Adoption of Agricultural Technologies in Kenya: How Does Gender Matter?

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Abstract

This paper uses plot level data to investigate the agricultural technologies adoption across male and female plots managers in Kenya with particular attention on complementarity or substitutability of several technologies on a plot. Using Multivariate probit model we found that all the technologies under consideration complement each other. The analysis further shows that women plot managers are more likely to adopt soil and water conservation but are less likely to apply animal manure relative to male managed plots. But we find no gender differences for adoption of maize-legume intercropping, maize-legume rotation, improved seed varieties, minimum tillage and inorganic fertilizer.

Key words: Complementarity, Gender, Agricultural Technology Adoption, Multivariate Probit, Kenya

JEL classification: O13, Q16

1. Introduction

In this study we examine gender and technologies adoption, by analyzing adoption of several agricultural technologies across jointly managed plots, female- and male-managed plots in Kenya. We investigate whether gender may play an important role in influencing technologies adoption decisions. Different groups differ in their characteristics, endowments and technology adoption behaviors. For instance, it has generally been observed that women headed households are resource poor in Sub-Sahara Africa (SSA) and Kenya is no exception. On access to resources, there are gender specific constraints that women face in SSA such as less education, inadequate access to land, low level of production assets and livestock ownership. These have direct effect on technology adoption where women are usually less likely to adopt new technologies that are resources demanding. In our study areas women own fewer cattle compared to men and this could have implications on low adoption of animal manure by female farmers. Based on the desire to increase soil fertility and retain soil moisture, farmers adopt several technologies in a plot. The study also tests if the technologies under consideration are compliments or substitutes.

Gender issues in Africa have been of continuing interest to researchers and policy makers for decades. The main proposition underlying this interest is that an African woman plays a key role in farm work where they are responsible for family food security and home production. In spite of their family farm contribution, women lag behind in ownership of key family assets and livestock, access to entitlements, power struggle in controlling family resource allocation and their social status is generally low compared to their male counterparts. It has been realized by many Non-Governmental organizations (NGOs), development partners and governments that large scale adoption of new agricultural technologies is essential for sustainable production of food in Africa where food insecurity is common. These technologies have to address the needs and adaptability of the female farmer who play an important role in smallholder agriculture. IFPRI (2005) assessment of the impact of vegetable and fishpond technologies on poverty in rural Bangladesh concludes that targeting women in agricultural technology dissemination can have a greater impact on poverty than targeting men.

It has generally been observed that Sub-Sahara African agriculture has stagnant productivity that is very low especially when contrasted with the green revolution in South Asia (World Bank 2007). Notable is soil nutrient depletion and the declining or stagnating maize and legume yields. Several factors attributed to this low productivity includes declining soil fertility, low or poorly distributed rainfall, slow and limited adoption of yield improving technologies such as fertilizer and improved seed varieties, among other factors. Farmers with extremely low ability to purchase soil fertility enhancing inputs like fertilizers can adopt maize-legume intercropping which has been argued as one of the cheapest way to counter the declining soil fertility in African agriculture. As a method of improving soil fertility and moisture retention, conservation agriculture (CA) technologies such as crop rotation and minimum tillage have been tested and proved to work well especially in Latin America (McKell and Peiretti 2004, Landers 2007). However, CA requires farmers to apply both more labor and more purchased inputs to achieve their higher yields making women to be disadvantaged in the adoption of these technologies.

This study departs from the gender differential literature in that we use female and male plot manager rather than the female- and male-headed household. This disaggregation at the plot level between female- and male-managed plots is more concrete compared to household head gender disaggregation because the sex of the household head is not a clear-cut of who makes decisions (Peterman *et al*., 2010). Usually the development of most of the agricultural technologies is not based on a comprehensive analysis of gender roles and as a result they do not offer equal opportunities for women and men to participate and benefit. In addition, the productivity of labor will be altered depending on accessibility of the technology between men and women. There is a clear need; therefore, to have analysis that takes into account the social and economic situations of the farmers as well as consideration of gender within which the technologies will be adopted.

While reasonable attention has been paid to differential adoption to inputs such as improved seeds varieties and chemical fertilizer (Doss and Morris 2001; Bourdillon *et al*., 2002; Chirwa 2005; Freeman and Owiti 2003), there is lack of evidence on gender differences for adoption of technologies such as maize-legume intercropping, maize-legume rotation and minimum tillage. This study aims to fill this gap. Adoption of these technologies could be influenced by gender differential because of their resource requirements especially labor and land. For instance, intercropping is associated with female farmers who have less land while crop rotation and minimum tillage are usually practiced by farmers with larger plots.

