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THE ROLE OF CASSAVA IN SMALLHOLDER MAIZE MARKETING
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THE ROLE OF CASSAVA IN SMALLHOLDER MAIZE MARKETING IN ZAMBIA AND MOZAMBIQUE

By

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ABSTRACT

THE ROLE OF CASSAVA IN SMALLHOLDER MAIZE MARKETING IN ZAMBIA AND MOZAMBIQUE

By

Hunter H. Nielson

This study investigates the relationship between cassava production and maize marketing for smallholder farming households in Zambia and Mozambique. Three different econometric models are estimated for two years of data each in Zambia and Mozambique to explore the relationship between cassava hectares and kilograms of maize sold. It is hypothesized that households with cassava stocks in addition to maize are better able to meet their staple food consumption needs, thereby freeing surplus maize for sale. Findings indicate that cassava hectares are positively related to maize market participation and level of maize sales for two good rainfall years in Zambia. In Mozambique cassava hectares have little impact on maize sales in a good rainfall year, and a slightly greater impact during a year of poor rainfall. These results indicate that cassava hectares are an important determinant for maize sales in Zambia, and imply that in Mozambique households may depend upon cassava more during years of poor maize production.

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1. INTRODUCTION

1.1 Problem Statement

Maize and cassava are the two most widely produced food staples in sub-Saharan Africa. Millions of smallholder farm households rely on these two crops to meet their consumption needs. Maize is the region's primary food staple, supplying approximately 325 kcal per person per day on average, while cassava, the second most important food staple supplies approximately 270 kcal per person per day (FAOSTAT). Historically, maize has been more politically strategic than cassava and has received the lion's share of public investment in production and marketing. Rarely, if ever, do policy makers consider the important contribution cassava makes to food security, and very little research has been done to explore the relationships that exist between the two crops.

Compared to cassava, maize is marketed to a higher degree and has been important since colonial times for feeding both rural and urban populations. In Zambia, approximately 37% of the total value of household income comes from maize while less than 15% of income comes from cassava (Zulu, 2007). Boosting maize production and increasing market participation has long been a strategic goal for governments in the region as a way to feed a rapidly urbanizing population. Unfortunately, attempts to achieve this goal have met with only partial success. Maize production in Southern Africa remains well below potential despite various government attempts to improve it. Likewise, although governments have tried to invigorate maize markets in the region with policies intended to increase supply, only about one quarter of smallholder farming households sell their surplus in any given year.

A number of studies have attempted to shed light on the determinants of household marketing behavior in developing countries. In most cases, market participation choices are studied with methods similar to those used to address technology adoption questions (Barrett, 2007). Factors frequently identified as influential to food marketing include farm size, capacity to bear risk, human capital, labor availability, access to credit, land tenure, and market access (Feder, 2007). Recent empirical attempts to identify and measure the determinants of market participation in Africa have focused on one or another of these factors (Goetz, 1992; Boughton, 2007; Barrett, 2007).

In broad terms, smallholder food market participation depends on the availability of household productive assets, relative commodity prices, adequacy of market infrastructure, and ability to meet food consumption needs. The last of these points is arguably the most pressing for smallholder maize farmers. At harvest time, a household assesses their maize harvest to determine if it is adequate to meet the household's needs before deciding to sell. Due to highly variable annual maize production, some households will not have maize surplus available for sale in all years. Additionally, uncertain availability of maize in local markets and the large wedge between producer prices and retail prices may lead households to sell only a small portion of their surplus while some households refrain from selling maize at all.

Improving household access to other staple foods such as cassava may increase maize sales behavior by increasing household food security. Cassava is a drought-resistant perennial crop that is resistant to the rainfall shortfalls that often disrupt maize production. In cases in which the maize harvest is low, cassava can substitute for maize in household consumption. Households that produce cassava in addition to maize can meet their staple food needs even if the maize harvest is poor.

1.2 Objectives of the Study

Recognizing the importance of maize and cassava to smallholder farmers in SSA – and the potential for increased market participation to boost economic growth – this study incorporates cassava as an important explanatory variable in maize market participation models. Specifically, the study aims to understand the affect cassava availability has on a household's maize marketing decision. Simply put, does cassava – a food substitute for maize in household consumption – act as a catalyst for maize sales?

Improving food security and boosting maize marketing is a priority for Zambia and Mozambique, yet market participation studies that empirically estimate the determinants of participation are few. To specifically incorporate cassava into an empirical analysis of household maize marketing behavior is unique to this study, and should shed light on, and increase interest in, the interaction between cassava and maize in the discussion of rural farm welfare and marketing behavior.

1.3 Focus Countries

To explore these questions empirically, this study focuses on two countries in Southern Africa: Zambia and Mozambique. These two countries are interesting for a number of reasons. First, Zambia and Mozambique share similar agro-ecological environments. Second, both countries are intermittent surplus maize producers and exporters, and have high potential to meet demand for maize in the Democratic Republic of Congo (for Zambia) and Southern Malawi (for Mozambique). Third, contrasting institutional and policy environments allow for interesting comparison. And finally, in a region of the world with notoriously scarce agricultural data, Zambia and Mozambique are anomalies. In both nations, national level household agricultural surveys are available that represent some of the most accurate and in-depth information available on agricultural households in the region.

1.4 Organization of the Study

Chapter 2 outlines the importance of maize and cassava in Zambia and Mozambique and places the discussion in a historical context. National level and spatially disaggregated summaries of maize and cassava production are presented, and variation by Agro-ecological zone is discussed. Chapter 3 provides a brief discussion of the importance of market participation for economic growth, both generally, and in the context of Zambia and Mozambique. It includes an overview of the current maize marketing situation in the two countries and describes factors that enable or inhibit full market participation. Chapter 4 provides a discussion of the survey and geospatial data used in the study. Chapter 5 outlines the analytical approach and hypothesis. Chapter 6 describes the empirical models and methods used in the study. Chapter 7 is a presentation of results. And Chapter 8 provides conclusions and suggestions for further study.

2. IMPORTANCE OF MAIZE AND CASSAVA

2.1 Historical Perspective

The importance of maize as a politically strategic crop in Southern Africa is rooted in an historical context extending back to the beginning of the twentieth century with European colonization. Like many other countries, Zambia's current policy environment is closely tied to its history.

In the early 1900's, Zambia (then Northern Rhodesia) was controlled by the British South Africa (BSA) Company, whose principal goal was to exploit the land and people of Zambia for the benefit of shareholders in England. By the early 1920's, Zambian mining was expanding, and the BSA Company began to look for reliable sources of food to provide for the workers and rapidly growing towns. Because African farming systems had been so badly disrupted by the large scale migration of males to mining centers, the BSA Company believed that African farming was incapable of meeting demand. This belief led the BSA Company to seek agricultural goods from European settler farmers who had been given exclusive access to the best land.

Through the 1920's, the Northern Rhodesian mines expanded, and the demand for maize was largely met through private marketing channels. However, by the 1930's, the global depression caused the closure of several mines, and the subsequent loss of demand drove prices downward. Despite having lost access to the prime agricultural land near the major north-south corridor, African farmers tripled their sales volume from the 1920's through the 1930's while settler farmers expanded by only 25 percent. The increasing pressure from African farmers – who could produce at lower cost – and declining prices led the colonial administration to establish what would be the beginning of a long history of government intervention in Zambian maize marketing with the establishment of the Maize Control Board (MCB) in 1936.

The MCB skewed incentives to benefit European producers at the expense of African producers, established maize as the dominant staple food in the country, encouraging its production at the expense of other crops, and set the precedent for state intervention in agriculture that persists today. From this point forward, the government would accept the responsibility for creating a stable market environment with maize at its core. State involvement in agriculture took on a range of schemes that involved Africans to a greater or lesser extent. What remained constant was a bias toward Europeans, farmers near the line of rail, and maize over other crops. However, from the beginning of European involvement in Northern Rhodesia, agriculture has had a low priority with respect to other sectors. Beginning with the BSA Company, mining and urban activities were considered paramount, with agriculture serving a subsidiary role (Wood, 1990)

After independence in 1964, maize continued to be the single most important crop for Zambian farmers. Zulu et al (2007) describe how the government entered into a "social contract" with smallholder African farmers to redress the neglect they received under the colonial government. About three quarters of the population resided on farms and relied on farming as their primary livelihood. Therefore, the newly formed Zambian government used maize production incentives and input subsidies as the primary vehicles to improve rural welfare. From Independence to the 1980s, maize yields rose dramatically as a consequence, even in northern areas traditionally considered unsuited for maize production (Kokwe, 1997).

The maize boom came at a very high and ultimately unsustainable cost. Beginning with new leadership in 1991, pressured by the international community to adopt standard structural adjustment policies, the government stopped the pan-territorial pricing policy that was common in previous decades. At the same time, government reduced its maize purchases. As a result of these dramatic changes to the long standing status quo of government assistance in maize production and marketing, widespread crop diversification took place. Farmers moved away from maize toward other crops that had been marginalized over the years of the maize boom. From 1990 to 1999, maize area declined 22% while cassava increased 65% over the same time period (Zulu, 2000)

The results of the government cutbacks were controversial in Zambia. In 2001 the government returned to pan-territorial pricing and introduced the Food Reserve Agency (FRA), another form of government buying agent. While the volumes of food purchased by the FRA were reduced in the new millennium the FRA announced its intention to purchase as much as 25% of the marketed crop (Zulu, 2007).

In Southern Africa, policy reflects and accentuates the importance of maize in the national economy. Zambia channeled the majority of producer and consumer subsidies into maize at the expense of other crops (Tschirley et al, 2006). To this day, even though the magnitude of intervention has dropped from the post independence years, price supports and fertilizer subsidies are in place for Zambia to such a degree that nearly 50% of the total agricultural budget was devoted to the FRA and fertilizer support in 2005 (Jayne, 2007).

The early history of Mozambique's relationship to maize is similar to that of Zambia's, but has tended toward a more market-oriented approach in recent years. Post independence government policies were highly controlling and included a marketing parastatal and pan-territorial producer prices. In the early 1990's, controls were reduced and a greater degree of privatization was allowed. Fixed producer prices were abolished and the marketing parastatal AGRICOM had collapsed. The *Instituto de Cereais de Mocambique* (ICM) replaced AGRICOM in 1995 and was endowed with a broad mandate to provide inputs and market information, to maintain a strategic grain reserve, and to act as the buyer of last resort. However, unlike Zambia's FRA, ICM essentially behaved like a private trader and relied exclusively on private bank financing, not government funding.

In comparison to Zambia, maize production in Mozambique has remained relatively free of government interference once the controls were lifted. However, as discussed in Chapter 3, the strategic importance of maize for both countries continues to influence government policy with regard to marketing and trade.

2.2 Importance of Maize and Cassava

This section examines the importance of maize and cassava to smallholder farming households in terms of production and consumption at the national level.

2.2.1 Zambia

In Zambia, maize is the dominant staple crop and cassava ranks a distant second. According to household surveys conducted for the harvest years 1999/2000 and 2002/2003, about half as many households produce cassava as compared to those which produce maize (Table 1); this imbalance can largely be attributed to the country's long history of production and marketing subsidies favoring maize. In contrast, cassava has received limited attention only in recent years.

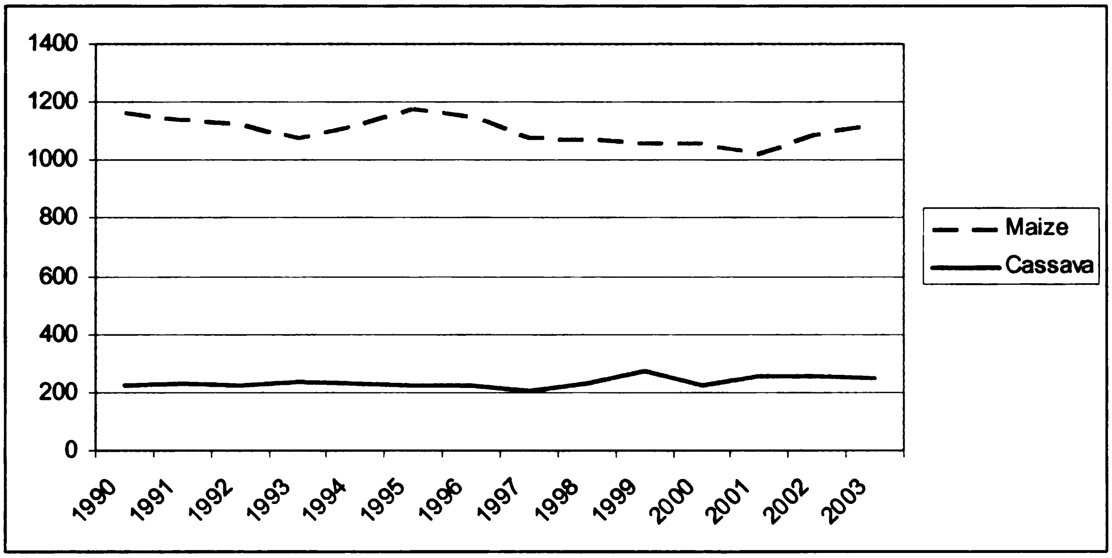
Table 1: Zambia national level maize and cassava production

ZAMBIA	% of HH Growing		Mean Production (kg/hh)*	
	Maize	Cassava	Maize	Cassava
1999/00	77%	39%	948	578
2002/03	83%	47%	857	553

* Mean production of those who grew each crop
Source: Zambia Supplemental Surveys

Corresponding to the large proportion of households growing maize compared to cassava, consumption patterns in Zambia are heavily weighted toward maize, and have been essentially stable through time. Figure 1 compares maize and cassava consumption using kilocalories per capita per day at the national level from 1990 through 2003. On a per-capita basis, maize accounts for roughly six times the daily caloric intake of cassava. This is likely a reflection of the distinctly regional nature of cassava consumption preferences, that cassava is very rarely sold outside cassava production regions, and that households that consume cassava are also likely to consume maize.

Figure 1: Zambia national level maize and cassava consumption, Kcal/person/day

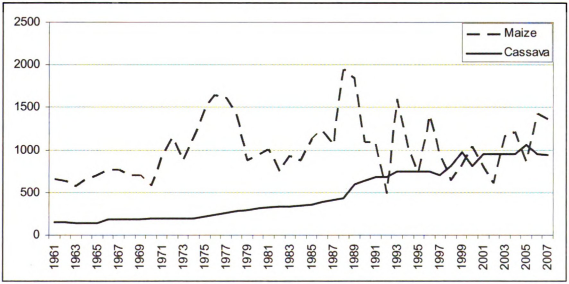


Source: FAO

Figure 2 below demonstrates that national production has been highly variable throughout the 1990's and into the early 2000's. Because a successful maize harvest in Zambia is mostly dependent on adequate precipitation, maize production is highly correlated with rainfall. Extreme fluctuations in weather in Southern Africa, therefore, lead to fluctuations in maize output. Global climate change stands to exacerbate this situation. Jain (2007) notes that dry spells have been on the rise in Southern Africa, and the length of the rainfall season has been decreasing. Since 1990, there have been at least two major droughts in Southern Africa (Zulu, 2000). Given this environment, the greater resilience of cassava production to rainfall fluctuations is an important asset for food security.

When looking at national cassava production, it is informative to consider how cassava is produced. Cassava is a root crop that is not harvested in the first year of its growth. In the second and third year (and sometimes longer) farmers dig up the roots according to their consumption needs. Therefore, unlike maize, which is harvested and recorded at one time, cassava production takes place over time as households collect small quantities from mature fields according to their needs. This is important for two reasons. First, it complicates the data collection exercise because households are expected to recall and be able to accurately measure several small harvests of cassava at the time of survey enumeration. Second, the total harvest figures are much less a reflection of the status of potential stocks than a reflection of how much cassava a household chose to harvest in a given year. Therefore, when analyzing cassava production in figure 2, it is worth remembering that they do not necessarily reflect the total harvestable amount of cassava, but rather the amount that was needed.

