Assessing the Influence of Conservation Agriculture On Household Wellbeing and Maize Marketing in Tete and Manica Mozambique

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William Edward McNair
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To the Graduate Council:

I am submitting herewith a thesis written by William Edward McNair entitled "Assessing the Influence of Conservation Agriculture On Household Wellbeing and Maize Marketing in Tete and Manica Mozambique" I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Economics.

Dr. Daniel De La Torre Ugarte, Major Professor

We have read this thesis and recommend its acceptance:
Dr. Dayton M. Lambert
Dr. Michael D. Wilcox
Dr. Neal Eash

Accepted for the Council:
Carolyn R. Hodges
Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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ABSTRACT

In recent years there has been a movement on the part of farmers, governments, Non-Governmental Organizations (NGO), and the international community to promote the use of sustainable agricultural practices. In Sub-Saharan Africa, this has translated into programs with the expressed aim of increasing smallholder farmer adoption rates of conservation agriculture (CA). This thesis contributes to the analysis of the adoption of conservation agriculture by smallholder farmers in Sub-Saharan Africa by assessing the economic status of CA adopters in the providences of Manica and Tete, Mozambique.

Chapter II of the thesis examines the *ceteris paribus* correlation between smallholder farm household economic wellbeing with the use of conservation agriculture. Household wellbeing indicators are regressed on household demographic attributes, farm management practices, and a variable indicating the CA adoption status of farms. Of particular interest is the association between the use of conservation agriculture practices and a set of composite wellbeing indices comprised of livestock and asset ownership, and housing material quality. The results suggest that, holding other factors constant, CA households have higher wellbeing index scores related to asset ownership and housing material quality, but lower index scores related to livestock ownership.

Chapter III of the thesis analyzes smallholder marketing of maize and use of CA by farmers. The chapter examines the factors associated with the likelihood of a household participating in maize markets as a vendor or buyer, and the subsequent quantity of maize transacted. A censored regression model estimates the intensity of market participation because a large number of households do not buy or sell grain. Of particular interest is the correlation between the adoption of CA practices and the likelihood a household sold or purchased maize.

Results suggest that households using CA were more likely to sell maize and less likely to purchase maize for household consumption. However, the overall quantities sold by CA adopters and non-adopters were not different. Households using CA also exhibited different maize marketing patterns with transactions more evenly distributed throughout the year, as compared to non-CA households whose transactions were concentrated during times when food was scarce.

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Introduction

Problem identification and explanation

Diminished land productivity caused by soil erosion generates 400 Billion US dollars in lost agricultural production per year worldwide (Eswaran and Reich, 2001). Soil loss can lead to desertification, food insecurity, and social instability in the long term. Soil erosion also lowers crop yields and reduces farm income. Conventional farming practices are linked to soil losses of up to 150 tons per hectare (ha^{-1}) annually in Africa (FAO, 2001a; FAO, 2001b; Knowler and Bradshaw, 2007). In Mozambique, estimated soil nutrient loss for conventional farmers is considerably lower (51 kg ha^{-1}); not among the worst, but still considered unsustainable (Morris et al., 2007). The problem of soil loss and land degradation is widespread in Mozambique, with 63% of arable land considered to be at moderate to very high risk of degradation (Eswaran and Reich, 2001). To mitigate these problems, organizations and agencies such as the United States Agency for International Development (USAID), The Food and Agriculture Organization of the United Nations (FAO), and the Government of Mozambique have supported programs promoting the adoption conservation agriculture (CA) in vulnerable agroecosystems.

The Government of Mozambique and the international community have an interest in reducing the degradation of arable land to moderate losses in soil productivity. This is a concern for most Mozambicans because the country is relatively food insecure, as exemplified by the food riots that occurred in 2008 resulting from global increases in maize prices (Torero, 2010). The FAO also estimates 8.1 million Mozambicans, 38% of the total population, are undernourished (FAO, 2012b). Food insecurity is more prevalent among Mozambican children, with 41% undernourished (FAO, 2012b).

Land degradation leads to income losses for smallholder farmers through reductions in crop sales (FAO, 2012b). In Mozambique, lower yields are an economic concern for the government because most livelihoods are directly tied to agriculture (Almeida et al., 2009). Lower yields typically translate into less food and higher maize prices. Farming and fishing are the principal income sources for households in Mozambique. Small-scale agriculture accounts for most of the nation's food production as well as economic activity (Sitoe 2005). In the Tete and Manica provinces smallholder farming accounts for approximately 90% of all employment in the region (Mozambique, Ministry of State Administration 2005a; 2005b; 2005c). Due in part to low yields, the percentage of marketed surplus is low, with some estimates placing all non-cash crop sales at less than 10% of total production. This is a concern because crop production accounts for two thirds of farm income in Mozambique (Boughton et al., 2007).

Research continues to demonstrate that conservation agriculture reduces soil erosion, boosts soil fertility, and may increase farmer wellbeing through higher income, more stable yields and more efficient use of inputs (FAOc, 2001; Kassam et al., 2009; Thierfelder and Wall, 2010). The importance of sustainable agriculture practices and the goal of increased marketing of production is outlined in sub-sections 3 and 4 in the agriculture section of the 2010-2014 Mozambican government's strategic plan for poverty reduction; incentivize and increase the production of market oriented agricultural production and promote the use of sustainable practices in the use of land and forest resources (Government of Mozambique, 2010). However, research on the interaction between sustainable agriculture production, household wellbeing, and market participation remains limited.

Research objective

The objective of this thesis is consistent with The University of Tennessee's research objective 4 of the project supported by the USAID's Sustainable Agriculture and Natural Resource Management Collaborative Research Support Program (SANREM CRSP): to determine the impacts of conservation agriculture on gender equity and household income and wellbeing.

Chapter II examines this objective by measuring the economic wellbeing of households in Tete and Manica Mozambique using a series of indices that proxy dimensions of household wellbeing. The indices focus on animal ownership, productive asset ownership, and the quality of housing construction materials along with access to water and sanitation. Each index is regressed on household, production, and community characteristics to estimate the *ceteris paribus* correlation between conservation agriculture (CA) adoption and the wellbeing indicators. The null hypothesis is that CA adoption is, holding other variables constant, uncorrelated with household wellbeing.

Chapter III examines household the sale and purchases of maize. Market participation is explained by regressing household, farm production, community and marketing attributes, and a binary variable indicating use of CA on household participation in local maize markets. A second regression explains the quantity transacted for sales and purchases of maize as a function of household characteristics, farm attributes, and the use of CA technologies. The null hypothesis is that market participation rates and the quantity of maize transacted are not different between households using CA and other households.

Literature review

Conservation agriculture in Mozambique

Projects supported by non-government organizations (NGOs) and governments promote conservation agriculture in Sub-Saharan Africa to address lower productivity caused by soil erosion and nutrient losses. There are three guiding principles of CA; 1) minimum soil disturbance (e.g., no-tilling and direct planting of seed); 2) permanent organic soil cover with plant residues; and 3) cover cropping and crop rotations (FAO, 2012c; Thierfelder and Wall, 2010).

The diffusion of CA across Mozambique is constrained by institutional and logistical challenges. One factor impeding extensive adoption of CA is that the practice is generally knowledge intensive, presupposing farmer understanding of soil nutrient cycles, causal affects between erosion and soil fertility, and the role of cover crops or residues in evapotranspiration. In Mozambique, the links between individuals with knowledge about CA and its adoption by smallholder farmers is tenuous. Since the end of the civil war in 1992, the government has had difficulty expanding agricultural extension efforts. There were only 696 extension agents for the entire country between 1999-2004 (Almeida et al., 2009). Of these 696, few were trained in conservation agriculture and only 5 had Master's Degrees in Agronomy (Almeida et al., 2009).

Low literacy rates coupled with a plurality of local languages challenges extension efforts. There are 52 languages spoken in Mozambique, complicating the transfer of knowledge between extension agents and farmers. In the Angonia and Tsangano districts, 11% of the population speaks Portuguese (the national language) with illiteracy rates in both districts around 80% (Mozambique, Minister of State Administration 2005a; 2005b). This results in a situation where successful extension projects have to be conducted in local languages, which may increase the cost and time involved in disseminating information (Morris et al., 2007). Nevertheless, CA adoption continues to progress in Mozambique through continuing work by NGO's and government extension efforts.

Farming in Mozambique

Smallholder agriculture dominates Mozambique's agricultural sector, with 98% of production occurring on farms smaller than 5 hectares; the average farm size is 2.4 hectares (Almeida et al., 2009; Heltberg and Tarp, 2002). Mozambican farmers primarily grow maize and cassava. Maize is more commonly grown, with 80% of all farmers engaged in its cultivation (Sitoe, 2005). However, maize is the second most important crop in terms of economic value, accounting for 23% of total market value, surpassed only by cassava, which accounts for 26% of total market value (Almeida et al., 2009). Maize is cultivated throughout Mozambique, but cassava is unsuited to many agroecological zones and is grown mostly on the coastal plains (Government of Mozambique, Minister of Agriculture, 2009). Consequently, maize is the primary consumed staple accounting for between 50-90% of all caloric intake (Erenstein, 2003; Ekboir, 2002a).

Conventional or "traditional" maize farming in Mozambique is characterized by labor-intensive cultivation practices and relatively low yields. Yields range between 0.4 MT ha^{-1} and 1.3 MT ha^{-1}, due in part to the low input use and credit constraints (Howard et al., 1999). Conventional farming practices vary by region, but certain practices and conditions are common across the country. Primary among these is that maize production is labor intensive relying mainly on manual labor to build ridges, prepare and clean fields, and remove weeds.

Agricultural production in Mozambique may be labor intensive, but only 16% of farmers hire labor (Sitoe, 2005). Land preparation activities are accomplished manually because few farmers own tractors and only 11% cultivated fields using animal traction (Almeida et al., 2009; Sitoe, 2005). The use of animal traction is unevenly distributed throughout Mozambique, with more frequent use of draft animals in the southern region where the Tsetse fly is less common (Sitoe, 2005). Mechanized farming as well as the use of draft animals is beyond the means of most farmers. Farmers practicing conventional agriculture generally use hoes to prepare land for cultivation (Almeida et al., 2009; Sitoe 2005).

Farmers till, believing that tillage controls weeds. Tillage practices often leave fields denuded of cover crops, exposing soils to weather. In contrast, farmers practicing CA may be instructed to plant maize in basins dug with hoes, planting cover crops between the holes (Paulo et al., 2007). Another common method used by CA adopters is direct seeding, using no-till planters, jab planters, or dibble sticks (Paulo et al., 2007). Leaving maize residue in fields is also a common practice, but residue density often differs on fields managed with conventional and CA practices. Farmers adopting CA are encouraged to prevent animals from grazing on fields, whereas animals are typically permitted to forage residues on fields managed with conventional practices (Sitoe, 2005; Grabowski, 2012).

Maize production in Mozambique is characterized by low input use (4% of farmers using fertilizer) compared to neighboring countries (e.g., Malawi) (Almeida et al., 2009; Morris et al., 2007; Uaiene, 2008). When fertilizer is used, it is usually under-applied at rates of 3.2 kg ha^{-1}. Pesticide and herbicide use is somewhat higher, with 6.7% of farmers indicating their use (Sitoe, 2005). Input use among farmers practicing conservation agriculture is also typically higher because of loan arrangements for inputs provided by extension or NGO's (Grabowski, 2012).

Loan arrangements typically entail farmers receiving inputs (fertilizer, herbicide, or improved seed) with future production as collateral. Farmers cultivating cash crops, such as cotton or tobacco, tend to use relatively more chemicals and fertilizers because commodity purchasers such as Mozambique Leaf Tobacco (MLT) often provide these inputs (Sitoe, 2005).

In Mozambique, 86% of agricultural production is rain fed (Almeida et al., 2009). Irrigation is limited because of the high capital cost of pumps and groundwater scarcity in some regions. Consequently, 73% of the risk associated with maize crop failure in Mozambique has been attributed to drought (Government of Mozambique, 2006).

Survey data

This research uses data from a survey of 558 households conducted March 19-April 7, 2012. The survey was conducted in two provinces of Mozambique, Tete and Manica. The surveys were conducted in two districts in Tete, Angonia and Ulongue. In Manica the survey was conducted in the Barue district. In total, twenty-two communities were surveyed; twelve had been exposed to CA. Communities were designated as *exposed* to CA if there were current or previous extension efforts present in (or who had worked with) the community training farmers how to implement CA systems (table 1). If there were no extension efforts in the community, then it was designated as an *unexposed* community (table 1). Candidate villages were identified by the NGO Total Land Care (TLC) extension agents working in the survey area, according to their proximity to the provincial capitals of Angonia and Barue (Ulongue and Catandica, respectively). The survey was conducted by University of Tennessee personnel and trained enumerators with help from Mozambican government, NGO extension services, TLC, and the International Maize and Wheat Improvement Center (CIMMYT) staff.

Community involvement and voluntary participation by community leaders was crucial to the success of the surveys. Community leaders facilitated communication between villagers and the enumerators by providing survey list frames and household counts of the village. This collaboration expedited the survey by providing more in depth population data than was available through public sources. In exposed communities, community leaders indicated which households had received training in CA, with all CA adopters interviewed when available.

In *unexposed* and *exposed* communities, systematic random sampling was used to select respondents that had not adopted CA (Lohr, 1999). The number of non- CA households surveyed was determined by general population figures provided by community leaders. Those not engaged in CA but living in exposed communities were also selected using a systematic random sampling procedure. Approximately 10% of the population living in the 22 villages was surveyed (N = 552).

Surveys were conducted in Portuguese or in one of the local languages (Chichewa in Tete and Shona/Chibarue in Manica). The survey was an eight-page questionnaire designed to collect data about; 1) household demographics, 2) socio-economic characteristics, 3) access to various livelihood assets and land ownership, 4) characteristics of farms using CA, 5) access to and type of agricultural services and training, 6) use of agricultural inputs, and 7) access to inputs and maize markets. Enumerators were instructed to locate household and field GPS position when possible. The survey is included at the end of the thesis in its original Portuguese form, as well as an English translation. Both forms were written by the author, with guidance from Drs. Dayton M. Lambert, Michael D. Wilcox, and Mr. Ivan Cuvaca.

Table 1. Survey sample and population

	Angonia/Tete	Barue	Total
Total households in population sample:	3215	2041	5256
Exposed:	2244	757	3001
Unexposed:	1068	1284	2352
Adopt:	97	107	204
Survey total:	365	194	559
Number of households surveyed:			
CA	75	78	153
Exposed:	141	73	214
Unexposed:	134	14	148

Sources: Data compiled by Dr. Dayton Lambert

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Chapter II. Smallholder wellbeing and conservation agriculture

Smallholder household wellbeing

Researchers have used household income as a benchmark for comparing household wellbeing (Lauglo, 2001; Sahn and Stifel, 2003). Other studies measure household wellbeing based on asset and livestock ownership, or household building material quality (Silici, 2010; Arian and Vos, 1996). Household income and wealth are related to agricultural production through factors such as access to land or inputs, which are indirectly related to household wellbeing (Government of Mozambique, Minister of State Administration 2005a, 2005b, 2005c). Smallholder field ownership is typically correlated with household wealth (Jayne et al., 2003; Boserup, 1985). Nevertheless, land in Mozambique cannot be legally transferred, and only inherited through kinship (Government of Mozambique General Assembly of the Republic, 2010). Households cannot increase agricultural production by transferring land except through marriage, but farmers can augment production using fertilizers, chemical herbicides and pesticides, and improved seed varieties (Jayne et al., 2003, Moris, 2007). Animal ownership is also a large component of household wealth in Sub-Saharan Africa (Pica-Ciamarra et al., 2011). Livestock ownership is ubiquitous in Mozambique. Cattle, chickens, goats, and pigs are the most commonly raised animals (Government of Mozambique, Minister of State Administration 2005a, 2005b, 2005c). Cattle ownership is more common in the southern region of Mozambique because the Tsetse fly is less common (Sitoe, 2005).

In Sub-Saharan Africa, female-headed households are typically poorer, owning less land and reporting lower levels of education (Awotide et al., 2012; Jayne et al., 2003). In Mozambique, females attend school at considerably lower rates and are far more likely to be illiterate compared with males. Women are also less likely to be employed in off farm salaried positions, with salaried employment rates 6 – 10 times lower than males (Government of Mozambique, Minister of State Administration 2005a; 2005b; 2005c).

Literacy and education rates are low in Mozambique, with illiteracy rates ranging between 70-80%. School enrolment is also low, with 60-80% of individuals never attending school (Government of Mozambique, Minister of State Administration 2005a, 2005b, 2005c). Literacy and education are linked to reductions in household poverty and generally higher indicators of household wellbeing. Education enables households to mobilize farm resources more effectively, as well as increase a household's ability to market agricultural goods (Lauglo, 2001).