The general objective of this study is to analyze gender differences in agricultural technologies adoption in Kenya. We also want to know whether there is complementarity or substitutability among various technologies. The specific objectives are: (1) to analyze the gender roles in the farming behavior of farmers in the study areas. (2) To evaluate the gender differences in the adoption of minimum tillage, soil and water conservation (SWC), maize-legume intercropping, maize-legume rotation, manure application, inorganic fertilizer and improved seed varieties (Maize and Legumes). (3) To check complementarity or substitutability among the technologies considered in this study and lastly, to draw policy implication from the results.

The contribution of this paper is three fold. First, it is one of a very few empirical studies on the link between gender and agricultural technology adoption in sub-Saharan Africa. Unlike many gender studies in the literature, we disaggregate gender at the plot level between female- and male-managed plots. Given the fact that agricultural productivity and agricultural technology adoption has remained low in Africa than on any other continent, new empirical insights on agricultural technology adoption and its determinants are essential to better policy design. Second, we rely on multiple plot observations to jointly analyze factors that influence agricultural technologies adoption. One novelty of this study is to consider multiple technologies unlike the usual studies in technology adoption which study single technology. In reality it is common practice for farmers to simultaneously adopt different technologies on their plots. Third, we consider the complementarity and substitutability among the various technologies under consideration. Thus we address a shortcoming of most of previous technology adoption studies which do not consider the possible interrelationship among the agricultural technologies adopted by farmers (Yu *et al.,* 2008).

The major finding of the present paper is that all the technologies under consideration have positive correlations meaning that the agricultural technologies under study complement each other in a plot where they are adopted. The analysis further shows that gender differential in some technology adoption do exist. Women plot managers are more likely to adopt SWC but are less likely to apply animal manure relative to male managed plots. Jointly managed plots are less likely to adopt minimum tillage and more likely to adopt maize-legume intercropping and improved seed varieties relative to male managed plots. But we find no gender differences for adoption of maize-legume intercropping, maize-legume rotation, improved seed varieties, minimum tillage and application of inorganic fertilizer. The results further show that the adoptions of agricultural technologies are strongly influenced by plot characteristics and household factors such as plot size, plot ownership, soil fertility, extension services, access to credit, and age.

The rest of the paper is organized as follows. Section 2 discusses overall agriculture and technology adoption in Kenya. Section 3 reviews gender issues in agricultural technology adoption literature. Section 4 describes the data, sampling procedures and the descriptive statistics. Section 5 discusses the methodology and section 6 discusses the results. Finally, section 7 concludes.

2. Agricultural technology adoption in Kenya

In Kenya, the agricultural sector directly contributes 24 percent of the Gross Domestic Product (GDP) and 27 percent of GDP indirectly through linkages with manufacturing, distribution and other service related sectors. It also employ about 70 percent of the country’s labor force and contributing 60 percent of export earnings, being the highest foreign exchange earner in Kenya (GoK 2004). Due to these reasons the Government of Kenya (GoK) has continued to give agriculture a high priority in agricultural sector development strategy. Agricultural development is ranked high in Vision 2030 for achievement of food security in Kenya. The vision aims at increasing GDP from agriculture through an innovative, commercially oriented and modern agriculture (GoK 2007). These interventions are mainly through better yields in key crop such as maize, legumes etc. This can only be achieved if we are able to understand the farming technologies adopted by farmers and the drivers of the adoption behavior.

Land degradation which contributes to low and declining farm productivity is common in many parts of SSA and Kenya is no exception. Efforts to alleviate land degradation in Kenya involves investment in soil and water conservation (SWC) technologies such as *fanya juu* terraces, mulching, Napier grass strips, grass strips, trees on boundaries, soil bunds and stone bunds. Minimum tillage is relatively a new technology in Kenya which is slowly being adopted by farmers. These technologies prevent washing away of nutrients by erosion and better retention of soil moisture. Mwangi *et al*., (2001) claim that soil erosion has caused losses in maize grain yield of up to 83 percent in Central Kenya. They also conducted on farm trials which results in higher maize grain yields in plots with SWC measures. In particular, they found that *fanya juu* terraces increased maize grain yields by 23.1 percent and Napier grass strips by 12.1percent relative to their control plots. Additional benefits of *fanya juu* terraces and Napier grass strips are the production of fodder for animals. Thus, SWC also compliments manure production.