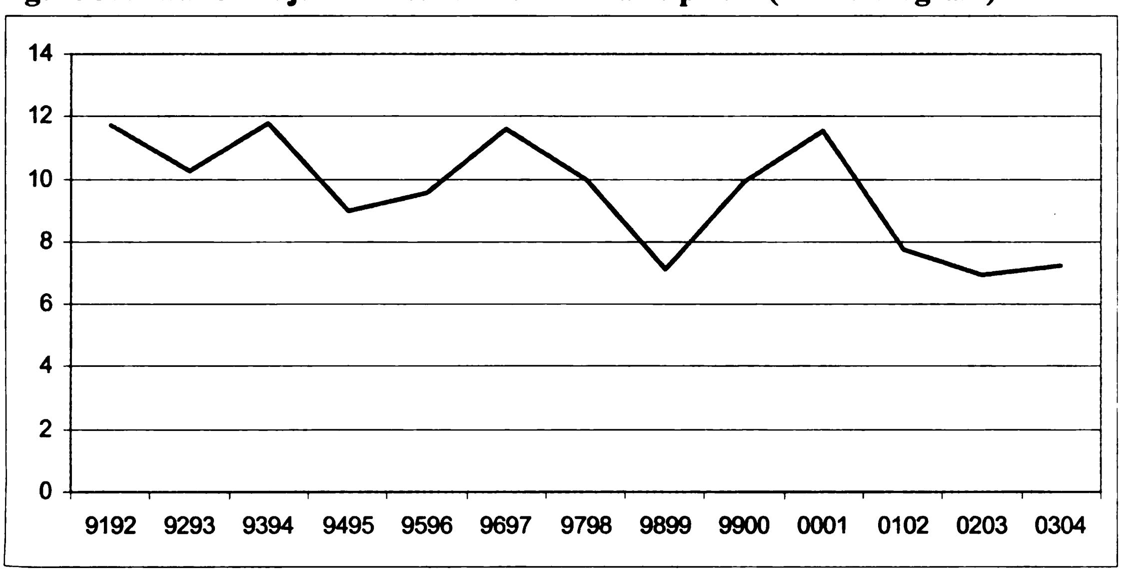
Figure 2: Zambia maize and cassava production ('000s MT)



Source: FAO.

The relative instability of maize is important for the discussion at hand. While maize is highly productive, the volatility of production, coupled with high and steady demand shown in Figure 1 creates food insecurity for rural households. Additionally, highly volatile maize production creates highly volatile farm-gate prices for households attempting to sell maize. Figure 3 is the inflation adjusted median of district-level maize prices from 1991/92 to 2003/04. The volatility of prices is a reflection of the volatility of production. This volatility is passed through the value chain, translating into unstable retail maize meal prices for urban consumers.

Figure 3: Inflation adjusted district median maize prices (ZMK/kilogram)



Source: Zambia Post Harvest Surveys

2.2.2 Mozambique

According to Walker et al (2006) a large percentage of the rural population in Mozambique considers maize (49%) and cassava (40%) their primary food staple. Additionally, about 98% of those who consider cassava and maize their primary staple also produce the crop themselves. With such a large percentage of the country's population relying on their own production to satisfy their need for staple food calories, it is clear that both maize and cassava are key determinants of Mozambican food security (Walker, 2006).

The percentage of farming households that produce cassava in Mozambique is quite different from Zambia. As Table 2 shows, roughly 80% of households produce maize and roughly 70% of households produce cassava. Unlike Zambia, Mozambican agricultural policy has been less biased toward maize over the years, and tastes for cassava have developed more fully than in Zambia where only the north of the country has a long tradition of cassava production.

Table 2: Mozambique national maize and cassava production

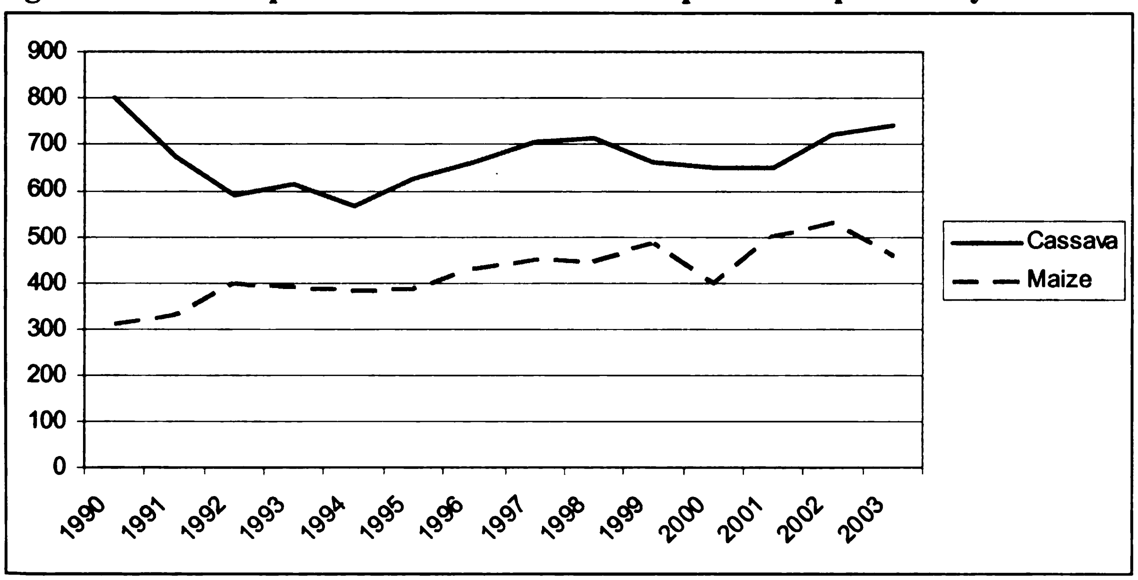
MOZAMBIQUE	% of HH Growing		Mean Production (kg/hh)*	
	Maize	Cassava	Maize	Cassava
2001/02	81%	71%	480	709
2004/05	78%	71%	281	1435

* Mean production of those who grew each crop
Source: TIA

Table 2 also illustrates the productive potential of cassava in years when maize harvests are below normal. The 2004/2005 harvest was poor in all parts of Mozambique, a fact reflected in the low mean maize production figures that year compared to the average rainfall year of 2001/2002. In contrast, cassava production more than doubled from 2001/2002. It is logical that households in Mozambique increase the amount of cassava they harvest as a way to make up for reduced maize production.

Corresponding to the greater prominence of cassava in the production figures above, national households consumption of cassava is also higher than maize (Figure 4). This is the opposite situation from Zambia, in which maize was most prominent. This is likely a reflection of the spatial distribution of population and crop production in Mozambique. The north of the country is home to 60% of the total rural population, and produces both cassava and maize in high quantities; the center and south have lower populations and are less likely to produce cassava.

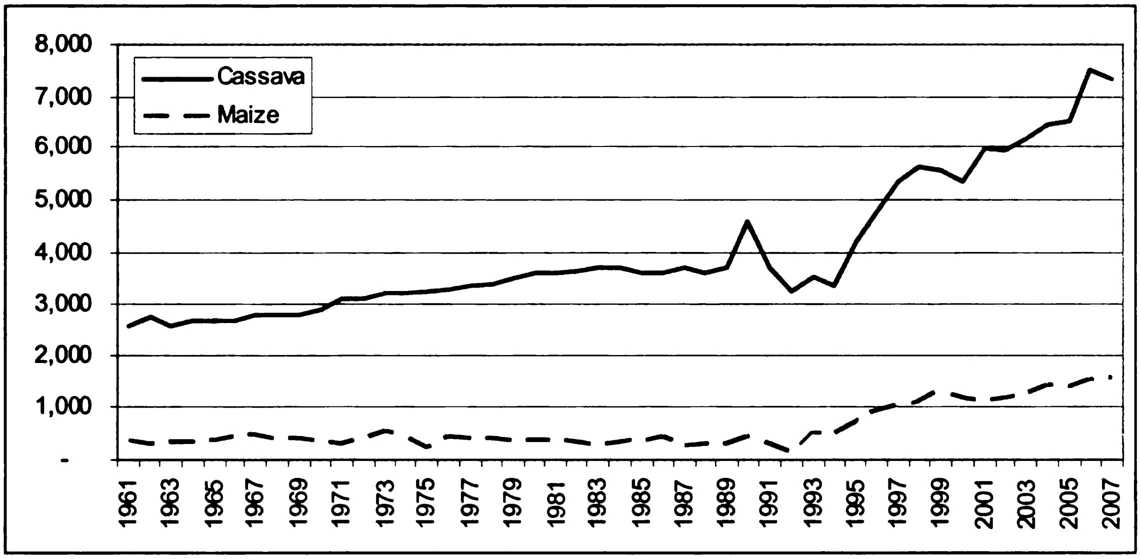
Figure 4: Mozambique maize and cassava consumption Kcal/person/day



Source: FAO

Maize and cassava production in Mozambique is also markedly different from Zambia. Overall tonnage of cassava in any given year is much greater than maize, and the gap seems to be widening. Figure 5 does not indicate whether the disparity is due to poor maize harvests or whether cassava planting has increased more rapidly over the years than maize.

Figure 5: Mozambique maize and cassava production ('000s MT)

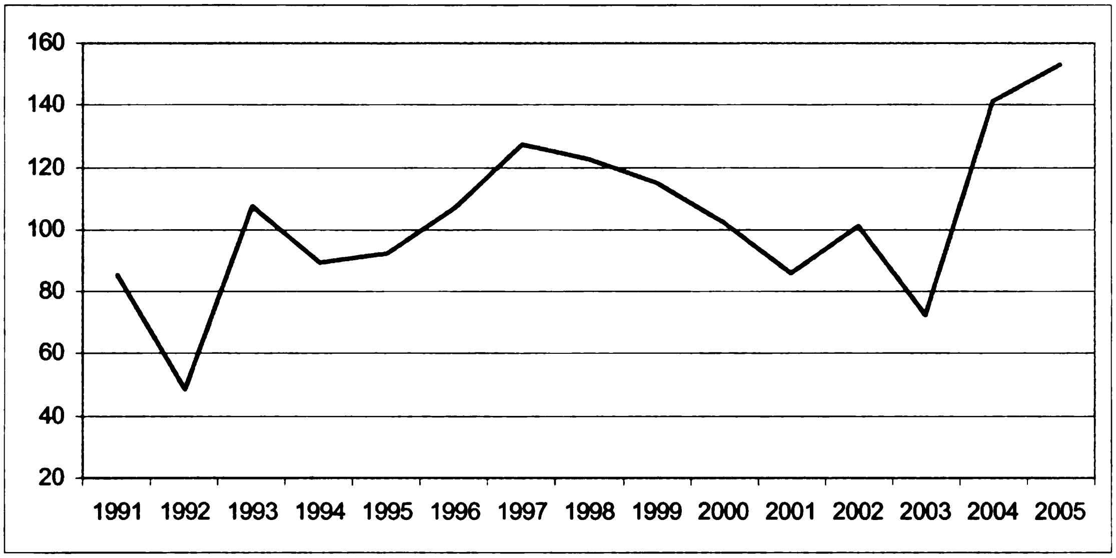


Source: FAO

Although the volatility in maize production seen in Zambia is not as evident in Mozambique, the variation in prices is considerable (Figure 6). Additionally, seasonal maize deficits lead households to increase their consumption of other crops, including cassava, dramatically. In one study, households that relied on maize for 60% of their caloric intake during the post-harvest season reduced their reliance to less than 40% during the hungry season (Rose, 1999).

The spatial distribution of production in Mozambique likely has an impact on volatility, and normally prevents large-scale maize shortfalls from occurring. The next section shows that the central and northern areas of the country produce the bulk of the maize, and are situated in mid- to high-rainfall zones. The low-lying north of the country infrequently suffers from poor rainfall which keeps production steadier from year to year.

Figure 6: Inflation-adjusted maize producer prices (USD/MT)



Source: FAO

2.3 Spatial Dimensions of Production and Consumption

A great deal of variability in the production of cassava and maize is masked in the national-level discussion of the previous section. For both Zambia and Mozambique, the relative importance of maize and cassava differs depending on the region of the country. This section describes the analytically important concept of Agro-ecological Zones (AEZs) before disaggregating the countries' production data into AEZs for discussion.

2.3.1 Climate and Agro-ecological Zones

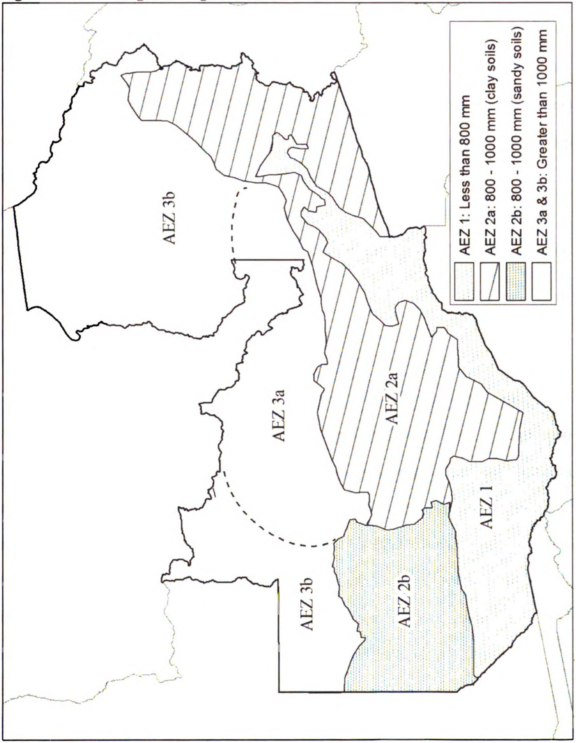
Zambia

In general, northern Zambia receives the highest average annual rainfall and the southern region and valley areas receive the least. The north enjoys the longest growing season, while the central and southern regions experience shorter growing seasons, often characterized by dry spells that negatively impact maize production. The Zambian

Government has divided the country into four distinct agro-ecological regions defined by rainfall, temperature, and soil type. Below is a description of each AEZ corresponding to Figure 7.

AEZ 1 includes the Zambezi and Luangwa Valley areas in the south and east. This hot, low-lying zone is characterized by less than 800 mm of rainfall per annum (Jain, 2007). The distribution of rainfall is erratic, drought is recurrent, and under normal conditions the growing season lasts from 60 – 90 days. The zone is best suited to the production of small grains and livestock rearing, and is not particularly well suited to maize or cassava. Nevertheless, maize is grown by a large proportion of small-scale farm households in this zone owing to the long-standing reliance on maize as the staple food of Zambia. Agricultural production is typically lower here than in other areas of the country, and households are likely to depend on food from outside the area to meet their needs for part of the year.

Figure 7: Zambia Agro-ecological Zones



Source: Adapted from Zambia Central Statistical Office

AEZ 2 covers the center of the country, stretching from the western to the eastern borders, wrapping around the Luangwa Valley in the East. This zone is characterized by average rainfall between 800 mm and 1000 mm per year and is subdivided by soil type into two Zones: AEZ 2a and AEZ 2b. This region is highly productive for both food and cash crops. Region 2b, confined to the far West and the Zambezi flood plain, is made up of sandy soils and has high potential for cassava and rice production as well as cattle rearing. Though the zone is prone to periodic drought, the majority of small-scale farmers here devote a large portion of their available land to maize. The growing season in AEZ 2 ranges from 90 – 190 days (Jain, 2007).

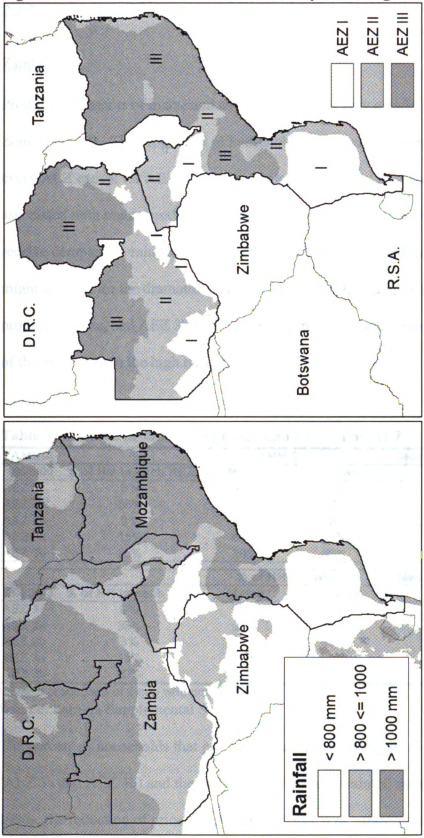
AEZ 3 is the largest agro-ecological region of the country. It comprises almost half of the territory of Zambia, stretching from the northwest to the northeast of the country. AEZ 3 is the highest rainfall zone in the country with average rainfall ranging from 1000 mm to 1400 mm per year. The length of the growing season ranges from 140 – 200 days, and although AEZ 3 is known as a highly productive cassava growing area, maize is a major crop here as well. For the purposes of this study, AEZ 3 is broken into two parts to reflect difference in household crop production and marketing opportunities. Districts near highly urbanized mining areas have more ready access to inputs, and higher effective demand for commodities. This area is classified AEZ 3a. AEZ 3b is characterized by a highly rural population, poor infrastructure and remoteness from markets.

Mozambique

In an effort to standardize the AEZs between Zambia and Mozambique, Zambia's government-established AEZs are used as a template from which the Mozambique zones are derived (Figure 8). As noted earlier, the AEZs in Zambia are largely, but not exclusively determined by rainfall[1]. For simplicity, rainfall is used to define the AEZs in Mozambique. In order to categorize rural farming households in Mozambique by agro-ecological zones that approximately match the definitions used in Zambia, the physical boundaries of the Zambian AEZs are overlaid on the Worldclim Africa-wide 30 year average rainfall dataset using Geographical Information Systems (GIS) software[2]. By adjusting the classification of the rainfall gradient layer to approximately match the boundaries of the Zambian AEZs, Mozambican zones are classified. These zones correspond to the three broadest Zambian AEZs: Zone 1: < 800 mm; Zone 2: >800 <=1000; Zone 3 > 1000.

