What determines gender inequality in household food security in Kenya? Application of exogenous switching treatment regression

Menale Kassie[1], Simon Wagura Ndiritu[2], Jesper Stage[3]

[1]Scientist-Agricultural & Development Economist at CIMMYT (International Maize and Wheat Improvement Center), Nairobi, Kenya; e-mail: m.kassie@cgiar.org.

[2]Department of Economics, University of Gothenburg, Sweden and CIMMYT (International Maize and Wheat Improvement Center), Nairobi, Kenya; e-mail: Simon.wagura@economics.gu.se

[3] Department of Social Sciences, Mid Sweden University, Sweden; e-mail: Jesper.Stage@miun.se.

Abstract

The paper contributes to an understanding of the link between gender of household head and food security using household and plot level survey data from 88 villages and five districts in rural Kenya. We use an exogenous switching treatment regression effects approach to assess the gender food security gap. The study establishes that the female food security gap is attributable to observable differences in endowments and characteristics, but also to some extent to differences in the responses to those characteristics. We find that female headed households (FHHs) could have been more food secure, if they had had the male headed households' (MHHs) observable resources and characteristics. Even if that had been the case, however, our results indicate that FHHs would still have been less food secure than the MHHs. The analysis further reveals that that FHHs' food security influenced by many factors: household wealth, social capital network, land quality, input use, access to output markets, information and water sources. Policies targeting increasing FHHs resources access, reducing discrimination, strengthening local institutions and services and better road network will increase the food security status of the female farmer.

Keywords: food security, gender, discrimination, exogenous switching treatment regression, Kenya
JEL classification: O13, Q18

1. Introduction

In this paper, we study the food security of male- and female-headed households, using rich household- and plot- level survey data generated by the Kenya Agricultural Research Institute (KARI) in Partnership with the International Maize and Wheat Improvement Center (CIMMYT). More specifically, we aim to answer the following questions: Are female-headed households more likely to be food insecure compared to male-headed households? If so, why? Using better data and more sophisticated econometric techniques than previously applied to this problem, we are able to disentangle the effects of different types of gender inequalities in agriculture to a greater extent than previously possible.

Gender inequalities and lack of attention to gender in agricultural development contribute to lower productivity, higher levels of poverty, as well as under-nutrition (World Bank, FAO and IFAD, 2009; FAO 2011). The 2012 World Development report dedicated to *Gender Equality and Development* warns that the failure to recognize the roles, differences and inequities between men and women poses a serious threat to the effectiveness of agricultural development strategies (World Bank 2012).

In many countries in Africa, there has been a significant increase in the percentage of female-headed households (FHH) in recent years. Although African women are often responsible for providing food to their families both in female- and male-headed households (MHH), they generally have less access to land than men, less access to education, and are expected to carry most of the burden for housework and childcare. In addition to such easily observable inequality, there is also prevalent, less easily identifiable, discrimination in the form of less secure tenure, more superficial extension advice, rationing out of credit markets, and other subtle forms of social and cultural discrimination. This has implications for technology adoption, food security and access to markets. Increasing women's access to land, livestock, education, financial services, extension, technology and rural employment has the potential to boost their productivity and generate gains in agricultural output, food security, economic growth and social welfare (FAO, 2011; Meinzen-Dick et al., 2010). However, this will only address the effects of the easily observable forms of discrimination discussed above. The more subtle forms of discrimination might well remain, and could continue to cause worse outcomes for female headed households.

Although there is a considerable literature on the relationship between gender and agricultural productivity and technology adoption in Sub-Saharan Africa, gender gaps in food security have received far less rigorous empirical attention.[1] Our paper thus contributes to the literature in several directions. First, we consider the household's own perception of food security, which provides a better assessment of the food security situation throughout the year. The use of subjective measures, including self-reported poverty (see e.g. Deaton 2010, who argues for wider use of self-reported measures from international monitoring surveys) and people's subjective perceptions of their economic welfare (see e.g. Ravallion and Lokshin 2002 who used subjective economic welfare measures in Russia) is a growing field, and our paper represents one of the first applications to food insecurity.

Second, unlike earlier studies (e.g., Mallick and Rafi, 2010) that used pooled regression, we use an exogenous switching treatment regression effects approach which allows us to identify the effects of observable and unobservable discrimination against women on their food security status. This lets us understand the effects of both observable and unobservable gender discrimination on food security. To our knowledge, we are the first to disentangle different forms of discrimination against women and in particular apply impact evaluation methodologies in the context of gender impact on food security. Finally, we use plot level data which makes it possible to control for plot characteristics which have a direct impact on crop production which subsequently impacts food security.

The next section presents a survey of selected literature on food security. In section 3 we describe an exogenous switching regression (ESR) treatment effects approach to evaluate the responses of food security to gender. Section 4 covers the data, description of the variables and the descriptive statistics. The empirical results and discussions are found in section 5. Then section 6 concludes the paper with discussions on policy implications.

2. Food Security

Food security is a broad concept that includes issues related to the nature, quality, food access and security of the food supply (Iram and Butt 2004). The 1996 World Food Summit in Rome defined that "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO 1996). Hence, there is no single way of measuring food security.

Food insecurity has a temporal dimension. It is defined as transitory when a person suffers from a temporary decline in food consumption and as chronic when a person is

[1] For a comprehensive review of econometric evidence on gender differences in agricultural productivity and technology adoption in the developing world see Peterman et al. (2010; 2011).

continuously unable to acquire sufficient food (Chung et al., 1997). During transitory food insecurity a household can potentially adopt several coping strategies; however, for poor households one of these strategies is often to deplete productive assets, which may lead to chronic food insecurity in the longer term.

There is a growing literature on food security in developing countries. Using pooled regressions (with a gender dummy used as indicator in the regression) at the household level, Feleke et al. (2005) and Kidane et al. (2005) probed the household food security in rural households of Ethiopia. The studies link food security and adoption of new technologies (adoption of high yield varieties of maize and fertilizer application). They concluded that technology adoption increases household food security. Other factors analyzed include farm size, livestock ownership, education of head of household, household size and per-capita production of the household. With the exception of household size, all the other factors increase food security. However, these studies only assessed gender differences using a gender dummy; the possibility that gender might affect the impact of the explanatory variables, e.g. that an extra year of education or a slightly larger farm might have different impacts depending on the gender of the household head, was ignored.