Community characteristics correlated with lower poverty rates and higher household wellbeing indicators are interactions with agricultural extension services, infrastructure, and access to loans. Extension efforts have a positive impact on rural livelihoods by transferring knowledge (about best management practices) increasing agricultural production (Jayne et al., 2003). Proximity to roads is also correlated with higher farm incomes, due in part to the reduced costs of market transactions (Hanjra et al., 2009). Household access to credit sources is also positively correlated with household wealth and wellbeing indicators (Diagne and Zeller, 2001)

Conceptual framework

Household income and wellbeing are linked to fertility, mortality, female empowerment and economic wellbeing (Montgomery et al., 2000; Boserup 1985), but household income and consumption expenditures are difficult to measure in rural areas of developing countries (Howe and Hargreave, 2008; Montgomery, et al., 2000; Moser and Felton 2007; Vyas and

Kumaranayake, 2006). Instead, indices are often used in many cases to indirectly measure income, expenditures, and more generally household wellbeing. Indices are useful in circumstances where multiple currencies are used in a region or where price differentials are uncertain among common goods (Moser and Felton, 2007; Howe and Hargreave, 2008). Wellbeing indices may also capture long-term information about household economic status through measurements of materials used to build houses, access to sanitation, or durable goods purchases (Howe and Hargreave, 2008). Another advantage of using indices to proxy household economic wellbeing is that they facilitate the comparison of factors that may or may not have inherent monetary value but are correlated with wealth and wellbeing (Legese et al., 2010). Howe and Hargreave (2008) proposed a set of asset indices to proxy household consumption and expenditures, providing a measure of relative household wealth in the absence of price and income data. This method is considered a suitable proxy of household income, with research finding a strong correlation between asset indices and consumption (Moser and Felton, 2007).

Indices measuring household wellbeing among smallholder farmers regularly include data about the quality of house construction materials, food and water resources, and asset and livestock ownership (Legese et al., 2010; Silici 2010; Filmer and Pritchett, 2001). Reporting multiple indices summarizing the components of household wellbeing is a good practice, providing a more complete picture of household and community economic status than would be captured with a single index (Silici, 2010; Böhringer and Jochem, 2007).

Household wellbeing indices

Three indices were calculated to proxy household wellbeing; a *Livestock index* (I^L), an *Asset index* (I^A), and a *House construction index* (I^C). The calculations apply Silici (2010) and

Arian and Vos's (1996) methods. The indices provide a snapshot of the relative wealth of CA adopters and conventional farmers in exposed and unexposed villages. The *livestock index* measures the relative wealth of respondents in terms of livestock ownership. The *asset index* measures the relative wealth of productive assets owned by respondents and includes farm tools, implements, and transportation modes. The *house construction index* measures the quality and durability of materials used in the construction of a house, and household access to water and sanitation (Zeller et al., 2006).

The *livestock* and the *asset indices* are calculated using the number of assets or livestock units owned. The *livestock index* is calculated using six variables indicating ownership of chickens, pigs, goats, cattle, ducks and rabbits. The number of variables included in the index determines the weight of each variable. For example, with six variables the weights for the *livestock index* are:

(1) $\frac{1}{N} = \frac{1}{6} = 0.1667.$

The *asset index* measures the ownership of productive assets including axes, hoes, backpack sprayers, irrigation pumps, sickles, shovels, animal drawn ploughs, oxcarts, wheelbarrows, machetes, motorcycles, and bicycles. Similar to the *livestock index*, the weight of each variable is determined by the number of variables included in the index (Silici, 2010), for example:

(2) $\frac{1}{N} = \frac{1}{12} = 0.0833.$

Normalization of the indices facilitates comparison across the measures between households (Böhringer and Jochem, 2007). One normalization method assigns a score based on the quartile to which a household belongs with respect to the number of units of the variable they own (Silici, 2010). Applying this approach yields five possible scores for each variable: 0, 1, 2, 3 or 4; with 0 representing households that did not own any units (table 3). The score is normalized by dividing the quartile level by the maximum score attainable, and then multiplying the value by 100 (for example, 3/4 x 100 = 75). This procedure produces 5 possible scores, 0, 25, 50, 75, and 100, each corresponding with a quartile break (table 4).

Smallholder households are likely to be asset deficient with a large percentage of households owning only one unit of an asset (Bryceson, 2002). This may create problems when assigning scores based on quartiles. For example, respondents may be assigned to the third quartile if they own one asset, producing "lumpy" scores. One approach attending to this problem is to assign a score of 50 to all households who own one unit, 100 to households owning more than one unit, and 0 to households who own nothing in that category.

The *livestock* and *asset indices* are calculated as:

(3) $$I = \sqrt{\frac{1}{N} \sum_{n=1}^{N} x_n^2}$$

where x_n a score corresponding to each variable $n = 1,\ldots N$ included in the index.

Table 1: Calculation of the *livestock index*: example

Variable:	Units owned:	Quartile sample for ownership of this animal:	Score:
Chicken	9	3	75
Pig	0	0	0
Goat	2	2	50
Cattle	1	1	25
Duck	0	0	0
Rabbit	4	2	50

Based on the example data in table 1, the *livestock index* I^L for a household is:

$$I^L = \sqrt{\frac{75^2+0^2+50^2+25^2+0^2+50^2}{6}} = 43.30.$$

The *house construction index* applies Arias and Vos's (1996) method because the component variables are qualitative and categorical (as opposed to continuous variables like livestock). The variables included in the *house construction index* preclude the assignment of scores based on a distribution because all but one of the variables are discrete/categorical (0,1,2,3,4) or binary (0,1). Consequently, a second score assignment method is used to assign scores based on the quality of the materials used in the construction of houses (table 3). The variables used in the *house construction index* are normalized by dividing the assigned variable score by the maximum variable score attainable and multiplying it by 100. The number of variables included in the index also weights the *house construction index*. The index score is calculated as equation 3, and an example of the *house construction index* is provided in table 2.

Table 2: Calculation of the *house construction index*: example

Variable:	Material/Quality	Score for this variable	Normalized score
Wall	Masonry	3	100
Floor	Brick	2	100
Roof	Plastic sheeting	0	0
Bathroom	External	1	50
Electricity	No	0	0
Water source	Pump	2	66.6
Transportation	Yes	1	100
Number of rooms	2	1	33.3

Based on the example data, the housing construction index I^c for a household is:

$$I^C = \sqrt{\frac{100^2+100^2+0^2+50^2+0^2+66.6^2+100^2+33.3^2}{8}} = 68.9.$$

Empirical model

The following empirical models are used to estimate the correlation between the index scores for households, *i*, and demographic, farm production, and marketing characteristics. Of particular interest is the correlation between the adoption of CA and index scores. The empirical models for the indices are:

(4) $$I_i^L = \beta_0 + \beta_1^L Agehh_i + \beta_2^L mhh_i + \beta_3^L Education_i + \beta_4^L Famsize_i + \beta_5^L Adultpercent_i + \beta_6^L Incomefarm_i + \beta_7^L Laborincome_i + \beta_8^L CA_i + \beta_9^L Fieldsize_i + \beta_{10}^L Fielddistance_i + \beta_{11}^L ExposedVillage_i + \beta_{12}^L Barue_i + \beta_{13}^L FemaleTransactor_i + \beta_{14}^L NetSeller_i + \gamma^{LC} I_i^L + \gamma^{LA} I_i^L + \varepsilon_i^L,$$

$$(5)\quad I_i^A = \beta_0 + \beta_1^A Agehh_i + \beta_2^A mhh_i + \beta_3^A Education_i + \beta_4^A Famsize_i + \beta_5^A Adultpercent_i + \beta_6^A Incomefarm_i + \beta_7^A Laborincome_i + \beta_8^A CA_i + \beta_9^A Fieldsize_i + \beta_{10}^A Fielddistance_i + \beta_{11}^A ExposedVillage_i + \beta_{12}^A Barue_i + \beta_{13}^A FemaleTransactor_i + \beta_{14}^A NetSeller_i + \gamma^{AL} I\, I_i^L + \gamma^{AC} I_i^C + \varepsilon_i^A,$$

$$(6)\quad I_i^C = \beta_0 + \beta_1^C Agehh_i + \beta_2^C mhh_i + \beta_3^C Education_i + \beta_4^C Famsize_i + \beta_5^C Adultpercent_i + \beta_6^C Incomefarm_i + \beta_7^C Laborincome_i + \beta_8^C CA_i + \beta_9^C Fieldsize_i + \beta_{10}^C Fielddistance_i + \beta_{11}^C ExposedVillage_i + \beta_{12}^C Barue_i + \beta_{13}^C FemaleTransactor_i + \beta_{14}^C NetSeller_i + \gamma^{CA} I_i^C + \gamma^{CL} I_i^L + \varepsilon_i^C,$$

where each index is regressed on a set of explanatory variables which include whether a household practiced CA, household attributes, farm characteristics, regional variables, and the indices. The indices may be co-determined (figure 2). The error terms ($\varepsilon^A, \varepsilon^L, \varepsilon^C$) are assumed to independently and identically distributed with a mean of 0 and a constant variance. However, there is the possibility that the noise component elements across the index equations are contemporaneously correlated (Mittelhammer et al, 2000, pg. 378).

Variables used in the empirical model

Household demographic variables include head of household characteristics, household composition, and income sources (table 7). Age, education level, and the gender of the household head are also included as explanatory variables. Previous studies provide little indication that household head age (*Agehh*) would be a significant predictor of household wealth status (Awotide et al., 2012). Education is measured with a binary variable denoting whether the household head has attended middle school. Education is expected to be positively correlated with household wellbeing (Lauglo, 2001). Female-headed households (*Mhh*) are expected to have lower household wellbeing indices, because female-headed households tend to be poorer and relatively asset deficient (Government of Mozambique, Minister of State Administration 2005a, 2005b, 2005c).

Household size (*Famsize*) is included in the empirical models. It is expected that larger households will be relatively wealthier. Previous studies find that family size and wealth are correlated (Boserup, 1985). The association between household composition and the wealth indicators is measured by the percentage of family members between the ages of 15-65 (*Adultpercent*). It is expected that household wellbeing will be relatively higher in households with more family members belonging to this group, as households that have a higher percentage of adults are more likely to earn income from selling crops (Boughton et al., 2007).

Income generated from agricultural sales (*Incomefarm*) and from wage labor (*Laborincome*) are also included in the empirical model. It is expected that households earning a higher percentage of income from agricultural sales will have higher wellbeing index scores. Households earning a higher percentage of income from labor sources are expected to have lower wellbeing index scores. This is due to agriculture being the primary source of household income in the region, with labor sold primarily to other farmers (Mozambique, Ministry of State Administration 2005a; 2005b; 2005c).

Farm production characteristics include field size (ha) (*Fieldsize*), distance from the household to each field in walking minutes (*Fielddistance*), and an indicator variable whether the household practiced CA (*CA*). Field size is expected to be positively correlated with household wellbeing (Mather et al., 2011). The variable *Fielddistance* calculates the weighted average distance (in minutes) walking to a fields. Each field is weighted to reflect its proportion of total field size, with weights are determined by:

(7) $$W_k = \frac{F_k}{\sum_{k=1}^{K} F_k},$$

where F is a farmer's field size (ha), $k = 1, \ldots K$ number of fields a farmer owns, and W_k is the weighted size of a field. The weighted distance to a farmer's fields is:

(8) $$Fielddistance = \sum_{k=1}^{K} (W_k T_k),$$

where T is the distance to a field in minutes from the farmers house to a field. In the author's experience in the surveyed communities, fields that are farther from the household tend to be larger and are the main production fields. Therefore, it is hypothesized that households that live farther from their fields (Fielddistance) are expected to have higher index scores.

Whether a household practiced conservation agriculture is indicated by the binary variable *CA*. Conservation agriculture practices in this study are defined as sowing maize using no-till methods and leaving at least 25% of crop residue on the field. This definition of no-till includes the use of seed basins. A farmer is considered a conservation agriculture adopter if they practiced CA on at least one of their fields (on average farmers operated 2.3 fields), in addition to self-reporting that they practiced conservation agriculture. Previous findings demonstrate that fields managed with conservation agriculture produce more stable (and possibly higher) yields (FAOc, 2001; Kassam et al., 2009; Thierfelder and Wall, 2010). Agricultural sales are the main source of household income in the surveyed region, so it is expected that CA households will have higher incomes resulting in higher wellbeing for households that practice CA. The *CA* variable is orthogonally restricted, so that the coefficient of this variable can be tested with respect to the population mean of the indices (Neter et al., 1996).

Two binary variables are included to control for community characteristics that might be associated with the wellbeing indices. The first indicates households residing in Barue (*Barue*). Barue residents are expected to report higher index scores because the climate of Barue is suited to the production of a wider variety of crops than Tete (FAO country profile, 2012). The second community characteristic denotes whether a household is a non-CA adopter residing in a village where CA extension efforts have taken place (*ExposedVillage*). Like the variable denoting *CA*, *ExposedVillage* is orthogonally restricted, so that the coefficient of this variable is interpreted as a difference from the population mean. Households residing in exposed villages, but that have not adopted CA are not expected to have significantly different index scores than the population mean.

Marketing characteristics include the gender of the household's primary market transactor (*FemaleTransactor*) and whether a household is a net maize seller (*NetSeller*). The gender of the transactor is indicated with a binary variable (1 for female, 0 otherwise). Households where females are the primary trader are expected to report lower wellbeing index scores due to suggesting that female traders are less likely to market cash crops (e.g., cotton or tobacco), and more likely to market staple crops of relatively lower value (English et al., 2008). A household's marketing position is measured with a binary variable indicating whether a household is a net maize seller. Households that are net maize sellers are expected to have higher index scores because the sale of agricultural products is the main source of household income in the surveyed regions (Government of Mozambique, Minister of State Administration 2005a, 2005b, 2005c).

Estimation and model specification

The association between the wellbeing indices and the covariates are analyzed using a non-causal regression framework because it is exceedingly difficult to establish causation given the cross-sectional nature of the survey. Instead, *ceteris paribus* correlations are drawn between the explanatory variables and different aspects of household wellbeing. Figure 1 presents a stylized map of the empirical models, explaining the hypothesized relationships between the variables and the instruments used to test exogeneity assumption for each index included in the models.

The model selection applies a three step processes considering (1) the potential endogeneity of the indices, (2) the relevance of the instruments used to test endogeneity, and (3) the correlation structure of the error terms. The model selection processes is understood as a decision tree (figure 2). Potential estimation procedures include Ordinary Least Squares (OLS), Seemingly Unrelated Regression (SUR), Two Stage Least Squares (2SLS), and Three Stage Least Squares (3SLS).

It seems reasonable to believe that the indices would be highly correlated with each other (yet the index variables included as explanatory variables may be endogenous). On the other hand, causality between the indices is difficult to untangle because they are likely codetermined. Wooldridge's (2004) method (a Hausman type test) is used to test the null hypothesis that the indices are exogenous. For example, focusing on the *livestock index* equation:

(9) $I^L = \beta_0 + \beta^L X + \gamma^{LC} I^C + \gamma^{LA} I^A + u_L$,

where β^L is a vector representing the coefficients β_1^L- β_{14}^L and X is a matrix of explanatory variables X_1-X_{14}. In the example, there are two potentially codetermined explanatory variables; I^A and I^C. To determine whether I^A and I^C are statistically exogenous, reduced form linear models of I^A and I^C are specified, including instrument variables (Z) that are correlated with I^A and I^C but uncorrelated with u_L;

(10) $I^A = \pi_0^A + \pi_1^A Z^A + V_A$,

(11) $I^C = \pi_0^C + \pi_1^C Z^C + V_C$.

The residuals $\hat{V}_A$ and $\hat{V}_C$ are introduced into equation 9;

(12) $I^L = \beta_0 + \beta X + \gamma^{LC} I^C + \gamma^{LA} I^A + \delta_1 \hat{V}_A + \delta_2 \hat{V}_C + v$,

Equation 12 (a reduced form version of I^L) is estimated with OLS. The null hypothesis tests whether the coefficients of $\hat{V}_A$ and $\hat{V}_C$ are statistically different from zero (H_0: $\delta_1 = \delta_2 = 0$). If the null hypothesis is rejected, then the variables I^A and I^C are statistically endogenous and the estimation procedure follows the 2SLS/3SLS branch of the decision tree (figure 2). If the null cannot be rejected, then an OLS or SUR estimation procedure is warranted (figure 2).

The validity of this procedure depends on the suitability of instruments (*Z*) used in the test. If the instruments used to identify equations 10 and 11 are weakly correlated with the variables hypothesized to be exogenous (e.g., I^A and I^C) then the test results for equation 12 are difficult to interpret (Wooldridge, 2004). Bound et al. (1995) suggested a method for testing the relevance of the instruments used in equations 10 and 11. The test involves estimating these equations (10 – 12) with OLS, focusing on the joint significance of the coefficients associated with the instruments. The null hypothesis of the test is H_0: $\pi = 0$ (Bound et al., 1995; Roodman, 2009).