[1] Other factors such as soil composition were also considered, but incorporating them was beyond the scope of this thesis. The rainfall-based AEZs used here are an approximation, but appear to be fairly consistent with known cropping patterns.
[2] ESRI ArcGIS 9.2 was used for all GIS analysis in this paper.

Figure 8: Classification of AEZs based on 30 year average rainfall



2.3.2 Spatial Distribution of Production

Zambia

Production patterns of maize and cassava in Zambia vary greatly by Agro-ecological Zone (Table 3). The proportion of households that produce maize is greater than 80% in every AEZ except for AEZ 3b, and is greater than 90% in the two regions most often associated with maize production. It is worth remembering that AEZ 3a and AEZ3b receive comparable rainfall, but do not share infrastructure and market access. This might account for the dramatic difference between AEZ 3a, in which 81% of households produced maize, and AEZ 3b in which less than 40% produce maize despite the location of the two zones in the high rainfall belt.

Table 3: Zambia production of maize and cassava by AEZ

ZAMBIA		% of HH Growing		Mean Production (kg/hh)*	
1999/00	% of HH in each AEZ	Maize	Cassava	Maize	Cassava
AEZ 1	8%	91%	2%	1,098	8
AEZ 2a	38%	97%	5%	2,034	37
AEZ 2b	9%	80%	62%	408	373
AEZ 3a	15%	81%	39%	941	566
AEZ 3b	30%	39%	86%	262	1,908
		% of HH Growing		Mean Production (kg/hh)*	
2002/03	% of HH in each AEZ	Maize	Cassava	Maize	Cassava
AEZ 1	9%	93%	2%	799	1
AEZ 2a	38%	97%	7%	1,725	29
AEZ 2b	8%	84%	81%	398	463
AEZ 3a	15%	86%	54%	987	506
AEZ 3b	30%	52%	92%	373	1,765

* Mean production of those who grew each crop

Source: Zambia Supplemental Surveys

The percent of households that produce cassava is much higher in the high rainfall zones (AEZ 3a and AEZ 3b) and the sandy-soils of the mid-rainfall zone (AEZ 2b). In the 1990s, the reduction of price supports and abolition of pan-territorial pricing for maize, coupled with the development and dispersion of early-maturing and pest-resistant cassava planting material led many households to diversify their crop production away from maize. Cassava production between 1992 and 1998 increased 71% in Northern Province (located in AEZ 3b) alone (Zulu, 2000). Particularly in AEZ 3b, farmers began to seek crops such as cassava that could stabilize their staple food supply (Zulu, 2007).

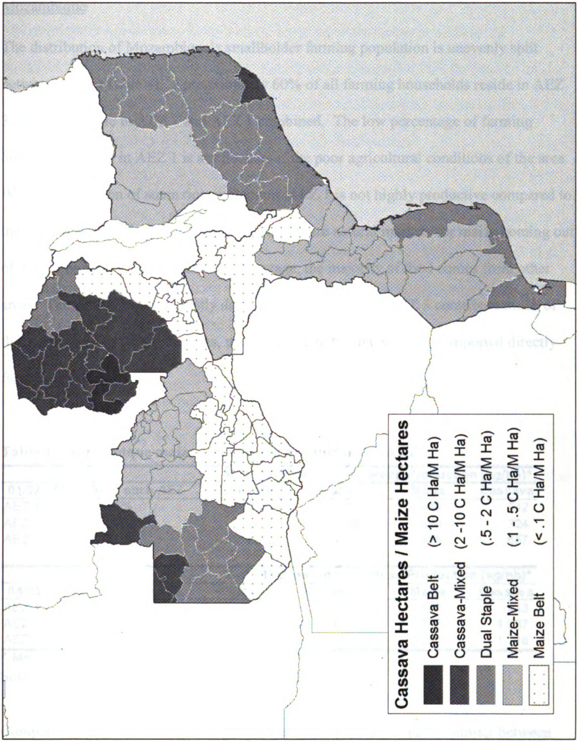
Mean household maize production for those who produce maize is highest in AEZ 1, AEZ 2a, and AEZ 3a. However, in the two years displayed in Table 3, which are similar in terms of national annual rainfall, notable production variation was experienced in the two drier zones compared to AEZ 3a. Both AEZ 1 and AEZ 2a had significantly lower maize production in the second year. Whether the decline is due to localized dry-spells which are more common in the lower rainfall zones, or to the timing of planting or access to inputs, Table 3 demonstrates that production in the areas responsible for the majority of the nation's maize can fluctuate considerably. It also shows that production in zones in the high-rainfall belt can be dramatically different than the low rainfall zones. AEZ 3a deviated only slightly between the two years, and moved in the opposite direction to AEZ 1 and AEZ 2a. AEZ 3b, the remote high rainfall area, experienced a sizeable increase in the second year.

Mean household production of cassava is at least twice as high in AEZ 3b as in any other zone. Cassava thrives in warmer, wetter areas, and grows well in sandy soils. Populations in AEZ 3b have a longer history with cassava and the majority of rural households consume cassava as their primary staple food. Most of the production is consumed by the same households that produce it. In contrast, the small amount of cassava produced in AEZ 1 and AEZ 2 is likely to be sold as snack foods in towns, at bus stops, and around public events (Haggblade, 2007).

Another way to compare the relative importance of maize and cassava is to compare the size of landholdings devoted to each crop. In figure 9, dark areas on the map indicate a high ratio of cassava area to maize area, and light areas on the map indicate a high maize to cassava ratio[3]. It is clear that the northern areas of Zambia are dominated by household cassava production, while the central, southern, and eastern parts of the country are dominated by maize production. Note that the area in the center-north of the country has a lower cassava to maize hectares ratio compared to other areas in the high-rainfall zone, corresponding to the proximity of urban demand created by the mining industry there.

[3] In Zambia, districts are represented to display the relative importance of each crop.

Figure 9: Spatial distribution of cassava and maize hectares



Source: Zambia Supplemental Surveys & Mozambique TIA

Mozambique

The distribution of Mozambique's smallholder farming population is unevenly split between AEZs (Table 4). Approximately 60% of all farming households reside in AEZ 3, and 40% reside in AEZ 2 and AEZ 1 combined. The low percentage of farming households living in AEZ 1 is a reflection of the poor agricultural conditions of the area. With the exception of some rice production, AEZ 1 is not highly productive compared to the other regions. The urban areas of the South are natural markets for maize coming out of AEZ 1 but due to the climatic disadvantage, the majority of food comes from other areas. The central regions mostly dominated by AEZ 2 and AEZ 3 contribute much of the maize grain to the urban areas, while the maize for maize meal is imported directly from South Africa.

Table 4: Mozambique maize and cassava production by AEZ

		% of HH Growing		Mean Production (kg/hh)*	
01/02	% of HH in each AEZ	Maize	Cassava	Maize	Cassava
AEZ 1	15%	88%	52%	449	342
AEZ 2	29%	86%	71%	525	724
AEZ 3	57%	76%	76%	385	657

		% of HH Growing		Mean Production (kg/hh)*	
04/05	% of HH in each AEZ	Maize	Cassava	Maize	Cassava
AEZ 1	11%	91%	49%	157	443
AEZ 2	29%	84%	67%	286	1,237
AEZ 3	60%	77%	81%	286	1,718

* Mean production of those who grew each crop

Source: TIA

Compared to Zambia, the percentage of households growing maize is similar between AEZs, and is quite high. Over three-quarters of households in all zones produced maize in both years considered here. However, as in Zambia, the lowest percentage of households producing maize is the wettest zone, AEZ 3. The population distribution of Mozambique is important to keep in mind when considering the percentage of households in each zone that produce maize, because although a high proportion of households in each of the AEZs produce maize, the total quantities produced differ greatly as a consequence of population and rainfall distribution.

Northern Mozambique, which falls almost entirely in AEZ 3, is often the lone surplus maize producer in times of regional stress. During the severe regional drought of 1992, rainfall and production in Northern Mozambique was only mildly affected. Typically this region produces surplus maize which is consumed within the region or exported to the large deficit areas of Malawi[4]. Compared to 2001/2002 harvest season, which was an average rainfall and production year, the 2004/2005 year saw significant decreases in maize production in all three AEZs. However, although households in AEZ 3 produced on average three quarters as much in 2004/05 compared to 2001/2002, the reduction was proportionally much smaller than the other two zones (Table 4).

Overall, the percentage of farming households that produce cassava is higher in Mozambique than in Zambia. The proportion of households producing cassava in high rainfall zone is comparable to the high rainfall zone of Zambia, but in AEZ 1 and AEZ 2 the proportion is much higher. In even the lowest rainfall zone, roughly half of all households produced cassava in Mozambique. It is interesting that in the 2004/2005, when rainfall was below average for all zones, the production of cassava increased in

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[4] Such was the case during the Southern Africa Food Crisis in 2002.

each zone. This is consistent with the manner in which households harvest cassava, digging up roots as needed. If maize harvests are compromised by poor rainfall, one would expect households to rely on cassava as a substitute. The magnitude of the increase was more than double for AEZ 3 and nearly so for AEZ 2.

The production figures in Table 4 illustrate the volatility of maize and the potential for cassava to fill the gap in times of poor maize production. Maize harvests were decimated in 2004/2005 in all three zones, and cassava production spiked in response. The perennial nature of cassava's maturation process makes it an invaluable food security crop. Once the plant is established, it is very resilient to dry spells, and is able to be harvested even when maize performs poorly.

Referring again to the map of cassava and maize area planted above (Figure 9), it is clear that cassava and maize are grown in conjunction in more areas than in Zambia[5]. Where in Zambia the north has very high ratios of cassava to maize hectares, and the south has very high ratios of maize to cassava hectares, the picture in Mozambique is somewhat less extreme. There are larger areas of "maize mixed" and "dual staple" zones in Mozambique owing to the fact that so many households in all regions of the country produce both crops. While the pattern is less extreme, it is still clear that cassava is most important in the North and along the coastal areas, while maize is most important in the central and interior areas.

[5] In Mozambique, the unit of display is the *estrato*, which is a conglomeration of several districts with similar agro-ecological characteristics. This is the smallest unit available for displaying TIA data accurately.

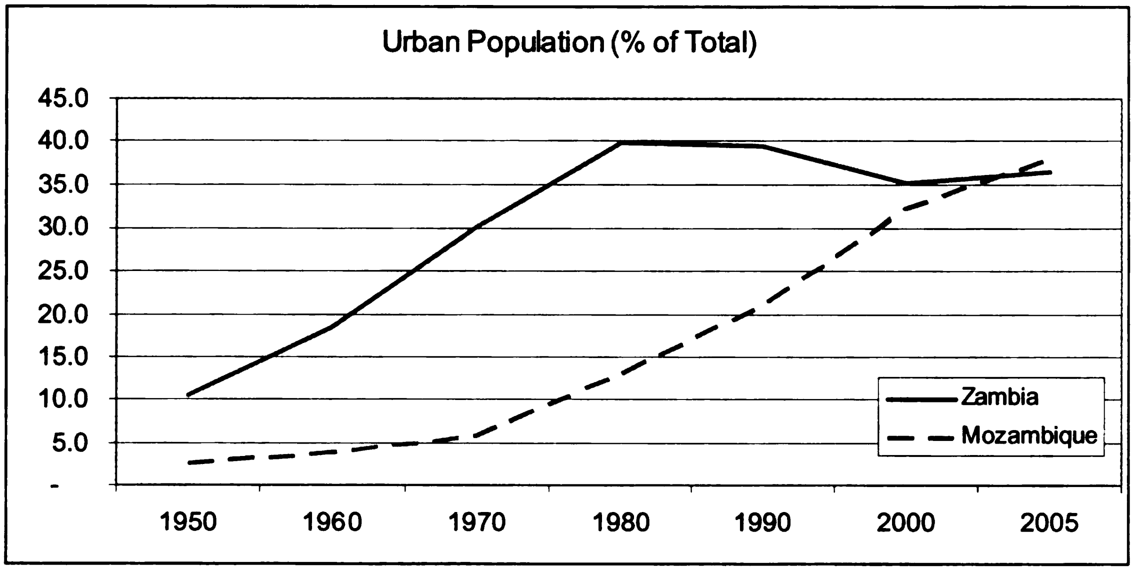
3. MARKET PARTICIPATION

3.1 Importance of and Factors Affecting Market Participation

The population of Zambia and Mozambique has been shifting from farms to the cities for some time (Figure 10). While the proportion of Zambia's population residing in urban areas has been well underway since before Independence, in Mozambique the trend began in the late 1970's. In both countries, an urbanizing population puts pressure on national food systems (Tschirley, 2006). Governments are challenged to help spur the marketing of local food production to keep pace with urban demand. Increasing the number of households who can profitably commercialize their agricultural goods by identifying circumstances in which farmers produce and sell marketable surplus is central to this goal.

Many rural households, particularly the poorest, have few opportunities for off-farm employment. Selling agricultural surplus is often the best avenue for acquiring necessary goods and services. The poorest tercile of households in Zambia gain only about 5% of gross household income from off-farm sources and the second tercile gains less than 25%. This group, which represents nearly three-quarters of the smallholder farming population, gains the remaining income from agriculture (Zulu, 2007).

Figure 10: Zambia and Mozambique, percent of population living in urban areas



Source: http://globalis.gvu.unu.edu/

For households to realize significant gains from trade in agriculture, they must transition from subsistence production to specialization, honing their comparative advantage by producing fewer crops in order to realize welfare gains from trade. As household welfare increases, demand for off farm goods and services increases; as farming households increase demand, it stimulates non-farm sectors of the economy. Whereas subsistence households must provide the majority of inputs and products themselves, with properly functioning markets and increased specialization, products can increasingly be purchased and sold in markets (Boughton, 2007).

While the goal of increased commercialization has been in sight for some time, attempts to reach it have encountered several pitfalls. The first of these became known as the "food price dilemma". Following independence, many African leaders believed that policies designed to "get prices right" were the key to increasing food supply and would eventually lead to national food self-sufficiency and economic growth. In the 1980s it was thought that if food prices were sufficiently high, rural producers would respond by increasing output which would meet the needs of the growing urban population (Jayne, 1999). This attempt to stimulate production through high prices simultaneously put pressure on consumers in the retail market. Moreover, in spite of the higher prices, farmers did not expand supply as expected. It quickly became clear that prices are necessary but not sufficient to stimulate and sustain the desired supply response.

By the end of the 1980's, little improvement had been registered from pricing policies alone. It was recognized that household-specific market failures in food and labor led a large proportion of smallholder farmers to rationally choose self-sufficiency over commercialization. In a general sense, most markets exist, but the costs of entering the market may be higher than the gains from doing so, leading some households to participate in the market, while some do not. (de Janvry, 1991). Transport costs, information costs, and the opportunity cost of time are examples of obstacles to market access that can prohibit market participation. Additionally, markets can be geographically isolated and only partially competitive. Farmers face prices that are volatile from year to year and highly negatively correlated with their own production. Additionally, the large wedge between producer and retail prices leaves only the wealthiest farmers in a position to enter the market on a sustained basis (Fafchamps, 1992). The higher the transactions costs, the riskier the transaction and the more likely households are to refrain from trading.

Recent studies have focused on market participation as a function of available household assets (Boughton, 2007) building on the idea that a household must meet a minimum threshold to be able to participate in the market, otherwise the household falls into a "low equilibrium poverty trap" (Barrett, 2002). Small-scale farmers in rural Africa face a number of non-price related constraints to market participation. Specific determinants such as land access, animal ownership, farm size, access to information, and availability of labor all impact market participation.

Households need access to improved production technologies and to public and private assets to successfully market foodstuffs. Omitting any one of these key elements is sufficient to prevent a household from responding to otherwise favorable market conditions (Barrett, 2007). Productive technologies such as improved seed and husbandry techniques and improvements in public goods such as infrastructure and market information sharing are important factors in market participation.

3.2 Summary of Maize Sales in Zambia and Mozambique

The previous section addressed the importance of marketing for smallholder welfare and economic growth. It was noted that there are several factors that must be accounted for before a household will enter into a crop market. This section summarizes the maize selling trends in Zambia and Mozambique, both nationally, and at the AEZ level to demonstrate the unequal distribution of maize selling both within wealth groups and geographically.

3.2.1 Zambia

In Zambia, the agricultural sector is the main livelihood for more than 60% of the population. Agriculture accounts for approximately 20% of GDP, and employs nearly two-thirds of the labor force (FAO, 2006). Although maize is a very important cash crop for Zambian households, the distribution of maize sales is highly skewed. In Table 5, farming households are divided into mutually exclusive groups based on maize production and marketing behavior: households that do not grow maize, households who grow maize but do not sell and households that sell maize separated by quartiles of quantity sold.