Other studies have also found that wealth, ownership of assets such as land or livestock, and income are good predictors of food security (e.g. Iram and Butt 2004; Babatunde et al., 2008). A household with such resources is expected to better withstand shocks in production or prices that could create food shortages. More generally, food insecurity is linked to high food prices, poverty and low agricultural productivity (Nyangweso et al., 2007; Misselhorn, 2005; GoK 2008; Dávila 2010; Lewin 2011). Dávila found that higher prices for maize affected Mexican households' living standards and food security both in urban and rural areas, with the poorest net buyers of maize being the most affected. In Malawi, Lewin shows that a 25 percent increase in the price of maize flour would increase the likelihood of food insecurity in Northern Malawi by 12 percent, while a similar increase in fertilizer prices would increase food insecurity by 30 percent in the central region. Using dietary diversity among household in a poor Vihiga district in Kenya, Nyangweso et al. found that household income, number of adults, ethnicity, savings behavior and nutritional awareness are critical when addressing the question of food security from the demand side.

A number of different interventions have been shown to improve the food security situation. For instance, participation in dry lands interventions (e.g. Makueni district Agricultural Project, Kenya) such as irrigation have been shown by Lemba (2009) to have significant impacts on household food security, which was attributable to improved access to resources (mainly for production). Similar results were found for irrigation schemes in Malawi (Lewin 2011). In Nepal, Tiwari *et al.* (2010) assessed the effects of maize varietal intervention to improve productivity and food security. They found that food availability increased as a result of the improved varietal intervention with greater relative benefits to poor farmers compared to rich farmers. Nyangito et al. (2004) identified the economic and trade policy reforms introduced in Kenya. They found that market access for food imports has improved since the reforms, but the capacity to import food has declined, making the country more food insecure.

Most of these studies concentrate on objective food security measures at the household level. These measures look at the consumption (converted into calories) or expenditure data. Pinstrup-Andersen (2009) proposes that conditional on a set of assumptions about household behavior, total household income and food prices can be used to estimate the household food security. He further points out that consumption based estimates are an outcome of access to food, household food acquisition and allocation behavior. A food consumption method does not provide a full assessment of the food security because they fail to take into account the vulnerability and sustainability elements of food security. Consumption has a large seasonal volatility and most studies use only a single-round survey that frequently focuses on the last month before the survey was run; therefore, consumption data may systematically under- or over-report the true food security, depending on the time of year at which the survey was conducted.

A recent study, Mallick and Rafi (2010), therefore adopted subjective food security measures to overcome the shortcoming of the food consumption method pointed above. Based on all food sources (own production, food purchases, food from safety nets and welfare programs, harvesting from communal resources, etc.), the respondents were asked to assess the food security status of their households over the last twelve months as being in one of the following four categories: food shortage throughout the year (chronic or severe food insecurity); occasional food shortage (transitory food insecurity); no food shortage but no surplus (break-even); or food surplus. We follow their approach here.

It has generally been argued that, due to various forms of discrimination, female-headed households are more vulnerable to food insecurity and non-monetary aspects of poverty. For example, cultural restrictions on women's ability to participate fully in food production activities in some of the poorest areas of South Asia have left them particularly vulnerable in times of economic crisis (Kabeer 1990). Babatunde et al. (2008) conducted a gender-based analysis of vulnerability to food insecurity in Nigeria, and found that female headed households were indeed more vulnerable to food insecurity than male headed households. McLanahan (1985) found that children in female-headed households had lower rates of socio-economic attainment than children in male-headed households. If female-headed households utilize all available resources including engaging school going children to income generating activities to survive, then they end up with low education level attainment; thus, the risk of transmitting poverty and food insecurity to the next generation is higher. Kennedy and Peter (1992) found that the proportion of income controlled by women has a positive influence on household caloric intake.

Although discrimination of women is acknowledged in the literature, little rigorous work has been done that attempts to disentangle the various forms of discrimination women face with a focus on their impact on food security. Earlier studies typically use a binary gender indicator to capture all impacts. Thus, for instance, Mallick and Rafi (2010) use a pooled regression where they assume that the same set of covariates have the same impact on the probabilities for MHHs' and FHHs' food status, so that gender only shifts the intercept but not the slope of the coefficients. They find no significant differences in the food security between MHHs and FHHs among the indigenous ethnic groups in Bangladesh.

Women face different forms of discrimination, however. Some forms of discrimination can be easily captured in surveys; smaller, or poorer quality, plots are easily identifiable, as are lower levels of education, and both are likely to affect agricultural productivity and food security. Petty day-to-day discrimination – such as greater reluctance on the part of input providers to provide credit for fertilizer purchases for FHHs than for MHHs, less scope to borrow money or to buy food on credit, or more superficial advice from extension officers – can also affect food security but can be harder to capture in a survey. This is partly because it is less visible in itself, and partly because it tends not to be seen as worthy of note by respondents who have internalized the social norms associated with these forms of discrimination. Comparing MHHs and FHHs across the board, as earlier studies have done, permits identification of the overall impact of gender discrimination on food security, but not the effects of specific types of discrimination.

This has implications for policy interventions, especially interventions aimed at improving the food security status of FHHs in particular. If the problem is primarily one of discrimination in e.g. access to land or access to education, then explicit policy interventions banning these forms of discrimination will be called for. On the other hand, if e.g. technology adoption is less frequent among FHHs, or if education has less impact on food security for FHHs, e.g. because of poorer extension services or because of discrimination in small-scale credit for input purchases, then addressing the problem will require long term changes in social norms rather than outright bans. Identifying the precise causes of FHH food insecurity is therefore important from a policy perspective.