The instrumental variables used for I^A and I^L are the approximate values of the assets and animals reported by farmers (in Meticals) (Z^A and Z^L, figure 1). For the *asset index* I^A, this information was available for following tools and implements; axes, hoes, backpack sprayers, sickles, shovels, animal drawn plows, oxcarts, wheelbarrows, machetes, motorcycles, and bicycles. For the *livestock index* I^L, this information was available for chickens, pigs, goats, cows, ducks, and rabbits. The instruments for I^C (Z^C, figure 1) are more difficult to ascertain because questions about the value of house construction materials were not included in the survey. Consequently, the instruments for I^C are farmer use of credit, the number of fields rented from other households, household ownership of radios or televisions, and if the household head worked in salaried position. If the coefficients for the instruments are jointly insignificant, then using them in equations 10 or 11, or in a 2SLS/3SLS model, may produce inconsistent estimates.

The final step in the model selection procedure entails determining whether the error terms of the index equations are correlated using Breusch and Pagan's (1980) (BP) test. The null hypothesis tests whether the error terms of the three equations are correlated; H_0: corr $(\varepsilon^L, \varepsilon^A, \varepsilon^C) = 0$. If the null hypothesis is rejected, then SUR or 3SLS, is used to estimate the equations;

depending on the results of the index exogeneity test (figure 2). When the error terms are correlated, SUR estimation produces more efficient estimates (Zellner, 1962). When the error terms are correlated and instrumental variables are used, 3SLS produces more consistent estimates of the standard errors and attends to the endogeneity of indices. This identification procedure (testing for variables endogeneity, instruments suitability, and correlated error terms) is repeated for each index equation (4, 5 and 6).

Hypothesis

Tukey's honestly significant difference (HSD) is used to test the null hypothesis that CA (*CA*) households do not have different index score means compared with other households in exposed (*EX*) and unexposed (*UN*) communities. For the *asset index* H_0: $\mu_A^{CA} = \mu_A^{EX}$ and $\mu_A^{CA} = \mu_A^{UN}$. For the *livestock index*, H_0: $\mu_L^{CA} = \mu_L^{EX}$ and $\mu_L^{CA} = \mu_L^{UN}$, and for the *house construction index,* H_0: $\mu_C^{CA} = \mu_C^{EX}$ and $\mu_C^{CA} = \mu_C^{UN}$. The regression estimates are used to test the hypothesis that CA adoption does not have a correlation with household wellbeing, H_0: $\beta_8{}^L = 0$, H_0: $\beta_8{}^A = 0$, and H_0: $\beta_8{}^C = 0$, holding other factors constant.

Farmers practicing CA are hypothesized to have higher household wellbeing indices than non-adopting households. This hypothesis is motivated by previous research reporting increases in crop production associated with CA production coupled with agricultural sales being the largest source of household income in the surveyed region (Kassam et al., 2009; Thierfelder and Wall, 2010). It is hypothesized that, holding other factors constant, CA adopters will have lower *livestock index* scores because the premium associated with residue for livestock consumption competes with use of residue to protect soil (Sitoe 2005; Almeida et al., 2009).

Descriptive statistics

Conservation agriculture adopters reported the highest index scores. Among the indices, the lowest average score was the *livestock index*, with an index value of 27.48 across all households (table 6). Households using CA reported the highest average *livestock index* score of 32.07, followed by conventional farmers in exposed villages and farmers in unexposed villages with average *livestock index* scores of 26.61 and 24.86, respectively. The difference in means between CA farmers and all other households is significant at the 5% level (table 10). This was unexpected, as it was hypothesized that CA farmers would have lower *livestock index* scores. Households with more diverse agricultural enterprises appear more likely to experiment with CA.

The *asset index* score was second highest average (35.42). Households using CA reported the highest average *asset index* score of 41.07, followed by conventional farmers in exposed and unexposed villages with average scores of 35.54 and 31.93, respectively (table 6). The difference in the means of this index between CA farmers and all other households is significant at the 5% level (table 10). The *house construction index* has the highest index score, 44.69 (table 6). Like the other indices, the *house construction index* follows a pattern where farmers practicing CA had the highest index (49.40), followed by conventional farmers in exposed (44.72) and unexposed villages (40.67) (table 6). The differences between all groups are significant at the 5% level (table 10). This result concerning the asset and house construction indices was expected, because it was hypothesized that CA farmers would have, on average, higher index values. Households that adopted CA were hypothesized to report higher index scores because crop yields are less variable on CA fields; which is important given that the sale of agricultural production is the number one source of household income in the region.

Most respondents (77%) indicated residing in a male-headed household. The degree to which males were the household head varied, ranging from 69% of households for conventional farmers in unexposed communities to 85% of households for CA adopters. The mean difference in the head of household gender for CA farmers and conventional farmers in unexposed villages is significant at the 5% level. Life expectancy in Mozambique is presently 50 years (UNICEF, 2010). The mean household head age for a CA farmer is 45.5 years, as compared to 43.03 for conventional farmers in unexposed villages and 40.8 for conventional farmers in unexposed villages. The difference in the head of household age is significant at the 5% level for CA farmers and conventional farmers in unexposed villages (table 10).

Household size includes all individuals who reside in the primary residence. The definition is extended to non-family members. For households practicing CA, the mean household size was 6.35 persons. Households practicing conventional farming in exposed and unexposed communities reported family sizes of 5.87 and 5.66, respectively. There is no significant difference in household size at the 5% level. The household composition is similar among the groups; with approximately 50% of the members aged 15-65, with differences in household composition among the groups insignificant at the 5% level. Individuals reported having little formal education, with only 5.6% of CA and conventional farming households in exposed communities having attended middle school, and approximately 7.4% of conventional farmers in unexposed communities having attended middle school. Differences between groups are not significant at any conventional level.

Approximately 98% of the households indicated that maize was the principal crop consumed, with 89% of consumed maize produced by the household. Income derived from working for a wage is not significantly different among the groups; with wage income accounting for, on average, 19.6% of all household income. However, the percentage of household income derived from agricultural sales is different at the 5% level for CA households and conventional farmers. Farmers practicing CA earned, on average, 82.8% of income of their agricultural income from farm sales as compared with 71.4% and 71.2% for conventional farmers in unexposed and exposed villages, respectively.

Total land holdings varied among the groups. Conservation agriculture households operated about twice as many hectares compared with households in unexposed villages (2.13 ha and 1.19 ha, respectively). The landholdings of farmers in unexposed communities are intermediate, with an average of 1.74 ha. The difference in land holdings between CA farmers and conventional farmers in unexposed villages, as well as the difference between conventional farmers in exposed and unexposed villages, is significant at the 5% level (table 10). Average distance to fields was not different among the groups average (52.45 minutes) (table 10).

Farmers practicing CA were more likely to participate in the market as vendors, with 71.2% of CA farmers selling maize, compared to 55.18% and 42.56% of conventional farmers in exposed and unexposed communities selling maize, respectively (table 10). The difference in market participation rates is also significant at the 5% level. Among households participating in the market, the difference in females as the primary transactor is significant at the 5% level for CA farmers and conventional farmers in unexposed villages, with females the primary trader in 24% of the CA households as compared to 39% for conventional farmers in unexposed villages (table 10). Females are the primary market transactors in approximately 32% of conventional farming households in exposed communities.

Results

Model diagnostics

The overall fit of the system is respectable, explaining more than 72 percent of the variation in the index scores. Variance inflation factors were calculated for the design matrix of each model. All variance inflation factor scores were less than 10, suggesting that multicollinearity was not inflating standard error estimates (O'brien, 2007).

Bound's F test suggests the instruments are relevant (table 11). Wooldridge's test for exogeneity does not suggest the indexes included in the regressions are endogenous (table 11). Accordingly, the 2SLS/3SLS branch of the decision tree was ruled out in favor of the OLS/SUR branch (figure 2).

Finally, the Breusch-Pagan test indicated that the error terms of three equations are highly correlated ($\chi^2 = 150$, $P < 0.0001$, degrees of freedom = 2). Given these results, SUR is used to estimate the empirical model (equations 4, 5, and 6).

Regression results

Demographic variables are significantly correlated with the household wellbeing indices. Holding other factors constant, the *asset index* for households headed by males was 5.07 higher than female-headed households ($P < 0.0001$) (table 12). This finding is consistent with previous studies as well as the Mozambique government census, which found higher rates of poverty among households headed by females (Government of Mozambique, Minister of State

Administration 2005a, 2005b, 2005c). Education is also positively associated with the *asset index* at the 10 % level, holding other factors constant, households where the head of household has attended middle school have scores that are 3.2 points higher (P = 0.086).

All else equal, *asset index* scores were higher for larger households; an increase in household size of 1 individual corresponds with an increase of 0.884 points for this index (P < 0.0001). Conversely, family size is negatively correlated with the *house construction index*; with every 1-person increase in family size, the *house construction index* decreases by 0.52 points (P = 0.0752). The percentage of household income derived from farming as well as off farm labor are both negatively correlated with the *house construction index* (P = 0.001 and P = 0.013, respectively). A 10% increase in the proportion of household income derived from both of these farm income sources is correlated with a 1-point decrease in the construction index. The findings are similar for increased in household income derived from the sale of labor (day laborer), with a 10% increase in the income derived from labor correlated with a 1 point decrease in the construction index. Households with more diversified incomes sources may be better off in terms of the wellbeing indices examined here.

Households practicing CA had, on average, higher asset and *house construction index* scores and lower *livestock index* scores. Holding other factors constant, *asset index* scores were 1.18 points higher for farmers practicing CA compared with the population mean (P = 0.1025). The *house construction index* score was 2.56 points higher for CA adopters than the population mean (P = 0.0164). However, all else equal CA households reported *livestock index* scores that were 3.7 points lower than the population average (P = 0.0035). This finding may be attributed to CA farmers focusing on crop production at the cost of animal ownership. In contrast to conventional practices, CA farmers are usually instructed by extension personnel to retain crop residue on fields as soil cover, competing directly with the use of crop residues for forage. This result is consistent with previous research which found that households adopting CA have, on average, less livestock (Silici, 2010).

Holding other factors constant, field size is correlated with an increase in the *livestock index* (P = 0.051); an increase of field size by 1-ha is associated with a 0.842 increase in the *livestock index* score. Average field distance from the house is correlated with an increase in the *asset index* score; for every one minute increase in the field distance from the respondent's house, the *asset index* score increased by 0.19 (P = 0.0574).

All else equal, Barue residents have significantly higher asset and livestock indices scores, with *asset index* scores 5.48 points higher than households in Tete (P < 0.0001). The *livestock index* was 5.01 points higher for Barue residents compared to households in Tete (P < 0.0001). Barue residents had *house construction index* scores that are 9.48 points less than Tete residents (P < 0.0001). Although both Barue and Tete are in the same country, Barue residents appear to be better off in terms of asset and *livestock index* scores compared with Tete households. This may be due to the two regions being in different agroecological zones. Different rainfall patterns and soil types may provide comparative advantage to Barue farmers translating into higher productivity higher crop sales and eventually wealth. Households in villages where CA extension efforts had occurred, but that did not practice CA had, on average, 1.09 lower *asset index* scores than the population average (P = 0.071). This suggests that farmers practicing CA farmers may be better off in terms of asset ownership than non-adopters in the same community.

As hypothesized, the indices appearing as explanatory variables were highly correlated in each equations with the dependent variable indices (P < 0.0001). A 1-unit increase in the *asset* *index* score was associated with a 0.93 and 0.65 point increase of the livestock and house construction indices, respectively. All else equal, a 1-unit increase in the *livestock index* was associated with an increase in the asset and house construction indices of 0.303 and 0.154, respectively. A 1-unit increase in the construction index was associated with an increase in the asset and livestock indices by 0.30 and 0.15, respectively. The findings suggest that increases in one dimension of household wellbeing increase other aspects of household wellbeing.

Conclusions

A number of findings were revealed in this research; the most important being the *ceteris paribus* correlation of conservation agriculture with household wellbeing. The findings raise additional questions regarding the adoption of conservation agriculture and household wellbeing. Coupled with literature on Sub-Saharan African poverty, the findings may provide guidance for future analysis of the relationships between extension efforts and poverty reduction policy in Mozambique.

One of the primary findings is that conservation agriculture adopters have, *ceteris paribus*, higher asset and construction index scores. However households having adopted conservation agriculture had lower *livestock index* scores compared with non-CA households, all else equal. In other words, households practicing CA tended to have more farm tools and implements and lived in houses built of more durable and higher quality materials than other households. This was expected given, the competing nature of conservation agriculture (residue management) and animal grazing. Households make a decision how to use the limited resources at their disposal. Households raising livestock are required to feed their animals with what their landholdings can produce, because few Sub-Saharan African households purchase livestock feed

(Chakeredza et al., 2007). Consequently, most households rearing livestock require grazing animals on crop residues. This does not appear to be the case with CA farmers who are encouraged to retain crop residues.

Descriptive statistics and multivariate regression results suggest that households practicing CA are better off than conventional farmers in terms of certain aspects of household wellbeing than other households in their community. However, causation is difficult to establish due to the cross-sectional nature of the survey. The question remains: are CA adopters better off because they adopted CA, or are CA adopters wealthier to begin with? Household attributes analyzed here suggest a situation where CA farmers are better off than the population *ceteris paribus*, and are thus able to bear the risk associated with the adoption of new technologies.

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Appendix I. Tables and figures

Table 3. Quartiles of the variables used to construct the *livestock* and *asset indices*

Variable:	Min	Q1	Q2	Q3	Max
Asset index					
Axe	0	1	1	2	20
Hoe	0	2	3	5	21
Sprayer	0	1	1	1	3
Irrigation Pump	0	1	1	1	2
Sickle	0	1	1	2	12
Shovel	0	1	1	1	7
Plow	0	1	1	1	3
Ox Cart	0	1	1	1	7
Wheelbarrow	0	1	1	1	2
Machete	0	1	1	2	21
Motorcycle	0	1	1	1	2
Bike	0	1	1	2	6
Livestock index					
Chicken	0	4.0	8	15	120
Pig	0	1.5	3	7	15
Goat	0	3.0	4	6	100
Cattle	0	2.0	3	6	20
Duck	0	4.0	5	7	10
Rabbit	0	3.0	6	8	30

Sources: Calculated by the author.

Table 4. *Livestock* and *asset indices* scores

Variable/Index:		Variable scores/number of households reflecting each score: 0	25	50	75	100
Asset index						
Axe	Units (1)	0	.	1	.	≥2
	N (2)	182	.	184	.	100
Hoe	Units	0	1	2	3	≥5
	N	3	34	130	228	92
Sprayer	Units	0	.	1	.	≥1
	N	416	.	64	.	7
Sickle	Units	0	.	1	.	≥2
	N	207	.	197	.	83
Shovel	Units	0	1	1	1	≥1
	N	373	.	94	.	20
Plow	Units	0	1	1	1	≥1
	N	455	.	23	.	9
Ox Cart	Units	0	1	1	1	≥1
	N	436	.	47	.	4
Wheelbarrow	Units	0	1	1	1	≥1
	N	475	.	11	.	1
Machete	Units	0	1	1	1	≥2
	N	353	.	87	.	47
Motorcycle	Units	0	1	1	1	≥1
	N	465	.	22	.	2
Bike	Units	0	1	1	1	≥2
	N	221	.	201	.	65
Livestock index						
Chicken	Units	0	1	4.0	8	≥15
	N	193	66	81	67	80
Pig	Units	0	1	1.5	3	≥7
	N	413	20	13	27	14
Goat	Units	0	1	3.0	4	≥6
	N	282	21	67	76	41
Cattle	Units	0	1	2.0	3	≥ 6
	N	378	11	57	19	22
Duck	Units	0	1	4.0	5	≥ 7
	N	469	1	6	8	3
Rabbit	Units	0	1	3.0	6	≥8
	N	458	5	8	4	7

Sources: Calculated by the author. (1) Units refer to the number of units owned that fall into the index score interval. (2) N refers to the number of people receiving that score.

Table 5. ***House construction index*** **scores**

Variable:	**Variable score/Description**			
	0	1	2	3
Wall:	Plastic, metal sheeting, other	Plant material, mud brick	Wood	Masonry
Floor:	Dirt	Tile, brick Cement, Other		
Roof:	Plastic sheeting, other	Plant material	Metallic sheeting, tile	
Bathroom:	None	External	Internal	
Electricity:	No	Yes		
Water source:	Lake, pond, river	Stream	Pump	Piped water, water tank
Transportation:	None	Bike, motorcycle or oxcart		
Number of Rooms:	1	2	3	3 < rooms

Table 6. Descriptive statistics of the *asset, livestock*, and *house construction indi*ces

Index/Subgroup:	Average	St. Dev.	N
***Livestock index*:**			
CA	32.07 (a)	20.53	125
Conventional Farmers In Exposed Communities	26.61 (b)	21.30	214
Conventional Farmers In Unexposed Communities	24.86 (b)	19.45	148
***Asset index*:**			
CA	41.07 (a)	14.03	125
Conventional Farmers In Exposed Communities	34.54 (b)	13.70	214
Conventional Farmers In Unexposed Communities	31.93 (b)	12.67	148
***House construction index*:**			
CA	49.40 (a)	13.99	125
Conventional Farmers In Exposed Communities	44.72 (b)	14.85	214
Conventional Farmers In Unexposed Communities	40.67 (c)	14.85	148
Index Average:			
CA	24.38 (a)	10.21	125
Conventional Farmers In Exposed Communities	20.38 (b)	10.58	214
Conventional Farmers In Unexposed Communities	18.93 (b)	9.46	148

Sources and notes: Calculated by the author. Index scores range from 0-100. Means followed by the same letter in the same index groups column are not significantly different at the 5% level.