Nearly three quarters of smallholder farmers in Zambia produce maize, but only 35-37% of maize producing households actually sells any maize. It is immediately clear that of the households who sell, a very small percentage is responsible for the lion's share of quantity sold. Seven percent of households for each year of data for Zambia are responsible for about 80% of the total marketed supply of maize. In a recent study focused on the Zambian maize market, Zulu et al (2007) noted that the top 5% of maize selling households enjoyed incomes of 8 to 9.2 times those of the non-maize selling group. The welfare gains from maize market participation, then, accrue to a very small proportion of the smallholder farming sector.

Table 5: Maize marketing in Zambia and Mozambique

(1)	ZAM 1999/00		ZAM 2002/03		MOZ 2001/02		MOZ 2004/05	
(2)	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)
(3) Grew no maize	25%	-	19%	-	20%	-	22%	-
(4) Made no sales	47%	-	52%	-	59%	-	60%	-
Maize Selling Households								
(5) Quartile 1	7%	3.5	7%	6.5	5%	4.1	4%	3.3
(6) Quartile 2	8%	20.0	7%	21.0	5%	10.5	4%	7.8
(7) Quartile 3	6%	39.2	7%	47.6	7%	34.0	6%	31.5
(8) Quartile 4	7%	210.0	7%	295.0	5%	204.0	4%	97.4
(9) Total	100%	272.7	100%	370.1	100%	252.6	100%	140.0

(1) Country and survey year to which the data refers
(2) Column (a) is the percentage of the population who participated in the activities below.
Column (b) Is the total maize sales in ('000 MT).
(3) Percentage of small-scale farming households in each country who did not produce maize.
(4) Percentage of households who did produce some maize, but sold none of their production.
(5) - (8) Quartiles of maize sales. Quartile 1 is smallest, Quartile 4 is highest

The spatial distribution of maize sales in Zambia is also highly concentrated. Disaggregated by agro-ecological zone, the percent of households selling maize and the percent of total sales is clearly highest in AEZ 2a. This zone is fairly well connected in terms of infrastructure. The bulk of the maize sales take place near the major north-south roadway and the eastern-most highway. In these areas, maize production has been highly encouraged since colonial times and farmers have a culture of producing maize for sale.

While AEZ 2a is clearly the most active in terms of total sales volume, it is not the zone with the highest proportion of maize producers who sell. In both years, a higher percentage of households in AEZ 3a (40 – 45%) grew and sold maize than in any other zone. It appears that households near the mining areas and cities of AEZ 3a make maize marketing decisions differently than households in AEZ 3b. This helps support the observation that infrastructure and proximity to markets plays an important role in maize marketing in Zambia.

Table 6: Zambia spatial distribution of maize sales

ZAMBIA					
1999/00	**1**	**2**	**3**	**4**	**5**
AEZ 1	9%	63%	28%	4%	10.1
AEZ 2a	3%	62%	35%	67%	184.0
AEZ 2b	20%	64%	17%	2%	6.6
AEZ 3a	18%	42%	40%	17%	47.3
AEZ 3b	57%	24%	18%	9%	25.3
Total	24%	48%	28%		273.3
2002/03					
AEZ 1	7%	78%	15%	3%	9.8
AEZ 2a	3%	69%	28%	62%	228.0
AEZ 2b	16%	65%	19%	2%	5.8
AEZ 3a	14%	41%	45%	20%	75.4
AEZ 3b	47%	26%	26%	14%	51.3
Total	19%	52%	28%		370.3

Column: 1: Percent of all HH that did not produce maize
2: Percent of all HH that produced maize, but made zero sales
3: Percent of all HH that produced and sold maize
4: Percent of total sales
5: Total Sales ('000 MT)

On the opposite end of the spectrum, households in AEZ 1 and AEZ 2b are among the most likely to produce maize (> 63% and > 64%, respectively), but are responsible for the smallest quantities of marketed. Distance from urban markets is partly responsible for this trend, but it is also true that households in these areas, which are less productive than AEZ 2a, suffer from relatively meager harvests, leaving little surplus for sale. AEZ 1 is characterized by the lowest rainfall, and AEZ 2b is known for sandy soils that are not well suited to maize production.

Figure 11 classifies and maps the Primary Sampling Units (PSUs) in the two countries (Survey Enumeration Areas (SEAs) for Zambia, *Unidade Primaria de Amostragem* UPA for Mozambique) into quartiles of total maize sales. The circle sizes represent the total sales quartile classification of each unit; these are country specific and do not represent absolute magnitudes of sales between countries. The map is intended to highlight the geographic dispersion of maize sales within each country.

In Zambia, the shaded circles represent the top 25% of maize selling SEAs between the 1999/00 and 2003/04 seasons. Likewise, shaded circles in Mozambique represent the top 25% of maize selling households at the UPA level for the 2001/02 and 2004/05 seasons. Because neither survey has accurate spatial locations for households, the next-smallest unit is used[6].

The distribution of the top 25% of maize sales in Zambia is very concentrated along the north-south highway which stretches from the border with Zimbabwe in the South through Lusaka to the Copperbelt on the Congo border. Other obvious clusters are in productive and populous Eastern Province bordering Malawi and Mozambique and near Lake Tanganyika in Northern Province. The patterns in Mozambique are discussed in the following subsection.

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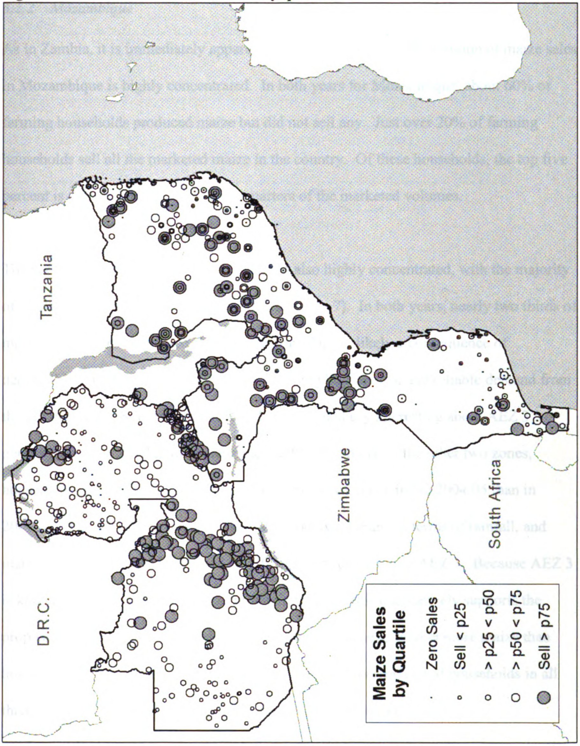
[6] PSU *centroids* are used to locate the data based on latitude and longitude information collected during the survey. In Mozambique, many UPAs were recorded without spatial information. For display, UPAs without spatial reference are located at the district-level *centroid*. For this reason, a number of circles in Figure 11 have a "bull's eye" pattern where data for more than one UPA overlap.

Figure 11: Distribution of maize sales by quartile



Source: Zambia Supplemental Surveys & Mozambique TIA 2002, 2005

3.2.2 Mozambique

As in Zambia, it is immediately apparent from Table 5 that the distribution of maize sales in Mozambique is highly concentrated. In both years for Mozambique, about 60% of farming households produced maize but did not sell any. Just over 20% of farming households sell all the marketed maize in the country. Of these households, the top five percent is responsible for about three quarters of the marketed volumes.

The geographic distribution of maize sales is also highly concentrated, with the majority of marketed volumes taking place in AEZ 3 (Table 7). In both years, nearly two thirds of marketed volumes originated from this region. This is likely a consequence of dependable rainfall, a large population of farming households, and reliable demand from the urban areas of Southern Malawi. What is particularly interesting about AEZ 3's performance compared to the other zones is that in contrast to the other two zones, households in AEZ 3 marketed a higher percentage of maize in the 2004/05 than in 2001/02. The 2004/05 growing season was a below-average in terms of rainfall, and many farming households suffered significant crop loss, even in AEZ 3. Because AEZ 3 is known to be a cassava and maize producing region, this qualitatively supports the proposition that households producing both crops are able to market more maize than households without cassava. However, because a high percentage of households in all three zones produce maize and cassava, further analysis is necessary.

Table 7: Mozambique spatial distribution of sales

MOZAMBIQUE					
2001/02	**1**	**2**	**3**	**4**	**5**
AEZ 1	15%	77%	8%	10%	24.8
AEZ 2	15%	68%	16%	34%	87.3
AEZ 3	24%	49%	27%	56%	141.0
Total	20%	59%	21%	100%	253.1
2004/05					
AEZ 1	15%	80%	5%	3%	3.5
AEZ 2	19%	68%	13%	28%	39.9
AEZ 3	25%	53%	22%	69%	96.6
Total	22%	60%	18%	100%	140.0

Column: 1: Percent of all HH that did not produce maize
2: Percent of all HH that produced maize, but made zero sales
3: Percent of all HH that produced and sold maize
4: Percent of total sales
5: Total Sales ('000 MT)

In addition to selling the largest volumes of maize, households in AEZ 3 are the most likely to grow maize for sale. AEZ 1 is the least likely to sell, with less than 10% of households entering the market in either survey year, followed by AEZ 2 in which approximately 15% of households sold.

3.3 Factors that impede maize sales

3.3.1 Physical factors

Farming households in Zambia and Mozambique face similar constraints to maize marketing. Chief among these constraints is the inability to satisfy food consumption needs. The previous section called attention to the fact that a small number of maize sellers account for the majority of marketed volumes. These households have identified ways to satisfy food requirements either through other income streams which allow them to purchase adequate food, or because they have the ability to produce adequate stocks to satisfy consumption and to be available for sale.

Poor infrastructure and long distances to market raise the cost of selling maize and deter households from marketing their surplus. Even if a household has a surplus, the benefit from selling may be less than the cost of making the sale. Included in these transactions costs attributable to distance are price discovery costs and the opportunity cost of time. Figure 12 illustrates the vastness of the region and the relatively sparse road network that links the major cities with the rural production areas[7].

Finally, uncompetitive markets for maize can prevent households from profitably selling their surplus. If markets are not competitive, traders are able to purchase maize at a low price. This is fundamentally the same as adding a cost to the maize selling household which is equal to or greater than the benefit from seeking out a trader willing to purchase at a higher price.

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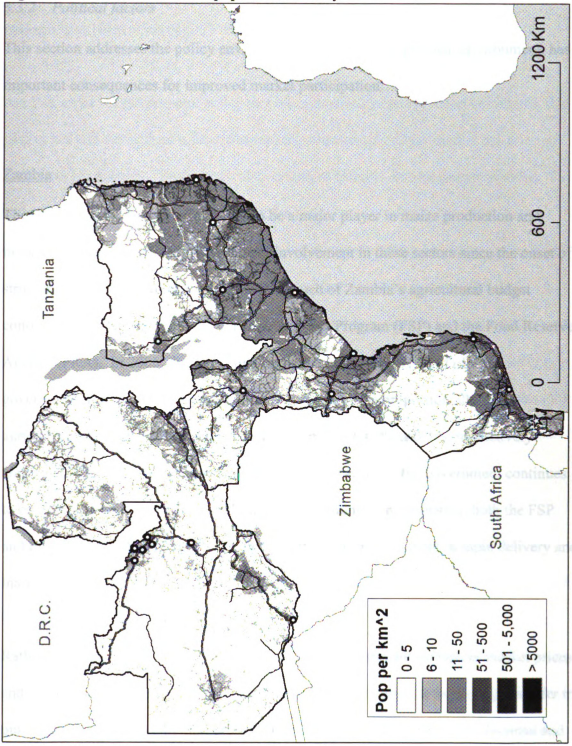
[7] Portions of the road network in Figure 12 are more poorly maintained than they appear.

Figure 12: Road network and population density



Source: CIESN/CIAT, 2005

3.3.2 Political factors

This section addresses the policy environment which, like the physical environment, has important consequences for improved market participation.

Zambia

The Government of Zambia continues to be a major player in maize production and marketing. Despite reducing government involvement in these sectors since the onset of structural adjustment policies in the 1990's, much of Zambia's agricultural budget continues to be funneled into the Fertilizer Support Program (FSP) and the Food Reserve Agency (FRA). In 2005, these two line items accounted for over half of the government's expenditures on agriculture. In contrast, the proportion allotted to agriculture infrastructure and irrigation development was 2% and 3%, respectively (Jayne, 2007). This skewed resource allocation indicates that the government continues to rely on old habits rather than exploring new solutions. Unfortunately, both the FSP and the FRA have the potential to reduce private sector involvement in input delivery and maize marketing.

Rather than supporting private trade in Zambia, the government influences market prices and supply through the operations of the FRA. Often, government buying agents offer to purchase maize at above-market prices. Doing so limits private sector involvement and can eliminate incentive to export. Moreover, FRA agents can be inefficient and are frequently low on cash which can lead to delays between transfers of maize to receipt of payment (Whiteside, 2003). The FRA is a drain on public resources and if inefficiently managed can harm small-scale farmers and private traders alike.

Another aspect of government policy that has potentially negative effects on smallholder farmer welfare stems from a fundamental misunderstanding of the market behavior of rural farm households. Trade restrictions on maize imports are frequently imposed. The restrictions are founded on the belief that the majority of smallholder farmers derive income from maize sales. Therefore the higher prices caused by restricting imports is expected to lead to expanded domestic maize marketing which in tern improves smallholder welfare. These restrictions continue despite recent studies that have revealed that the majority of smallholder farmers, particularly the poorest group, are actually net *buyers* of maize. Net buyers purchase more maize during the marketing season than they sell, if they sell at all. Thus, higher prices may reduce the welfare of most smallholders (Zulu, 2007).

Conversely, Zambia imposes export restrictions on maize grain in an effort to retain maize for deficit areas of the country during years of below-average national production. Eastern province is a highly productive maize area for which Lilongwe, Malawi is a natural market. Export restrictions in the form of fees, licenses, or outright bans limit the ability of farmers in Eastern Province to meet the demand. However, export restrictions are only effective at stemming formal trade flows while the informal channels remain active in the absence of enforcement. Even in the absence of outright export bans, small-scale traders may eschew formal trade channels in an effort to avoid the delays stemming from acquisition of required permits for formal trade that can only be obtained in the provincial capital. It is thought that up to 80% of maize exported to Malawi is done informally as a consequence (Whiteside, 2003).

Mozambique

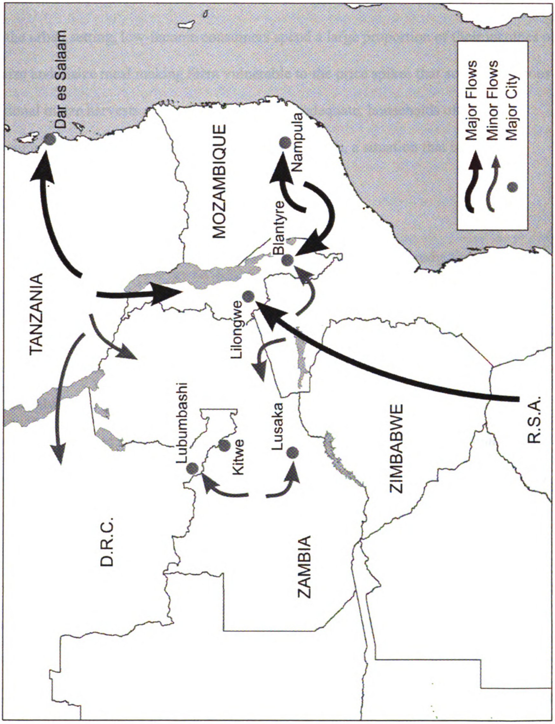
The private sector in Mozambique has been able to respond to the relatively open policy environment and has succeeded in linking surplus and deficit areas. Cross border trade is important both for small holder farmers and urban consumers in Mozambique.

The urban areas of Southern Mozambique are set within rural areas known for marginal maize production. Unable to address the growing urban maize demand from local production alone, the southern cities rely partly on the central region which in most years is capable of supplying surplus production. However, the central region alone can not satisfy the need for maize, and therefore relies heavily on imports of maize grain from South Africa. Although maize is routinely imported, regulations greatly benefit large millers in Maputo/Matola. Large millers are able to import maize grain, paying only a minimal fee provided that the maize is milled once in Mozambique. Import dues for imported maize meal and value-added tax for imported maize grain that is not subsequently milled are significantly higher (Whiteside, 2003).

Maize is a tremendously important cash crop for small-scale farmers in northern Mozambique. The highly populated southern region of Malawi is surrounded by maize producing areas of Mozambique and is the natural market for Mozambican maize surplus. Both formal and informal trade is active in the area. While it remains difficult to calculate accurately, Whiteside (2003) estimated that in 2002, which was a year of high demand in Malawi and normal production in Mozambique, over 300,000 MT of maize crossed into Malawi through formal channels, and almost 225,000 crossed through informal channels.