3. Econometric estimation methodology and strategy

In order to overcome the challenges discussed above, we use an exogenous switching regression (ESR) in a counterfactual framework. For the subjective food security measure we follow Mallick and Rafi (2010) and use a four-category food security assessment (1= chronic food insecurity, 2 = transitory food insecurity, 3 = breakeven, and 4= food surplus) made by the household as our outcome variables. In parts of the analysis we merge the first two and the last two categories into “food insecure” and “food secure” households, respectively.

3.1 Exogenous switching treatment regression (ESR) effects

Pooled regression (a dummy regression where a binary gender variable is used) may not be appropriate to assess the effect of gender on food security. This is because pooled model estimation assumes that the set of covariates have the same impact on FHHs and MHHs (i.e. common slope coefficient for both group). This implies that there is no interaction between gender variable and other explanatory variables; indicating that gender has only an intercept effect or parallel shift effect, which is always the same irrespective of the values taken by other covariates that determine food security. However, as discussed earlier, numerous variables might have different impacts for FHHs and MHHs; in our sample, the Chow test rejected the assumption of parallel shift (equality of coefficients for MHHs and FHHs) at a 0.1% significance level ($\chi_2(34) = 123.32$*** and = 142.96*** for binary food security and ordered food security outcome variables, respectively), giving a strong indication that gender-specific coefficient estimates are likely to be more informative.

The exogeneous switching treatment regression (ESR) framework can capture such interactions between gender and other household characteristics by estimating two separate equations (one for MHHs and one for FHHs) which is specified as follows:

$$(1) \quad \begin{cases} y_{im} = x_{im}\beta_m + u_{im} & \text{if } G = 1 \\ y_{if} = x_{if}\beta_f + u_{if} & \text{if } G = 0 \end{cases}$$

where the subscripts m and f denote, respectively, MHHs and FHHs. The two y variables are the food security outcomes for the two groups, G is a gender dummy variable set equal to 1 for

MHHs and zero otherwise, the two x vectors are vectors of household and plot characteristics that determine food security, the two β vectors capture how MHH and FHH food security, respectively, respond to those household and plot characteristics, and u is the error term with zero mean and constant variance.

Equation 1 may not allow us to directly examine the role of gender on food security both groups of households because their characteristics could be different. Following Carter and Milon (2005) and Di Falco et al. (2011) and the impact evaluation literature, we compute the average food security for both MHHs and FHHs by comparing the expected values of the outcomes of MHHs and FHHs in actual and counterfactual scenarios. The "actual" MHH and FHH scenarios are the ones actually observed in the data. The "counterfactual" scenarios show what the food security status for FHHs would be, if they had had the same characteristics as the MHHs but continued to respond to those characteristics in the way they do now, and vice versa. Alternatively, what the food security status of FHHs would be if the returns (coefficients) to their characteristics had been the same as the current returns to MHHs' characteristics, and vice versa. The estimates from ESR allow computing the expected values in the real and hypothetical scenarios presented in Table 1 and defined below:

$$(1a)\ \ E(y_{im}|G=1)=x_{im}\beta_m$$

$$(1b)\ \ E(y_{if}|G=0)=x_{if}\beta_f$$

$$(1c)\ \ E(y_{if}|G=1)=x_{im}\beta_f$$

$$(1d)\ \ E(y_{im}|G=0)=x_{if}\beta_m$$

Equations (1a) and (1b) represent the actual expectations observed from the sample, while equations (1c) and (1d) are the counterfactual expected outcomes. Using these conditional expectations and considering the gender variable as a "treatment" variable, the average gender food security outcome differences derived as follow.

The change in MHHs's food security (MFS), if they had had the same characteristics as they do now, but the same returns to those characteristics as FHHs have now, is given as the difference between (1a) and (1c)

$$(2)\ \ M\text{FS}=E(y_{im}|G=0)-E(y_{if}|G=1)=x_{im}(\beta_m-\beta_f)$$

Similarly, the expected change in FHHs's food security (FFS) if they had had the same returns to their characteristics as the MHHs have, is given as the difference between (1b) and (1d)

(3) $F\text{FS} = E\left(y_{if} \middle| G=0\right) - E\left(y_{im} \middle| G=0\right) = x_f\left(\beta_f - \beta_m\right)$

Equations (2) and (3) are equivalent to the average treatment effect on the treated and on the untreated, respectively, in the impact evaluation literature and the coefficient effects in the literature of wage decomposition where MHHs (FHHs) had FHHs's (MHHs's) coefficients or alternatively the returns (coefficients) to characteristics are the same for both groups. In our study, they indicate what outcomes MHHs would have had if the unobservable factors facing them had been the same as those currently facing FHHs, and vice versa.

<Insert Table 1 here>

As shown in Table 1, the above framework can also be used to compute the heterogeneity effects as the difference between (1a) and (1d) and (1b) and (1c). MHHs and FHHs do in fact have different observable characteristics, and this would have an impact even if their responses to the characteristics had been the same. The heterogeneity effects show, respectively, what the difference would have been if all households had had the current MHH responses and the current FHH responses to the observable characteristics.

The parameters β_m and β_f are estimated using probit and ordered probit models. Ordered probit regression is used because the response on food security is ordered in nature. However, because some of the categories have few observations relative to others, we also estimate a binary probit model to check results robustness. In doing this, as mentioned earlier, the four categories are combined into two: food secure (combining break-even and food surplus) and insecure (combining chronic and transitory food insecurity)

4. Data and Description of Variables

We use detailed primary household and plot survey data from 589 farm households and 2,779 plots (defined on the basis of land use), in 88 villages in 5 districts in Kenya where maize-legume systems are predominant. The survey was conducted in January to April 2011 using trained and experienced enumerators who knew the farming systems and spoke the local language.

In the first stage in the sampling procedure, five districts from two regions of Kenya were selected based on their maize-legume production potential: Bungoma and Siaya districts from western region and Embu, Meru South, and Imenti South districts from eastern region. Each of the two zones was assigned equal number of sample households. The households within a zone were distributed within the two respective districts according to the number of households per district (proportionate sampling). Multi-stage sampling was employed to select lower levels sampling clusters: divisions, locations, sub-locations and villages. In total, 30 divisions were selected - 17 from western Kenya and 13 from Eastern Kenya. Efforts were made to ensure representativity of the sample depending on the population of the study areas. Proportionate random sampling was designed where the total number of households in each of the division was compiled. Out of the list, the villages to be surveyed were randomly picked from the list prepared. The number of villages surveyed in each division was proportional to the total number of households in each of the division. Furthermore, a list of households was made from each of the selected villages and the households to be surveyed were randomly picked from this list. The number of households surveyed in each village was proportional to the number of households in that village.