An increasing number of Kenyan farmers report declining soil fertility to be a major constraint to farming. Inorganic fertilizers and animal manure are widely used to improve soil fertility, but there are challenges with availability, accessibility, and affordability, especially for chemical fertilizers. Animal manure has also benefits of maintaining soil organic matter level but has insufficient nutrients to maintain soil fertility and needs to be supplemented with chemical fertilizers (Jama *et al*.,1997). In mixed farming crop-livestock interaction is a complimentary adoption strategy where farmers rely on livestock to produce manure while the crops supply the livestock with fodder. Marenja and Barrett (2007) statistics shows that manure and fertilizer inputs are complementarities due to the beneficial interactive effects of manure on fertilizer efficiency. Similarly, Jama *et al*. showed that positive results could be achieved using inorganic fertilizer and manure in western Kenya. In the same region, Duflo *et al*. (2008) experimented on fertilizer use with farmers on their own farms and found that estimated annualized rates of return of 70 percent. Thus, when fertilizer is used in limited quantities, the yield increases it generates make it a profitable investment even without other complementary changes in agricultural practices. Despite the potential returns to applying limited quantities of top dressing fertilizer, fertilizer use is still low in

Kenya. When farmers are asked why they do not use fertilizer, the usual response is that they want to use fertilizer but do not have the money to purchase it.

There is evidence that fertilizer is complementary with improved seed and other changes in agricultural practice that farmers may have difficulty in implementing. Based on experimental farms evidence (see KARI 1994, reported in Duflo *et al*., 2008), the Ministry of Agriculture recommends that farmers use hybrid seeds, Di-Ammonium Phosphate (DAP) fertilizer at planting, and Calcium Ammonium Nitrate (CAN) fertilizer at top dressing, when the maize plant is knee-high. Maize is a stable crop in Kenya where the Ministry of Agriculture recommends the use of modern maize varieties to increase farm productivity. However the adoption rates are still low in most of the rural areas. The average maize yield is about 2 t/ha; however, potential yields of over 6 t/ha are possible through the increased use of fertilizer, improved seed, and crop husbandry practice (Makokha *et al*., 2001).

Low soil fertility among small scale farmers in Kenya is mainly caused by continuous cultivation without a fallow period and insufficient crop rotation due to small farm sizes. Crop rotation enables the plot to replenish lost nutrients and avoid the build-up of soil borne diseases. For instance, legumes in crop rotations supply biologically fixed atmospheric nitrogen to the soil which could substitute or compliment inorganic nitrogen fertilizer (Muthoni and Kabira 2010). In the moist savanna agroecological zones of West Africa, Sanginga *et al.* (2002) found that maize grain yields generally are higher when the crop is planted following soybean than in continuous maize cultivation. Thus proper crop rotation especially with inclusion of a legume might help to conserve soil fertility and increase cereal productivity in small scale farms managed by resource poor farmers in Kenya.

Farmers intercrop maize with legumes such as beans, pigeon pea, groundnuts, cowpea and soybean in Kenya. Maize- legumes intercrop has several benefits to the farmer including an increase in yield per area of land, reduction in farm inputs, diversification of diet, increased labor utilization efficiency, and hedge against risk of crop failure as different crops have different patterns of growth and are affected by different pests and diseases (Willey 1985; Odhiambo and Ariga 2001; Kamanga, *et al.* 2003; Tsubo *et al*. 2005). In western Kenya, Odhiambo and Ariga found that intercropping maize and beans in the same hole had the highest grain yield which was 78.6 percent above yield in pure maize strand. The systems of maize–legume intercrop are able to improve soil fertility by reducing the amount of nitrogen nutrients taken from the soil (Adu-Gyamfi *et al*. 2007). But farmers might still have to use fertilizer or manure to increase the yield of their maize crop since Maize-legume intercropping may not significantly improve the soil nitrogen levels especially for plots with poor soils fertility. Hence, Maize-legume intercrop is a compliment to the use of inorganic fertilizer and animal manure. Lastly, combinations of different agricultural technologies are adopted because of their synergies to improve soil fertility and hence higher crop productivity.

