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Does Household Headship Affect Demand for Hybrid Maize Seed in Kenya?

An Exploratory Analysis Based on 2010 Survey Data

by

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EXECUTIVE SUMMARY

Women are central to food production and maize is a dominant food staple in Sub-Saharan Africa, but published gender analyses of hybrid seed use in Sub-Saharan Africa are uncommon. Building on previous work, this paper tests the effects of headship definitions on hybrid seed use and explores the variation between male- and female-headed households and among female-headed households in Kenya. Analysis is based on survey data collected by Tegemeo Institute of Egerton College during the 2009-10 cropping season.

Gender specialists have demonstrated that whether a farmer is a man or a woman is not, in and of itself, the most important factor affecting adoption of agricultural technologies. Controlling for farmers' access to productive resources, wealth, education, or marital status may eliminate gender differences in adoption rates, also modulating gender differences in adoption impacts. In a recent policy review, gender analysis experts noted that few studies have examined socio-economic differences among women when analyzing decision-making, such as technology adoption.

The purposes of this paper are to: 1) compare the determinants of hybrid seed use between households headed by men and women; 2) explore the heterogeneity among female-headed households and how this affects the use of hybrid seed; and 3) generate hypotheses for the design of more in-depth survey research on gender and maize productivity in Kenya. Determinants of adoption are identified by estimating double hurdle and Tobit regressions based on a reduced form model of household decision-making. The structure of variation among household groups is examined with discriminant and cluster analysis.

The vast majority of female heads in Kenya are widows. Female-headed households are not easily segmented into distinct groups based on observed variables. As expected, with respect to most types of assets (including adult labor), and income, they represent a statistically different population from households headed by a resident male. Consequently, their maize productivity is also lower. However, these factors held constant, headship is not an important determinant of demand for hybrid seed or experience using it, and hybrid seed use is not a discriminating variable among households. One reason why, we posit, is the long experience of Kenya farmers using hybrid seed.

CONTENTS

LIST OF TABLES

ACRONYMS

AEZs	agro-ecological zones
DFID	Department for International Development
FAO	Food and Agriculture Organization of the United Nations
IDRC	International Development Research Centre
KARI	Kenya Agricultural Research Institute
KNBS	Kenya National Bureau of Statistics
MSU	Michigan State University
OSSREA	Organisation for Social Science Research in Eastern and Southern Africa
USAID	United States Agency for International Development

1. INTRODUCTION

Despite the centrality of women in food production in Sub-Saharan Africa, the dominance of maize as a food staple, and extensive analysis of maize research and development in that region (e.g., Byerlee and Eicher1997; Smale, Byerlee, and Jayne 2011), *gendered* analyses of hybrid maize adoption are not easy to find. Some well-known historical references—largely descriptive and often conjectural—compare maize preferences, processing methods and women's trade of maize products among major maize-producing cultures (Miracle 1966; McCann 2005). In Kenya, as elsewhere, unpublished dissertations and theses provide economics insights (e.g., Kibaara 2005), but by their nature and because they are often based on relatively small samples, these are often location- and period-specific.

Where maize is a major food staple in Sub-Saharan Africa, it is generally grown as crop for both consumption and sales. Often, small-scale farm households who produce maize for consumption sell it at various points throughout the season to meet immediate cash needs, purchasing it back when consumption needs arise. To assure the supply of food, policies encouraging the production of hybrid maize through subsidized input packages, credit and extension services were common in the post-independence period until they were dismantled under structural adjustment programs, only to be revived under the guise of voucher systems in recent years (Smale, Byerlee, and Jayne 2011). It seems that among development researchers the consensus is that in maize-based systems, maize is neither a men's nor a women's crop. Some researchers have argued that because of the way they are promoted, maize hybrids, as compared to local varieties, are men's cash crops (Gladwin 1992). McCann (2005) contends that maize began its African career as a women's garden crop.

Gender specialists have demonstrated that whether a farmer is a man or a woman is not, in and of itself, the most important factor affecting adoption of agricultural technologies (e.g., Doss 1999). Controlling for farmers' access to productive resources, wealth, education, or marital status may eliminate gender differences in adoption rates, also modulating gender differences in adoption impacts. For example, Doss and Morris (2001) demonstrated that gender-linked differences in the rates of adoption of modern maize varieties and chemical fertilizer in Ghana resulted from gender-linked differences in access to complementary inputs—land, labor, extension and market extension services. Similarly, in early research in Malawi's maize-based farming system, Gladwin (1992) concluded that whether a farmer was a man or a woman did not influence seed and fertilizer adoption when access to credit and cash were held constant. Consistent with this finding, Smale and Heisey (1994) showed that female-headed households in Malawi were equally like to apply fertilizer and similar amounts of nitrogen/ha, but they were significantly less likely to grow maize hybrids because they did not have access to the resources to qualify for credit or to belong to credit clubs. In an analysis of a nationwide cropping system trial survey in Malawi, Gilbert, Sakala, and Benson (2002) found no significant gender differences in crop yields when inputs were supplied. The 2012 World Development Report summarizes data, which indicates that if women farmers had the same access as men to fertilizers and other inputs, maize yields would increase by 11 to 16% in Malawi, 17% in Ghana, and as much as 19% in Western Kenya.

In a recent policy review, Quisumbing and Pandolfelli (2009) noted that few studies have examined socio-economic differences among women when analyzing decision-making, such as technology adoption. During the early 1990s, Peters' anthropological research on the Zomba plateau of Malawi revealed the potential bias of lumping female-headed households together for targeting policy interventions. Among women who were recognized as household heads (*de jure* female-headed households), she distinguished between widows, who were often destitute, and women who benefited from substantial remittances sent to them from migrant husbands in South Africa. A third group, which Peters called *de facto* household heads, were wives of men who were frequently absent while searching for local labor opportunities. These women were responsible for many day-to-day farm management decisions.