The survey covered detailed household, plot, and village information. Trained enumerators collected a wide range of information on the households' production activities, plot-specific characteristics, demographic and infrastructure information for each household and village. The enumerators also collected a number of other plot attributes: soil fertility, where farmers ranked their plots as poor, medium or good (a dummy variable was set equal to 1 for the selected rank and zero for the others); soil depth, where farmers ranked their plots as deep, medium deep or shallow (a dummy variable was set equal to 1 for the selected rank and zero for the others); distance of the plot from the household dwelling, in minutes of walking. Other information collected at the plot level was tenure status of plots (participation in land rental markets by renting or renting out land), crop production estimates, and inputs associated with each type of agricultural activity.

Key socioeconomic elements collected about the household include age, gender, and education level of head of households, family size, household wealth indicators (livestock, farm size, and other physical assets), social capital network including membership in farmers' organizations and number of traders the respondent knows in their vicinity.   Information at village level were also collected including distance to nearest output markets, extension office and water sources.

The household survey also includes individual rainfall shock variables derived from respondents' subjective rainfall satisfaction, in terms of timelines, amount, and distribution. The individual rainfall index was constructed to measure the farm-specific experience related to rainfall in the preceding three seasons, based on such questions as to whether rainfall came and stopped on time, whether there was enough rain at the beginning and during the growing season, and whether it rained at harvest time.[2] Responses to each of the questions (yes or no) were coded as favorable or unfavorable rainfall outcomes and averaged over the number of questions asked (five questions), so that the best outcome would be equal to 1 and the worst to zero.[3]

(a) Descriptive statistics

MHHs and FHHs are 81 and 19 per cent of all the households in the sample, respectively. 82 and 18 per cent of the total plots (2779 plots) are operated by MHHs and FHHs, respectively.

Definitions of variables used in the analysis and summary statistics and statistical significance tests on equality of means for continuous variables and equality of proportions for binary variables for male- and female-headed households are presented in table 2.

<Insert table 2 here>

The results in table 2 show that about 11 per cent of the FHHs suffer from chronic food insecurity, compared to 5 percent of the MHHs. Similarly, 47 and 41 per cent of the FHHs and MHHs suffer from transitory food insecurity, respectively. The difference in chronic food insecurity between MHHs and FHHs is statistically significant. On the other hand, 39 (14) per cent of the MHHs fall under the categories of break-even (food surplus) compared to 32 (10) per cent of the FHHs. 53 per cent of the MHHs are food secure (break even and food surplus are combined into food secure) compared to 42 per cent of the FHHs. This difference is statistically significant. FHHs, on average, have smaller farms and less education than their male counterparts. The differences in farm size and education level are statistically significant. As shown in Table 3, the probability of being food secure increases with farm size and level of education, as does food expenditure.

<Insert Table 3 Here>

Apart from absolute farm size difference, FHHs have lower quality land. 13 per cent of the cultivated area owned by FHHs fall in the poor soil fertility category, compared to 8 per cent owned by MHHs. Forty-nine per cent of the total cultivated land owned by MHHs is classified as good to medium fertile land, compared to 39 per cent of FHHs owned land. This difference may be associated with low use of land quality enhancing inputs (fertilizer and

[2] We followed Quisumbing (2003) to construct this index.

[3] Actual rainfall data would, of course, be preferable, but getting reliable village-level data in most developing countries, including Kenya, is difficult.

manure) and the fact that plots managed by FHHs are relatively far from their dwellings. In addition, FHHs rent out more land than MHHs. This may affect the quality of land if tenants do not manage rented land well.

MHHs and FHHs also differ in their bicycle ownership; MHHs own both assets to a greater extent, and the difference is statistically significant. Bicycles are an important means of transport, not merely for personal transportation but also for transporting produce.

The unconditional summary statistics and tests in the tables above in general suggest that FHHs are more food insecure, and that they lack important resources that have repercussions on their welfare including food security. However, because food security is an outcome of the interaction of several factors, we need to add careful multivariate analysis to study the causal effect of gender of household head on food security.

5. Empirical results and discussion

This section presents results from probit model, ordered probit model and exogenous switching regression. We first briefly discuss the determinants of food security before we discuss the causal effect of gender on food security.

(a) Determinants of food security

Estimated parameters for the probability of food security determinants are presented in Tables 4-6.[4] We report both the average marginal effects (AME) and robust standard errors. In the probit model, the dependent variable is a binary food security status variable which equals one if the household is food secure and zero otherwise, while in the ordered probit model, we used the ordered categorical food security variables discussed earlier.

<Insert Tables 4-6 here>

As indicated in Table 4, the average marginal effects of covariates are different for MHHs and FHHs. This supports the Chow test result, and thus further supports running separate food security regressions for the two groups. In addition, some of the covariates that

[4] We estimated the models with and without including potential endogenous regressors (fertilizer, seed and manure use, access to credit, membership to groups/associations, participation in land market), however, we report results with potential endogenous variables to save space and because the food security impact results are numerically close. Results are available upon request.

explain the food security status of MHHs do not explain the FHHs food security status and the vice-versa.

The results reveal that both household and plot level factors conditioned the food security status of MHHs and FHHs. The probabilities of FHHs falling into the different food security categories are influenced by access to social capital networks (grain traders and membership in rural institutions), physical capital (farm size and farm equipment ownership), natural capital (soil fertility) access to services (markets, information and water), human capital (age), access to labor (family size), distance from plot to dwelling, input use (chemical fertilizer and improved seeds), and geographic location variables (district dummies). Similarly, human capital (age), physical capital (farm size, farm equipment and bicycle ownerships), access to services (markets, information and water), input use (manure and chemical fertilizer), natural capital (soil fertility), participation in land rental markets, and geographic location variables (district dummies) all significantly affect MHHs' food security status.