Table 7. Explanation of variables used in the regressions

Variable Name	Variable Explanation
Dependent Variables	
Assetindex	Dependent variable in model 1, explanatory variable in models 2 and 3
Livestockindex	Dependent variable in model 2, explanatory variable in models 1 and 3
Constructionindex	Dependent variable in model 3, explanatory variable in models 1 and 2
Independent Variables	
Household Characteristics	
Agehh	Age of the head of household in years
Mhh	Gender of household head (1= male, 0 = female)
Education	Head of household having attended middle school (1 = yes, 0 = otherwise)
Famsize	Total number of individuals in the household
Adultpercent	Percent of household aged 15-65
Farmincome	Percent of household income derived from farm sources
Laborincome	Percent of household income derived from labor sources
Production Characteristics	
Cafarmer	Household having adopted CA practices (1 = CA, 0 = conventional farmer)
Totalfieldsize	Total field size in hectares
Weightdistance	Average distance to fields (minutes)
Community Characteristics	
CFExpsvillage	Conventional farmer residing in a village where CA extension efforts have occurred (1=yes, 0 = no)
Barue	Residence in Barue province (1 = yes, 0 = no)
Market Characteristics	
Femaletransactor	Gender of primary market transactor (1 = female, 0 = male)
Netseller	If a household is a net seller of maize (1 = yes, 0 = no)

Table 8. Household demographics

	Exposed Villages		Unexposed villages
	Conservation agriculture (CA) adopters	Conventional Farmers	Conventional Farmers
Head of household (HH) gender:			
Male	106 (84.8%)	167 (78.77%)	102 (69.38%)
Female	19 (15.2%)	45 (21.23%)	45 (30.62%)
N	125	212	147
HH age:			
Mean	45.50	43.03	40.8
Std Dev	12.97	13.92	12.66
Min	24	19	16
Max	91	85	67
N	114	191	134
Household head having attended middle school:			
Yes	5.6%	5.6%	7.4%
No	94.4%	94.4%	92.6%
Family size:			
Mean	6.35	5.87	5.66
Std Dev	2.64	2.76	2.62
Min	2	1	1
Max	18	25	16
N	125	214	147
Percent of family aged 15-65:			
Mean	51.26	49.79	50.39
Std Dev	20.79	20.52	21.39
Min	0	0	12.5
Max	100	100	100
N	124	214	147
Total field size in hectares:			
Mean	2.13	1.74	1.19
Std Dev	2.54	2.30	0.93
Min	0.12	0.04	0.20
Max	20.23	27.51	7.68
N	123	207	147

Sources: Calculated by the author.

Table 9. Sources of household income, staple crop consumption, and number of years practicing CA

	Exposed villages		Unexposed villages
	Conservation agriculture (CA) adopters	Conventional Farmers	Conventional Farmers
Percent of household income derived from farm income:			
Mean	82.88	71.4	71.2
Std Dev	29.7	35.8	36.2
Min	0	0	0
Max	100	100	100
N	125	214	147
Percent of household income derived from wage labor:			
Mean	14.24	22.3	20.4
Std Dev	28.63	34.4	3.31
Min	0	0	0
Max	100	100	100
N	125	214	147
Percent of household income derived from pension or remittances:			
Mean	1.12	0.79	3.26
Std Dev	8.25	0.55	15.8
Min	0	0	0
Max	70	50	10
N	125	214	147
Principal food staple:			
Maize	123 (98.4%)	211 (98.6%)	140 (95.24%)
Other	2 (1.6%)	3 (1.4%)	7 (4.76%)
N	125	214	147
Source of maize:			
Produced	91.12	89.01	86.25
Purchased	8.48	10.88	13.06
Credit	0	0	0.2
Aid	0.4	0.5	0.4
Number of years practicing CA:			
Mean	3.19	.	.
Std Dev	2.39	.	.
Min	0	.	.
Max	15	.	.
N	121	.	.

Sources: Calculated by the author.

Table 10. Means comparison of households and farm characteristics

Variable	**CA mean**	**CF exposed mean**	**CF unexposed mean**	**Population mean**	**N**
Household Characteristics					
Agehh	45.5 (a)	43.03 (ab)	40.8 (b)	42.99	439
Mhh	84.8% (a)	78.77% (ab)	69.38% (b)	77%	487
Education	5.6% (a)	5.6% (a)	7.4% (a)	7.14%	487
Famsize	6.35 (a)	5.87 (a)	5.66 (a)	5.93	485
Adultspercent	51.26% (a)	49.79% (a)	50.39% (a)	50.35%	485
Staple1produced	91.12% (a)	89.01% (a)	86.25% (a)	88.7%	485
Farmincome	82.8% (a)	71.4% (b)	71.2%(b)	74.3%	486
Laborincome	14.2% (a)	22.3% (a)	20.4% (a)	19.6%	486
Production Characteristics					
Totalfieldsize	2.13 (a)	1.74 (a)	1.19 (b)	1.67	477
Fielddistance	47.39 (a)	54.29 (a)	54.99 (a)	52.45	485
Marketing Characteristics					
Femaletransactor	24% (a)	32.08% (a)	39.19% (b)	32.16	487
NetSeller	71.2% (a)	55.18% (b)	42.56% (c)	55.37%	485
Indices					
I^L	32.07 (a)	26.61 (b)	24.86 (b)	35.42	487
I^A	41.07 (a)	34.54 (b)	31.93 (b)	27.48	487
I^C	49.4 (a)	44.72 (b)	40.67 (c)	44.69	487

Sources and notes: Values calculated by the author. Means followed by the same letter in the same row are not significantly different at the 5% level (Tukey's Honestly Significant Difference).

Table 11. Model selection results

Variable	*Asset index*	*Livestock index*	Construction index
	F value and P > F	F value and P > F	F value and P > F
Wooldridge's test for endogeneity			
Asset index	0.45 (0.636)	.	.
Livestock index	.	0.84 (0.4337)	.
House construction index	.	.	0.56 (0.5726)
N	418	418	418
DF	16	16	16
Bound et al.'s test of instrument relevance			
Asset index	10.25 (0.0001)	.	.
Livestock index	.	9.02 (0.0001)	.
House construction index	.	.	2.55 (0.0079)
N	418	418	418
DF	32	32	32
Breusch and Pagan test results for correlation between error terms			
χ^2	150.337		
P value	0.0001		
N	479		
DF	2		

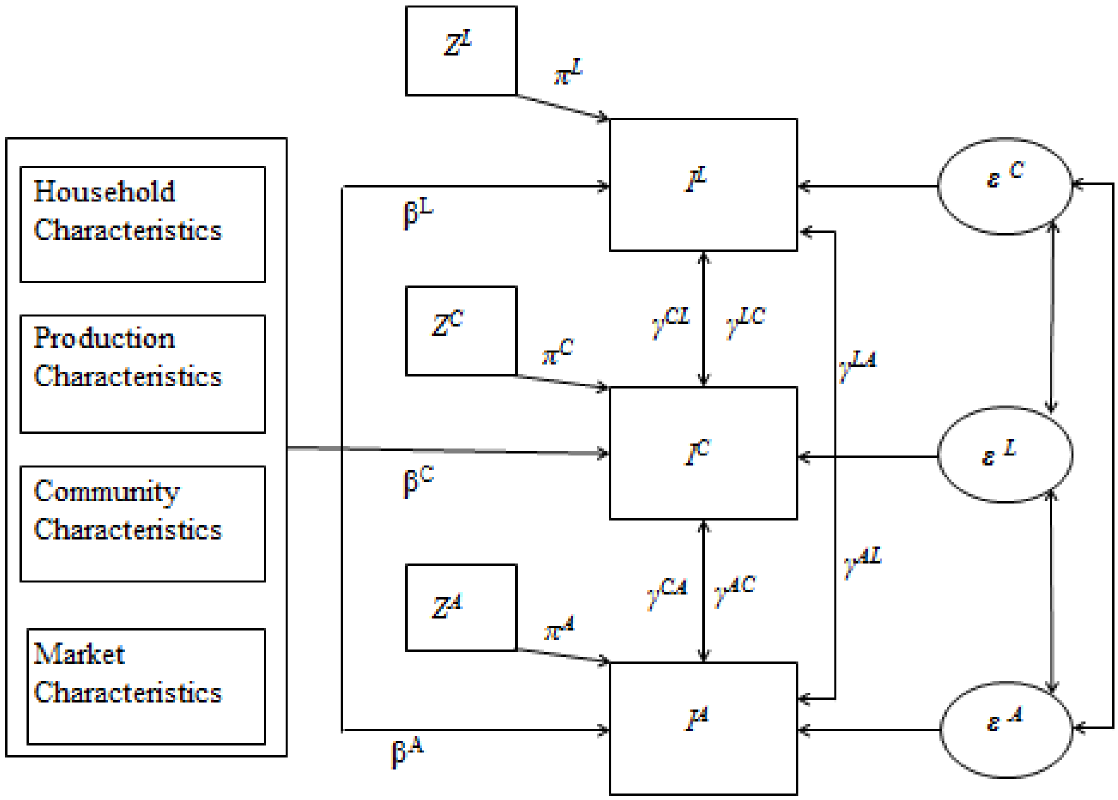
Sources and notes: The test for endogeneity refers to the endogeneity of the dependent variables on the index being regressed (row) (Wooldridge, 2004; Bound et al., 1995; Breusch and Pagan, 1980).

Table 12. Seemingly Unrelated Regression (SUR) results

Variable	*Asset index* Estimate	Pr > T	*Livestock index* Estimate	Pr > T	Construction index Estimate	Pr > T
Intercept	-1.094	0.7785	-21.006	0.0021	38.203	<.0001
Household Characteristics						
Agehh	0.0032	0.9264	0.0571	0.3576	0.01623	0.7575
Mhh	5.0726	<.0001	-2.709	0.1959	-2.5986	0.1426
Education	3.2072	0.0866	-3.578	0.2738	-2.6186	0.3432
Famsize	0.8841	<.0001	-0.327	0.3455	-0.5234	0.0752
Adultpercent	0.0331	0.1693	0.0068	0.8717	-0.0426	0.2316
Farmincome	0.1646	0.5052	0.7308	0.0902	-1.1903	0.0010
Laborincome	0.2049	0.4352	-0.015	0.9726	-0.9496	0.0137
Production Characteristics						
Cafarmer	1.1846	0.1025	-3.711	0.0035	2.56289	0.0164
Totalfieldsize	0.1219	0.6242	0.8423	0.0519	0.21794	0.5544
Weightdistance	0.0191	0.0574	-0.023	0.1800	-0.0159	0.2846
Community Characteristics						
Barue	5.8499	<.0001	5.0149	0.0178	-9.4865	<.0001
CFExpsvillage	-1.090	0.0712	-0.085	0.9359	0.97327	0.2770
Market Characteristics						
Femaletransactor	-1.011	0.2800	0.2282	0.8892	-0.4502	0.7449
Netseller	-0.249	0.7936	0.5026	0.7626	-0.1374	0.9221
Indices						
Asset index	.	.	0.9252	<.0001	0.65273	<.0001
Livestock index	0.3036	<.0001	.	.	0.15475	0.0002
Construction index	0.3000	<.0001	0.2167	0.0002	.	.
Model Fit						
R^2		0.714				
N		419				

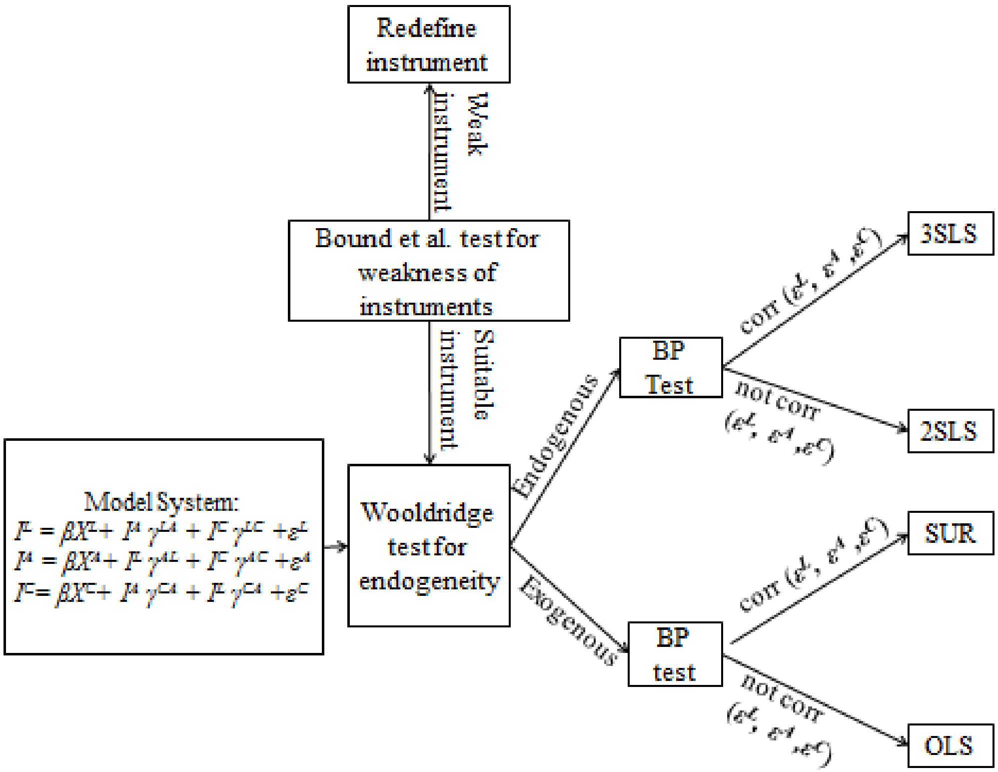
Sources and notes: Calculated by the author.

Figure 1. Path diagram of the empirical model



Key: Superscript *L*, *C*, and *A* refer to the livestock index, house construction index and asset index, respectively. The script *Z* refers to the instrument variables, β to the vector of the explanatory variables, and ε to the error term.

Figure 2. Representation of the decision tree used in model selection



Chapter III. Conservation agriculture and maize markets

Maize markets

Smallholder agricultural marketing been extensively researched, but there is comparatively little research examining technology adoption and smallholder maize marketing in Southern Africa. There is even less literature examining the relationship between smallholder grain purchases and agricultural technology adoption in this region. This may be because smallholder participation in maize markets is relatively low in Sub-Saharan Africa, with few farmers oriented towards producing grains for markets (Barrett, 2008). Research attributes lack of market participation to shallow local markets, poor infrastructure, credit constraints, and transportation costs (Barrett, 2008; de Janvry, et al., 1991).

Maize market transactions are seasonal as reflected by price and quantity variability. Maize markets in Mozambique can be categorized into three distinct periods; harvest, the post-harvest period, and the lean period (Jayne et al., 2010). The harvest period lasts from April to late July, including harvest and the subsequent months. The greatest volume of maize sales occurs during the harvest period, resulting in lower maize prices (Uaiene, 2004). Government and farmer reported prices reflect this trend, with prices dropping sharply at the beginning of the harvest period and climbing towards the end of the season (figure 1). The post-harvest period begins in August and lasts until November. During the post-harvest period, the total quantity of maize sold decreases as excess stocks are depleted and prices rise (figure 1 and 2) (Jayne et al., 2010). The lean season begins in December, lasts until March, and is characterized by high maize prices and low sales volume (figure 1). Most maize is purchased during the lean period when household stocks are low (figure 3).

The period when households participate in maize markets affects income, as reflected by differences in maize prices between the lean period and the harvest periods (table 1) (Uaiene, 2004). Households participating in the market during the harvest period report the lowest average maize prices (6.5 kg^{-1} Meticals (M)). Households transacting during the lean period report the highest average maize prices of 9.91 M kg^{-1} (table 1). Farmers practicing conventional agriculture in exposed and unexposed communities participate more frequently in maize markets during the lean period. The disparity in the number of transactions occurring per month for both groups is significant at the 1% level (χ^2 = 38, and 104 for conventional farmers in exposed and unexposed communities, respectively, both with 11 degrees of freedom).

Maize vendor's reported the lowest average maize price of 7.6 M kg^{-1}. Households who did not participate in the market reported an average maize price of 10.4 M kg^{-1}. Households that were maize vendors reported average maize prices of 11.3 M kg^{-1}(table 1). This price structure is familiar to many Sub-Saharan African grain markets, where a gap between the prices received by vendors and the price purchasers pay is usually evident (de Janvry et al., 1991; Jayne et al., 2010; Barrett, 2008).

Total maize market transactions for the 2010-2011 period was 139,663 kg. This is the aggregate of bulk sales and purchases, with sales accounting for approximately 90% of all market transactions (126,270 kg). Total maize purchases amount to 13,393 kg, or approximately 10.6% of the recorded sales.