Figure 13 illustrates some of the regional maize trade patterns in the Southern African region and illustrates the importance of trade for Mozambique in particular. Often, areas of surplus production are separated from their logical market by international boundaries. To the extent that maize can flow across these boundaries unimpeded, both producers and consumers can benefit. Highly productive areas such as Northern Mozambique benefit from unimpeded access to the nearby urban consumption centers in Malawi (Haggblade, 2008).

Figure 13: Trade flows, Southern Africa



Source: Adapted from Haggblade, 2008

3.4 Potential consumption shock absorbers

In the urban setting, low-income consumers spend a large proportion of their incomes on maize and maize meal making them vulnerable to the price spikes that accompany poor national maize harvests. Because incomes are inadequate, households often reduce consumption to unacceptable levels during price spikes, a situation that impacts the health of household members.

In rural areas, farming households rely on a combination of own production and purchases to meet their needs. Because the majority of small-scale farmers are net buyers of maize in both Zambia and Mozambique, the availability of affordable maize grain and maize meal is also important to them. For many households, especially in Zambia, maize is the only staple food produced in adequate quantities to meet the bulk of the household's caloric needs. If production is inadequate, households rely on markets if possible to fill the consumption gap, but if prices are out of reach – and if they have no backup crop to rely on – they have little choice but to reduce consumption.

Long-term national food security requires access and availability of maize for both rural and urban households. Currently, Zambia and Mozambique are plagued with periodic production and price fluctuations which in turn lead to consumption volatility. At its essence, reducing consumption volatility implies maintaining stable retail prices that are within the reach of consumers, and ensuring that rural households are able to meet their own consumption needs either through own production or purchase. Reducing consumption volatility improves food security; there are at least two possible ways to accomplish this goal: open trade and the widespread production of alternate food crops.

As we have seen in the previous section, Zambia and Mozambique have a mixed record when it comes to open trade. Zambia's ad-hoc approach to trade policy – barring imports in an attempt to boost production and barring exports to retain food stocks – is less flexible than Mozambique's. As a consequence, Zambia is unable to react to periodic production deficits and therefore faces chronic food insecurity in certain rural areas and highly variable maize meal prices in urban areas. Mozambique relies on imports to feed the southern cities, but does not always allow free movement of commodities across the border to Malawi, compromising the rural incomes of Northern Mozambicans.

Promoting the production of alternative food staples to maize could potentially act as a consumption smoothing mechanism as well. Planting crops that are substitutes for one another in consumption, but that do not have highly correlated yields, is ideal. Cassava and maize are an example of crop diversification that has the potential to smooth household consumption. Because cassava is a root crop that is resistant to rainfall fluctuations, it can be left in the ground up to four years and harvested when maize crops are severely depleted (Nweke, 2002).

The ability of cassava to produce a reliable harvest during below-average maize production years has a two-fold benefit to households who produce both crops. First, it enables households to maintain a reasonable level of staple food consumption in their own households. If maize is sufficient to meet the need, they can consume maize, but if it is not, they can substitute maize with cassava. In Zambia and Mozambique, the households that grow both staples likely consume some portion of both crops in a normal year, depending on their preferences, and increase the ratio of cassava to maize in years when the maize harvest is poor.

The second potential benefit of growing cassava in addition to maize is the flexibility to respond to high maize prices. One persistent problem for most smallholder farmers is the high inverse correlation between their maize harvests and the farmgate prices for maize. In bad maize harvest years, when maize growing households ordinarily have no surplus to sell, maize prices are attractive. Conversely, when maize production is high, and households have surplus to sell, prices are low. If households produce only maize, they have little flexibility to respond when prices are high and little incentive to respond when prices are low. If, however, the household produces cassava in addition to maize, they can shift their consumption bundles toward cassava and sell maize during times of high maize prices, thereby supplying the market and gaining cash revenue without reducing consumption.

4. DATA & SAMPLING METHODS

4.1 Zambia Supplemental Survey to the Post Harvest Survey

Since 1991, Zambia has conducted a nationally representative Post Harvest Survey administered by Zambia Central Statistical Office (CSO) and the Ministry of Agriculture and Cooperatives (MACO). Additionally, two supplemental surveys to the PHS were conducted for harvests in 2000 and 2003. In both the PHS and the supplemental surveys, all districts of Zambia were sampled[8]. Within each district, a random sample of survey clusters were identified, from which households were randomly selected. Small and medium scale farm households – the focus of this study – were interviewed separately from large scale households. For convenience throughout the paper, small and medium scale households are referred to together as the "smallholder" sector.

The sampling frame for the PHSs conducted between 1991 and 2000 is based on the Census Supervisory Areas (CSA) and Survey Enumeration Areas (SEA) defined using the 1990 census. Changes in population distribution have led to the necessity of recalibration the sample frame following the completion of the 2000 census, and was implemented beginning in 2004. The data collected prior to 2004 is still nationally representative sample of households, but it is less efficient than the latest sampling frame (Megill, 2004).

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[8] 54 districts from 1991 – 1996, and 72 districts thereafter.

The supplemental surveys to the PHS were conducted in coordination with CSO, MACO, and Michigan State University (MSU). In the first supplemental survey, conducted in May 2001, households sampled in the 1999/2000 PHS were re-interviewed and asked additional questions not included in the original PHS in order to enrich the scope of the dataset. The original PHS omitted several important variables (including cassava production information) that were captured by the supplemental survey. The first supplemental survey successfully re-interviewed 6922 households out of 7694 from the 99/2000 PHS, and asked them to recall production and sales information from the 1990/2000 cropping year. The second supplemental survey successfully re-interviewed 5344 of the first supplemental survey's households, asking them to recall information from the 2002/2003 harvest season. Together with the first supplemental survey, this established the first household-level panel dataset for smallholder farmer harvest information in Zambia.

4.2 Mozambique National Agricultural Household Survey (TIA)

Data utilized in the analysis of Mozambique is drawn from the national household agricultural survey known as the *Trabalho do Inquerito Agricola* (TIA). Collected through the Mozambique Ministry of Agriculture, the TIA provides nationally representative panel data on household level production and marketing of food and non-food crops. The 2002 TIA sampled approximately 4900 randomly selected households living in 80 out of 120 rural districts in Mozambique and subsequent years are more comprehensive. The TIA is a recall survey carried out after the peak crop marketing season and focuses on collecting detailed information on crop production and marketing and household incomes. This study utilizes data from two representative years of the TIA: TIA 2002 and TIA 2005.

The limitations of the TIA are similar to those of the Zambia supplemental surveys; the TIA relies on farmers to recall production and marketing information from earlier in the year, reducing to some degree the accuracy of the information. Additionally, because the TIA does not collect information from every district in Mozambique, the ability to extrapolate to the national level is perhaps more difficult. However, the data available in the TIA has several advantages over the Zambia PHS. The survey instrument of the TIA has been largely unchanged since TIA 02, and has includes a full complement of relevant variables. Additionally, the accuracy of the crop information is enhanced by a system of data collection that measures a sample of fields to adjust household recall of hectares planted, and helps farmers accurately determine the share of a field planted to a crop by separating colored beans according to intercropped ratios. The TIA, like the supplemental surveys, is the most accurate panel information available for analysis of this kind.

4.3 Geospatial Data

This study makes extensive use of Geographic Information Systems and spatial data to put the household level production and marketing information in a geographic context. The types and sources of geographic data are diverse and have only been easily accessible to researchers outside of geography departments for the past few years. The ability to interact spatial information with information available in the nationally representative agricultural surveys is a key feature of the empirical analysis in this study.

Geographic datasets can be overlapped with other types of data to create new information. The agricultural production surveys carried out in Zambia and Mozambique all contain geographic information that is largely underutilized in ordinary analysis. In both Zambia and Mozambique, information on the location of households from the production surveys can be approximated to sub-district level. Matching the information contained in the surveys with the geographic data created by other means enables us to add geographic data relevant to household records that were not originally collected in the surveys.

Two key pieces of geographic information are utilized in this study: a) Euclidian distance from Primary Survey Unit to primary road and b) seasonally accumulated and long-term average rainfall. For distance to primary roads, data is created using GIS software to compute the straight-line distance to primary roads from the approximate locations of households. This distance is converted to kilometers and the variable is then appended to the dataset for each year and incorporated into the statistical analysis.

For seasonal rainfall, monthly precipitation grids from NASA's Tropical Rainfall Measuring Mission (TRMM)[9] are summed from November to May, the approximate maize growing season in Southern Africa. By overlaying the resulting seasonal rainfall surface atop the spatially located Primary Survey Units in Zambia and Mozambique, a

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[9] TRMM data used in this study were acquired using the GES-DISC Interactive Online Visualization and Analysis Infrastructure (Giovanni) as part of the NASA's Goddard Earth Sciences (GES) Data and Information Services Center (DISC).

continuous variable for rainfall is created. Using the same TRMM data, the standard deviation of rainfall is calculated.

Similarly, using a combination of geospatial datasets, comparable agro-ecological zones are delineated as described in chapter 2 for both Zambia and Mozambique based on a high-resolution, interpolated, 30-year average rainfall model from WorldClim (see Hijmans, 2005 for description of WorldClim database).

5: ANALYTICAL APPROACH AND HYPOTHESIS

The unit of interest to this study is the small-scale farming household that relies primarily on own maize production to meet household staple food needs and to obtain non-farm goods and services via cash from sales. This section describes the household environment and sequential nature of household decision making that leads to the hypothesis and econometric models of subsequent sections.

5.1: Household decision making

At the onset of the rainy season, the household determines how much maize and other crops to sow given available labor, land, and productive assets, but is unable to know exactly what the maize yield will be at harvest time. Throughout the six month maize growing season, the household attempts to maximize its chances of harvesting an adequate crop given factors such as illness, labor availability, and farming skill, but unpredictable rainfall generates widely variable harvests from year to year. Only once the crop is harvested can the household make consumption decisions and begin to consider marketing available surplus.

Maize marketing is a two-step decision in which households first decide whether to enter the market, and then decide how much of their crop to sell. A number of factors influence these decisions such as available surplus, price, transportation costs, information costs and negotiation ability. If a household produces only maize, the available surplus equals the total harvest minus household consumption. For many, this will be a very small quantity and due to varying market access, lack of necessary assets or high transactions costs, some households may rationally choose to abstain from market participation altogether, remaining in autarky (Boughton, 2007). If, however, the household produces cassava as a substitute for maize in consumption, the quantity of maize available for sale can potentially equal the quantity of cassava consumed. In an extreme scenario a household with both crops could consume cassava as the sole staple, reserving the entire maize harvest of for sale.

The nature of cassava, which continues to increase in volume in the ground and can be harvested anytime between two and four years after planting, makes it a reliable storehouse of calories for the household, and can act as insurance for times in which the maize harvest fails. Collinson (1983, p. 26) describes the household's strategic use of cassava as a substitute for other crops using an example from Tanzania:

> "Particular crops are often grown especially for insurance. Cassava is a case in point with the Sukuma [Tribe]. It is not a preferred starch staple, but its high productivity in terms of bulk and its capacity for storage in situ in the ground for up to three years make it an ideal famine reserve crop. The aim of the farmer will be to have cassava available and mature in future periods of expected food crisis. Cassava requires little work after being weeded at the beginning of its second season. In Sukumaland the labor required for planting is minimized by intercropping and by planting the cassava at a time when there are few other demands on labor. This late planting means the sacrifice of optimal yields, but it still gives five to ten times the bulk of grain crops per unit of labor used. When cassava supplies are low after a famine season, reestablishment may take first priority when the rains arrive. The amount of mature cassava likely to be available will influence decisions on the urgency of staple grain supply and contingency plantings of late grains in a poor season. It will thus be important in the allocation of resources to other crops."

Because an investment in cassava gives households the ability to smooth staple consumption, it can also provide them more flexibility with regard to maize sales than households who produce maize only. This is the foundation on which the hypothesis below is built.

5.2: Hypothesis

Given the relationship between maize and cassava, and based on the previous chapters' discussion of their importance to smallholder farmers, the hypothesis of interest concerns the relationship between cassava production and maize sales. Explicitly, the hypothesis to test is that maize sales are positively related to cassava area planted.

5.3: Key variables for hypothesis testing

Equation 5.1 describes the household's maize marketing decision. Kilograms of maize sold, Sm_i, defined by the quantity of maize harvested, Qm_i, minus household consumption, Cm_i, is hypothesized to be a function of household maize harvest, Qm_i, maize price Pm_i, cassava area Kc_i, geographic variables g_i, demographic variables d_i, wealth and income variables, y_i, and productive assets, a_i.

$$(5.1) \quad Sm_i = Qm_i - Cm_i = f(Qm_i, Pm_i, Kc_i, g_i, d_i, y_i, a_i)$$

Standard factors influencing maize sales include kilograms of maize harvested, (Qm_i) and price of maize (Pm_i). Including these variables in the econometric modeling is important to evaluate the impact of cassava hectares (Kc_i) in a *ceteris paribus* context. Questions of endogeneity stemming from the inclusion of maize production as an explanatory variable are resolved by the above discussion of the sequential nature of the production and sales decisions. Because production and sales decisions do not take place simultaneously, there is no endogeneity bias.

The geographic variables that make up (g_i) in Equation 5.1 include Euclidian distance to primary road, and seasonal mean and standard deviation of rainfall. These variables are included to hold constant aspects related to marketing that have a strong regional connection and are likely to influence the cost to marketing goods. Demographic variables (d_i) include the age and gender of the household head and the number of members in the household. The latter variable is an indication of available household labor and consumption levels. The former two variables are expected to influence household transactions costs and flexibility to respond to market signals. Income variables (y_i) include salaries, ownership of businesses and remittances[10]. These variables are thought to change a household's incentives to participate in maize markets by giving them other income earning alternatives. Finally, productive assets (a_i) include total land available to the household, cattle ownership, and transport and radio ownership. These variables influence a household's ability to substitute income, increase maize production, or reduce search and other transactions costs.

[10] These variables are only available for the analysis in Mozambique.

6. EMPIRICAL ANALYSIS

6.1 Estimation Methods for Limited Dependent Variable Models

Limited Dependent Variable models are utilized when the dependent variable is substantially restricted and does not follow an approximately normal distribution. Because LDVs violate the normality assumption, they lead to biased and inconsistent estimations in OLS. Smallholder maize market participation is an example of a specific LDV called a corner solution problem. Distributions of this type are continuous over some range of observations, but "pile up" at zero (Wooldridge, 2002). Optimizing behavior for maize sales leads to a roughly continuous distribution over the subset of households who sell, but for the larger portion of households who do not sell, zero kilograms sold are observed.

Corner solutions have traditionally been dealt with using the Tobit model, but there are other, less restrictive limited dependent variable models suitable for this type of analysis. This section briefly discusses the Tobit model in the context of household maize marketing and introduces two alternative limited dependent variable models: the Heckman selection model and Cragg's Tobit alternative model.

The Tobit model (Tobin 1956) is familiar to economists seeking to model behavior in which the dependent variable takes on an approximately continuous distribution after being censored at some (usually zero) point. There are a number of examples of so-called "corner solution" problems in which a non-trivial proportion of the population chooses a zero quantity or dollar value of something. Alcohol consumption and annual family charitable contributions are two familiar examples in which there is likely to be a large proportion of the population who do not participate in the activity, and the remaining portion of the population participates over a wide range of values (Wooldridge, 2006).

The Tobit model can be expressed by the following latent variable model:

(6.1) $y^* = \mathbf{x}\boldsymbol{\beta} + u, \quad u|x \sim \text{Normal}\ (0,\sigma^2)$

(6.2) $y = \max\ (0,y^*)$

where y equals the latent variable y^* when $y^* \geq 0$ and $y = 0$ when $y^* < 0$. Because y^* is a latent variable that follows a roughly continuous distribution, y must have a continuous distribution over strictly positive values.

For the purposes of this paper, the unconditional expectation $E(y|x)$ is of particular interest. For the Tobit model, this can be expressed by the following:

(6.3) $E(y|x) = \Phi(\mathbf{x}\boldsymbol{\beta}/\sigma)\mathbf{x}\boldsymbol{\beta} + \sigma\varphi(\mathbf{x}\boldsymbol{\beta}/\sigma)$

The first term refers to the probability that $y > 0|x$, and the second refers to $E(y|y > 0, x)$. The second term incorporates the inverse Mills ratio which indicates that the expected value of $y > 0$ is conditional on $\mathbf{x}\boldsymbol{\beta}$ plus a positive term. The equation indicates that when y follows a Tobit model, $E(y|x)$ is a nonlinear function of $\mathbf{x}$ and $\boldsymbol{\beta}$. The following expression illustrates the method for computing partial effects of a change in x_j:

(6.4) $dE(y|\mathbf{x}) / dx_j = \boldsymbol{\beta}_j \, \Phi(\mathbf{x}\, \boldsymbol{\beta}/ \sigma)$

where the coefficient, $\boldsymbol{\Phi}$, is the cumulative probability of $\mathbf{x}\, \boldsymbol{\beta}/ \sigma$.