The number of traders that FHHs know influences positively the likelihood of FHHs being food secure. A one percent increase in the number of traders, significantly reduces the probability of chronic and transitory food insecurity by 0.3 and 0.5%, respectively, and increases the probability of breakeven food security and food surplus, respectively, by 0.4% each. Traders can improve market access through regular supply of inputs and outputs as well as through provision of credit (interlinked contract). However, this variable has no significant effect on neither of the MHHs food security indicator outcome variables. Membership in rural institutions or farmers' groups increases the probability of FHHs food security and breakeven food security and food surplus. This is probably because social capital networks may serve as an important resource that FHHs can use to help mitigate the impact of adverse shocks (Quisumbing, 2003). However, social capital network variables only affect breakeven and food surplus MHHs. Distance to the nearest output market, water and information significantly decreases the probability of food security both for FHHs and MHHs.

Use of chemical fertilizer improves the food security for both FHHs and MHHs (measured using both the binary food security variable as well as the categorical variable). Use of improved seeds has a positive impact on FHH food security while use of manure has a positive impact for MHHs. These results suggest that improving access to inputs can play a significant role in increasing the food security condition of rural households.

Soil quality indicator (soil fertility and depth) variables have a positive effect on the likelihood of food security, indicating that increasing the productivity of land can contribute to reducing food insecurity in rural areas of Kenya. Finally, farmers in Embu, Imenti south, Meru south and Siaya districts seem more food secure compared to farmers in Bunguma district.

(b) Impact of gender of household head on food security

The switching regression results were used to estimate the conditional probability of food security expectations and to evaluate the treatment effects of gender. Results on the average causal effect of gender on food security are provided in Tables7-8.[5] The results reveal that the gender food security differential is apparently caused by differences in both observable and unobservable characteristics. FHHs could have been more food secure had they had MHHs' resources and characteristics. However, the results also indicate that there is some sources of unobserved heterogeneity that makes FHHs less food secure than the MHHs.

Considering cells (a) and (b) in table 7 which shows the observed expected probability of food security, the probability of food security of FHHs is 14.6 % less (0.575 versus 0.429), on average, than the MHHs. However, with the counterfactual condition (d) that the FHHs had MHHs' response coefficients, this difference would be reduced to about 5.8% (0.575 versus 0.517). Similarly, with the counterfactual condition (c) that the MHHs had the FHHs' characteristics, the probability of FHHs being food security would still be 11.4% lower. Under both counterfactual conditions, the FHHs have less probability of food security, indicating that there are some important sources of heterogeneity that makes the FHHs less food secure than the MHHs regardless of their observed characteristics. The last column of Table 7 presents the treatment effects of gender on probability of food security. In the counterfactual case (d) that the FHHs had the characteristics of MHHs, their average probability of food security would be 8.8% higher than it is now. Similarly, in the counterfactual case (c) that MHHs had the characteristics of FHHs, the mean probability of food security would be 3.3% less if they had FHHs' characteristics.

The results of the ordered probit model (table 8) also tell a similar story, where the probability of being chronic and transitory food insecurity of FHHs could have been significantly lower if they had the MHHs characteristics but nonetheless higher than those of the MHHs. Unobserved heterogeneity has also contributed in chronic and transitory gender

[5] The food security difference results obtained from the models with and without the potential endogenous variables are numerically close, so results from the regressions without endogenous variables are not reported but are available upon request.

food insecurity differences. The probability of being breakeven food security and food surplus of FHHs would also be increased by 4.2% (0.390 versus 0.348) and 6.7% (0.143 versus 0.076), respectively, it they had the MHHs characteristics.

These results imply that differences in observed resource endowments, and unobservable discriminations against women, both have an impact on the difference in food security between the genders.

6. Conclusions and policy implications

Using recent household and plot survey data from maize-legume systems in rural Kenya, we examine the reasons why female-headed households (FHHs) are more likely to be food insecure compared to male-headed households (MHHs).

All the farmers in our dataset reported their perceived food security. This gives us an opportunity to explore the subjective measure of food security, which provides a full assessment of the food security situation throughout the year where households consider their vulnerability.

The descriptive statistics, as well as statistical tests, suggest that FHHs are more food insecure; they are less well endowed with several important resources, which has repercussions on their welfare including food security. About 12 per cent of the FHHs suffer from chronic food insecurity compared to 6 percent of the MHHs. The difference in chronic food insecurity between MHHs and FHHs is statistically significant. With statistically significant difference, about 53 per cent of the MHHs are food secure (break even and food surplus are combined into food secure) compared to only 41 per cent of the FHHs. Tabulation of food security and food expenditures by land and education level shows that the probability of being food secure and food expenditures increase with farm size and level of education.

The econometric results confirm that FHHs are, in general, more likely to be food insecure than their male counterparts. However, we find that this cannot be explained by the differences in observable endowments alone; the exogenous switching regression shows that even under the counterfactual conditions where MHHs and FHHs are made more similar, the FHHs still have less probability of food security. This indicates that there are important additional gender-specific sources of food insecurity that make the FHHs less food secure than the MHHs regardless of their observed characteristics.

These results have important policy implications; they imply that although some of the gender differences in food security could be addressed through policy interventions of various kinds, important differences – presumably linked to gender-specific social norms, and differences in the way in which male and female farmers are treated – would still remain. Nonetheless, our study does identify several openings for policy interventions that could address some of the gender imbalances in fairly short order. The determinants of food security form parametric results suggest that FHHs food security increases with quality of extension workers, land quality, and farm size, while distance to the market reduces the probability of food security.

For the quality of extension staff, policy makers should focus on improving the skill of extension staff for efficient and effective dissemination of technologies and other important information that has impact on food security. Since area expansion is infeasible due to land scarcity in Kenya, policy makers focusing on land augmenting practices can help farm households to escape food insecurity. Although little can be done with respect to distance to markets, policy interventions could improve road quality and traffic through improving existing road networks and maintaining existing ones. Such investment is likely to have a positive impact on market integration, productivity and food security.