Smallholder marketing of maize generally occurs as one of three types of transaction (Jayne et al., 2010). The first transaction type is one where a household sells surplus maize to another household in the community. Generally, these transactions are relatively smaller because purchases are made for immediate or near-term household consumption.

The second type of transaction entails a farmer traveling to a regional market to sell surplus maize. This type of transaction is limited by the availability of and quality of roads, and access to transportation. These logistical constraints increase transaction costs for market participators, resulting in higher prices than those reported in smallholder communities. Relatively few households participate in this type of transaction. Households that sell larger quantities and are typically relatively wealthier households because they can afford the extra cost associated with searching for (and maintaining relationships with) buyers and transportation (Fafchamps and Vargas Hill, 2005; English et al., 2008). Most households are often priced out of this type of transaction because of transaction costs beyond the village periphery (de Janvry et al., 1991; Fafchamps and Vargas Hill, 2005).

The final type of transaction entails maize traders purchasing maize either directly from farmers in the village or from farmers who travel to larger regional markets to sell grain. Reyes et al. (2012) found that high volume grain traders purchased the majority of peasant-marketed surplus grains in Angola. Traders would then sell produce in larger communities where the market price was higher. In neighboring Malawi, Jayne et al. (2010) found that mobile traders able to cover a geographical area encompassing multiple towns or villages bought most of the grain purchased in a particular season. High volume traders can capitalize on the seasonal price fluctuations, purchasing maize at harvest when prices were low and selling pre-harvest when household and community stocks were lowest (Jayne et al., 2010). These trends are reflected in the household survey data used in this research. Approximately 92% of all maize sales occurred with grains traders, as compared with 4% directly sold to neighbors in the community.

Like maize sales, maize purchases generally followed a seasonal pattern. The seasonality of purchases is inverse to sales (although on a smaller scale), with sales peaking pre-harvest and dropping to almost zero during harvest time (figure 1). Smallholder maize purchases were typically for consumption, with purchases made when household stocks were low. In neighboring Malawi, per capita maize consumption is estimated to be about 100 kg per year (Smale, 2013). Generally, purchases occurred during the lean period when maize prices were highest (figure 1 and figure 3). Approximately 70% of the respondents indicated they purchased maize from a vendor or a store, compared with approximately 20% who purchased maize from neighbors or friends. In the communities surveyed, female-headed households were more likely to purchase maize than male-headed households, with 28% of the purchases occurring in a female headed household (which only accounted for 22% of all households).

Conceptual model

The conceptual model used to analyze the association between CA use and maize market participation follows de Janvry et al.'s (1991) examination of smallholder farm household production and consumption (Brooks et al., 2008; Taylor and Aldmen, 2003). This model examines the factors influencing household decisions determining labor allocation, consumption, and agricultural production decisions. This thesis applies a stylized version of the agricultural household model (AHM), focusing on maize production and consumption decisions by smallholder farmers in Mozambique.

A number of assumptions are maintained in this thesis. First, markets are assumed to be complete with respect to of labor, inputs (seeds, fertilizer), and maize. Households are also assumed to be price takers; in other words, the price for these goods and services are exogenous (Sing et al., 1986; de Janvry et al., 1991; Benjamin, 1992). Another assumption is that all surplus maize is sold (more elaborate models introduce the possibility of storage) (Sadoulet and de Janvry, 1995). The consumption and production decisions for a household in this model are presumed to be separable, meaning that maize production and consumption decisions are made sequentially (Sing et al., 1986; de Janvry et al., 1991). Consequently, consumption and production decisions are analyzed as separate agricultural production and utility maximization decisions. Household crop production is determined first, with the budget constraint of utility maximization (consumption) augmented by agricultural profits. For example, households are assumed to maximize profit from agriculture, subject to a technical constraint (g) that states maize production is non-negative:

(1) $$Max_{Q_a,x,l}\,\pi = p_a Q_a - p_x x - wl,$$

$$s.t.\ g(Q_a, x, l; Z^q, CA) = 0,$$

where p_a is the price of maize, Q_a denotes maize production, and CA denotes the use of conservation agriculture. Maize is produced by using labor quantity l and input quantities x. The price of labor (wage) is denoted by w, and p_x are input prices. Maize production is a function of exogenous variables (Z^q) denoting fixed factors and producer characteristics including household, production, and community characteristics.

The reduced form equations defining production and input demands are (Sadoulet and de Janvry, 1995):

(2) $Q_a = Q_a(p_a, p_x, w; Z^q, CA)$ (maize supply function),

(3) $x = x\,(p_a, p_x, w; Z^q, CA)$ (demand function for inputs),

(4) $l = l\,(p_a, p_x, w; Z^q, CA)$ (demand function for labor),

(5) $\pi^* = \pi^*\,(p_a, p_x, w; Z^q, CA)$ (maximum profit).

Given profit from agriculture, denoted by π^* (an indirect profit function), a household maximizes consumption of maize, leisure, and other non-agricultural goods:

(6) $Max_{C_a, C_m, C_l}\, u(C_a, C_m, C_l; Z^h)$,

where C_a is maize consumption, with households "purchasing" any maize that is consumed by the household whether it is produced by the household or purchased in the market (Sing et al., 1986). The consumption of non-agricultural goods is denoted by C_m, and C_l is the consumption of leisure. Utility is subject to the income constraint:

(7) $p_m C_m + p_a C_a + w C_l = \pi^* + wE$,

where $C_l + l^s = E$ (a time endowment constraint) and l^s is the time spent working.

The demand functions for maize consumption, nonagricultural goods consumables, and leisure are summarized by the reduced form equations:

(8) $C_i = C_i(p_a, p_m, w, y^*; Z^q)$, $i = a,m,l$,

where $y^* = p_a Q_a - p_x x - wl + wE$ (evaluated at the optimal levels of demand).

The following conditions reflect the utility households enjoy by maximizing their marketing position (as a buyer, vendor, or by not participating in the market):

(9) $Q_a - C_a > 0$: (net seller),

(10) $Q_a - C_a < 0$: (net buyer),

(11) $Q_a - C_a = 0$: (no market participation).

Denote $Q_a - C_a > 0$ as QS and QB the absolute value of $Q_a - C_a < 0$; these values are the amount of maize sold or purchased by a household participating in maize markets. In smallholder communities, there are typically price bands between the price vendor receive (equation 9) and the price buyers pay (equation 10), which correspond with these quantity decisions (de Janvry, et al., 1991). Few, if any, households engage in purchases and sales of maize during the same marketing period because of this kinked price structure (Boughton et al., 2007; de Janvry, et al., 1991). Households not buying or selling are often priced out of the market (Taylor and Aldmen, 2003). Production and transaction costs can also shift maize production costs above or below the market price, making it economically infeasible for a household to conduct transactions as either a buyer or vendor (de Janvry, et al., 1991; Boughton et al., 2007; Mather et al., 2011). If the production costs of maize falls below the price band, households will participate in the market as vendors; above, and they will purchase maize.

Household response to these price shifts are difficult to determine using AHM models because production and consumption decisions are often coterminous (de Janvry et al., 1991; Brooks et al., 2008; Taylor and Aldmen, 2003). As producers, households benefit from maize price increases, with higher prices incentivizing production as well as increasing revenue. From the consumer's perspective, higher maize prices increase the opportunity cost of consuming one's own production. With a normal good (which maize is), higher maize prices typically lead to decreases in consumption. However, as net selling household budget constraints are simultaneously increased (due to the increasing profit from agriculture), consumption increases (de Janvry et al., 1991; Brooks et al., 2008). Taylor and Aldmen (2003) conclude that if the positive effect of increased consumption outweighs the negative Slutsky effect of the increased maize price, then households will consume more maize as prices increase. This suggests that maize may appear to be, at least from a short-term perspective, a Giffen good.

Household utility is unobservable; however, a household's decision whether to participate in the market may be observed. A household will be a vendor, buyer, or stay out of the market based on the consumption levels that maximize household utility, subject to the prevailing prices and income constraints. Consumption in turn depends on π^*, which is a function of the quantity of maize produced and input prices, and is assumed to be determined independently of consumption when markets are complete. Of particular interest are the *ceteris paribus* relationship between the use of conservation agriculture (a variable in the production set) on market participation, and the subsequent quantity transacted in markets.

Grabowski (2012) observed that CA households had greater access to chemical fertilizers and pesticides through loans from NGO's. A similar situation was observed in the surveyed communities, with many CA farmers reporting fertilizer loans from TLC or other NGO's with maize production as collateral. Furthermore, CA technologies have been shown to increase grain production. Consequently, it is hypothesized that due to increased input use, and increased in production associated with CA, the adoption of CA will be associated with the increased likelihood that a household will maximize their utility by participating in maize markets as a vendor ($Q_a - C_a > 0$).

The quantity of maize sold or purchased is only observed in households that participate in the market. This codetermination poses some challenges to examining the *ceteris paribus* association between CA adoption, market participation, and participation intensity. A familiar approach attending to this issue applies Heckman's (1976) two-stage participation model.

Empirical model

The empirical models explaining market participation and transaction quantities are hypothesized to be a function of exogenous variables representing household, producer, community, and market characteristics. The market participation equation is:

$$(12) \quad U_i^{s*} = \gamma_0^s + \gamma_1^{\,s} Agehh_i + \gamma_2^{\,s} mhh_i + \gamma_3^s Education_i + \gamma_4^s Famsize_i + \gamma_5^s Constructionindex_i + \gamma_6^s Producedpercent_i + \gamma_7^s Laborincome_i + \gamma_8^s CA_i + \gamma_9^s ExposedVillage_i + \gamma_{10}^s Animaltraction_i + \gamma_{11}^s Fieldsize_i + \gamma_{12}^s Fertilzer_i + \gamma_{13}^s Barue_i + \gamma_{14}^s Dry_i + \gamma_{14}^s Maizeprice_i + \gamma_{15}^s Transportation_i + u_i^s,$$

where U_i^{s*} is a latent variable signaling when a household participates in the maize markets as a vender, and u_i^s is an independent and identically distributed (iid) error term with an expected mean of zero and constant variance. The quantity sold equation is:

$$(13)\quad QS_i = \beta_0^s + \beta_1^s Agehh_i + \beta_2^s mhh_i + \beta_3^s Education_i + \beta_4^s Famsize_i + \beta_5^s Constructionindex_i + \beta_6^s CA_i + \beta_7^s ExposedVillage_i + \beta_8^s Animaltraction_i + \beta_9^s Fieldsize_i + \beta_{10}^s Fertilzer_i + \beta_{11}^s Barue_i + \beta_{12}^s Dry_i + \beta_{13}^s Maizeprice_i + \beta_{14}^s Transportation_i + \beta_{15}^s FemaleTransactior_i + \beta_{16}^s Neighbor_i + \beta_{17}^s LeanPeriod_i + \beta_{18}^s Harvestperiod_i + \varepsilon_i^s \mid U_i^{s*} > 0,$$

where ε_i^s is (iid) disturbance with an expected mean of zero and constant variance. Maize sold is conditional on participation in the market as a vendor. In this application, the percentage of maize consumed from household production (*Producedpercent*) and the percentage of household income derived from labor (*Laborincome*) are omitted from the quantity sold model to satisfy exclusion restrictions (Boughton et al., 2007).

The variables used in the sales equation are also hypothesized to determine maize purchases. The maize purchasing decision is also a latent variable (U_i^{b*}) in its arguments:

$$(14)\quad U_i^{b*} = \gamma_0^b + \gamma_1^b Agehh_i + \gamma_2^b mhh_i + \gamma_3^b Education_i + \gamma_4^b Famsize_i + \gamma_5^b Constructionindex_i + \gamma_6^b Producedpercent_i + \gamma_7^b Laborincome_i + \gamma_8^b CA_i + \gamma_9^b ExposedVillage_i + \gamma_{10}^b Animaltraction_i + \gamma_{11}^b Fieldsize_i + \gamma_{12}^b Fertilzer_i + \gamma_{13}^b Barue_i + \gamma_{14}^b Dry_i + \gamma_{14}^b Maizeprice_i + \gamma_{15}^b Transportation_I + u_i^b,$$

where u_i^b is an iid disturbance with a mean zero and constant variance. The quantity of maize sold is linear in arguments:

$$(15)\quad QP_i = \beta_0^b + \beta_1^b Agehh_i + \beta_2^b mhh_i + \beta_3^b Education_i + \beta_4^b Famsize_i + \beta_5^b Constructionindex_i + \beta_6^b CA_i + \beta_7^b ExposedVillage_i + \beta_8^b Animaltraction_i + \beta_9^b Fieldsize_i + \beta_{10}^b Fertilzer_i + \beta_{11}^b Barue_i + \beta_{12}^b Dry_i + \beta_{13}^b Maizeprice_i + \beta_{14}^b Transportation_i + \beta_{15}^b FemaleTransactior_i + \beta_{16}^b Neighbor_i + \beta_{17}^b LeanPeriod_i + \beta_{18}^b Harvestperiod_i + \varepsilon_i^b \mid U_i^{b*} > 0,$$

where ε_i^b is also an iid random variable with an expected mean of zero and constant variance. Like the sales model, the purchases model omits *Producedpercent* and *Laborincome* in order to satisfy exclusion restrictions.

The dependent variables for the quantity sold and quantity purchased are in natural logs. The lognormal transformation is also consistent with the expectation that quantities sold (or purchased) are non-negative. Total quantity purchased and sold are also positively skewed and the log transformation provides a more robust measure of the distribution's central tendency (Hansen, 2013).

The explanatory variables in equations 12-15 are discussed in the following order; household characteristics, producer characteristics, community characteristics, and marketing characteristics. All variables discussed below are present in the equations (the market participation equations and the maize quantity purchased/sold equations), unless noted otherwise.

A variable measuring the percent of maize consumed produced on a household's farm (*Producedpercent*) is included to proxy household dependence on markets for maize consumption. It is hypothesized that households consuming a higher percentage of maize from their own production will be less likely to engage in the maize market as a buyer because they are able to meet household needs. The results concerning the *Producedpercent* and the probability that a household will engage in the market as a vendor are unknown, as a household that produces 100% of its consumption could be a vendor or does not participate in the market. The percentage of household income derived from wage labor (*Laborincome*) is used to proxy earnings from off- farm work on the decision to participate in the market. It is expected that households deriving a higher percentage of their income from wage labor will be more likely to participate in the market as vendors (Boughton et al., 2007).

The age, education, and gender of the household head are included as explanatory variables. Previous research suggests that that the household head of age (*Agehh*) is unrelated to the likelihood of participating in a market as a vendor as well as the volume transacted (Mather et al., 2011). However, previous studies find that the age of the household head is expected to decrease the likelihood of a participating in the market as a buyer, as well as the total quantity purchased (Goetz, 1992). Education is measured with a binary variable denoting whether the household head attended middle school. Education is expected to be positively associated with the likelihood a household participates in the market as a vendor, and the total quantity sold. Households headed by an individual with relatively more education are expected to be more likely to purchase maize, as education may decrease transaction costs (Lauglo, 2001). Previous studies find that female-headed households (*Mhh*) are less likely to be net sellers, and sell less when participating in markets (Boughton et al., 2007). Conversely, it is hypothesized that female-headed households will be more likely to participate in the market as vendors and, on average, purchase more. Larger households (*Famsize*) are expected to be more likely to participate in markets as a buyer, as well as purchase more maize (Goetz, 1992). Previous studies find that larger households are less likely to participate in the market as vendors, and sell less when they do participate (Jaleta and Gebremedhin, 2010). A variable proxying the quality of materials used in the construction of a house (*Constructionindex*) is included as a wealth proxy. It is expected that households with higher indices will be more likely to participate in the market as a maize vendor, and will sell more (Boughton et al., 2007; Mather et al., 2011).

Field size (*Fieldsize*) is expected to be positively correlated with the probability of participating in the market as a vendor, as well as the maize quantity sold (Mather et al., 2011; Heltberg and Tarp, 2002). It is hypothesized that field size will be negatively correlated with the probability a household will engage in the market as a buyer. Past studies find that ownership of animal drawn plows (*Animaltraction*) is associated with market participation as a vendor and also the quantity sold (Boughton et al., 2007; Mather et al., 2011; Heltberg and Tarp, 2002). It is hypothesized that plow ownership will be negatively correlated with the probability of engaging in the market as a buyer, and the quantity of maize purchased due to previous findings suggesting that these households are more likely to be net grains buyers. A dummy variable is used to proxy fertilizer use. Fertilizer use (*Fertilizer*) is expected to increase the probability of participating in the market as a vendor and the quantity sold, because fertilizer use generally increases yields (Morris et al., 2007). Conversely, households using fertilizer are expected to be less likely to participate in the maize markets as buyers.

