an extremely useful tool to help CFU and the Zambian government increase the use of conservation farming. Table 7 shows the results of the same regressions in Table 6 but using the panel dataset from 2007-2009. The results are positive, but not significantly different than the original probit estimates in Table 4. This is most likely due to the large amount of attrition within the dataset.

Table 7.
Title Deed IV Regressions (2007-2009

	(1)	(2)
VARIABLES	cf_farmer	cf_farmer
female		0.0343***
married		-0.00407
title_deed_ownership	0.225***	0.261***
college		0.0584
secondary_school		0.135***
primary_school		0.0593***
no_workers_fam_members		0.0129***
total_cattle		-0.00394***
total_area		-0.00492
total_area2		-6.53e-05
year	0.0830***	0.112***
Observations	15,166	12,717
First Stage F-Statistic	189.19	46.22

Source: CFU Data 2007-2009
*** p<0.01, ** p<0.05, * p<0.1

6.2 Discussion & Concerns

The results examining the relationships between conservation outcomes and household characteristics analysis differ slightly from the analysis in Ashraf, Jack and Reed (2010). They found no relationship between education and adoption, but as the results show in Table 5 the data suggests a possible positive relationship between secondary school and adoption but a negative relationship between college education and adoption. Ashraf, Jack and Reed (2010) also found no relationship between farm size and conservation farming, but Table 5 shows that there is a positive relationship. Table 5 also reinforces a number of the other hypotheses put forth in Ashraf, Jack and Reed (2010), especially the importance of regional effects, which requires more examination.

The above estimates of the impact of property rights on conservation farming adoption are the main findings in the analysis. The marginal effects estimates of property rights on adoption of conservation farming in Table 5, Table 6 and Table 7 support the findings in Ali, Deininger and Goldstein (2011) that there is a positive and significant impact of increased property rights on conservation farming adoption. The results also bolster the findings in Feder et al. 1988; Alemu 1999; Gebremedhin and Swinton 2003; Joireman 2001; Rahmato 1992, which found a positive relationship between land security and conservation farming, but treated land tenure as exogenous. However, the results contradict Neef (2002) which found increases in land security had no impact on conservation techniques in Benin and Niger. One possible reason for the different results associated with the impact of property rights on conservation farming adoption is the use of different outcome variables and different definitions of property rights and land security. A number of papers use outcome variables that require measuring the amounts of land under different techniques, while others use binary variables or a combination of variables to determine whether a household is using conservation farming. These types of variables, especially in a developing country setting, can vary greatly, suggesting that Knowler and Bradshaw (2007) were correct in recommending that analysis be done on a case by case basis.

The instrumental variable estimates in this paper are valid only for the households that were induced by the distance to capital instrument. Therefore, households that wouldn't have obtained property rights if not for being located close to the district capital are the households that the estimates pertain to. These households may not be the average household, and therefore this casual impact may not be relevant for the average impact for all households. Heterogeneity of property rights is an issue, but the results clearly suggest that land tenure is a big obstacle to the adoption of conservation farming in Zambia for a subgroup of the population and that continued research on the impacts of property rights is necessary.

The main concerns about the results have to do with using distance as an instrumental variable. While Table 4 was able to show that distance seemed random based on the observables found in the CFU data, it is likely that distance is also related to important unobservables that should be included in the adoption model. Input and output costs are variables that are probably correlated with distance and should be included in the adoption model, but are not available in the CFU data. Input costs of products that are important to conservation farming such as fertilizer and herbicides are going to be more costly as a household moves farther away from the district capital. Similarly, output costs associated with bringing goods to the market will be correlated with distance from the capital and should also be included within the original adoption model. Another variable that is correlated with distance and should also be included in the adoption model is the scarcity of land. Households that are farther from the capital face lower opportunity costs for using traditional farming as land is less scarce compared to households that are closer to the district capital.

These unobservable variables could possibly be driving the significant positive results of land tenure. Households that are farther away from the district capital are facing higher costs of adopting conservation farming, higher input costs, and lower costs of using traditional farming, the opportunity costs of using traditional techniques are lower because land is not as scarce, resulting in positively biased IV estimates.

However, the structure of CFU is extensive and they make all of the inputs necessary for conservation farming available, often at subsidized prices, as well as provide training sessions that stress the importance of conservation farming and the high costs of using traditional techniques. These concerns with the instrumental variable used are definitely well-founded, but given the data constraints instrumental variables estimation is the best empirical method to estimate the causal impact of property rights on adoption.

6.3 Conclusion

Land policy in Africa is an important issue for the development of the economy. A recent report by the African Union in 2009 discussed the use of property rights and land policy as a way to increase productivity and lower poverty rates. Daron Aceoglu's and James Robinson's recent book "Why Nations Fail," also suggested that private property rights are a necessity for states to escape from poverty. These recent studies, along with Coase's 1960 seminal paper on property rights, have made land policy reforms a possible policy prescription for developing countries in Africa. Obvious hurdles still exist, especially in Zambia, such as traditional rules and laws as well as cultural beliefs. The other problem that countries like Zambia face with land policy change is that, without functional established institutions, many of the benefits of shifting to private property may be crowded out by corruption or inefficiency. Instituting private property rights in Zambia without improving the current structure and efficiency of government institutions would be a waste. While property rights are a key piece to a countries development, if they are not implemented properly, the benefits will disappear.

Property rights are especially important for CFU and the government of Zambia, because they can provide the right incentive structure for farm households to use conservation farming techniques. Furthermore, the Zambia government, along with Norway, is putting over $80 million into CAP II. They should do as much as they possibly can to effectively increase the use of conservation farming with this funding. Making changes to the current land policy is one way they could increase the number of adopters, but they must also improve their institutions to lower transaction costs and provide farmers with the incentive necessary to get them to invest in their land for the future and leave the plough where it belongs: in the past.

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