This paper is an initial exploration into the use of hybrid maize seed female-headed households in Kenya, based on 2010 survey data collected by Tegemeo Institute. The analysis has three purposes. The first is to compare the determinants of hybrid seed use between households headed by men and women. As suggested by Peters, headship is defined according to gender, marital status, and residence. Determinants are identified by estimating double hurdle and Tobit regressions based on a reduced form model of household decision-making. The second purpose is to explore the structure of variation among household groups through discriminant and cluster analysis. The third objective is to generate hypotheses and recommendations for the design of more in-depth survey research on gender and maize productivity in Kenya.

Next, we summarize some insights regarding maize and women farmers in Sub-Saharan Africa, gleaned from published literature. In Section 3, we present descriptive information about male- and female-headed households. The regression approach and shown in Section 4. In Section 5, we report the findings of the discriminant and cluster analyses. Conclusions are drawn in Section 6, following by some recommendations for policy and future research in Section 7.

2. MAIZE AND WOMEN FARMERS IN SUB-SAHARAN AFRICA

Two volumes are often cited with respect to the history of maize as a crop in Sub-Saharan Africa, and each presents a different perspective on women's involvement in maize production and the origins of maize in Africa. Miracle's (1966) *Maize in Tropical Africa* mentions farmwomen (housewives primarily in relation to the trade of processed maize products in rural economies, such as Nigeria (*ogi* and *agidi*) and Ghana (makers of *kenkey*). Miracle cites historical records that describe the time-consuming process of preparing *ufa woyera* in Malawi, and processing of other primary maize products in other countries across the continent. Unlike Miracle, who argues that maize arrived first in Eastern Africa via the Portuguese slave trade, McCann (2005) argues that maize was Africanized first in West Africa. In *Maize and Grace*, he seems to view maize as originally a women's crop, portraying them as the source of names for maize varieties and maize products. Women grew maize in West Africa when it was still a "garden" crop, before it became a more valuable cash crop in the "male domain" (p. 37). He depicts maize as initially a women's plant in Ethiopia, cultivated as a horticultural rather than a field crop. According to McCann, a Ph.D. dissertation in 1972 by Margaret Jean Hay reports that in 1917, Luo women named a novel white-dent maize variety *orobi*, after Nairobi, which had been founded in 1901. Luo women are described as naming maize varieties, exchanging seed, and managing the crop within the household livelihood strategy. McCann describes women as small farm managers in southern Africa, providing food and beer to sustain workers' families and men in the cities and mines.

A recent study by Macharia et al. (2010) addressed gender differentiation in technology choice in a holistic way, defining gender as "embracing all socially-given attributes, roles, activities and responsibilities connected to a person, either male or female, in a given society" (p. 58). The authors note that gender concepts were not explicitly recognized in the Kenya Agricultural Research Institute (KARI) strategy until 1998. According to the authors' definition, important gender categories include men and women, boys and girls, young and elderly, male- and female-headed households. Thus, headship is only one element of a gender analysis of technology adoption.

The study of Macharia et al. (2010) examines the profitability of soil fertility and management practices in small-scale maize-based production systems in the Central Province of Kenya. The researchers found that the household head was the main decision-maker in households they interviewed, deciding which crops to grow, which soil and fertility management practices to use, when to obtain a loan, and the strategic direction of development on the farm. Male-headed households differed from female-headed households in terms of their initiatives and innovations. As has been repeatedly demonstrated in Kenya, the education household heads was a critical factor in the choice of development initiatives, which new farming techniques they adopted, and the changes made in farming enterprises. The authors noted, however, that wives generally decided on the maize varieties grown.

Applied economics research that focuses specifically on gender-differentiated aspects of hybrid seed use and maize productivity in Sub-Saharan Africa is hard to locate in published literature. In fact, dated research conducted in Malawi and Ghana (mentioned in the introduction), Zambia, and Western Kenya is salient in this respect. A monograph written by Shubh Kumar (1994) based on the research conducted in Eastern Province of Zambia associates the ability to use oxen to expand area with production of hybrid maize (outside the tsetse fly areas), and the use of oxen with more laborers per farm, both of which pose constraints for women farmers. The analysis by farm size indicated that under three ha, female-headed households had much lower rates of adoption than male-headed households did. The reverse was true for the three to five ha category. Above five ha, all households grew hybrids. Kumar concluded that once resource constraints (labor, land, oxen) were removed, gender of household head was insignificant in the decision to grow maize hybrids.

Research by Moock (1976) in Western Kenya examined the impacts of migration on the maize management of remaining household members. Moock's work was conducted in Vihiga Division, where even then, high population densities resulted in very small farm sizes and 'circular' patterns of labor migration, particularly by the male head of household. Moock estimated separate yield-response regressions for male- and female-headed households. He found that the relationship of schooling to yields was positive for women, but not for men. Migration by women heads was detrimental to technical efficiency because they lost skills when they migrated with their entire family, but not for men, who continued to manage the farm and other farm household members in absentia. Moock also concluded that men benefited from extension while women did not, which he attributed to the male orientation of the services provided.

An area of relatively high population densities and migration rates, Western Kenya is also an area with high maize productivity potential. Most of the published work on women and maize in Kenya appears to have been conducted in this province. Achieng et al. (2001) analysed maize productivity among members of women's groups and a primary school in Western Kenya. Their study was not designed to compare users and non-users among participants, or participants and non-participants, but to demonstrate the potential for farmers to achieve high maize yields and sustain fertilizer use when adequate credit and information about agronomic practices was made available to them.