Conservation agriculture (*CA*) is a variable indicating whether a household practiced conservation agriculture. A farmer is considered a conservation agriculture adopter if they practiced CA on at least one of their fields (on average, farmers operated 2.3 fields), in addition to self-reporting that they had adopted conservation agriculture. Conservation agriculutre practices are defined as sowing maize using no-till and covering at least 25% of the field with crop residue. This definition of no-till includes the use of seed basins. Previous findings suggest that fields managed under the aegis of conservation agriculture produce more stable and possibly higher maize yields (FAOc, 2001; Kassam et al., 2009; Thierfelder and Wall, 2010). It is expected that CA users will be more likely to participate in maize markets as vendors, sell relatively more due to higher yields typically associated with conservation agriculture, as well their increased access to inputs such as fertilizer (FAOc, 2001; Kassam et al., 2009; Thierfelder and Wall, 2010; Grabowski 2012). It is also expected that CA adopters will be less likely to purchase maize due in part to their increased access to inputs. A variable is also included denoting whether a household is a non-CA adopter residing in a village where CA extension efforts occurred (*ExposedVillage*). As the majority of households in the exposed communities were not CA adopters, it is expected that households that did not adopt CA will not be more or less likely to market, or market in differing quantities, than the population average. Both *ExposedVillage* and *CA* are orthogonally restricted, so that the coefficients of these variables are interpreted with respect to the population participation and quantity marketed means (Neter et al., 1996).

Two variables are included to control for community characteristics that might affect marketing. The first variable identifies households residing in Barue province (*Barue*). Barue households are expected to be more likely to participate in the maize markets as vendors, and less likely to participate as buyers because the climate and soil of Barue is suited to the production of a wider variety of crops than Tete (FAO country profile, 2012). The variable *Dry* measures the respondent's perception of the quality of rain in the proceeding season, with possible answers reflecting drought, good rain, and too much rain. The variable is binary, with 1 indicating a farmers belief that rain was insufficient in the previous season, 0 otherwise. Households reporting favorable rain are expected to be more likely to engage in the market as a vendor and in increased quantities, as good growing conditions are associated with better maize production (Almeida et al., 2009). Households that do not report favorable rain are expected to be more likely to participate in the market as a buyer to make up for production shortfalls.

The gender of the of the primary market transactor (*FemaleTransactor*) is included, with previous research suggesting that females are more likely to participate in commodity markets market (English et al., 2008). The quantity transacted for these households is not expected to differ from other households. It is expected that households reporting higher maize prices (*Maizeprice*) will be more likely to participate in the market as purchasers. Households reporting a lower market price are more likely to participate in the market as vendors. This behavior corresponds with the expectation implied by the price band model of de Janvry and others (de Janvry et al., 1991; Jayne et al., 2010; Barrett, 2008). Maize vendors receive prices that are lower than the prices paid by maize purchasers because of transaction costs. Among other reasons, it is hypothesized that this price band exists due to grain purchasers engaging in arbitrage. The price bands may be seasonal, exacerbated by a lack of adequate storage facilities.

A number of marketing characteristics in the outcome equation are not included in the selection equation because they are unobserved in the sub-group of market non-participants. These variables include the distance to the transaction point (*Marketdistance*), whether the transaction occurred with family or friends (*Friendfamilytransaction*), and the season when a transaction occurred (*LeanPeriod* and *Harvestperiod*).

Households traveling farther to the market are expected to sell relatively greater quantities of maize (Fafchamps and Vargas Hill, 2005). Households purchasing maize during the lean period (*LeanPeriod*) are expected to purchase more maize than in other periods (Jayne et al., 2010). Conversely, households selling maize are expected to sell relatively more maize during the harvest period (*Harvestperiod*) (Jayne et al., 2010). The variable transportation (*Transportation*) indicates ownership of an oxcart, bike, motorcycle, or a car. It is hypothesized that ownership of at least one of these transportation modes will increase the likelihood of participating maize markets as a buyer or a vendor, and will be associated with higher volumes of maize transacted (Mather et al., 2011). A binary variable is included that indicates whether a household transacted with neighbors. It is hypothesized that households selling to a neighbor will sell less than households selling to professional buyers (Jayne et al., 2010). Households purchasing maize from a friend or acquaintance are not expected to purchase different quantities than households purchasing from professional buyers.

Methods and procedures

The empirical model suggests that the decision to participate in the market and the quantity traded may be coterminous (Goetz, 1992). This simultaneity would render OLS estimation of the outcome portion of the model inconsistent and biased (Boughton et al., 2007: Heltberg and Tarp, 2002). There are various approaches to attend to this two-tiered decision making process. As applied in this research, the bivariate sample selection model (Heckman's two-stage model) accounts for potential bias caused by households self-selecting into the population of maize buyers or vendors (Greene, 1993; Cameron and Trivedi, 2005). The participation/quantity decision model is motivated from the perspective of vendors, and later extended to household decisions to purchase maize.

A household participates in the market if the utility in doing so exceeds some unobservable threshold (Lubungu et al., 2012). Random utility models are typically used to analyze decisions due to the unobservable latent nature of utility (McFadden, 1974). A random utility model is used to explain the household decision to participate in local maize markets as vendors. For example, define U_i^{ps} as the expected utility for household *i* derived from participating in the market as a vendor, and U_i^{nps} the expected utility from not participating in the market. The difference in the utility from these two choices is denoted by the latent variable U_i^{s*} ($U_i^{s*} = U_i^{ps} - U_i^{nps}$).

There is a threshold at which a household participates in the market as a vendor such that $U_i^{s*} > 0$ (Goetz, 1992). The utility a household enjoys from participating in a market transaction as a vendor is hypothesized to be represented by the linear approximation:

(16) $U_i^{s*} = \gamma^{s\prime} x_i^s + \varepsilon_i^s \qquad \text{var}(\varepsilon_i^s) = \sigma_{\varepsilon s}^2,$

where: $U_i^s = 1 \text{ if } U_i^{s*} > 0,$

$U_i^s = 0 \text{ if } U_i^{s*} \leq 0,$

where $\varepsilon^s{}_i$ is independently and identically distributed with a mean of zero and a constant variance, and x_i^s are variables determining participation and includes production characteristics (e.g., CA use, fertilizer use, field size), household characteristics (e.g., family size, education), and community characteristics (e.g., whether extension services are present in a community, agroecological zone).

The probability of participating in the market is modeled using the standard normal distribution (Φ),

(17) Prob ($U_i^s = 1$) = Φ ($\gamma^{s\prime} x_i^s$), and

Prob ($U_i^s = 0$) =1 - $\Phi^s(\gamma^{s\prime} x_i^s)$,

The quantity of maize sold (QS) by a household is represented by:

(18) $QS_i = \beta^{s\prime} Z_i^s + u_i^s$ observed only if $U_i^s = 1$,

(u_i^s and ε_i^s) ~ bivariate normal [0,0,1, σ_{us}, ρ],

where u_i^s is independently and identically distributed with a mean of zero and a constant variance, σ_u is the standard deviation of the error term u, and ρ is the correlation coefficient between the disturbances of the participation and outcome equations. The variable Z_i^s is a vector of household characteristics determining the quantity of maize sold (note that Z_i^s excludes some variables included in the participation decision for purposes of identification) (Cameron and Trivedi 2005).

The expected value of the maize quantity sold is:

(19) $E[QS_i \mid QS_i \text{ is observed}] = E[QS_i \mid U_i^{s*} > 0] = E\,[QS_i \mid \varepsilon^s{}_i > -\gamma^{s\prime} x_i^s]$

$= \beta^{s\prime} Z_i^s + E[u_i^s \mid \varepsilon_i^s > -\gamma^{s\prime} x_i^s] = \beta^{s\prime} Z_i^s + \sigma_{us}\lambda_i^s(\alpha_{\varepsilon i}^s)$,

where

(20) $$\alpha_{\varepsilon i}^{s} = \frac{-\gamma s \prime x_i^s}{\sigma_\varepsilon},$$

and

(21) $$\lambda_i^s(\alpha_{\varepsilon i}^s) = \frac{\phi(\gamma^s \prime x_i^s/\sigma_\varepsilon^s)}{\Phi(\gamma^s \prime x_i^s/\sigma_\varepsilon^s)}.$$

The variable $\lambda_i^s(\alpha_{\varepsilon i}^s)$ is the inverse Mills ratio (IMR), with ϕ the normal probability density function (Greene, 1993).

For the participation equation, the marginal effect of continuous variable *k* is:

(22) $$\frac{\partial Pr(U_i^s=1)}{\partial x_{ik}} = \phi(\gamma^{s\prime} x_i^s)\ \gamma_k^s$$

For a binary variable in the participation equation, the marginal effect is:

(23) $$\frac{\partial Pr(U_i^s=1)}{\partial x_{ik}} = \Pr(U_i^s = 1|x_i^s, x_{ik}^s = 1) - \Pr(U_i^s = 1|x_i^s, x_{ik}^s = 0).$$

The marginal effect of a continuous variable included in both the participation and the quantity sold equations is:

(24) $$\frac{\partial E\ [QS_i|U_i^{s*}>0]}{\partial Z_{ik}^s} = \beta_k^s - \gamma_k^s \left(\frac{\rho\sigma_u}{\sigma_\varepsilon}\right) \delta_i\ (\alpha_{\varepsilon i}^s),$$

where $\delta_i = \lambda_i^2 + \alpha_{\varepsilon i}^s \lambda_i^s$

When the explanatory variable is binary and included in both the participation and vending equation the marginal effect is (Cameron and Trivedi, 2005):

(25) $$\frac{\partial QS_i}{\partial x_{ik}} = \frac{\phi(\gamma' x_i^s, x_{ik}^s = 1)}{\Phi(\gamma' x_i^s, x_{ik}^s = 1)} - \frac{\phi(\gamma' x_i^s, x_{ik}^s = 0)}{\Phi(\gamma' x_i^s, x_{ik}^s = 0)}.$$

The same decision making structure is maintained for households participating in markets as buyers:

(26) $$U_i^{b*} = \gamma' x_i^b + \varepsilon_i^b, \qquad \text{var}\,(\varepsilon_i^b) = \sigma_{\varepsilon b}^2, \text{ and}$$

(27) $$QB_i \mid U_i^{b*} > 0 = \beta' Z_j^b + u_i^b, \qquad \text{var}\,(u_i^b) = \sigma_{ub}^2,$$

where explication follows from the above arguments. The marginal effects for the buyer selection model, and the quantity purchased model are similarly calculated.

The outcome equation is log transformed, so the marginal effects estimates are multiplied by 100 to estimate the percentage change in quantity transacted given a 1 unit change in continuous covariates (Wooldridge 2004, page 45).

Estimation procedures

Summary of the descriptive statistics between the group means are compared using Tukey's honestly significant difference (HSD) at the 5% type I error rate (table 10). The bivariate sample selection model is estimated using maximum likelihood (Ouma et al., 2010). The suitability of the bivariate sample selection model is tested with the likelihood ratio likelihood ratio (LR) test, with the null hypothesis that the disturbances of the first and second stage (e.g, sales selection and sales quantity) are uncorrelated; H_0: $\rho = 0$. If the null hypothesis cannot be rejected, then the market participation and maize quantity sold/purchased equations can be estimated as separate probit and OLS equations. The Wald test is used to test evaluate model fit, testing the null hypothesis that the coefficients of the selection and outcome equations are jointly not different from zero. Variance inflation factors are calculated to test for multicollinearity (Walton et al., 2010; O'brien, 2007). The regression is limited to households with field ownership at or below the 99th percentile. This includes any household owning less than 8.9 hectares, with households owning 8.9 ha to 50 ha not included in the regression. This is done as it was thought that these households would skew the regressions results which was confirmed when the model was run with and without this constraint.

Descriptive statistics of farm and household characteristics

Most variable comparisons were discussed in Chapter II (tables 5, 8 and 9).

Approximately 7% of households owned a plow, with plow ownership rates among CA farmers and conventional farmers not different at the 5% level. Relatively more CA farmers used fertilizer, with approximately 53% of those practicing CA using fertilizer as compared to 15.8% and 20.9% in exposed and unexposed communities, respectively. This may be due to the loan programs available to farmers who adopt CA. In the author's experience in the surveyed region, NGO's (such as TLC) provide loans for fertilizer or herbicide to households participating in conservation agriculture demonstration plots (81% of CA farmers participated in demonstration plots). Future maize production is used as collateral for these loans, with households paying back the loans with a pre-determined quantity of maize. Fertilizer use between CA farmers and farmers in exposed an unexposed communities is significant at the 5% level.

The distance to the market and with whom a household transacted are similar among the groups, with approximately 10% of households conducting a transaction with an acquaintance or neighbor at an average distance of 51 minutes. Conventional farmers in exposed communities reported the lowest maize price (7.53M kg^{-1}) compared to 9.39M kg^{-1} and 10.77M kg^{-1} for CA farmers and conventional farmers in unexposed communities, respectively. The difference in the maize price reported by conventional farmers in exposed and unexposed villages is significant at the 5% level.

The marketing patterns of the three groups are different, with 39% of CA adopter market transactions occurring during the lean period, 48% of the market transactions by conventional farmers in exposed communities, and 71% for conventional farmers in unexposed communities occurring in the same period. The difference in marketing periods is significant at the 5% level among CA farmers and conventional farmers (table 4). Conversely, the three groups exhibit similar marketing patterns during harvest season, with approximately 22% of all transactions occurring at this time. The difference in ownership rates of a transportation mode is significant at the 5% for CA farmers and conventional farmers. Approximately 71% of CA farmers owned some means of transportation, compared with 55% and 49% of conventional farmers in exposed and unexposed communities, respectively (table 4). The difference in ownership rates of transportation modes is not significant for conventional farmers compared in exposed and unexposed communities.

Regression results

Model diagnostics

Variance inflation factors do not suggest that multicollinearity is a problem; variance inflation factor scores were less than 10 in the maize sales and purchases models. For the maize sales model, the likelihood ratio (LR) test indicates that the market participation decision and corresponding maize quantities purchased were correlated (table 6). The buyer participation decision and quantity marketed were also correlated (table 7). The null hypothesis that the coefficients were jointly uncorrelated with the participation/quantity transacted decision were rejected for both models (χ^2 test statistic for the sales model is 189.66, with 44.5 the χ^2 test statistic for the purchases model).

Maize Sales

Market participation decision to sell maize

Most household characteristics are uncorrelated with the decision to participate in markets as a maize vendor. That gender of the household head is uncorrelated with sales transactions is remarkable, given that previous studies found that female-headed households in Mozambique were less likely to participate in the market as vendors, with households headed by women selling less (Boughton et al., 2007; Reyes et al., 2012). Education and the size of the family do not appear to be associated with the probability of participating in the market as a vendor. The percentage of maize consumed by the household produced on their own landholdings was also correlated with the decision to sell maize. All else equal, a 10% increase in the amount of maize consumed by a household that was produced on by their own plots was associated with a 0.32% increase in the probability of participating in the market as a buyer ($P < 0.0001$).

Farmers practicing CA were more likely to participate in the market as a vendor. All else equal, CA farmers were 13.5% more likely to sell maize than other farmers ($P = 0.001$). This finding corresponds with Grabowski's observation that CA households often receive input loans from NGO's, which may incentivize CA adopters to sell maize production to pay back the loan. All else equal, a 1 hectare increase in farm size increased the probability that a household will participate in the market by 3.61%. This finding is consistent with previous research that found larger farms are more likely to participate in markets as vendors ($P = 0.034$) (Mather et al., 2011).

Community characteristics are insignificant predictors of household participation in maize markets as vendor. Households in Barue and those reporting dry conditions are neither more nor less likely to participate in the market as a vendor than other households.

Of the marketing characteristics included in the sales participation equation, maize price is the only variable correlated with market participation as a vendor. Holding other factors constant, maize price was correlated with a 0.4% decrease in the likelihood of a sale occurring ($P = 0.037$). For farmers participating in the market as vendors, the maize price (a reflection of production costs) is generally equal to or below the market price, with increases in the price of maize decreasing the likelihood of participating in the market as a vendor (de Janvry et al., 1991).

Maize quantity sold model

Household characteristics are insignificant predictors of the quantity of maize transacted by a household.

Field size, conventional farmers in exposed villages, and fertilizer use were the only production characteristics associated with the volume of maize sold. Conventional farmers in exposed villages sold, on average, 18.34% (17.6 kg) more maize than the population average (P = 0.052) (table 7). This finding is intriguing given that this subgroup is less likely to participate in maize markets as vendors. An additional hectare of land holdings was associated with an increase in the quantity sold by 14.8% (14.3 kg) (P = 0.004). This result is consistent with previous research, which found farmers managing larger fields sold more maize (Boughton et al., 2007; Mather et al., 2011; Heltberg and Tarp, 2002). Fertilizer use was associated with higher maize volumes sold. Households using fertilizer sold, on average, 44% (42.7 kg) more than other households (P = 0.011).

All else equal, households in Barue sold 152% (146 kg) more maize than households in Tete (P = 0.0001). This finding, may suggest that households in Barue have a lower cost of maize production, and on average, produce more. Households experiencing dry growing conditions reported selling 52% (45.71 kg) less maize than other households (P = 0.014) (table 7). This is most likely due to decreases in production due to insufficient rain.