The Tobit model estimates the probability of an observation being positive at the same time as it estimates the magnitude of the response. The model assumes that the effect of the explanatory variables responsible for the actor's participation decision ($y = 0$ versus $y > 0$) must also be responsible for the quantity decision (the magnitude of y when it is positive), and that they affect both decisions the same way, resulting in a single set of coefficients. In some cases, however, requiring each stage to be estimated simultaneously may not accurately reflect the decision making process.

In the discussion of household market participation, the debate over the simultaneous nature of the decision making process has been challenged by some researchers. Bellamere and Barrett (2006) described the situation this way:

> "If households make participation and volume decisions simultaneously, they effectively pre-commit to a volume before learning information available to them only once they arrive at market. This *ex ante* decision making effectively gives the traders with whom the household interacts market power by rendering the household's demand (supply) inelastic with respect to new market information (e.g.,

> prices) they discover, leaving poor pre-committed households vulnerable to exploitation by astute traders. If, however, households make marketing decisions sequentially, then they retain greater flexibility once they arrive in a market, making their purchases or sales volume decisions ex post based on new information discovered at market, thereby reducing traders' capacity to extract much or all the gains from trade. (pp 324)"

One model that explicitly separates the participation decision and the quantity or amount decision is the Heckman selection model. Heckman (1979) proposed an estimation technique that addresses the problem of zero observations generated by non-participation due to respondent's self-selection. The model uses a two-step procedure in which a full sample Probit estimation is followed by a censored OLS estimation applied to the non-zero subsample. The Heckman estimation technique is a generalized version of the Tobit model that accounts for the possibility of omitted variables that influence both decisions (Wooldridge, 2006; Wodajo, 2008).

The classic example of a self-selection problem for which the Heckman technique is used concerns the wage offer for married women. In this example, there are two equations that must be evaluated: (i) the probability that a married woman will enter the workforce, and, (ii) the observed wage conditional upon entering the workforce. The selection problem arises because the wage offer is observable only for working women. In this situation, the analyst must correct for sample selection bias by evaluating the first part of the question separately from the second. The Heckman model allows for the possibility that the two decisions do not depend on the same set of factors and separately identifies the affect of each factor on each decision. In the wage offer example, the likelihood of entering the workforce may be based on income from the husband and the presence of young children in the home, whereas the wage offer equation may be related to the woman's education level and experience. It is clear that some variables have an impact on the participation equation but are not appropriate for the wage offer equation (Heckman, 1979, Wooldridge, 2006).

In Heckman's two-step estimation method, the first step refers to the participation (selection) equation and the second to the amount or quantity equation. The equation of interest is the quantity decision:

(6.5) $y = \mathbf{x}\boldsymbol{\beta} + u, \quad E(u|\mathbf{x}) = 0$

and the selection decision is:

(6.6) $s = 1[\mathbf{z}\gamma + v \geq 0]$

where $s = 1$ if y is observed, and zero otherwise. The elements of **x** and **z** are always observed, by assumption; $\boldsymbol{\beta}$ is the coefficient on **x**, and γ is the coefficient on **z**. It is assumed that the selection equation depends on observed values, **z** and unobserved error v, and that **z** is exogenous to the continuous equation. The major assumption that justifies the Heckman selection model is that the error terms of the two models, u_i and v_i, are correlated, and therefore must be taken into account.

Estimating the Heckman model in two steps involves a Probit for all n observations and a censored regression on the positive observations that includes the inverse Mills ratio for each observation as an additional independent variable. To account for the correlation caused by the sample selection bias, the inverse Mills ratio is included as an additional regressor in the second stage of the estimation.

The Probit model for the selection decision takes the following form:

(6.7) $P(s = 1|z) = (\dot{\Phi}\mathbf{z}\gamma)$

and

(6.8) $E(y|z,s = 1) = \mathbf{x\beta} + \rho\lambda(\mathbf{z}\gamma)$

The equation above shows that the expected value of y given $\mathbf{z}$, and the observation of y (that the selection decision is positive) is equal to $\mathbf{x\beta}$ plus ρ which is determined from the inverse Mills ratio in the second equation. If $\rho = 0$, then OLS on the selected sample consistently estimates $\boldsymbol{\beta}$. But if $\rho \neq 0$, it would be akin to running OLS on a model with a missing variable, leading to bias (Wooldridge, 2006).

The third estimation technique considered here is the Cragg truncated normal hurdle model. It is also an extension of the Tobit model in which the requirement for simultaneous selection and quantity decisions are relaxed (Cragg 1971). The technique combines the likelihood function of Probit (for the selection decision) and truncated normal regression (for the continuous decision), but, unlike Heckman's model, assumes no correlation between the errors of the first and second equation, conditional on a properly specified model (Wooldridge, 2006).

Cragg Truncated Normal Hurdle Model:

(6.9) $$w^*_i = \mathbf{x\beta} + u$$

$$y_i = w^*_i \qquad \text{if } s_i = 1 \textit{ and } w^*_i > 0$$

or $$y_i = 0 \qquad \text{else}$$

This indicates that the observed quantity y_i is non-zero when participation is recorded and a positive quantity of y is observed. Cragg's model is estimated through a combination of a Probit function for the participation decision and truncated regression estimated with maximum likelihood for quantity decision. One way to express this is:

Expression for the participation decision follows a Probit:

(6.10) $$P(s = 1|x) = \Phi(\mathbf{x\gamma})$$

Continuous decision given y > 0 and x follows a truncated regression:

(6.11) $$f(y|x, y > 0) = [\Phi(\mathbf{x\beta}/\sigma)]^{-1}\varphi[(y - \mathbf{x\beta})/\sigma]/\sigma,\ y > 0$$

which leads to the density for y|x:

(6.12) $$f(y|x) = [1 - \Phi(\mathbf{x\gamma})]^{-1[y=0]}\{\Phi(\mathbf{x\gamma})[\Phi(\mathbf{x\beta}/\sigma)^{-1}\varphi[y - \mathbf{x\beta}/\sigma]/\sigma\}^{1[y>0]}$$

Unlike the Tobit model the Cragg model allows for the two parts of the estimation to be estimated independently, and while the first hurdle of Cragg's model is identical to that of the Heckman model, the second stage is estimated with maximum likelihood rather than OLS. An advantage to the Cragg model is that it is relatively straightforward to calculate average partial effects of (y|x).

In summary, the Tobit model is well established, and partial effects are calculable, but the model is limited by the restrictiveness of the assumption that the participation and quantity decisions are based on the same mechanisms. The Heckman model is less restrictive, and has the added benefit of taking into account unobserved variables that affect both parts of the model, but interpretation of results is not straightforward, and computing partial effects for comparison with the Tobit model is beyond the scope of this paper. Finally, while the Cragg double hurdle model can be estimated jointly and partial effects can be calculated, the assumption of strict independence between the participation and quantity decisions is still open to debate.

6.2 Methods

6.2.1 Variables

The aim of the econometric techniques utilized in this thesis is to estimate the impact of cassava hectares on kilograms of maize sold. To reach this goal, two of the models require the specific identification of the participation variable. The Heckman model and the Cragg double hurdle model both estimate a Probit model in the first stage; for the question at hand the binary dependent variable = 1 if the household sells maize and = 0 otherwise. For the Tobit model, this variable is not explicitly utilized, but is implicit in the technique. The dependent variable of the Tobit, and of the second stages of the Heckman and Cragg model is kilograms of maize sold.

The cassava hectares variable is the independent variable of particular of interest to this study. In order to evaluate it *ceteris paribus*, a number of other independent variables are included that fall into the following broad groups: demographic variables, wealth and income variables, and asset variables. Tables 8 and 9 provide a description of each variable, indicate the type of variable it is (continuous or binary), and display their population weighted means. Due to the differences in survey design between Zambia and Mozambique, not all variables are identical for the two countries. However, the available variables that are most likely to have an affect on maize sales are included.

Table 8: Zambia explanatory variables and means

ZAMBIA			1999/00		2002/03	
Variable	Description	Binary	mean	sd	mean	sd
hectc	Hectares of cassava	No	0.16	0.314641	0.32	0.52537
kg_harvm	Kilograms of maize harvested	No	1,090.30	1917.405	1020.45	1844.786
kg_har~2	Kilograms of maize harvested (squared)	No	4,864,654.00	2.98E+07	4443911.00	3.23E+07
pricem	Median district maize price	No	254.02	68.48158	517.69	103.9516
km_road	Euclidian distance to main road (kilometers)	No	81.63	90.72472	81.31	90.54029
trmm	Accumulated seasonal rainfall	No	800.40	98.00268	894.25	243.3907
std	Standard deviation of seasonal rainfall	No	81.39	13.55918	79.01	18.88724
mem	Number of household members	No	6.06	3.107201	5.51	2.602877
hedgen	Male is head of household	Yes	0.79	0.404777	0.79	0.406118
age	Age of household head	No	43.97	15.18706	48.65	15.49707
tothect	Total hectares of land available to household	No	1.44	1.325603	1.22	1.329122
radio	Household owns a radio	Yes	0.34	0.47407	0.47	0.499155
bike	Household owns a bicycle	Yes	0.42	0.493425	0.48	0.499795
mbike	Household owns a motorcycle	Yes	0.00	0.067257	0.01	0.098927
car	Household owns an automobile	Yes	0.00	0.061735	0.01	0.077516
lvstck	Houshold raises cattle	Yes	0.30	0.460363	0.63	0.481994

Source: Calculated from the data

Table 9: Mozambique explanatory variables and means

MOZAMBIQUE			2001/02		2004/05	
Variable	Description	Binary	mean	sd	mean	sd
hectc	Hectares of cassava	No	0.21	0.3358442	0.27	0.4032218
kg_harvm	Kilograms of maize harvested	No	520.85	1144.211	382.75	1030.449
kg_har~2	Kilograms of maize harvested (squared)	No	1580238.00	1.22E+07	1208150.00	1.08E+07
pricem	Median district maize price	No	2.45	0.5959466	3.39	2.413693
km_road	Euclidian distance to main road (kilometers)	No	65.69	63.91475	66.14	67.94479
trmm	Accumulated seasonal rainfall	No	809.51	237.8919	750.18	240.0402
std	Standard deviation of seasonal rainfall	No	92.23	19.13484	58.98	25.80604
mem	Number of household members	No	5.63	3.421662	6.77	4.078399
hedgen	Household head is male	Yes	0.76	0.425661	0.78	0.4120277
age	Age of household head	No	43.92	15.19227	46.22	15.02391
tothect	Total hectares of land available to household	No	1.77	2.104756	2.09	2.284342
ownbiz1	Sale of animal/vegitable products (meticais)	Yes	567.09	3920.976	31.61	308.1122
ownbiz2	Other sales, ex: retail (meticais)	No	1562.50	11304.04	97.08	1270.683
salary	Other salary (meticais)	No	606.86	4063.639	896.52	5221.1
remit	Remittances (meticais)	No	117.70	726.4972	646.41	3430.664
bike	Household owns a bicycle	Yes	0.28	0.4466065	0.33	0.469427
mbike	Household owns a motorcycle	Yes	0.01	0.1026649	0.01	0.0975934
truck	Husehold owns a truck	Yes	0.03	0.1573511	0.03	0.1741166
lvstck	Household raises cattle	Yes	0.01	0.0823622 -	-	

Source: Calculated from the data

6.2.2 *Estimation techniques*

Using the explanatory variables above, Tobit, Heckman, and Cragg double hurdle models are estimated using each country's household survey data. For Zambia, the first and second supplemental surveys are used (data from 1999/00 and 2002/03, respectively), and in Mozambique the 2002 TIA and the 2005 TIA are used.

Each econometric technique adds insight to the question of maize market participation, but each has its own limitations. It is beyond the scope of this paper to identify the best econometric technique to fit the question at hand. Therefore, the paper utilizes the available qualities of all three econometric models to triangulate qualitative and quantitative effects. No attempt to pinpoint exact magnitudes of explanatory variables is made, but partial effects are calculated where possible to indicate approximate magnitudes

None of the coefficients from these three models can be interpreted as partial effects. Direct comparison of results thus requires post-estimation computation of the unconditional partial effects. Guidance for calculating UAPEs follows Wooldridge (2002, p. 543) for the Tobit model and Burke (forthcoming, 2009) for the Cragg double hurdle model. For the Cragg model, standard errors are calculated and bootstrapped to calculate significance for the unconditional average partial effects. For the Heckman model, programming the statistical software to compute average partial effects is possible, but beyond the scope of this paper. Therefore, the results from the Heckman model can only be relied upon to help indicate direction and significance of results, and to compare with the output from the other two models.

In the results tables that follow, it is clear that the first stage of both the Heckman and Cragg models return identical results. This is because the first stage of both techniques utilizes a Probit model on all observations using all variables. Marginal effects of the Probit model are utilized for interpretation of the results in the next chapter, and are listed in the tables. The marginal effects from the Probit model are the best estimation of the probability that a household enters the maize market given a change in the variable of interest.

7. RESULTS

Key variables expected to influence maize marketing include cassava hectares (hectc) the kilograms of maize harvested (kg_harvm), price of maize (pricem), kilometers to primary roads (km_road), and seasonal rainfall (trmm) (Table 10). Additional variables are included to allow the discussion of the primary variable in a *ceteris paribus* context. The following discussion is a detailed description of the results for the cassava hectares and other key variables, and the following subsection briefly discusses results from some of the additional variables.

Because several econometric techniques are used on several data sets, this section is separated by country and by year for convenience of discussion. The data for Zambia represent two approximately normal rainfall years, in which no wide-spread maize crop loss or unusual maize price spikes occurred. However, in Mozambique, the data represent one good rainfall year (2001/02) and one poor rainfall year (2004/05). These differences in rainfall between years provide further insight to the results presented below.

To facilitate the discussion of the main results, the tables included in this section only contain the variables of primary interest to the study. The complete tables containing the output from all explanatory variables can be found in Appendix 1.

7.1 Detailed Discussion of Primary Variables

7.1.1 Zambia: 1999/00 (good rainfall year)

Results from the Zambia 1999/00 survey year for the hectares of cassava variable (hectc) show a generally positive relationship to kilograms of maize sold. Positive and statistically significant results are obtained from the Tobit model, the first stages of the Heckman and Cragg models, the marginal effects from the Probit model and the unconditional average partial effects (UAPEs) for the Cragg model. In each of the two-step models, an additional hectare of cassava is positively related to entering the maize market with marginal effects of approximately 8%. UAPEs from the Cragg and Tobit models indicate that a household who cultivates another hectare of cassava will sell from between 60 and 222 kilograms more maize, respectively. Contrary to expectation, the second stage of the Heckman is negative and significant and the second stage of the Cragg is positive and insignificant.

Maize price (pricem) and maize kilograms harvested (kg_harvm) are both significant and positively related to maize sales in most of the model results. As with the hectares of cassava variable, and contrary to expectation, the kilograms of maize harvested is insignificant in the second stage of the Heckman model. UAPEs for both variables are reasonably small, indicating that a small change in price or harvest will have a small change in maize sales: an extra kilogram harvested yields between .17 and .5 kilograms sold.

The results overwhelmingly confirm that distance to primary road is negatively related to maize marketing. In all cases, the coefficient on the distance variable (km_road) is negative; and with the exception of the second stage Heckman, the results are statistically significant as well. Magnitudes from the UAPEs of Cragg and Tobit indicate that for each additional kilometer, a household can expect to sell between .6 and .8 of a kilogram less maize.

The Tobit model and the first stages of the Heckman and Cragg model indicate a positive and significant relationship between accumulated rainfall (trmm) and increased maize sales. However, the second stages of both the Heckman and the Cragg models show a negative result, and the UAPE for the Cragg model, while positive, is not statistically significant. This variable is an attempt to quantify the observed differences in crop mixture and sales behavior outlined in earlier sections. It seems that while living in higher rainfall areas boosted the probability of maize market participation, it does not necessarily increase the quantity of maize marketed.

7.1.2 Zambia 2002/03 (good rainfall year)

Results from 2002/03 are identical to 1999/00 for hectares of cassava and kilograms of maize harvested (Table 10). Marginal effects of an additional hectare of cassava increase the probability of market participation by nearly 10%, and UAPEs indicate an increase in maize sold of between 51 and 178 kilograms. As in 1999/00, the marginal change in maize sales following a one kilogram increase in maize production ranges from 0.15 to 0.48 kilograms.