Applied economists have increasingly recognized the importance of differentiating analyses of maize seed use and productivity by gender of household head, incorporating dummy variables for headship in their econometric analyses. For example, in their analysis of fertilizer use on maize in Zambia, Ricker-Gilbert, Jayne, and Chirwa (2011) found that the gender of the household head had no effect on maize yields, although hybrid seed use, nitrogen use, use of animal or mechanical power were important factors. Also in Zambia, Kimhi (2006) found a negative relationship between female headship and area allocated to maize as well as maize yields, when controlling for a smaller maize plot sizes. In a sample of households interviewed in selected districts of major maize-producing zones, Langyintuo and Mungoma (2008) found that gender of household had no effect on either the likelihood of hybrid use or the area share allocated to hybrid seed. The lack of statistical significance held across households when they were grouped by wealth index into poorly- and well-endowed segments. Salasya et al. (2007) evaluated the factors influencing the adoption of stress-tolerant maize in Western Kenya, finding that the dummy for gender of household head was not statistically significant in the probit equation. In the Coastal Lowlands of Kenya, Wekesa et al. (2003) also found that the gender of the household head was of no significance in the decision to grow maize hybrids. Ouma et al (2002) found that gender was a significant determinant of adoption if hybrid seed and basal fertilizer in Embu District in Kenya. So were, however, manure use, hiring of labor, and extension—all of which are likely to be associated with gender of household head. Other variables, such as age and education of household head, farm size, credit and education were not found to be statistically significant.

In none of these cases is the potential correlation between headship and other independent variables, such as labor supply, access to credit and extension, education, farm size and other capital assets, discussed. Although we may assume that diagnostic tests have been conducted, this has potentially disturbing statistical consequences. As is well known, use of dummy variables may result in multicollinearity among independent variables, affecting the standard errors of coefficients and leading to failure to reject the null hypothesis. In such circumstances, researchers may falsely conclude that headship has no effect on adoption.

Since a critical review of the literature by Quisumbing in 1996, the relative efficiency of men and women farmers appears to have been addressed by increasingly rigorous econometrics. Quisumbing concluded in her review that lower yields on farms managed by women resulted from lower amounts of inputs and resources used. Kibaara (2005) estimated a stochastic frontier for maize production in Kenya with survey data collected by Tegemeo in 2003/4, concluding that households headed by women were less technically efficient. In this case, as in the adoption studies mentioned above, a dummy variable was used to measure headship, and we are not certain from the analysis presented whether headship was statistically related to other explanatory variables.

Focusing again on Western Kenya, Alene et al. (2008) estimated a normalized, restricted profit function to test the relative efficiency of men and women maize farmers. The authors found no evidence of gender-related differentials in either technical or allocative efficiency. However, neither men nor women were highly efficient. Education and extension drives overall maize supply, but only extension contact had a significant effect on the efficiency of women farmers.

3. CHARACTERISTICS OF MALE- AND FEMALE-HEADED HOUSEHOLDS IN KENYA

3.1. Data Source

The data employed here are from the Tegemeo/MSU Panel Household Surveys conducted since 1997. The sampling frame was prepared in consultation with the Kenya National Bureau of Statistics (KNBS) in 1997. Twenty-four (24) districts were purposively chosen to represent the broad range of agro-ecological zones (AEZs) and agricultural production systems in Kenya. Next, non-urban divisions in the selected districts were assigned to one or more AEZs based on agronomic information from secondary data. Third, divisions were selected from each AEZ proportional to the size of population. Fourth, within each division, villages and households were randomly selected. A total of 1,578 households were selected in the 24 districts within seven agriculturally oriented provinces of the country. The sample excluded large farms with over 50 acres and two pastoral areas. The first survey was conducted in 1997, with a much more restricted survey instrument than those applied in later years.

The attrition rate for the panel was 21% in 2010 compared to the initial survey, conducted in 1997. Reasons for non-participation in subsequent surveys were recorded. Some of the main reasons for this attrition are related to death of household heads and spouses leading to dissolution of households, and relocation of households from the study areas. Households in Turkana and Garissa districts were not interviewed after 2000. Only the 2010 survey data were used in the analyses presented here.

3.2. De Jure Household Heads

De jure male- and female-headed households are distributed differently across Kenya's geographical regions (Tables 1a, 1b). The highest concentration of recognized female heads is found in the Lower Midland 3-6 zone (39%), and the lowest, at only 17%, is recorded for the Upper Highland zone.

Table 1a. Percentage Distribution of Households by Recognized Head and Agro-Ecological Zone

	De jure head		
	Male	Female	Total
Coastal Lowland	77.63	22.37	100.00
Lowland	77.27	22.73	100.00
Lower midland 3-6	61.35	38.65	100.00
Lower midland 1-2	74.48	25.52	100.00
Upper midland 2-6	70.63	29.37	100.00
Upper midland 0-1	80.08	19.92	100.00
Lower highland	75.74	24.26	100.00
Upper highland	85.37	14.63	100.00
All zones	73.07	26.93	100.00

Source: Calculated by author from Tegemeo Institute survey data (2010)
Chi-squared test shows statistically significant differences by zone.

Table 1b. Percentage Distribution of Households by Recognized Head and Agro-Regional Zone

	De jure head		
	Male	Female	Total
Coastal Lowlands	81.48	18.52	100.00
Eastern Lowlands	76.67	23.33	100.00
Western Lowlands	52.46	47.54	100.00
Western Transitional	76.15	23.85	100.00
High Potential Maize Zone	75.22	24.78	100.00
Western Highlands	77.31	22.69	100.00
Central Highlands	79.09	20.91	100.00
Marginal Rain Shadow	81.58	18.42	100.00
All zones	75.62	24.38	100.00

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference of distribution by zone with Pearson chi-squared test at 1%.