Gender of the principal transactor, market distance, and the availability of transportation were correlated the quantity of maize sold. Female transactors sold, on average, 50% (48.8 kg) less maize than male transactors (P = 0.003). This result is interesting, given that the gender of the household head is not a significant predictor of the quantity of maize sold. All else equal, distance to the market (in minutes) was associated with higher sales volume; on average, an extra minute traveled was associated with a 0.35% (0.33 kg) increase in quantity of maize sold (P < 0.0001). This result is similar to Fafchamps and Vargas Hill's (2005) findings that concluded that high volume vendors would often travel elsewhere to sell their grain, seeking higher market prices. This is only feasible for households that market relatively larger quantities of maize due to the costs associated with transport and finding buyers. Households owning a means of transportation sold, on average, 47% (45.4 kg) more maize than households without access to personal transportation (P = 0.001) (table 7). This result is consistent with previous research that concludes households owning their own means of transportation sell more maize (Reyes et al, 2012).

Purchases

Maize buyer participation model

Of the household characteristics, only household size and the percentage of maize consumed that was produced by the household were significant predictors of the probability a household participated in the market as a buyer. Holding other factors constant, a 1-member increase in family size was associated with a 1.6% increase in the probability of engaging in the market as a buyer (P = 0.016). Previous research reports similar findings that larger households are more likely to purchase grain (Jaleta and Gebremedhin 2010; Gani and Adeoti, 2011). The percentage of maize consumed by the household produced on their own landholdings was also correlated with the decision to purchase maize. All else equal, a 10% increase in the amount of maize consumed by a household that was produced on their own fields was associated with a 0.05% decrease in the probability of participating in the market as a buyer (P < 0.0001). This result suggests that households that are able to produce a higher percentage of the maize they consume are less likely to participate in the market as a buyer.

Farmers who practiced CA were 9.4% less likely to purchase maize than other households (P = 0.005). This finding corroborates the hypothesis that CA households are more likely to be maize vendors. Holding other factors constant, a 1-hectare increase in field size is associated with a 3.5% decrease in the likelihood of participating in the market as a buyer (P = 0.057). This finding is consistent with previous research, which concluded that larger operations were, on average, more likely to consume their own grain (Boughton et al., 2007; Mather et al., 2011; Heltberg and Tarp, 2002).

Community characteristics are insignificant predictors of household participation in maize markets as buyers. Households in Barue and those reporting dry conditions are neither more nor less likely to participate in the market as a buyer compared with other households.

Ownership of personal transportation was associated with a decrease in the probability of purchasing maize by 11% (P < 0.0001). This finding was unexpected because access to transportation was hypothesized to reduce the transaction costs for both sales and purchases. Households able to afford a transportation mode may be more likely to be larger producers, and thus less likely to purchase maize. A 1-metical increase in the reported price of maize was associated with a 0.24% increase in the probability of a purchase occurring (P = 0.075). According to de Janvry et al., (1991), smallholder maize purchasers are more likely to pay higher prices for the same product than what vendors receive in the same market. The findings reported here are consistent with this observation, with maize vendors reporting the lowest maize prices (7.6 M kg^{-1}) followed by households not buying or selling (10.4 M kg^{-1}) and finally net maize buyers (11.3 M kg^{-1}) (table 1). This finding may be explained by the fact that most maize sales occur during the harvest season when prices are lowest, while most purchases occur during the lean period when prices are highest (figures 2 and 3).

Maize quantity purchased model

Household head age and household size were associated with the quantity of maize purchased. Holding other factors constant, an increase of one year in the age of the household head corresponds with a 2.8% (1.7 kg) decrease in the quantity of maize purchased (P = 0.001) (figure 4). On average, younger household heads purchased more maize, with the youngest household heads purchasing the greatest quantity of maize steadily declining thereafter. A 1-member increase in household size was associated with an 8.2% (5.3 kg) increase in quantity of maize purchased (P = 0.032). This finding is supported by previous literature (Goetz, 1992). Education is a significant predictor of the quantity of maize purchased. Households having attended middle school purchase, on average, 57% (35.9 kg) less maize than other households (P = 0.076) (table 7).

Production characteristics are not significant predictors of the quantity of maize purchased by households. Households having adopted conservation agriculture did not purchase maize in any differing quantities than non-adopters.

Households in Barue did not purchase maize in any different quantities than households in Tete. Households reporting dry growing conditions purchased 65% (40.5 kg) more maize than other households (P = 0.0029). It can be surmised that these households are purchasing maize to make up for any production shortfall that occurred due to dry growing conditions. Female transactors purchased 35% (21.9 kg) less maize than male purchasers (P = 0.093) (table 7).

Conclusions and policy implications

The objective of this chapter was to assess the factors influencing household marketing of maize, given the use of conservation agriculture, farm production characteristics, and household attribute. Previous research examining smallholder grain marketing in Sub-Saharan Africa has focused on the role of infrastructure, input use, or asset ownership/wealth in marketing decisions. Little research examines the relationship between technology adoption and smallholder grain purchases. Findings from this research provide additional insight into the factors influencing household marketing positions, their sales and purchasing patterns, and the role of conservation agriculture in marketing decisions.

Farm households who practiced CA marketed similar quantities of maize compared with other households. However, farmers practicing CA were 13.5% more likely to engage in markets as vendors and 9.5% less likely to purchase maize. The role of conservation agriculture in the different marketing patterns of adopters is difficult to untangle from the presence of NGO's and access to inputs. Previous researchers found that CA farmers were more likely to have access to inputs than other farmers due to loan agreements with NGOs. The author witnessed similar arrangements, with many CA farmers receiving input loans (from TLC or other extension groups) against future production. These loan arrangements provide a means of increasing production, and may explain why households that used CA were more likely to participate markets as vendors. However, CA households in the surveyed region were wary to report and talk about input loan arrangements. Consequently, it is difficult to discern whether the increased likelihood of selling maize is due to CA farmers selling their production to creditors, selling to receive cash to pay off loans, due to level increases in production associated with CA, or some combination of these factors.

Policy makers interested in increasing smallholder marketing of grains can choose from a number of actions to increase market participation and volume. Past research recommends increasing links to outside markets, providing access to low interest loans for inputs, or increasing household wealth as a means of increasing participation in the regions studied in Mozambique. The findings from this chapter suggest that CA adoption is likely to increase household participation in grain markets, results which may logically be driven by access to credit for inputs.

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Appendix II. Tables and figures

Table 1. Maize market price by subgroup and χ^2 test results for the distribution of market transactions

Group/Variable	χ^2	Pr > χ^2	N
CA farmers	19.04	0.0602	100
Conventional farmers in exposed communities	37.92	< 0.0001	170
Conventional farmers in unexposed communities	103.82	< 0.0001	112
Reported Maize Price Per Kilogram:			
	Buyer	Vendor	No market participation
Mean	11.3 (a)	7.6 (b)	10.4 (ab)
Standard deviation	17.13	9	13.12
N	118	306	123
Reported Maize Price Per Kilogram:			
	Lean period	Harvest period	Post-harvest period
Mean	9.91 (a)	6.5 (b)	9.86 (ab)
Std Dev	12	7.62	16.78
N	200	82	94
Total quantity purchased:			
	CA farmer	Conventional farmers (*exposed*)	Conventional farmer (*unexposed*)
Mean	45.06 (a)	62.80 (a)	65.80 (a)
Std Dev	5.21	2.61	3.20
N	9	47	46
Total quantity sold:			
	CA farmer	Conventional farmers (*exposed*)	Conventional farmer (*unexposed*)
Mean	124.40 (a)	107.60 (a)	55.04 (b)
Std Dev	4.99	3.86	3.77
N	88	114	63

Sources and notes: Values calculated by the author. The χ^2 test is performed on the distribution of market transactions per month. Means followed by the same letter in the same row are not significantly different at the 5% level (Tukey's Honestly Significant Difference).

Table 2. Variables used in the sales and purchases regressions

Variable Name	Variable Explanation	Model where included
	Dependent Variables	
Maize sale	1 = Sale, 0 otherwise	1
Maize quantity sold	Quantity sold (kilograms)	2
Maize purchase	1 = Purchase, 0 otherwise	3
Maize quantity Purchased	Quantity purchased (kilograms)	4
	Independent Variables	
Household Characteristics		
Agehh	Household head age	1,2,3,4
Mhh	Gender of household head (1 = male, 0 = female)	1,2,3,4
Education	Head of household education	1,2,3,4
Famsize	Household size	1,2,3,4
Constructionindex	Index; house construction and water sources	1,2,3,4
Producedpercent	The percentage of maize consumed from own plots	1,2
Laborincome	Percentage of household income derived from labor	1,2
Production Characteristics		
Cafarmer	Household having adopted CA practices (1 = CA, 0 = conventional farmer)	1,2,3,4
Expsvillage	Conventional farmer residing in a village where CA extension efforts have occurred (1 = yes, 0 = no)	1,2,3,4
Animaltraction	Household ownership of a plow (1 = yes, 0 = no)	
Totalfieldsize	Farm size in HA	1,2,3,4
Community Characteristics		
Barue	Residence in the province of Barue (1 = yes, 0 = no)	1,2,3,4
Dry	Inadequate rain in the previous planting season (1 = yes, 0 = no)	1,2,3,4
Market Characteristics		
Femaletransactor	Gender of transactor (1 = female, 0 = male)	3,4
Marketdistance	Distance to market (minutes)	3,4
MaizepriceKG	Farmer reported maize price (M kg^{-1})	1,2,3,4
Neighbor	Transaction (occurred with a friend or family member (1=yes, 0 = no)	3,4
Transportation	Ownership of a means of transportation (1 = yes, 0 = no)	3,4
Leanperiod	Lean period transaction (1 = yes, 0 = no)	3,4
Plentyperiod	Harvest period transaction (1 = yes, 0 = no)	3,4

Table 3. Descriptive statistics for households residing in the provinces of Tete and Barue Mozambique

	Exposed Villages		Unexposed villages
	Conservation agriculture (CA) adopters	Conventional Farmers	Conventional Farmers
Market participation:			
Yes	83 (82.18%)	171 (80.66%)	112 (75.68%)
No	18 (17.82%)	41 (19.34%)	36 (24.32%)
N	101	212	148
Gender of primary market transactor:			
Female	53 (42.4%)	110 (51.4%)	71 (47.97%)
Male	72 (57.6%)	104 (48.6%)	77 (52.03%)
N	125	214	148
Main currency:			
Metical (Mozambique)	110 (88%)	167 (78.04%)	135 (91.22%)
Kwacha (Malawi)	15 (12%)	47 (21.96%)	13 (8.78%)
N	125	214	148
Availability of transportation:			
Yes	89 (71.2%)	119 (55.61%)	73 (49.32%)
No	36 (28.8%)	95 (44.39%)	75 (50.68%)
N	125	214	148
Availability of animal traction			
Yes	12 (9.6%)	14 (6.54%)	6 (4.05%)
No	113 (90.4%)	200 (93.46%)	142 (95.95%)
N	125	214	148

Sources and notes: Values calculated by the author.

Table 4. Means comparison of variables used in the market participation models

Variable	CA mean	CF exposed mean	CF unexposed mean	Population mean	N
Household Characteristics					
Agehh	45.5 (a)	43.03 (ab)	40.8 (b)	42.99	439
Mhh	84.8% (a)	78.77% (ab)	69.38% (b)	77%	487
Education	5.6% (a)	5.6% (a)	7.4% (a)	7.14%	487
Famsize	6.35 (a)	5.87 (a)	5.66 (a)	5.93	485
Adultspercent	51.26% (a)	49.79% (a)	50.39% (a)	50.35%	485
Consturctionindex	49.4 (a)	44.72 (b)	40.67 (c)	44.69	487
Staple1produced	91.12% (a)	89.01% (a)	86.25% (a)	88.7%	485
Laborincome	14.2% (a)	22.3% (a)	20.4% (a)	19.6%	486
Production Characteristics					
Totalfieldsize	2.13 (a)	1.74 (a)	1.19 (b)	1.67	477
Animaltraction	9.6% (a)	6.54% (a)	4.05% (a)	6.57%	487
Fertilizer	53% (a)	15.8% (b)	20.9% (b)	26.89%	487
Community Characteristics					
Dry	12.8% (a)	8.8% (a)	8.7% (a)	10.3%	487
Marketing Characteristics					
Femaletransactor	24.0% (a)	32.08% (ab)	39.19% (b)	32.16%	487
Marketdistance*	56.84 (a)	56.68 (a)	44.31 (a)	51.84	364
MaizepriceKG	9.39 (a)	7.53(ab)	10.77(ac)	9.42	479
Neighbor*	8.73% (a)	12.86% (a)	5.35% (a)	9.59%	373
Leanperiod*	39.08% (a)	47.95% (b)	71.42% (b)	52.59%	373
Plentyperiod*	21.35% (a)	26.9% (ab)	15.17% (ac)	22.02%	373
Transportation	71.2% (a)	55.61%(b)	49.32% (b)	57.7%	487

Sources and notes: Values calculated by the author. Means followed by the same letter in the same row are not significantly different at the 5% level (Tukey's Honestly Significant Difference). * is calculated among only those households that participate in the market.

Table 5. Regression results for the maize sales model

Variable	Selection Model		Quantity Transacted Model	
	Marginal effect	PR> Z	Marginal effect	PR> Z
Household Characteristics				
Agehh	-0.0024	0.109	0.0027	0.596
Mhh	-0.008	0.873	-0.2347	0.231
Education	0.0707	0.362	0.1914	0.456
Famsize	0.0125	0.144	-0.0434	0.146
Constructionindex	0.0011	0.401	-0.0011	0.812
Producedpercent	0.0032	0.000		
Laborincome	0.0003	0.306		
Production Characteristics				
Cafarmer	0.1358	0.000	-0.1403	0.236
Expsvillage	-0.0293	0.308	0 .1834	0.052
Animaltraction	0.0633	0.517	-0.2583	0.428
Totalfieldsize	0.0361	0.034	0.1486	0.004
Fertilizer	-0.0703	0.168	0.4439	0.011
Community Characteristics				
Barue	0.0721	0.163	1.525	0.000
Dry	0.0598	0.353	-0.5252	0.014
Marketing Characteristics				
Femaletransactor			-0.5072	0.003
Marketdistance			0.0035	0.000
MaizepriceKG	-0.0040	0.037	0.0052	0.495
Neighbor			0.0470	0.868
Plentyperiod			-0.005	0.976
Leanperiod			0.2434	0.246
Transportation	0.0450	0.249	0.4725	0.001
Wald χ^2 (H_0: all βs = 0)	187			
$P > \chi^2$	0.000			
Log likelihood	-689			
ρ	0.97			
Likelihood ratio (LR) test of indep. eqns.(ρ = 0)	25.66 (P = 0.00)			
λ	1.66			
N	467		268 (56.65% of population)	

Sources and notes: Values calculated by the author.

Table 6. Regression results for the maize purchases model

Variable	Selection Model		Quantity Transacted Model	
	Marginal effect	PR> Z	Marginal effect	PR> Z
Household Characteristics				
Agehh	-0.0006	0.593	-0.0284	0.001
Mhh	0.0290	0.458	0.0023	0.993
Education	-0.0231	0.702	-0.5775	0.076
Famsize	0.0164	0.016	0.0864	0.032
Constructionindex	0.0002	0.837	0.0082	0.287
Producedpercent	-0.0056	0.000		
Laborincome	0.0001	0.742		
Production Characteristics				
Cafarmer	-0.0948	0.005	-0.0928	0.722
Expsvillage	0.0316	0.189	-0.0549	0.741
Animaltraction	-0.1181	0.233	1.235	0.117
Totalfieldsize	-0.0350	0.057	0.0202	0.870
Fertilizer	-0.0171	0.686	0.0466	0.851
Community Characteristics				
Barue	-0.0590	0.187	-0.1881	0.525
Dry	-0.0353	0.513	0.6510	0.029
Marketing Characteristics				
Femaletransactor			-0.3530	0.093
Marketdistance	0.0024	0.075	0.0019	0.250
MaizepriceKG			0.0094	0.159
Neighbor			0.0814	0.716
Plentyperiod			0.0654	0.834
Leanperiod			-0.3146	0.148
Transportation	-0.1107	0.0001	0.0365	0.861
Wald χ^2 (H_0: all βs = 0)	48.63			
P > χ^2	0.0002			
Log likelihood	-269			
ρ	0.73			
Likelihood ratio (LR) test of indep. eqns.(ρ = 0)	8.1 (P = 0.0044)			
λ	0.68			
N	471		93 (19.66% of population)	

Sources and notes: Values calculated by the author.

Table 7. Quantity purchased and sold

Variable	Sold (kilograms)	Purchased (kilograms)
Average quantity	96.28	62.28
Household Characteristics		
Agehh	0.25	-1.77
Education	18.42	-35.97
Famsize	-4.17	5.38
Constructionindex	-0.10	0.51
Production Characteristics		
Cafarmer	-13.51	-5.78
Expsvillage	17.65	-3.41
Animaltraction	-24.87	76.92
Totalfieldsize	14.31	1.25
Fertilizer	42.73	2.90
Community Characteristics		
Barue	146.83	-11.71
Dry	-50.56	40.54
Marketing Characteristics		
Femaletransactor	-48.83	-21.98
Marketdistance	0.33	0.11
MaizepriceKG	0.50	0.58
Neighbor	4.52	5.07
Plentyperiod	-0.48	4.07
Leanperiod	23.43	-19.59
Transportation	45.49	2.27

Sources and notes: Values calculated by the author.