3. Gender issues in Agricultural technology adoption

The agricultural sector has been evolving over the years as human population increases, pushing upwards food demand and need for agricultural productivity to increase. A key strategy to increase agricultural productivity is through the introduction of improved agricultural technologies and management systems (Doss 2006). This has motivated numerous studies to explain the determinants of technology adoption. These studies include adoption of inputs such as chemical fertilizer and high yielding varieties seeds and adoption of sustainable land management technologies and practices or conservation agriculture.

There is focus in the literature towards the study of adoption of improved maize varieties in different context (e.g. Ransom *et al*., 2003, Hintze *et al*., 2003, Paudel and Matsuoka 2008, Doss and Morris 2001). Despite the fact that maize is the most important cereal in many countries, these studies shows low levels of adoption of improved maize varieties. Major constraint to the adoption includes lack of seeds and information deficit or lack of knowledge of the new varieties. Doss and Morris found no significant differences in rates of modern maize varieties adoption between male and female farmers. Similarly, Bourdillon *et al*. (2002) and Chirwa (2005) found no gender differences in the adoption of improved seed in Zimbabwe and Malawi, respectively. In addition, Horrell and Krishnan (2007) found no significant difference in maize seed usage by female-headed households in Zimbabwe. However, Sanginga *et al.* (1999) found significant difference between male and female farmers in the adoption of soybean seeds in Nigeria.

Much of the studies on gender differences focus on use of chemical fertilizer, perhaps due to the significant role fertilizer plays in increasing agricultural productivity and the disturbing low adoption rates especially in SSA. In an influential paper, Doss and Morris (2001) found no significant differences rates of fertilizer use by male- and female- farmer in Ghana. Similarly, Bourdillon *et al*. (2002) and Freeman and Owiti (2003) found that the gender of the household head has no significant effect on the adoption and intensity of use of chemical fertilizer in Zimbabwe and Kenya, respectively. However, Gilbert *et al*. (2002) found a significant gender difference in fertilizer use in Malawi. Doss and Morris study on improved maize varieties and fertilizer adoption found that technology adoption decisions in

Ghana depend primarily on access to resources, rather than on gender *per se*. However their conclusion as they observe should be interpreted with caution because it does not necessarily mean that modern maize varieties and fertilizer are gender neutral technologies.

A fair amount of attention has been paid to the determinants of technology adoption in the economic development literature (Feder *et al.,* 1985), but from the perspective of gender little has been done in that; no account is taken of who participates in the technology adoption and to what extent. For instance, it has been argued that Conservation tillage practices, especially those pertaining to SWC, do not promote the fair participation of both women and men (Lubwama 1999). A literature survey by Quisumbing (1995) concludes that there is mixed evidence on technological adoption by gender. However, most of the technology adoption studies find that better educated farmers, regardless of gender, are more likely to adopt new technologies.

Sustainable land management technologies and practice or conservation agriculture that are widely studied includes: soil and water conservation, conservation tillage, cover crops practices, intercropping, crop rotation (e.g. Pender and Gebermedhin 2007, Arellanes and Lee 2003, Rajasekharan and Veeraputhran 2002, Herath and Takeya 2003; Lee 2005, Wallni *et al*., 2010). These studies identify the factors that determine adoption of each of these technologies. Notable, there is a missing link with gender aspects of the sustainable land management issues. In addition, due to nutrients supplements and moisture retention synergies, farmers adopt several technologies and there is need to study joint-ness of technologies. The novelty of the current study is to study several technologies that are adopted simultaneously by the farmer.

4. Data and descriptive statistics

The data used in this study is part of a baseline survey for a four year (2010 - 2014) program to intensify the maize-legume cropping systems under rainfed agriculture in the Eastern and Southern Africa (ESA) region. The program targeted maize and five main legumes grown in the region (beans, pigeon pea, groundnut, cowpea and soybean). This study is based on Kenyan data where 613 households and 2851 plots were sampled in January to April 2011 in western Kenya highlands (Siaya and Bungoma districts) and eastern Kenya highlands (Meru South, Imenti South and Embu districts) by International Maize and Wheat Improvement Center (CIMMYT) in Partnership with Kenya Agricultural Research Institute (KARI). The target sites are considered to have good potential for agriculture with relatively high rainfall (1,100 – 1,600 mm per year) and well drained soils. Both regions have a bimodal rainfall pattern and two cropping seasons i.e. March-April rains and September-November rains.