Using the classification developed by Tegemeo, female headship is prominent (48%) in the Western Lowlands, which corresponds to one of the most densely populated areas with the highest rates of 'circular' migration. The percentage of recognized female heads is nearly twice as high in the Western Lowlands as it is overall (25%). Nonetheless, because of relatively small subsample sizes, this group cannot be analyzed separately here.

The descriptive statistics shown in Tables 2 through 6 are consistent with general findings reported in much of the literature on male- as compared to female-headed households in Sub-Saharan Africa. Table 2 confirms that not only are most income and asset characteristics of male- and female-headed households in Kenya statistically different at the mean, but the hypothesis that they have equal variance is typically rejected. Of sources of income, only net livestock income is similar on average in 2010. Crop and livestock income shares are similar statistically, although male-headed households rely more on off-farm income.

Female household heads tend to be a few years older than male household heads, their households are smaller, and they remained at home for a longer period during the preceding year. The variance in periods away from home also differs between the two types of households. Distances to different types of physical and market infrastructure are the statistically equivalent at the mean and in terms of variance. This makes sense given the obvious fact that households are not distributed spatially according to gender of household head (Table 3).

Table 2. Income and Assets of De Jure Male and Female-Headed Households

	De jure head	Mean	Std. Deviation	Hypothesis test: Equal Variance	Hypothesis test: Difference of means
Total land holdings owned in acres	Female	3.70	4.24	***	***
	Male	5.94	10.38		
Cash credit (Ksh) received	Female	15118	39146	**	***
	Male	41060	119565		
Total net household income (Ksh)	Female	149064	168540	***	***
	Male	335810	557509		
Net crop income	Female	54804	71181	***	***
	Male	124502	332428		
Total net off-farm income	Female	58822	131027	***	***
	Male	137817	258218		
Net livestock income	Female	63096	130290		
	Male	59071	88617		
Crop share of household income	Female	0.52	1.61		
	Male	0.42	0.86		
Off-farm share of household income	Female	0.23	1.54		***
	Male	0.39	0.62		
Livestock share of household income	Female	0.25	0.44		
	Male	0.19	0.96		
Value of livestock (Ksh)	Female	41012	48108	***	***
	Male	74798	157389		
Value of household assets (Ksh)	Female	215919	522594	***	***
	Male	335732	894626		
Total value of assets (Ksh)	Female	256931	540231	***	***
	Male	410529	954008		

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference with t-test (mean) or Levene's test (variance) at 1 % (***) and 5% (**).

Table 3. Household Characteristics and Infrastructure Access of Male and Female-Headed Households

	De jure head	Mean	Std. Deviation	Hypothesis test: Equal Variance	Hypothesis test: Difference of means
Age	Female	62.22	13.15		***
	Male	59.83	13.19		
Months at home between June 09 & May 2010	Female	11.86	1.11	***	***
	Male	11.18	2.64		
Total number of members in 2010	Female	4.22	2.58		***
	Male	5.89	2.97		
Distance in kms from HH to nearest piped water source	Female	4.39	6.38		
	Male	4.05	6.66		
Distance in kms from HH to nearest health centre	Female	2.86	2.30		
	Male	2.86	2.47		
Distance in kms from HH to nearest electricity supply	Female	1.75	2.28		
	Male	1.66	2.02		
Distance in kms from HH to nearest National Cereals Produce Board (NCPB) depot	Female	4.03	3.54		
	Male	4.10	3.91		
Distance in kms from HH to nearest farm produce market	Female	12.28	9.66		
	Male	12.42	10.35		

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference with t-test (mean) or Levene's test (variance) at 1 % (***) and 5% (**).

Statistical differences in access to credit are not apparent, although female-headed households are less likely to have members who belong to producer groups, and they are less likely to work with or be willing to pay for extension. The likelihood that a household sold land in the past decade is higher for households headed by men (Table 4). This finding is related to land rights but also to the marital status of the two groups.

For the purposes of this paper, it is of particular interest that male and female-headed households began growing modern maize in the same year, on average (1991), although the variance in this characteristic differs statistically. That is, on average, both groups have grown maize hybrids for 20 years!

Table 4. Service Access of Male and Female-Headed Households

	De jure head	Percent Yes	Percent No	Statistical Difference
Did any member try to obtain cash credit in 2009/10 season?	Female	27.0	73.0	
	Male	27.2	72.8	
Did any member try to obtain in-kind credit in 2009/10 season?	Female	39.0	61.0	
	Male	42.2	57.8	
Receive cash credit?	Female	97.4	2.6	
	Male	92.7	7.3	
Receive credit in kind?	Female	98.2	1.8	
	Male	99.5	0.5	
Did household receive fertilizer subsidy over the past 3 years?	Female	9.9	90.1	
	Male	12.9	87.1	
Did household purchase or sell land in the past 10 years?	Female	7.1	92.9	**
	Male	13.2	86.8	
Did household actively seek extension advice on crop or livestock btw June 2009 & May 2010?	Female	47.9	52.1	**
	Male	56.2	43.8	
Does any household member belong to cooperative or group or out-grower group?	Female	64.5	35.5	***
	Male	72.7	27.3	
Has household participated in a cash transfer program in last 12 months?	Female	0.7	99.3	
	Male	0.3	99.7	
If extension services were availed at a fee, would household be willing to pay?	Female	52.7	47.3	**
	Male	59.5	40.5	

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference with Pearson chi-squared test at 1 % (***) and 5% (**).