Finally, future analysis using repeated observations (or panel data) may be needed to examine the relationship between gender and food security in order to control for unobserved specific heterogeneity and to see if the MHHs-FHHs food security gap persists over time. To the extent that gender-specific norms drive part of the difference in food security, as our results suggest, panel data analysis would help to show whether those norms are changing over time or not.

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Table 1. Conditional expectations, treatment effects and Heterogeneity effects

Household types	Male headed households' responses to characteristics	Female headed households' responses to characteristics	Treatment effects (difference caused by difference in response to characteristics)
Male headed households' characteristics	(a) $E(y_{im} \mid G=1)$	(c) $E(y_{if} \mid G=1)$	*MFS* = (a) – (c)

Female headed households' characteristics	(d) $E(y_{im} \mid G=0)$	(b) $E(y_{if} \mid G=0)$	FFS = (d) – (b)
Heterogeneity effect (HE) (difference caused by differences in characteristics)	HE_m = (a) – (d)	HE_f = (c) - (b)	

Table 2: Descriptive statistics and description of variables

		Male-headed households		Female headed Households		
		Mean	SD	Mean	SD	mean diff
		A		B		(A-B)
Outcome variables						
Food security	Household food security status (1=food secure; 0= food insecure)	0.533		0.412		0.121**
Chronic food insecurity	Household suffer from chronic food security(1=yes; 0=no)	0.056		0.117		-0.062*
Transitory food insecurity	Household suffer from transitory food security(1=yes; 0=no)	0.412		0.471		-0.059
Break-even food security	Household has break-even security(1=yes; 0=no)	0.385		0.319		0.065
Food surplus	Household has food surplus(1=yes; 0=no)	0.148		0.092		0.056
Treatment variable		0.80		0.20		
Gender	Head of household (1=male; 0=female)					
	Independent variables					
Plot characteristics and investment						
Improved seeds use	Adoption of any improved seed varieties(1=yes; 0=no)	0.46		0.43		0.03
Fertilizer use	Intensity of chemical fertilizers use (kg/ha)	87.7	124.52	69.4	104.22	18.3***
Manure use	Amount of manure use on a plot('000 Kg)	0.75	1.3	0.64	1.9	0.11*
Plot distance	Plot distance to dwelling (in walking minutes)	6.91	16.2	8.05	19.33	-1.14
Good fertile plot	Farmers' perception that plot has good fertile soil (1=yes; 0=no)	0.33		0.25		0.08***
Moderately fertile plot	Farmers' perception that plot has moderately fertile soil (1=yes; 0=no)	0.54		0.53		0.01
Poor fertile plot (ref)	Farmers' perception that plot has poor fertile soil (1=yes; 0=no)	0.13		0.22		-0.09***
Shallow depth plot (ref)	Farmers' perception that plot has shallow deep soil (1=yes; 0=no)	0.15		0.14		0.01
Moderately deep plot	Farmers' perception that plot has moderately deep soil (1=yes; 0=no)	0.65		0.67		-0.02
Deep plot	Farmers' perception that plot has deep soil (1=yes; 0=no)	0.21		0.19		0.01
Social capital network						
Trader	Number of traders that farmer knows (number)	7	7.57	5.17	4.12	1.74**
Membership	Household belong to a rural institution or farmers' group	0.74		0.74		0

Household characteristics and endowments						
Education	Education level of household head (years of schooling)	7.99	3.61	4.54	3.96	3.45***
Age	Age of household head (years)	48	12	52	12	-4.0***
Family size	Total family size (number)	5.97	2,61	4.81	2,71	1.17***
Own land (ref)	Own plot (1=yes; 0=no)	0.89		0.87		0.55
Rent in land	Rented in plot (1=yes; 0=no	0.1		0.1		-0.21
Rent out land	Rented out plot (1=yes; 0=no)	0.02		0.03		-0.15
Farm size	Total farm size(acre)	0.78	0.88	0.61	0.52	0.17**
Livestock	Livestock ownership (TLU)	2.37	2.68	1.76	1.65	0.61**
Asset owershiip	Asset value of major farm equipment ('000 KSh)	2.51	3.88	2.56	5.97	0.05
Bicycle	Household own bicycle (1=yes; 0=n0)	0.63		0.46		0.16***
Location characteristics						
Rain fall index	Rainfall satisfaction index(1=close to best)	0.58	0.32	0.56	0.3	0.03
Distance to market	Distance to the nearest output market (in walking minutes)	78.59	52.58	84.12	58.81	-5.53
Distance to water sources	Distance to the nearest water source(in walking minutes)	8.39	9.48	9.94	10.35	1.55
Distance to information source	Distance to the nearest extension office (in walking minutes)	67.71	56.89	68	58.50	0.28
Season	Crop production season (1=long rainy season;0=short rainy season)	0.53		0.52		0.02
Bungoma district(ref)	Bungoma District (1 = yes; 0 = no)	0.26		0.16		
Embu district	Embu district (1 = yes; 0 = no)	0.17		0.24		
Imenti south district	Imenti south district (1 = yes; 0 = no)	0.17		0.13		
Meru south district	Meru south district (1 = yes; 0 = no)	0.18		0.13		
Siaya district	Siaya district (1 = yes; 0 = no)	0.23		0.34		
	Number of Plot (household) observations	2274(486)		505(119)		

Note: *, **, and *** indicate significance at10, 5, and 1% level.