Table 10: Zambia key results

ZAMBIA	1	2	3	4	5	6	7	8
1999/00	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
hectc	429.1***	221.960	0.256***	-0.232**	0.256***	490.8	0.08156***	60.560***
	(84.88)		(0.0549)	(0.116)	(0.0549)	(502.2)	(0.01745)	(28.7721)
kg_harvm	0.718***	0.463	0.000434***	-0.0000813	0.000434***	2.358***	0.00013***	0.16641***
	(0.0247)		(0.0000178)	(0.0000845)	(0.0000178)	(0.144)	(0.00001)	(0.00886)
pricem	2.380***	1.514	0.000582*	0.00123*	0.000582*	24.41***	0.00018*	1.1131***
	(0.524)		(0.000320)	(0.000700)	(0.000320)	(3.673)	(0.0001)	(0.18408)
km_road	-1.275***	-0.607	-0.000636***	-0.000675	-0.000636***	-17.31***	-0.00020***	-0.82393***
	(0.401)		(0.000239)	(0.000524)	(0.000239)	(3.926)	(0.00008)	(0.20363)
trmm	1.240***	0.888	0.00109***	-0.00150***	0.00109***	-2.035	0.00034***	0.08534
	(0.427)		(0.000266)	(0.000574)	(0.000266)	(2.239)	(0.00008)	(0.13665)
2002/03								
hectc	336.4***	178.211	0.291***	-0.345***	0.291***	234.5	0.09579***	51.507***
	(54.79)		(0.0407)	(0.110)	(0.0407)	(367.3)	(0.01341)	(19.7094)
kg_harvm	0.738***	0.483	0.000475***	0.0000258	0.000475***	1.944***	0.00015***	.150634***
	(0.0232)		(0.0000228)	(0.0000830)	(0.0000228)	(0.110)	(0.00001)	(.007488)
pricem	0.882***	0.547	0.000778***	-0.000957*	0.000778***	-5.476**	0.00025***	-.1224207
	(0.302)		(0.000213)	(0.000539)	(0.000213)	(2.291)	(0.00007)	(.136812)
km_road	-2.226***	-1.008	-0.00178***	0.00212**	-0.00178***	-13.25***	-0.00058***	-.818804***
	(0.438)		(0.000313)	(0.000854)	(0.000313)	(3.556)	(0.0001)	(0.18917)
trmm	3.007***	2.848	0.00218***	-0.00214***	0.00218***	7.760***	0.00071***	.64176***
	(0.276)		(0.000201)	(0.000657)	(0.000201)	(1.761)	(0.00007)	(0.104358)

Standard errors in parentheses

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

1 Results from Tobit model

2 Unconditional Average Partial Effects after Tobit

3 First (selection) step in Heckman two step model

4 Second (quantity) step in Heckman two step model

5 First (participation) step in Cragg's Tobit alternative model

6 Second (quantity) step in Cragg's Tobit alternative model

7 Marginal effects from probit (from first step in Cragg's Tobit alternative)

8 Unconditional Average Partial Effects after Cragg's Tobit alternative with bootstrapped standard errors.

Variables: hectc = hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

The maize price variable for 2002/03 shows a mixed picture. It is positive and significant as expected for the Tobit model and the first stages of the two-step models, but negative and significant in the second stages. UAPEs give a mixed picture of the impact of maize price, with the Cragg UAPE showing no increase in maize sales given a price increase, and the UAPEs from Tobit showing a half-kilogram increase.

As expected, the kilometers to road variable is negative and significantly related to maize sales in 2002/03, with the exception of the second stage Heckman output which is positive and significant. UAPEs from Cragg and Tobit indicate that an extra kilometer of distance between farmer and main road reduces maize sales by nearly 1 kilogram.

Accumulated rainfall is positively related to maize sales in 2002/03 in all cases apart from the second stage of the Heckman, and UAPEs indicate between .8 and 3 kilograms increase for a marginal increase in rainfall.

7.1.3 Summary

In both years, the data overwhelmingly indicate that hectares of cassava are positively related to maize sales. This result is consistent in each case apart from the second stage of the Heckman model. Because the two-step models include the market participation and quantity decisions, it would be beneficial in future work to calculate UAPEs for the Heckman model for comparison with the Tobit and Cragg. With the information here, it is unclear whether UAPEs from the Heckman model would be positive or negative, influenced more by the market participation or quantity decision, but given the strongly positive results from the other models, it seems likely that the UAPE would be positive.

As expected, kilograms of maize harvested and maize price are positively related to maize sales in most of the model outputs. Although discrepancies in this result exist, particularly for maize price, this can be explained by the design of the price variable. The price variable reflects the district median price for each year which does not perfectly reflect producer prices or the price variability at the household level.

Kilometers to main road for both years are a negative influence on maize prices. This is a logical result, reflecting the increasing costs of market discovery and other transactions costs associated with remoteness, and strongly advocates for continued use of GIS as a tool to create accurate spatial data.

Finally, the accumulated rainfall variable indicates that marginal changes in rainfall do, *ceteris paribus*, have a positive relationship with maize sales. It is likely that accumulated rainfall is not the driving force behind this relationship, but rather it is reflecting the effects of unobservable variables highly correlated with rainfall.

7.1.4 Mozambique 2001/02 (good rainfall year)

Compared with Zambia, the results for Mozambique paint a mixed picture of the effect of cassava hectares on maize sales (Table 11). In 2001/02, results indicate that cassava hectares played little to no role in maize sales, while in 2004/05 the results are mixed. Among the other key variables, price of maize, kilometers to main road and accumulated rainfall also return unexpected results in some cases. The substantial rainfall difference between the two years is likely to have influenced the results and is potentially important to understanding the relationship between maize sales and the key explanatory variables.

Results for hectares of cassava in 2001/02 are not statistically different from zero except in the second stage of the Cragg model. While this result differs from expectation, and from the results obtained for similar years in Zambia, it may be a reflection of substantially different, unanticipated and unmeasured circumstances in Mozambique compared with Zambia.

Maize production and maize price are both positively related to maize sales for this dataset, although maize price is not statistically significant in the Cragg UAPE. An extra kilogram of maize harvested is predicted to yield between .07 and .27 kilograms of additional maize sold. Holding all things constant, it is clearly logical that larger harvests of maize will return higher average sales. That price is not strongly related to sales may again be a reflection of the little variation in the price variable. As in Zambia errors in farm-gate price measurement led to the use of district median prices for this study.

Unexpectedly, the distance to road variable is positive and significantly related to maize sales in most of the results for this year. The Tobit model and the first stages of the two-step models indicate this positive relationship, but encouragingly the second stages and the UAPE for the Cragg indicate negative, albeit not highly significant, results.

Like the distance to road variable, accumulated rainfall is positive and significant for Tobit and the first stages of the two-step models, but negative or insignificantly positively related in the other results. Because of the nature of this variable, being a proxy for unobservable variables related to rainfall, interpretation of this mixed result is difficult.

7.1.5 Mozambique 2004/05 (below average rainfall year)

Compared to the previous year for Mozambique, the 2004/05 year more closely resembles the results from the two years from Zambia (Table 11). The Tobit model and the first stage of the two-step models are positive, but the second stages are weakly negative. While the UAPE from the Tobit model indicates a 72 kilogram increase in sales with an additional cassava hectare, the resulting UAPE for the Cragg is not statistically significant, likely resulting from the rather small (less than 5%) increase in probability of market participation found by the marginal effects after the first stage.

As with all previous years, the maize harvest is positive and statistically significant in all but the second stage of the Heckman model. UAPEs from Tobit and Cragg indicate a modest increase in maize sales from between .08 and .3 kilograms with an additional kilogram of harvest.

Contrary to all previous years, the price of maize variable in Mozambique for 2004/05 is negative and significant in a number of results, and positive and insignificant in the remainder. This is clearly contrary to expectation, and is again likely to be a consequence of low variation in the district median price variable used in lieu of accurate farm gate prices.

Table 11: Mozambique key results

MOZAMBIQUE	1	2	3	4	5	6	7	8
2001/02	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
hectc	10.52	5.273	-0.0168	0.228	-0.0168	1959***	-0.00432	24.49205
	(49.97)		(0.0761)	(0.306)	(0.0761)	(611.0)	(0.01961)	(15.68405)
kg_harvm	0.458***	0.274	0.000653***	-0.000798	0.000653***	2.764***	0.00016***	.07023***
	(0.0227)		(0.0000379)	(0.000620)	(0.0000379)	(0.436)	(0.00001)	(.0092023)
pricem	56.29**	32.458	0.0783*	-0.145	0.0783*	772.7	0.02019*	14.14166
	(28.52)		(0.0413)	(0.190)	(0.0413)	(504.6)	(0.0106)	(10.66243)
km_road	0.825***	0.327	0.00142***	-0.00373*	0.00142***	-5.945*	0.00036***	-.0022121
	(0.238)		(0.000356)	(0.00208)	(0.000356)	(3.192)	(0.00009)	(.0670893)
trmm	0.994***	0.853	0.00163***	-0.00422**	0.00163***	-2.484	0.00041***	.0535912
	(0.0976)		(0.000138)	(0.00186)	(0.000138)	(1.663)	(0.00003)	(.0360956)
2004/05								
hectc	139.0***	71.7345	0.221***	-0.289*	0.221***	-579.9	0.0450***	3.876048
	(47.60)		(0.0530)	(0.157)	(0.0530)	(575.5)	(0.01079)	(11.6678)
kg_harvm	0.608***	0.3482	0.000908***	-0.000404	0.000908***	3.083***	0.000185***	.07724***
	(0.0315)		(0.0000388)	(0.000346)	(0.0000388)	(0.381)	(0.00001)	(.008988)
pricem	-19.83*	-9.3415	-0.0290**	0.0436	-0.0290**	255.3	-0.00592**	1.499112
	(11.00)		(0.0123)	(0.0330)	(0.0123)	(182.2)	(0.00251)	(3.00469)
km_road	-1.756***	-0.7912	-0.00180***	0.00156	-0.00180***	-18.83***	-0.00036***	-.29585***
	(0.321)		(0.000362)	(0.00111)	(0.000362)	(4.022)	(0.00007)	(.07235)
trmm	0.812***	0.4212	0.000928***	-0.00190***	0.000928***	-11.25***	0.00018***	-.08265**
	(0.151)		(0.000171)	(0.000553)	(0.000171)	(2.514)	(0.00003)	(.040870)

1 Results from Tobit model

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7 Marginal effects from probit (from first step in Cragg's Tobit alternative)

8 Unconditional Average Partial Effects after Cragg's Tobit alternative with bootstrapped standard errors.

Variables: hectc = hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

Standard errors in parentheses

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

Like both years for Zambia, the kilometers to main road is found to be negatively related to maize sales. In all but the second stage Heckman, the results are negative and highly statistically significant. The UAPEs suggest that for an additional kilometer separating the household from the main road, a reduction of between .3 and .7 of a kilogram is expected.

Lastly, the accumulated rainfall variable returns mixed results for this survey year. The Tobit and first stages of the Heckman and Cragg models are positive and significant, while the second stages are negative and significant. The Cragg UAPE indicates that the reduction in quantity outweighs the potential increase in probable market entry, returning a negative and significant result that is contrary to the UAPE of the Tobit model.

7.1.6 Summary

Unlike the results for Zambia, the Mozambique data do not suggest an overwhelmingly positive relationship between maize sales and cassava hectares. However, that the good rainfall year (2001/02) is less responsiveness than the high rainfall year is consistent with reports from farmers that during times of poor maize harvest, associated with meager precipitation, cassava is heavily relied upon as a substitute in consumption. Households with both crops would therefore be in a better position to sell maize, relying on their cassava stocks and taking advantage of the fact that non-cassava growing households do not have a substitute.

Price in the first year is positively related to maize sales as expected, and although the price variable in the poor rainfall year is negatively related to sales, contrary to economic theory, it is possible that the combination of an unusual marketing environment sparked by wide spread maize crop loss, coupled with the insufficiently accurate price variable is responsible for the result.

As in Zambia, increased maize production in both years of the Mozambique data is positively related to sales; higher production indicates that a household is more likely to satisfy its food requirements.

That kilometers to main road is negatively related to maize sales in one year and inconclusively related in the other is an unexpected and unexplainable result. It is perhaps the result of a combination of unobserved variables.

Unlike Zambia, the accumulated rainfall variable is inconclusively related to maize sales for both years in Mozambique. This may indicate that factors attributable to rainfall in Zambia are not equally important in Mozambique. Given the different historical, cultural, and agro-ecological climate in the two countries, perhaps this result should not be surprising.

7.2 Brief Discussion of Auxiliary Variables

Although the main purpose of the study is to discuss the relationship between cassava and maize sales, it is helpful to look at the other variables as well (Refer to the Appendix for the complete set of results). The pattern that emerges most clearly is that the need to satisfy household consumption is of paramount importance. Variables that are related to food supply or consumption are generally a significant factor for maize sales.

In the models, variables that mostly seem to positively affect maize sales are total hectares available to the household, and bicycle or radio ownership. These variables have the expected, positive sign in most cases. Having more maize and access to land indicates that a household is more likely to be able to satisfy its food requirements and owning a radio or bicycle indicates a household has better access to market information and can transport its own produce.

The variables most often negatively related to maize sales are the number of household members and the age of the household head. This former indicates that additional household members require higher quantities of food to be retained for consumption, thereby leaving less for sale. The latter suggests that older household heads may not be as able to search or negotiate for maize sales opportunities.

8. CONCLUSIONS

Involving smallholder producers in the maize market in Zambia and Mozambique has the potential to increase the food supply and stimulate economic growth through increased rural incomes and linkages to other sectors. Previous experience and research indicates that for households to produce food for sale in the market, a number of requirements must be met. First and foremost, household food security must be attained. Empirical studies that explore the determinants to market participation indirectly address food security as an important factor of participation. The major contribution of this study is that it explicitly includes the effect of cassava hectares as a substitute food staple on the estimates of household maize market participation, controlling for socioeconomic, demographic, and market access effects.

By evaluating results from the Tobit, Heckman, and Cragg models together, a general picture of the importance of cassava stocks to maize sales emerges in Zambia and Mozambique. The results indicate that in Zambia, cassava hectares are positively related to market participation and level of maize sales. For both years, UAPEs from the Tobit and Cragg models return positive results between 50 and 220 kilograms of maize sold per hectare of cassava. This increase is largely driven by the increase in market entry that cassava stocks make possible. Given that both of the datasets for Zambia represent years of good rainfall, and normal maize price fluctuations, it is likely that cassava stocks increase maize sales in all years. In poor maize years, it is thought that households would rely to a greater degree on cassava than in good years.

In Mozambique, results indicate that cassava hectares have little impact on maize sales in good rainfall years and greater impact during years of little rain. In the good rainfall year, only one result was positive and significant for the hectares of cassava variable, while in the below normal rainfall year, several results were positive and significant. As in Zambia, the bulk of the positive values relate to the probability of entering the maize market as a seller. However, because the UAPE for the Cragg model is not statistically significant, a positive relationship is not strongly confirmed.

The Mozambique results are consistent with household planting regimes that stagger cassava planting to buffer maize shortfalls from one year to the next. Because cassava is planted two years before it is consumed, and because it is resistant to poor rainfall, households may depend on the crop more during bad maize seasons[11].

8.1 Final Comments

This study demonstrates the importance of cassava hectares to maize market participation in Zambia. This information should help policymakers to prioritize agricultural spending, perhaps with renewed emphasis on diversifying smallholder staple crops. In Zambia, while cassava has long been recognized as a staple food crop, the potential consumption smoothing benefit of cassava production, leading to increased probability of maize sales, has largely been ignored. Likewise, compared to areas along the line of rail, large areas of Northern Zambia, where both maize and cassava are grown, remain

[11] Indeed, cassava breeders indicate that farmers may be reluctant to give up long-duration varieties, which they can harvest when they like over a multiple year period, because the long duration of maturation provides an extra measure of risk aversion for farmers (Steve Haggblade, pers com).

geographically marginalized by poor infrastructure. Perhaps due to its perception as a subsistence farming area, policy has not focused on this productive area of the country.

Given the results from Mozambique, policymakers should note that cassava's relationship to maize market participation increases in times of national maize deficit. Although the relationship in Mozambique is not as strong as in Zambia, increased focus on the interaction between staple foods seems warranted for both countries. Given what appears to be cassava's buffering role in household consumption, continued efforts to promote disease and insect-resistant cassava varieties is justified.

Though this study provides a tantalizing glimpse into the interrelationship between cassava and maize sales, a number of questions remain that call for further analysis. First, while this study attempted to utilize available econometric techniques to estimate its findings, one shortcoming is its inability to compare unconditional average partial effects between all three models. Future econometric work should focus on evaluating UAPEs for the Heckman model to compare with UAPEs from the Cragg and Tobit models. Second, the results from Mozambique showing differentiations between good and bad maize harvest years suggest that cassava's importance to maize sales is variable depending on the adequacy of maize harvest. Further studies of this kind should compare producer prices in good and bad maize production years to further test the extent to which the ability to substitute maize for cassava increases in importance as maize prices rise.