The two types of households are different with respect to all major maize production characteristics, such as area in maize, yield, quantities sold and harvested. They also differ for production costs. However, they face the same average maize seed and grain prices (Table 5). Consistent with the literature, differences in productivity are hypothesized to reflect differences in assets, income, use of extension and access to groups.

Table 5. Maize Production Characteristics of Male and Female-Headed Households

	De jure head	Mean	Std. Deviation	Hypothesis test: Equal Variance	Hypothesis test: Difference of means
Year HH first used improved maize seed	Female	1991.19	13.52	***	
(hybrid /OPV)	Male	1991.20	11.82		
Year HH first used inorganic/chemical fertilizer	Female	1987.38	12.84	***	**
	Male	1989.38	11.29		
Quantity (kg) of maize harvested	Female	765.65	1435.74	***	***
	Male	1369	4083		
Quantity (kg) of maize sold	Female	230	973	***	***
	Male	604	2907		
Maize price (Ksh/Kg)	Female	20.48	4.92		
	Male	20.40	5.36		
Total area (acres) under maize	Female	1.27	1.27	***	***
	Male	1.74	3.08		
Maize yield (kgs/ha)	Female	1741	1478	***	***
	Male	2218	1749		
Land prep cost 2010	Female	2871	5100	***	
	Male	3606	10875		
Fertilizer cost 2010	Female	5024	8314	***	***
	Male	10723	29709		
Seed cost 2010	Female	3829	6554	***	***
	Male	6329	13316		
Hired land preparation cost (Kshs)	Female	1493	2616	**	
	Male	1924	8618		
Kgs of maize seed planted	Female	11.10	11.97	***	***
	Male	14.72	30.58		
Price (Ksh) per kg of maize seed planted	Female	129.8	36.50		
	Male	129.7	32.49		

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference with t-test at 1 % (***) and 5% (**).

Use of hybrid maize seed was 85% among male-headed households and 74% among female-headed households in 2010. Both of these rates are high, although the rate among female-headed households is significantly lower. Female-headed households also used less of other practices; including fertilizer, soil and water conservation, and compost manure (Table 6).

Table 6. Use of Improved Maize Seed and Practices

	De jure head	Percent Yes	Percent No	Statistical Difference
Grow hybrid maize in 2009/10	Female	84.6	15.4	***
	Male	74	26	
Apply fertilizer to maize in 2009/10	Female	62.5	37.5	***
	Male	72.3	27.7	
Practice soil and water conservation practices	Female	84.0	16.0	***
	Male	91.2	8.8	
Compost manure	Female	5.0	95.0	**
	Male	9.7	90.3	

Source: Author, based on Tegemeo Institute survey data, 2010.
Statistical difference with Pearson chi-squared test at 1 % (***) and 5% (**).

Overall, the data demonstrate that recognized male- and female-headed households are distinct populations with respect to key economic variables, although the availability of and access to important infrastructure and service indicators is similar in some respects for both groups. Female-headed households have less access to groups and extension, and less willingness to pay for it. In addition, households headed by women use improved practices to a lesser extent, although nearly three-quarters of them grow hybrid maize, and on average, they have as much experience growing it as households headed by men.

3.3. Headship According to Marital Status and Residence

Tegemeo's survey instrument elicits the name and sex of the recognized household head, the head's marital status, and the number of months that the head was present at the house during the year preceding the survey.

As shown above, 73% of de jure household heads are men. Of these, 78% are monogamously married, 15% are polygamously married, 5% are widowed, and the remaining few are single or separated. The vast majority (86%) of de jure heads who are women are widows. The remaining minority consists of monogamously married women (5%), separated or divorced women, a few single women, and a few polygamously married women. Of the 75 household heads who were present six months or less of the year preceding the survey, 72 are men and only three are women (one married, and two widowed). The one woman in the sample who was married and absent had a husband who was chronically ill. Only one of the absentee men was single.

Based on this structure, four groups were formed in order to compare maize production characteristics: 1) households headed by a man who was present more than six months of the year; 2) households headed by women widows; 3) households headed by men who were absent six months or more; and 4) households headed by women who were single, married, divorced, or separated. Although heterogeneous, group 4 could not be subdivided further because of small numbers. The distribution of the Tegemeo sample by category is shown in Table 7.

Table 7. Sample by Category of Household Held, 2010

Category	Frequency	Percent
I Male head, present	956	73.4
II Female head, widow	256	19.7
III Male head, absent	64	4.9
IV Female head, non-widow	26	2.0
Total	1302	100.0

Source: Author, based on Tegemeo Institute survey data, 2010.
Note: definitions are in text.

As expected given the findings presented in Section 2, households headed by men who are present most of the year harvested nearly twice as much maize in 2010, and sold almost three times as much as households headed by women who are widows. They planted larger maize areas with more seed, and obtained an average of 2.2 t/ha, compared to only 1.76 t/ha.

The differences, however, between households head by women who are widows, and those who are de facto heads because their husbands are absent, or those female heads but not widows, is only apparent with respect to total area under maize and seed, which are related variables. Subsample sizes are particularly small for the non-widowed, female headed-households, and because the group is heterogeneous, values and tests are not particularly meaningful.

Table 8. Comparison of Maize Production Characteristics by Household Head Category

	Mean				
	I	II	III	IV	Statistical differences
Quantity (kg) of maize harvested	1369	734	772	944	I v. II, III,IV
Quantity (kg) of maize sold	601	231	214	282	I v. II, III, IV
Total area (acres) under maize	1.75	1.13	1.42	2.01	All groups
Maize yield (kg/ha)	2212	1763	1759	1553	I v. II, III, IV
Percent growing hybrids	84.2	74.3	81.3	60.9	I & III v II, IV; II v. IV
Kgs of seed planted	14.94	9.95	10.04	16.44	II & III v I, IV

Source: Author, based on Tegemeo survey data (2010).