Table 3: Food security and food expenditures by land category and education level

Quartiles	Land		Education	
	Food security (%)	Annual food expenditure (Ksh)	Food security	Food expenditure (Ksh)
1 (Lowest)	44	59885	50	62710
2(Lowest middle)	47	72946	48	63498
3 (Upper middle)	52	77437	52	79637
4(Highest)	61	87410	54	88951

Table 4 Determinants of binary food security status: Probit model

Explanatory Variables	Female headed households			Male headed households		
	AME	SE	P>z	AME	SE	P>z
Social capital network						
Trader	0.020***	0.003	0.000	0.001	0.001	0.340
Group membership	0.101***	0.036	0.005	-0.009	0.022	0.678
Household characteristics and endowments						
Education	0.003	0.005	0.600	-0.003	0.003	0.249
Ln(Household head age)	0.336***	0.052	0.000	-0.193***	0.035	0.000
Family size	0.019***	0.006	0.003	-0.001	0.004	0.835
Livestock	0.005	0.014	0.733	-0.004	0.004	0.276
Ln(Farm size)	0.156**	0.068	0.021	0.186***	0.031	0.000
Asset value	0.005*	0.003	0.070	0.003	0.002	0.228
Bicycle ownership	-0.012	0.036	0.744	0.086***	0.020	0.000
Plot characteristics and investments						
Plot distance	-0.001*	0.001	0.085	0.000	0.001	0.507
Deep fertile plots	0.141**	0.059	0.016	0.257***	0.030	0.000
Medium fertile plots	0.066	0.056	0.236	0.115***	0.029	0.000
Moderately deep soil plots	-0.018	0.055	0.742	0.028	0.032	0.383
Deep soil plots	0.006	0.051	0.914	0.049*	0.026	0.060
Fertilizer use	0.000*	0.000	0.098	0.000**	0.000	0.016
Improved seeds use	0.072**	0.033	0.030	-0.009	0.019	0.640
Manure use	-0.013	0.013	0.315	0.021***	0.007	0.002
Rented in plots	-0.007	0.054	0.889	0.059*	0.035	0.091
Rented out plots	-0.160	0.129	0.213	-0.075	0.070	0.286
Location characteristics						
Distance to extension office	-0.001**	0.000	0.022	0.000***	0.000	0.006
Distance to output market	-0.001***	0.000	0.000	-0.001***	0.000	0.003
Distance to water source	-0.010***	0.001	0.000	-0.003	0.001	0.000
Rainfall index	-0.028	0.064	0.655	0.035	0.033	0.294
Season	-0.004	0.031	0.894	-0.014	0.018	0.456
Embu district	0.380***	0.052	0.000	0.288***	0.033	0.000
Imenti south district	0.393***	0.048	0.000	0.444***	0.033	0.000
Meru south district	0.429***	0.051	0.000	0.351***	0.032	0.000
Siaya district	0.104	0.065	0.109	0.120***	0.030	0.000
Regression diagnostics						
Wald chi2(28)	502.29***			208.29***		
Pseudo R2	0.197			0.384		
Log pseudo likelihood	-1264			-219.2		
Number of plots(households) observations	2310(486)			521(119)		

Note: *, **, and *** denote significance level at 10, 5 and 1% level.

Table 5: Ordered probit model results on the determinants of FHHs food security status

	Chronic food insecurity			Transitory food insecurity			Breakeven food s	
	AME	SE.	P>z	AME	SE	P>z	AME	SE
Social capital networks								
Trader	-0.003**	0.001	0.028	-0.005**	0.003	0.037	0.004**	0.002
Group membership	-0.024**	0.011	0.037	-0.041*	0.025	0.100	0.035*	0.017
Household characteristics and endowments								
Education	-0.003	0.002	0.129	-0.005	0.004	0.167	0.004	0.003
Ln(Household head age)	-0.082***	0.022	0.000	-0.152***	0.039	0.000	0.122***	0.029
Family size	-0.001	0.002	0.508	-0.003	0.004	0.528	0.002	0.003
Livestock	-0.001	0.006	0.922	-0.001	0.011	0.923	0.001	0.009
Ln(Farm size)	-0.023	0.024	0.345	-0.042	0.045	0.350	0.034	0.036
Asset value	-0.004***	0.001	0.000	-0.008***	0.002	0.000	0.006***	0.002
Bicycle ownership	0.010	0.013	0.455	0.018	0.023	0.424	-0.014	0.019
Plot characteristics and investments								
Plot distance	0.001***	0.000	0.086	0.001*	0.001	0.063	-0.001*	0.000
Deep fertile plots	-0.049***	0.015	0.001	-0.103*	0.042	0.014	0.072***	0.023
Medium fertile plots	-0.026	0.016	0.108	-0.047	0.036	0.186	0.039	0.026
Moderately deep soil plots	-0.032*	0.017	0.056	-0.068	0.045	0.134	0.047*	0.025
Deep soil plots	-0.052***	0.016	0.001	-0.085**	0.034	0.013	0.076***	0.023
Fertilizer use	0.000***	0.000	0.003	0.000***	0.000	0.000	0.000***	0.000
Improved seeds use	-0.011	0.010	0.280	-0.021	0.022	0.324	0.017	0.016
Manure use	0.002	0.004	0.692	0.003	0.008	0.697	-0.003	0.007
Rented in plots	0.028	0.023	0.221	0.044	0.030	0.137	-0.041	0.031
Rented out plots	0.082	0.058	0.158	0.088**	0.035	0.013	-0.107*	0.065
Location characteristics								
Distance to extension office	0.000	0.000	0.684	0.000	0.000	0.686	0.000	0.000
Distance to output market	0.001***	0.000	0.000	0.001***	0.000	0.000	-0.001***	0.000
Distance to water source	0.002***	0.000	0.000	0.004***	0.001	0.000	-0.003***	0.001
Rainfall index	-0.050***	0.025	0.042	-0.094**	0.040	0.020	0.075**	0.034
Season	0.006	0.011	0.572	0.012	0.020	0.550	-0.009	0.016
Embu district	-0.087***	0.015	0.000	-0.241***	0.056	0.000	0.105***	0.021
Imenti south district	-0.089***	0.015	0.000	-0.250***	0.051	0.000	0.106***	0.021
Meru south district	-0.097***	0.016	0.000	-0.308***	0.069	0.000	0.114***	0.031
Siaya district	-0.034**	0.021	0.096	-0.066	0.046	0.153	0.045*	0.026
Regression diagnostics								
Wald chi2(28)	209.73***							
Pseudo R2	0.181							
Log pseudo likelihood	-485.4							
Number of (plots)households observations	521(119)							

Note: *, **, and *** denote significance level at 10, 5 and 1% level.