APPENDIX

Table 12: Zambia 1999/00 complete results

ZAMBIA	1	2	3	4	5	6	7	8
1999/00	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
Constant	-4385***		-2.230***	8.247***	-2.230***	-26622***		
	(286.8)		(0.173)	(0.827)	(0.173)	(2488)		
hadc	429.1***	221.960	0.256***	-0.232**	0.256***	490.8	0.08156***	60.560***
	(84.88)		(0.0549)	(0.116)	(0.0549)	(502.2)	(0.01745)	(28.7721)
km_road	-1.275***	-0.607	-0.000636***	-0.000675	-0.000636***	-17.31***	-0.00020***	-0.82393***
	(0.401)		(0.000239)	(0.000524)	(0.000239)	(3.926)	(0.00006)	(0.20363)
lmm	1.240***	0.868	0.00109***	-0.00150***	0.00109***	-2.035	0.00034***	0.08534
	(0.427)		(0.000266)	(0.000574)	(0.000266)	(2.239)	(0.00008)	(0.13665)
std	12.64***	9.130	0.00442**	0.00357	0.00442**	76.89***	0.00140***	3.9091***
	(2.969)		(0.00186)	(0.00384)	(0.00186)	(16.69)	(0.00059)	(0.95988)
pricem	2.380***	1.614	0.000682*	0.00123*	0.000682*	24.41***	0.00018*	1.1131***
	(0.524)		(0.000320)	(0.000700)	(0.000320)	(3.673)	(0.0001)	(0.18408)
kg_harvm	0.718***	0.453	0.000434***	-0.0000813	0.000434***	2.368***	0.00013***	0.16641***
	(0.0247)		(0.0000178)	(0.0000845)	(0.0000178)	(0.144)	(0.00001)	(0.00886)
kg_harvm2	-0.00000582***		-0.0000000141***	4.36e-09	-0.0000000141***	-0.0000493***	-0.0000000044***	
	(0.00000105)		(7.42e-10)	(3.02e-09)	(7.42e-10)	(0.00000403)	(0.0000)	
mam	-41.42***		-0.0222***	0.0247**	-0.0222***	-23.32	-0.00705***	
	(9.055)		(0.00601)	(0.0118)	(0.00601)	(32.94)	(0.00191)	
hadgen	62.74		0.0569	0.0719	0.0569	609.4	0.01787	
	(84.07)		(0.0502)	(0.105)	(0.0502)	(627.5)	(0.01559)	
age	-10.31***		-0.00775***	0.00913***	-0.00775***	1.861	-0.00246***	
	(2.047)		(0.00126)	(0.00309)	(0.00126)	(11.98)	(0.0004)	
lvstck	-332.4***		-0.143***	-0.000769	-0.143***	-1306***	-0.04486***	
	(67.68)		(0.0417)	(0.0854)	(0.0417)	(413.5)	(0.01283)	
totlhad	65.33***		0.0527***	-0.0437*	0.0527***	147.8**	0.0167***	
	(17.84)		(0.0123)	(0.0241)	(0.0123)	(65.72)	(0.0039)	
radio	146.6**		0.0779*	0.0300	0.0779*	1251***	0.02494*	
	(65.83)		(0.0407)	(0.0828)	(0.0407)	(410.3)	(0.01311)	
bike	186.5***		0.133***	-0.191**	0.133***	1043**	0.04243***	
	(65.71)		(0.0402)	(0.0883)	(0.0402)	(430.8)	(0.01291)	

Table 12: (cont'd)

mbike	452.2	0.214	0.173	0.214	128.3	0.0727585
	(318.1)	(0.251)	(0.381)	(0.251)	(918.4)	(0.09008)
car	784.3***	-0.257	0.583	-0.257	1736**	-0.0744839
	(288.0)	(0.222)	(0.381)	(0.222)	(737.4)	(0.0577)
lambda			-1.871***			
			(0.347)			
sigma	1739***				2615***	
	(29.31)				(108.0)	
Observations	6878	6878	6878	6878	6878	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

1 Results from Tobit model
2 Unconditional Av
3 First (selection) step in Heckman two step model
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Variables: hectc = hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

Table 13: Zambia 2002/03 complete results

ZAMBIA	1	2	3	4	5	6	7	8
2002/03	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
Constant	-2601***		-1.711***	8.616***	-1.711***	-11992***		
	(263.6)		(0.190)	(0.764)	(0.190)	(1890)		
hectc	336.4***	178.211	0.291***	-0.345***	0.291***	234.5	0.09579***	51.507***
	(54.79)		(0.0407)	(0.110)	(0.0407)	(367.3)	(0.01341)	(19.7094)
km_road	-2.226***	-1.008	-0.00178***	0.00212**	-0.00178***	-13.25***	-0.00058***	-.818804***
	(0.438)		(0.000313)	(0.000854)	(0.000313)	(3.556)	(0.0001)	(0.18917)
lrmm	3.007***	2.848	0.00218***	-0.00214***	0.00218***	7.760***	0.00071***	.64176***
	(0.276)		(0.000201)	(0.000657)	(0.000201)	(1.781)	(0.00007)	(0.104358)
std	-26.83***	-2.360	-0.0187***	0.0182***	-0.0187***	-83.16***	-0.00614***	-6.209497
	(3.365)		(0.00244)	(0.00704)	(0.00244)	(20.27)	(0.0008)	(1.37098)
pricem	0.882***	0.547	0.000778***	-0.000957*	0.000778***	-5.476**	0.00025***	-.1224207
	(0.302)		(0.000213)	(0.000539)	(0.000213)	(2.291)	(0.00007)	(.136812)
kg_harvm	0.738***	0.483	0.000475***	0.0000258	0.000475***	1.944***	0.00015***	.150634***
	(0.0232)		(0.0000228)	(0.0000830)	(0.0000228)	(0.110)	(0.00001)	(.007488)
kg_harvm2	-0.00000186**		-0.0000000120***	1.26e-09	-0.0000000120***	-0.0000329***	-0.00000000394***	
	(0.000000806)		(7.68e-10)	(2.42e-09)	(7.68e-10)	(0.00000283)	(0.0000)	
mem	-36.90***		-0.0236***	0.0121	-0.0236***	-21.99	-0.00777***	
	(10.21)		(0.00787)	(0.0177)	(0.00787)	(37.16)	(0.00259)	
hedgen	-75.87		-0.0537	0.213	-0.0537	1233*	-0.0178605	
	(78.60)		(0.0552)	(0.133)	(0.0552)	(684.4)	(0.01853)	
age	-5.397***		-0.00529***	0.00816**	-0.00529***	17.27	-0.00174***	
	(1.872)		(0.00135)	(0.00335)	(0.00135)	(10.75)	(0.00044)	
lvstck	37.43		0.0468	-0.118	0.0468	-163.4	0.0153386	
	(60.62)		(0.0432)	(0.103)	(0.0432)	(427.6)	(0.0141)	
tdhect	27.26		0.0340*	-0.0250	0.0340*	91.89	0.01120*	
	(20.47)		(0.0183)	(0.0348)	(0.0183)	(58.83)	(0.00603)	
radio	153.7**		0.0778*	-0.00225	0.0778*	2129***	0.02562*	
	(60.32)		(0.0435)	(0.103)	(0.0435)	(422.8)	(0.01434)	
bike	153.0**		0.177***	-0.192	0.177***	500.5	0.05806***	
	(64.55)		(0.0458)	(0.119)	(0.0458)	(489.3)	(0.015)	

Table 13: (cont'd)

mbike	370.7	0.0610	0.283	0.0610	3633***	0.02044
	(228.4)	(0.183)	(0.389)	(0.183)	(821.3)	(0.08229)
car	-159.9	-0.230	0.225	-0.230	-610.4	-0.0700352
	(227.3)	(0.228)	(0.372)	(0.228)	(553.8)	(0.08805)
lambda			-2.303***			
			(0.342)			
sigma	1483***				2257***	
	(27.37)				(93.86)	
Observations	5374	5374	5374	5374	5374	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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6 Second(quantity) step in Cragg's Tobit alternative model
7 Marginal effects from probit (from first step in Cragg's Tobit alternative)
8 Unconditional Average Partial Effects after Cragg's Tobit alternative with bootstrapped standard errors

Variables: hadc = hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

Table 14: Mozambique 2001/02 complete results

MOZAMBIQUE	1	2	3	4	5	6	7	8
2001/02	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
Constant	-1092***		-1.501***	11.14***	-1.501***	-11754***		
	(134.5)		(0.191)	(2.846)	(0.191)	(3237)		
hedc	10.52	5.273	-0.0168	0.228	-0.0168	1959***	-0.00432	24.49205
	(49.97)		(0.0761)	(0.306)	(0.0761)	(611.0)	(0.01961)	(15.68405)
km_road	0.625***	0.327	0.00142***	-0.00373*	0.00142***	-5.945*	0.00036***	-.0022121
	(0.238)		(0.000356)	(0.00208)	(0.000356)	(3.192)	(0.00009)	(.0670893)
tmm	0.994***	0.853	0.00163***	-0.00422**	0.00163***	-2.484	0.00041***	.0535912
	(0.0976)		(0.000138)	(0.00186)	(0.000138)	(1.653)	(0.00003)	(.0360956)
std	-6.378***	-1.327	-0.00961***	0.0197	-0.00961***	-49.65**	-0.00247***	-1.1496***
	(1.119)		(0.00162)	(0.0124)	(0.00162)	(20.40)	(0.00041)	(.428817)
pricem	56.29*	32.458	0.0783*	-0.145	0.0783*	772.7	0.02019*	14.14166
	(28.52)		(0.0413)	(0.190)	(0.0413)	(504.6)	(0.0106)	(10.66243)
kg_harvm	0.458***	0.274	0.000853***	-0.000798	0.000853***	2.764***	0.00016***	.07023***
	(0.0227)		(0.0000379)	(0.000620)	(0.0000379)	(0.436)	(0.00001)	(.0092023)
kg_harvm2	-0.0000127***		-0.0000000368***	0.0000000544	-0.0000000368***	-0.000115***	-0.0000000094***	
	(0.00000178)		(3.22e-09)	(3.69e-08)	(3.22e-09)	(0.0000202)	0.0000	
mem	-31.31***		-0.0366***	0.0729	-0.0366***	-21.96	-0.0094***	
	(6.477)		(0.00828)	(0.0492)	(0.00828)	(54.83)	(0.00213)	
hedgen	70.01*		0.0911	-0.0219	0.0911	4063***	0.02296*	
	(38.90)		(0.0556)	(0.245)	(0.0556)	(1267)	(0.01368)	
age	-5.165***		-0.00690***	0.0174*	-0.00690***	-11.30	-0.00177***	
	(1.070)		(0.00155)	(0.00956)	(0.00155)	(16.94)	(0.0004)	
tothect	43.80***		-0.000975	0.0604	-0.000975	125.1***	-0.0002514	
	(7.631)		(0.0143)	(0.0507)	(0.0143)	(46.97)	(0.00369)	
ownbiz1	-0.0301***		-0.0000290***	0.0000696	-0.0000290***	-0.0435	-0.0000074***	
	(0.00632)		(0.0000102)	(0.0000592)	(0.0000102)	(0.0354)	(0.000)	
ownbiz2	-0.000494		-0.00000346	0.0000158	-0.00000346	0.0219**	-0.000000892	
	(0.00138)		(0.00000251)	(0.0000112)	(0.00000251)	(0.0103)	(0.000)	
salary	0.00525		0.00000257	-0.00000936	0.00000257	-0.0401	0.000000663	
	(0.00334)		(0.00000517)	(0.0000199)	(0.00000517)	(0.0512)	(0.000)	

Table 14: (cont'd)

remit	0.00357	0.0000249	-0.000261	0.0000249	-1.039**	0.00000643
	(0.0256)	(0.0000349)	(0.000165)	(0.0000349)	(0.603)	(0.00001)
bike	35.41	0.0970*	-0.0297	0.0970*	726.5	0.02551*
	(33.71)	(0.0499)	(0.228)	(0.0499)	(489.0)	(0.01338)
mbike	-343.8*	-0.390	-0.0382	-0.390	-3042**	-0.08273*
	(176.0)	(0.263)	(1.076)	(0.263)	(1262)	(0.04407)
truck	301.2***	0.236	-0.161	0.236	1730**	0.067018
	(91.25)	(0.145)	(0.621)	(0.145)	(758.6)	(0.04484)
lvstck	-12.49	0.208	-0.914	0.208	-6341	0.0686276
	(183.2)	(0.257)	(1.081)	(0.257)	(5834)	(0.07863)
lambda			-3.802***			
			(1.466)			
sigma	712.9***				1508***	
	(16.45)				(138.3)	
Observations	4882	4882	4882	4882	4882	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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8 Unconditional Average Partial Effects after Cragg's Tobit alternative with bootstrapped standard errors.

Variables: hectc =hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

Table 15: Mozambique 2004/05 complete results

MOZAMBIQUE	1	2	3	4	5	6	7	8
2004/05	Tobit	UAPE	Heck (1st)	Heck (2nd)	cragg (1st)	cragg (2nd)	MFX probit	UAPE
Constant	-1332***		-1.520***	8.359***	-1.520***	-10356***		
	(136.2)		(0.146)	(1.187)	(0.146)	(2844)		
hedc	139.0***	71.7345	0.221***	-0.289*	0.221***	-579.9	0.0450***	3.876048
	(47.60)		(0.0530)	(0.157)	(0.0530)	(575.5)	(0.01079)	(11.6676)
km_road	-1.756***	-0.7912	-0.00180***	0.00156	-0.00180***	-18.83***	-0.00036***	-.29585***
	(0.321)		(0.000362)	(0.00111)	(0.000362)	(4.022)	(0.00007)	(.07235)
lmm	0.612***	0.4212	0.000928***	-0.00190***	0.000928***	-11.25***	0.00018***	-.08265**
	(0.151)		(0.000171)	(0.000553)	(0.000171)	(2.514)	(0.00003)	(.040870)
std	0.755	0.3920	-0.000168	0.00338	-0.000168	82.02***	-0.0000343	.91229**
	(1.528)		(0.00171)	(0.00411)	(0.00171)	(24.25)	(0.00035)	(.390923)
pricem	-19.83*	-9.3415	-0.0290**	0.0436	-0.0290**	255.3	-0.00592**	1.499112
	(11.00)		(0.0123)	(0.0330)	(0.0123)	(182.2)	(0.00251)	(3.00469)
kg_harvm	0.608***	0.3482	0.000908***	-0.000404	0.000908***	3.083***	0.000185***	.07724***
	(0.0315)		(0.0000388)	(0.000346)	(0.0000388)	(0.381)	(0.00001)	(.008988)
kg_harvm2	-0.000000782		-0.0000000529***	0.0000000371*	-0.0000000529***	-0.000108***	-0.0000000108***	
	(0.00000250)		(3.05e-09)	(2.16e-08)	(3.05e-09)	(0.0000177)	(0.0000)	
mem	-29.07***		-0.0369***	0.0499**	-0.0369***	25.24	-0.00762***	
	(6.046)		(0.00682)	(0.0230)	(0.00682)	(66.47)	(0.00138)	
hedgen	101.9**		0.0983*	-0.0688	0.0983*	2866***	0.01939*	
	(51.70)		(0.0567)	(0.141)	(0.0567)	(1083)	(0.01081)	
age	-7.494***		-0.00684***	0.00562	-0.00684***	-80.29***	-0.00139***	
	(1.385)		(0.00153)	(0.00462)	(0.00153)	(19.12)	(0.00031)	
tothed	10.92		-0.00277	0.101***	-0.00277	454.9***	-0.0005651	
	(10.18)		(0.0122)	(0.0309)	(0.0122)	(80.30)	(0.00249)	
ownbiz1	-0.0308		-0.0000353	0.000160	-0.0000353	-1.684	-0.00000721	
	(0.0766)		(0.0000837)	(0.000202)	(0.0000837)	(2.721)	(0.00002)	
ownbiz2	-0.0171		-0.0000103	-0.0000111	-0.0000103	-0.269	-0.0000021	
	(0.0134)		(0.0000161)	(0.0000643)	(0.0000161)	(0.229)	(0.000)	
salary	-0.0140***		-0.00000819	0.00000292	-0.00000819	-0.0468**	-0.00000167	
	(0.00476)		(0.00000565)	(0.0000114)	(0.00000565)	(0.0186)	(0.0000)	

Table 15: (cont'd)

rent	-0.00835	-0.0000110	0.0000205	-0.0000110	0.0616	-0.00000224
	(0.00893)	(0.0000113)	(0.0000263)	(0.0000113)	(0.111)	(0.000)
bike	160.1***	0.187***	-0.195	0.187***	1243**	0.03857***
	(41.14)	(0.0465)	(0.135)	(0.0465)	(484.4)	(0.0102)
mbike	147.6	-0.169	0.928	-0.169	3740***	-0.0312549
	(199.4)	(0.280)	(0.582)	(0.280)	(1188)	(0.04317)
truck	-28.30	0.00558	-0.136	0.00558	-1561**	0.0011375
	(101.8)	(0.120)	(0.261)	(0.120)	(798.1)	(0.02454)
lambda			-2.157***			
			(0.593)			
sigma	923.7***				1618***	
	(21.59)				(119.3)	
Observations	6136	6136	6136	6136	6136	Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

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Variables: hectc = hectares of cassava, kg_harvm = kilograms of maize harvested, pricem = district median maize price, km_road = kilometers to primary road, trmm = accumulated seasonal rainfall from the trmm dataset

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