4. REGRESSION ANALYSIS

Although the evidence above confirms the experience of Kenyan farmers growing hybrid maize, we know that now all farmers are commercially oriented and that, despite the progress made in liberalization seed and grain markets, markets do not function perfectly. When this is the context of farmer decision-making, the appropriate conceptual framework is the theory of agricultural household (Singh, Squire, and Strauss 1986). The framework includes profit-maximization as a special case when markets are perfect and production and consumption decisions are separable. When they are not, seed decisions are the outcome of choices of consumption amounts and product combinations to maximize utility, subject to market constraints. Formal derivations of crop variety choice decisions based on the theory of the household farm are found in Meng (1997); Van Dusen (2000); and Edmeades et al. (2003), but are not presented here.

In this framework, prices faced by the household are endogenous functions of the household characteristics that affect access to transaction information, credit, transport and other market services, such as human capital, farm assets, and experience, as well as the observed prices. Here, prices are expressed in terms of the seed-to-grain price ratio, measured as the price paid per kg for seed divided by the price received per kg of maize sold. Human capital variables include the highest educational level attained by the household head, the experience of the household head growing hybrid maize, and the adult equivalent household size, which serves as an indicator of labor supply. Age of the household head is highly correlated with years growing hybrid maize, and is not included separately but as a normalizing variable for experience. Assets include farmland owned and the current total value of all farm physical and livestock assets enumerated in 2010. Because receipt of cash credit, a financial asset, is potentially endogenous with the decision to grow hybrid seed, we considered including its predicted value. Cash credit is highly correlated with asset variables, but not significantly correlated (5%) with whether or not the household chose to grow hybrid maize. Therefore, the variable is not included. Analysis by Chamberlin and Jayne (2009) has confirmed that the density of maize traders in villages is a more accurate indicator of grain market access than distance, and this variable is used here, as well as distance to the nearest seller of certified seed. The social capital variable indicates whether or not anyone in the household is a member of a formal farmer group. Most of these variables have been presented above in the descriptive tables.

The demand for hybrid seed can be represented by the decision to grow hybrid seed (0,1) and the decision of how much seed to purchase, which is closely related to area planted. With a double hurdle regression model is estimated, the two aspects of the decision can be modeled separately. The descriptive statistics reported above suggest the need to test whether the regression should be estimated for male- and female-headed households separately, or treated with a dummy variable to represent group membership. The Swait-Louviere (log likelihood ratio) test comparing pooled and separate double-hurdle regressions leads to rejection of the null hypothesis (the value of test statistic, distributed chi2(18)=65.06, exceeding the critical value (37.16) with a P-value of 0.005). The null hypothesis is that pooling de jure male- and female-headed households does not impose a statistically significant restriction. In other words, the result suggests that the slope coefficients as well as the intercept are jointly different for de jure male- and female-headed households. Despite the significant correlations among many of the independent variables, the Variance Inflation Factor analysis does not show a factor higher than 1.48 (for total land owned) for any of the independent variables. The Variance Inflation Factor for headship is 1.27. Multicollinearity effects on hypothesis tests are unlikely. Given the descriptive statistics, the purpose of this paper, and the results of the Swait-Louviere test, separate regressions were estimated.

Results for the first two groups, including households headed by men who are generally present at home and households headed by women who are widows, are statistically robust, and demonstrate some similarities as well as some differences related to use of hybrid seed (Table 9). The double hurdle regressions were not statistically significant overall for Groups III and IV. For these groups, we estimated a Tobit regression. Even with the Tobit regression, results for absentee, male-headed households and non-widowed, female-headed households are weak, with only a few statistically significant parameters.

In Groups I and II, the number of years the head has been growing hybrid maize, normalized by his or her age, is the single most important indicator of whether the household grew hybrid maize in 2010 (in terms of both magnitude and significance). In some sense, this result simply represents the weight of *habit*. In the case of male-headed households, experience also increases the amount of hybrid seed purchased, by a large quantity, suggesting that seed demand grows with confidence in its use. Other indicators of human capital (formal education of head, adult-equivalent household size) have no effect on the decision to grow hybrids for either group, but household size, which measures available labor supply in the household, significantly increases the seed amounts purchased. This finding confirms that labor constrains area planted to hybrid seed. Either capital in owned land, or the total value of farm household assets, or both, are significant determinants for the decisions of Groups I and II. The density of maize traders present in the village is a more important determinant of the hybrid seed use than the distance to the nearest certified seed seller, supporting previous work by Chamberlin and Jayne. The lower the seed-to-grain ratio, the more likely households headed by women widows are to have purchased hybrid seed. The seed-to-grain price ratio is also negatively related to the amount of hybrid seed purchased for either Group I or Group II.

Group membership (counting all adults in the household) is also a major explanatory factor in the extent of hybrid seed purchased among resident, male-headed households. This variable is of no significance in households headed by women widows, and is perhaps the major distinguishing feature in the regression equations of the two groups. Approximately 71% of resident, male-headed households have members who belong to a producers’ association, as compare to 66% among households headed by women widows. A recent assessment of the impacts of USAID-funded programs in Kenya concluded that women were under-represented participants in the Kenya Maize Development Program relative to the population (Smale, Byerlee, and Jayne 2011).

Tobit regressions explaining the use of hybrid maize seed among households headed by absentee men and those headed by non-widowed women do not provide much additional information. Again, group membership is a significant variable among Group III households, but not for Group IV. Experience growing hybrids is again the major explanatory variable. Land owned is statistically significant in Group IV, although there is negative sign estimated for total assets in that group. The sign on the seed-to-grain price ratio is negative, as expected.