Table 6: Ordered probit model results on the determinants of MHHs food security status

	Chronic food insecurity			Transitory food insecurity			Breakeven food security			Food surplus		
Explanatory variables	AME	SE	P>z	AME	SE	P>z	AME	SE	P>z	AME	SE	P>z
Social capital network												
Trader	0.000	0.000	0.562	0.000	0.001	0.560	0.000	0.000	0.561	0.000	0.001	0.560
Group membership	-0.010	0.005	0.038	-0.026	0.014	0.059	0.014**	0.007	0.033	0.023*	0.012	0.067
Household characteristics and endowments												
Education	0.000	0.001	0.597	0.001	0.002	0.598	0.000	0.001	0.597	-0.001	0.002	0.598
Ln(Household head age)	0.012	0.008	0.146	0.032	0.021	0.139	-0.016	0.011	0.147	-0.028	0.019	0.138
Family size	0.000	0.001	0.879	0.000	0.002	0.879	0.000	0.001	0.879	0.000	0.002	0.879
Livestock	0.001	0.001	0.144	0.004	0.002	0.143	-0.002	0.001	0.144	-0.003	0.002	0.143
Ln(Farm size)	-0.044***	0.008	0.000	-0.115***	0.020	0.000	0.058***	0.010	0.000	0.101***	0.017	0.000
Asset value	-0.001***	0.001	0.017	-0.004**	0.002	0.017	0.002**	0.001	0.016	0.003**	0.001	0.018
Bicycle ownership	-0.025***	0.005	0.000	-0.06***	0.014	0.000	0.033***	0.006	0.000	0.054***	0.013	0.000
Plot characteristics and investments												
Plot distance	0.000	0.000	0.200	0.001	0.001	0.193	0.000	0.000	0.197	-0.001	0.000	0.193
Deep fertile plots	-0.047***	0.005	0.000	-0.142***	0.022	0.000	0.056***	0.005	0.000	0.133***	0.023	0.000
Medium fertile plots	-0.027***	0.006	0.000	-0.068***	0.019	0.000	0.036***	0.007	0.000	0.060***	0.018	0.001
Moderately deep soil plots	-0.016***	0.006	0.009	-0.047**	0.021	0.024	0.021***	0.007	0.004	0.043**	0.020	0.033
Deep soil plots	-0.008	0.006	0.165	-0.021	0.016	0.200	0.011	0.008	0.158	0.018	0.015	0.209
Fertilizer use	0.000***	0.000	0.001	0.000***	0.000	0.001	0.000***	0.000	0.001	0.000***	0.000	0.001
Improved seeds use	0.000	0.005	0.966	0.001	0.012	0.966	0.000	0.006	0.966	0.000	0.011	0.966
Manure use	-0.003*	0.002	0.055	-0.008*	0.004	0.051	0.004*	0.002	0.055	0.007*	0.004	0.050
Rented in plots	-0.026***	0.006	0.000	-0.085***	0.023	0.000	0.031***	0.005	0.000	0.080***	0.024	0.001
Rented out plots	-0.016	0.016	0.327	-0.048	0.057	0.404	0.019	0.017	0.265	0.044	0.056	0.429
Location characteristics												
Distance to extension office	0.000***	0.000	0.000	-0.001***	0.000	0.000	0.000***	0.000	0.000	0.001***	0.000	0.000
Distance to output market	0.000**	0.000	0.010	0.000***	0.000	0.008	0.000***	0.000	0.009	0.000***	0.000	0.009
Distance to water source	0.000*	0.000	0.045	0.001*	0.001	0.048	-0.001*	0.000	0.050	-0.001**	0.000	0.045

Rainfall index	0.016*	0.008	0.047	0.042*	0.021	0.046	-0.021**	0.010	0.044	-0.037**	0.019	0.047
Season	0.005	0.005	0.282	0.013	0.011	0.259	-0.006	0.006	0.287	-0.011	0.010	0.253
Embu district	-0.044***	0.005	0.000	-0.149***	0.025	0.000	0.047***	0.004	0.000	0.146***	0.029	0.000
Imenti south district	-0.054***	0.005	0.000	-0.230***	0.023	0.000	0.049***	0.009	0.000	0.235***	0.030	0.000
Meru south district	-0.051***	0.005	0.000	-0.185***	0.022	0.000	0.052***	0.005	0.000	0.184***	0.026	0.000
Siaya district	-0.015***	0.007	0.024	-0.039*	0.020	0.046	0.017**	0.007	0.017	0.036*	0.019	0.054
Regression diagnostics												
Wald chi2(28)	577.98***											
Pseudo R2	0.098											
Log pseudo likelihood	-2469											
Number of plots(households) observations	2310(486)											

Note: *, **, and *** denote significance level at 10, 5 and 1% level.

Table 7. Average probability of food security, treatment and heterogeneity effects(Dependent Varaiable: binary food security)

Household type	MHH responses	FHH responses	Treatment effect
MHH characteristics	0.575	0.542	0.033(0.009)***
FHH characteristics	0.517	0.429	0.088(0.018)***
Heterogeneity effects	0.058(0.012)***	0.114(0.017)***	

Table 8. Average probability of food security, treatment and heterogeneity effects(Dependent Varaiable: ordred food security)

Household type	Chronic food insecurity			Transitory food insecurity			Breakeven food security			Food surplus		
	Male headed	Female headed	Treatment effect	Male headed	Female headed	Treatment effect	Male headed	Female headed	Treatment effect	Male headed	Female headed	Treatment effect
Male headed	0.050	0.068	-0.018 (0.002)***	0.374	0.428	-0.054 (0.005)***	0.406	0.387	0.019 (0.004)***	0.170	117	0.053 (0.004)***
Female headed	0.066	0.096	-0.030 (0.007)***	0.402	0.481	-0.079 (0.010)***	0.390	0.348	0.042 (0.009)***	0.143	0.076	0.067 (0.007)***
Heterogeneity	-0.016	-0.028 (0.005)		-0.027 (0.007)***	-0.053 (0.009)**		0.016 (0.004)***	0.039 (0.008)*		0.027 (0.006)**	0.042 (0.007)***	

effect	(0.003)***	***			*			**		*		