Figure 1. Total kilograms of maize purchased and sold per month with prices

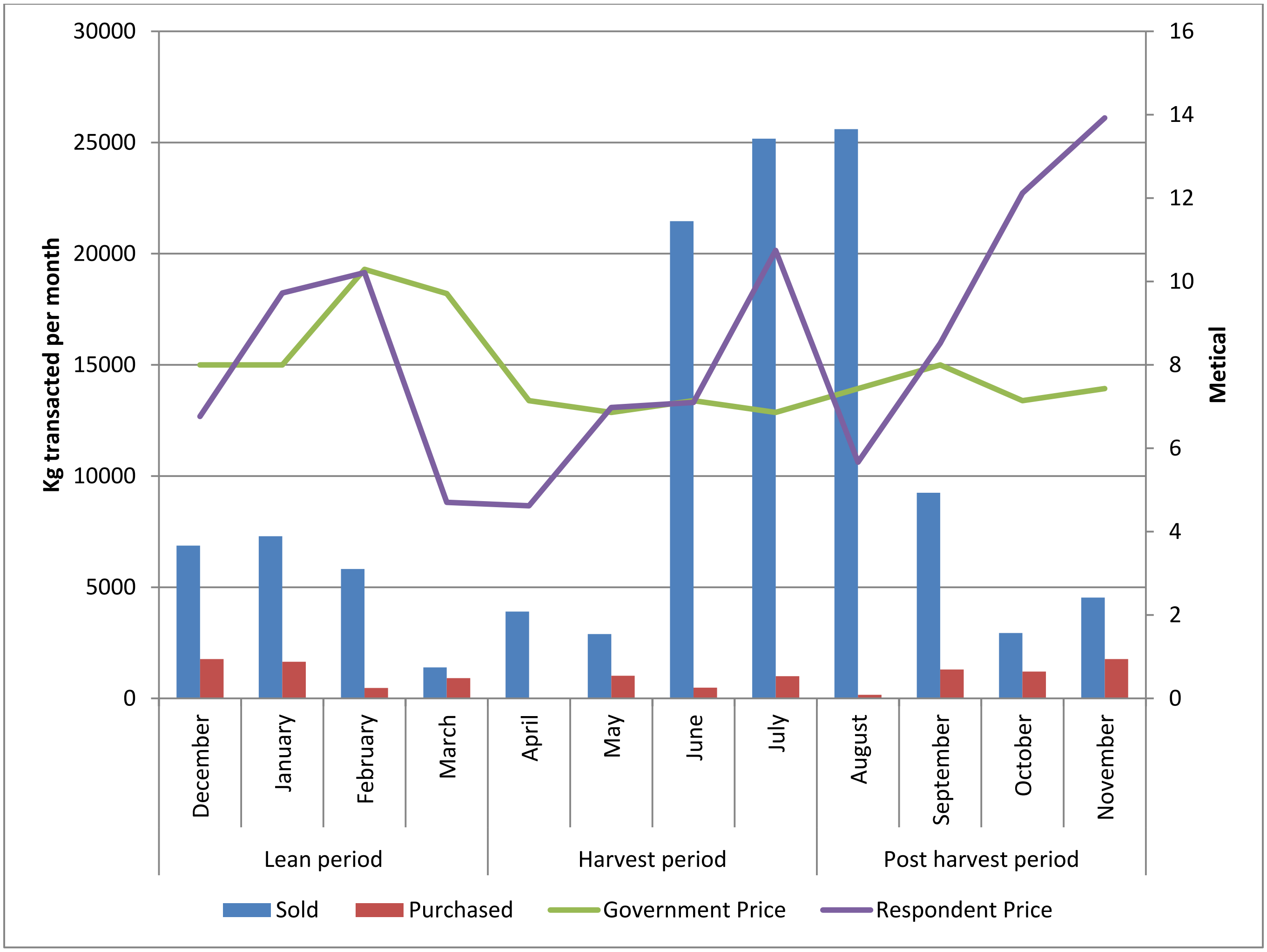


Figure 2. Total number of market transactions and price per kilogram

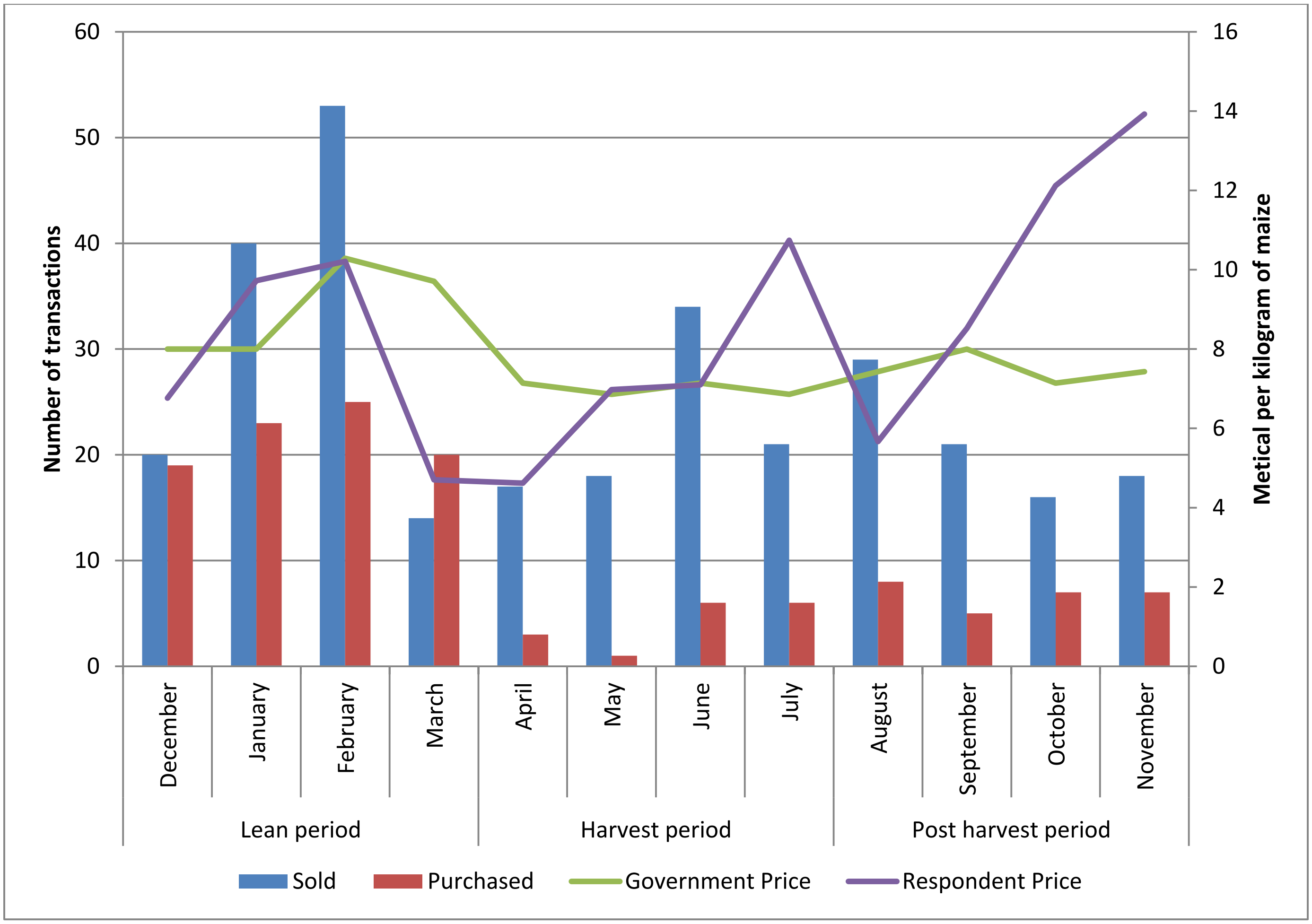


Figure 3. Maize purchasing patterns: Barue and Angonia

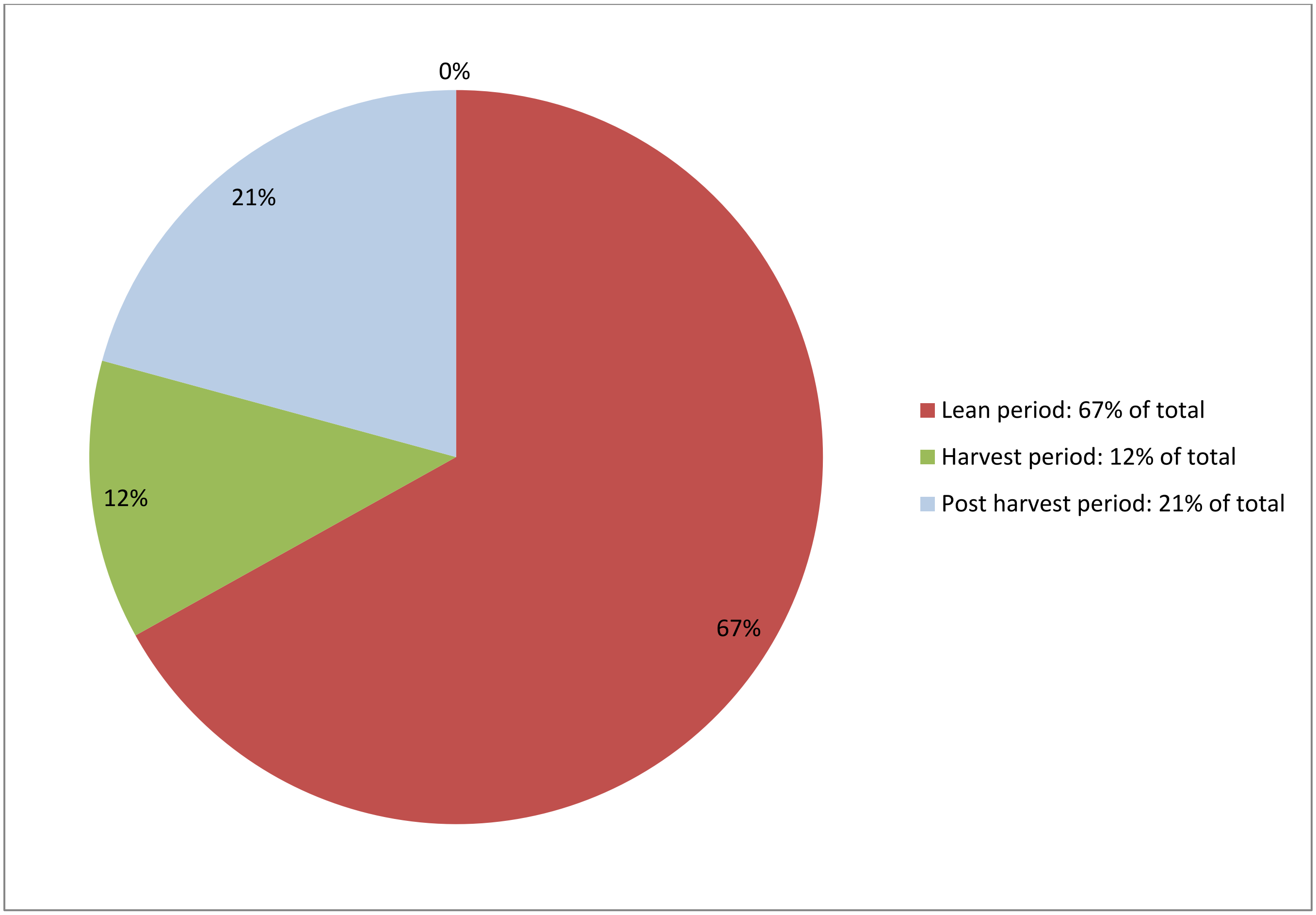
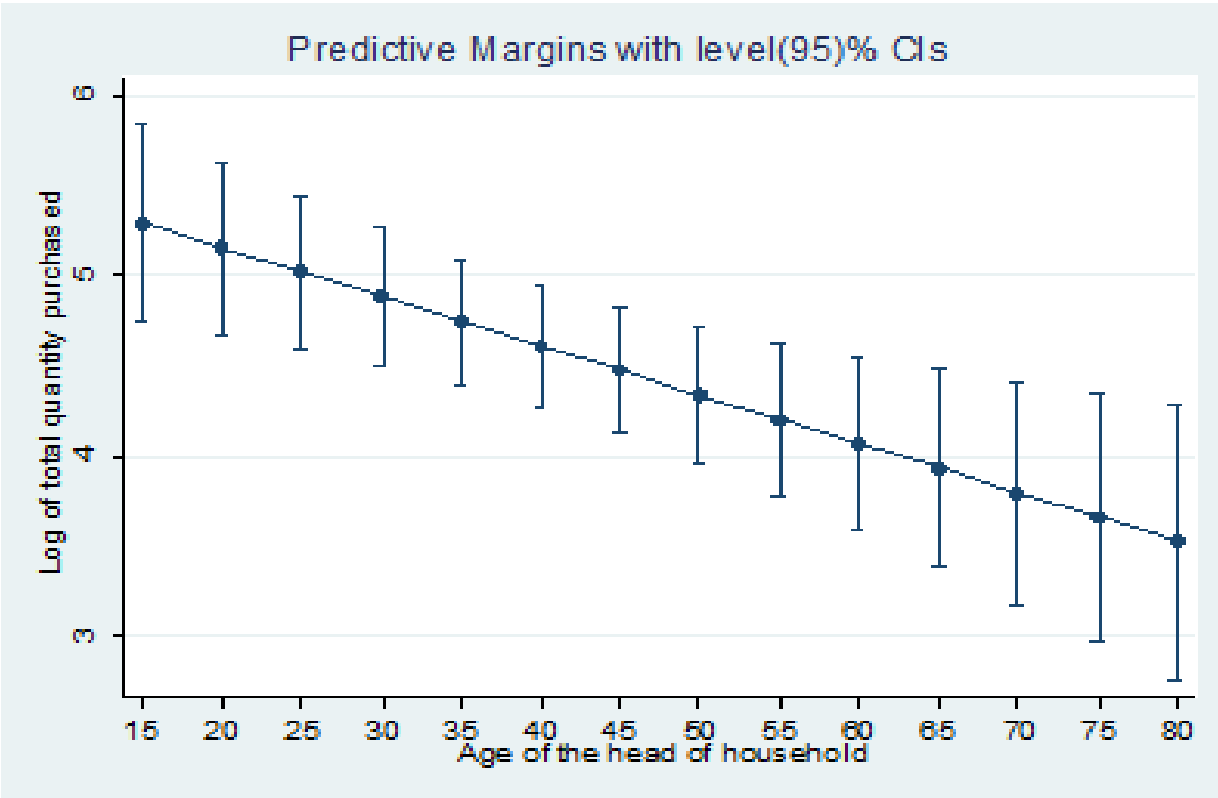


Figure 4. The marginal effect of age on the quantity purchased



Chapter IV. Summary and conclusions

This thesis focused on the adoption of conservation agriculture in the provinces of Tete and Manica, Mozambique, using data collected by the author, Nyasha Chipunza, Ivan Cuvaca and Drs. Dayton Lambert and Michael Wilcox, and eight Mozambique enumerators. The first chapter examined the correlation between CA adoption and a set of indices that proxy aspects of household wellbeing. Three indices were created, examining household wellbeing through asset ownership, livestock ownership, and access to sanitation and the quality of materials used in household construction. Households that practiced conservation agriculture had higher wellbeing indicator scores. However, *ceteris paribus* CA adopters had lower *livestock index* scores and higher scores related to the asset and construction indices. These results suggest that the adoption of conservation agriculture was a negatively correlated with livestock ownership rates, due to CA adopters decision to use cover crops and crop residues as prescribed by CA, as opposed to the conventional practice using crop residue for forage.

The second study hypothesized that CA farmers would participate in maize markets similarly to the rest of the community. This hypothesis was rejected. Results suggest that CA farmers were more likely to engage in maize markets as buyers and less likely to participate in the market as vendors. These results suggest that CA plays some role in increasing farmers competitiveness, thereby increasing the probability that a household will engage in maize sales. These findings may be influenced by the increased input use among CA farmers due to input loans from NGO's like TLC.

These results suggest that the adoption of conservation agriculture is correlated with the economic wellbeing of farmers using this technology. The sale and production of agricultural products is the number one source of household income in the surveyed regions. When coupled with the increased likelihood of participation in the market as a vendor , the results suggest that CA households have higher incomes derived from the sale of agricultural production. This may explain why CA households had, on average, higher wellbeing index scores than the non-adopters.

The results of this thesis need to be interpreted with care. One of the principal caveats of this paper is that due to the cross sectional nature of the survey. This limits the inferences that can be made regarding the first paper, as it remains difficult to establish why CA households have higher index scores. In the second paper, participation and quantity of maize sold may be confounded by input loans by NGOs. A multi-year study would increase the understanding of the subjects addressed here, with more light shed on smallholder maize market transactions, and household wellbeing.