Table 9. Determinants of Hybrid Maize Seed Use by Households, Compared among Categories of Household Head

	Double hurdle				Tobit		Tobit	
	Group I		Group II		Group III		Group IV	
	Coeff.	P>z	Coeff.	P>z	Coeff.	P>z	Coeff.	P>z
Decision to grow hybrid								
Education of head	0.0170	0.1230	0.0042	0.8070				
Adult-equivalent household size	-0.0351	0.1950	-0.0131	0.8340				
Years growing hybrids/age	1.5042	0.0000	1.3940	0.0330				
Household membership in group	-0.1596	0.3380	0.4252	0.1350				
Distance to certified seed seller	-0.0120	0.3760	0.0094	0.6380				
Number of maize traders	0.0319	0.0030	0.0375	0.0460				
Land owned	0.0473	0.0540	0.0118	0.7960				
Total value of assets ('000,000)	-0.0994	0.6050	1.2900	0.0390				
Seed to grain price ratio	-0.0090	0.8590	-0.1614	0.0430				
Constant	1.1086	0.0220	0.9888	0.2270				
Kgs of hybrid seed purchased								
Education of head	-3.131	0.2650	0.135	0.5680	0.107	0.7910	0.237	0.5410
Adult-equivalent household size	16.90	0.0230	2.77	0.0020	-0.28	0.7970	1.55	0.1670
Years growing hybrids/age	393.300	0.0140	6.399	0.5100	24.234	0.0400	38.595	0.0330
Household membership in group	176	0.0020	0.059	0.9880	10.21	0.0300	7.84	0.1980
Distance to certified seed seller	6.71	0.0400	0.26	0.5210	-0.15	0.6530	-0.12	0.7560
Number of maize traders	1.259	0.5670	0.568	0.0220	0.076	0.8000	-0.470	0.1260
Land owned	5.80	0.0000	1.90	0.0000	0.47	0.1180	1.80	0.0690
Total value of assets ('000,000)	19.70	0.0000	0.70	0.7160	0.73	0.8080	-21.30	0.0190
Seed to grain price ratio	-167	0.0050	-2.970	0.0530	-1.292	0.2960	5.899	0.0280
Constant	-24	0.8830	-8.1	0.5550	-3.6	0.7710	-60.0	0.0170
Number of obs. = 714			N = 198		N = 55		N=16	
Wald chi2(9) = 45.81			Wald chi2(9) = 21.60		LR chi2(9) = 13.63		LR chi2(9) = 25.64	
Prob > chi2 = 0.0000			Prob > chi2 = 0.0000		Prob > chi2 = 0.1360		Prob > chi2 = 0.0023	
Log likelihood = -2500.58			Log likelihood = -598.23		Log likelihood =-194.62		Log likelihood = -53.64	

Source: Author, based on Tegemeo survey data (2010).

4.1. Discriminant and Cluster Analysis

Canonical linear discriminant analysis indicates that the explanatory variables in the regressions do not predict group membership well for Groups III and IV, but for Groups I and II, they predict their representation closely to the proportion in the population. The heaviest loading factors on the first discriminant function, which explains 90% of the variation in the data, are education of the household head (0.86), adult-equivalent household size (0.45), total acres owned (0.18), and group membership (-0.15). The seed-to-grain price ratio was not included in this regression because it is an infrastructural variable that is more closely related to hybrid seed use than to characteristics of the household.

These statistics can be interpreted as a confirmation that the variables and variation we are able to observe in the data do not support that Groups III and IV are identifiable and distinct. In addition, human capital factors, including past hybrid use, education and the number of working-age adults distinguishes among households groups.

Applying the same type of analysis to test which variables discriminate among users of hybrid maize in 2010, the heaviest loading factors in the single discriminant function generated are the year the household began growing hybrid seed (-0.93), followed by the number of maize traders in the village (-0.23). The coefficient of the household head category is only (0.08).

Finally, a cluster analysis was conducted to detect groupings among all recognized female-headed households based on distances between observations with respect to multiple variables rather than marital status and residence alone. Hierarchical cluster analysis based on Ward's dissimilarity matrix was performed on socio-demographic, income and capital variables (human, natural, physical, financial, and social). Applying either the Duda-Hart or Calinski-Harabasz stopping rules, no cutoff in the number of clusters was evident below 13-14 (of 15 generated). Reducing the range of variables to only socio-demographic indicators (education, marital status, residence, household size) did not change this result. Furthermore, same analysis applied to recognized male-headed households revealed similar results. Finally, I forced a limit of three clusters and applied K-means partition cluster analysis. About 86% of female-headed, and 90% of male-headed households, were each cluster into only one of the three groups. Results are shown in Appendix 1.

5. CONCLUSIONS

Circular migration is a very important phenomenon in some parts of Western Kenya, but not throughout the country. This type of migration often also means that male heads return to the farms they manage and today, communicate by other means, retaining more contact with household members on a daily basis than would be the case for the long-distance migration. A reflection of this fact is that, unlike the situation described by Pauline Peters (1995), and which this paper took as a starting point, there is less differentiation among female-headed households based on de facto vs. de jure status than there may be in other countries of eastern and southern Africa.

The two dominant groups in the Kenyan population, as defined by 1) gender of recognized head, 2) marital status, and 3), residence, are households headed by men who reside on the farm over six months of the year and households headed by women who are widows. The vast majority of female-headed households in Kenya are widows, and in our 2010 sample, the remaining groups (non-widows and women in households with absentee heads) are too small in number to analyze in a statistically meaningful way. As expected based on the literature, de jure female- and male-headed populations are statistically unequal (both in terms of mean and variance) according to most observed income and capital (human, social, physical, natural, financial) assets. Comparing households headed by resident males and those headed by widowed women only underscores these differences.

Male- and female-headed households in Kenya are statistical equal in terms of the years they have grown hybrid maize, access to credit and infrastructure. Neither are early adopters. On average, both groups have grown maize hybrids for two decades (since 1991). Some of this time, of course, the husbands of now widowed women were involved in this decision. Nonetheless, households headed by women who are widows have lower maize productivity, most likely as a reflection of differences in income and capital—and not because they are less efficient. These differences may also have been a consequence of widowhood. This hypothesis remains to be tested formally in the Tegemeo data, and is based on findings reported in the literature for Western Kenya. Overall, our statistical findings support the working hypothesis that whether a farmer is a man or a woman is not, in and of itself, the most important factor affecting adoption of agricultural technologies (e.g., Doss 1999).

When post-stratified by gender of household head, surveyed households do not cluster into subgroups based on observed difference in means among socio-demographic, income, or capital indicators—despite the fact that male- and female-headed households differ significantly at the mean, and have unequal variances, for virtually all of these same indicators. Male and female-headed households appear to be distinct populations in rural Kenya, and this is especially the case for households headed by men who reside at home more than six months a year, and households headed by women who are widows. However, the heterogeneity within each group, as measured by analysis of the variation in these same variables within each group, is not easily structured into clusters. Clearly, a more comprehensive, social definition of gender is needed to guide this type of statistical analysis.

6. RECOMMENDATIONS

Future econometrics research should be careful when defining the meaning of headship to consider various elements of marital status, residence, and headship recognition, particularly in areas of Africa with a history of migration. These definitions have implications for post-stratification of survey data and for specification of regression function. In principle, if male- and female-headed households represent statistically different populations, separate rather than pooled regressions should be estimated. Depending on the regression model used, a modified Chow test or Swait-Louviere test will confirm where separate or pooled regressions make statistical sense. Use of dummy variables may result in multicollinearity among independent variables, affecting the standard errors of coefficients and leading to failure to reject the null hypothesis.

Larger statistical samples are needed to adequately address heterogeneity among female-headed households, and qualitative research is needed to make this sampling *smart*. Qualitative research can guide development of hypotheses related to gender-differentiated demand for hybrid maize seed in Kenya, incorporating a more comprehensive social definition of gender. The Western Lowlands, in particular, is one agro-regional zone where more in-depth study is justifiable given that nearly half of households in the sample were recognized as headed by women. Further analysis of Tegemeo panel data should explore: a) analysis of longitudinal data rather than data for a single survey year; b) association of seed and fertilizer use, by headship; and c) analysis of maize productivity, post-stratified by headship.

APPENDIX

Cluster Analysis of Recognized Male- and Female-Headed Households

cluster wardslinkage tacres age educ experience hhsize10 grpmem mobacc aez crpinc10 vnetlvinc offrinc10 totasval_10 if femalehead==1, name (fhhclus)

cluster stop

Number of clusters	Calinski/ Harabasz pseudo-F
2	141.16
3	186.81
4	183.62
5	207.69
6	211.90
7	210.60
8	209.17
9	209.37
10	210.28
11	216.76
12	215.32
13	214.67
14	213.81
15	214.78

. cluster stop, rule (duda)

Number of clusters	Duda/Hart Je(2)/Je(1)	pseudo T-squared
1	0.6026	141.16
2	0.5865	149.49
3	0.4156	66.10
4	0.6112	103.69
5	0.6867	73.91
6	0.0000	.
7	0.6629	65.09
8	0.5812	24.50
9	0.5967	21.63
10	0.5511	8.96
11	0.4858	27.52
12	0.7107	44.78
13	0.6688	13.87
14	0.6044	10.47
15	0.4385	2.56

. cluster wardslinkage   tacres age educ experience hhsize10 grpmem mobacc aez crpinc10 vnetlvinc offrinc10 totasval_10 if femalehead==0, name (mhhclus)

. cluster stop

Number of clusters	Calinski/ Harabasz pseudo-F
2	908.31
3	1132.60
4	1178.58
5	1143.75
6	1099.84
7	1111.83
8	1113.63
9	1127.24
10	1112.83
11	1106.46
12	1116.40
13	1128.77
14	1156.51
15	1172.54

. cluster stop, rule (duda)

Number of clusters	Duda/Hart Je(2)/Je(1)	pseudo T-squared
1	0.4614	908.31
2	0.5536	626.56
3	0.4828	106.06
4	0.3746	140.23
5	0.8040	164.82
6	0.5078	548.57
7	0.7162	42.80
8	0.4606	97.21
9	0.7478	34.40
10	0.6466	48.65
11	0.5704	9.79
12	0.5017	84.44
13	0.3717	20.28
14	0.2715	10.73
15	0.6475	33.21

. cluster kmeans tacres age educ experience hhsize10 grpmem mobacc aez crpinc10 vnetlvinc offrinc10 totasval_10 if femalehead==1, k(3) name (fhhclus)

. tabulate fhhclus3

fhhclus3	Freq.	Percent	Cum.
1	15	6.94	6.94
2	18	8.33	15.28
3	183	84.72	100.00
Total	216	100.00	

. cluster kmeans tacres age educ experience hhsize10 grpmem mobacc aez crpinc10 vnetlvinc offrinc10 totasval_10 if femalehead==0, k(3) name (mhhclus)

. tabulate mhhclus3

```
 mhhclus3 |      Freq.     Percent        Cum.
------------+-----------------------------------
          1 |        724       92.82       92.82
          2 |         55        7.05       99.87
          3 |          1        0.13      100.00
------------+-----------------------------------
      Total |        780      100.00
```

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