Before the actual survey, a reconnaissance visit to all the study sites in western and eastern Kenya was conducted. During the visits secondary data was collected. Comprehensive crop production, livestock production, basic socioeconomic profiles of the households, marketing information such as input and output markets was collected from the Ministry of Agriculture offices and other development organizations working in these two regions. In addition, informal discussions with farmers and key informants were also conducted. Based on the information collected, the sampling strategy was developed.

Purposive sampling methods were used to select two regions (western and Eastern Kenya) of the study, taking into account their maize-legume production potentials. A total of five districts were included in the sample: Bungoma and Siaya districts from western Kenya region and Embu, Meru South and Imenti South districts from eastern Kenya region. With a target of 600 households (300 in each region), each district in western Kenya was allocated 150 households while, in eastern Kenya, each district was allocated 100 households. 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 representation 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 village and surveyed households were randomly picked. Thereafter the numbers of the households surveyed in each selected village were randomly picked. The number of households surveyed in each village was proportional to the number of households in that village.

A detailed questionnaire was used to collect the required Maize-legume data and probed the socioeconomic characteristics of the households including gender, age, education level (years of schooling), family size, asset and livestock ownerships, membership in farmers' groups, economic activities, annual household expenditure. Others variables collected includes crop and livestock production and marketing, access to information and other farm production institutions. In addition to the households-level and village-level data, the survey has detailed information on plots level characteristics including agricultural technology adoptions and practices, soil fertility, soil depth, plot slope, plot size, plot manager and distance from the market.

Descriptive statistics

Table 1 shows the summary statistics regarding our variables of interest. We report information on the whole sample and further split the socio-economic characteristics into female –headed household and male-headed household testing if there are statistical differences between the means of the various variables under consideration. For the plot level information we split the sample on basis of who manages the plot (female- and male-managed plots and jointly managed plots). Out of 613 households 19.4 percent are the female headed households. We find that 29 percent of the plots are managed by women, a higher percentage than female headed household meaning there are plots managed by women though the household head is male. In fact 32 percent of the plots managed by woman belong to male-headed households' plots while 93 percent of the plots managed by woman are female-headed household plots.

--- Table 1 about here ---

Intercropping of crops is a common technology in the study areas where maize is usually intercropped together with legumes crops such as beans. About 36 percent of the plots are maize-legume intercropped with female managed plot at 43 percent and male managed plot at 31 percent, with a statistically significant difference. Similar pattern is observed for the maize-legume rotation with about 41 percent of the plots practiced maize-legume rotation with women dominating the practice. Perhaps women need to intercrop in order to get variety of food crops because they own and manage smaller plots compared to men. Maize is often rotated with legumes, such as pigeon peas and haricot beans.

The main SWC methods are: terraces, mulching, grass strips, trees on boundaries, soil bunds and stone bunds. Of the total plots cultivated, 67 percent of plots practiced SWC with majority of plots being the jointly managed plots. Of the agricultural technologies under consideration, there is least adoption of minimum tillage in the study area at about 5 percent with female managed plots only adopting at about 2 percent. The data indicates that there are no gender differences in the adoption of improved maize and improved beans varieties. About 40 percent and 41 percent of plots have improved maize and improved beans varieties, respectively. On average 67 percent of the plots grow improved seeds (improved maize and legumes). Woman managed plots shows a low application of animal manure and use of chemical fertilizer during planting and or top dressing. Inorganic fertilizer is used in 52 percent of the plots while application of animal manure is practiced in 46 percent of the plots. This could be explained by woman owning few cattle (about 2) compared to men (about 3).

The data seems to suggest that women have access to different quality of land as men. While men dominate in the management of good fertile soil, women are left to manage majority of the poor fertile soil. The data also suggests that there are significant differences in the mean plot size with women managing smaller plots. We uncover that there is gender differences in the ownership of plots between the women- and men-managed plots with majority (87 percent) owning the plot they cultivate. We observed differences in access to education, cattle ownership, income (proxy by expenditure), salaried employment and ownership of mobile phone between male-and female-headed households. However there are no differences in access to extension visits, asset ownership excluding livestock and total farm size. Majority (95 percent) of female-heads main occupation is farming. The data displays rather low average levels of education: an average of primary education (7 years) for most household heads with women having even lower education attainment (4.5 years). On average, it takes half an hour to get to the nearest market.

5. Methodology

Adoption behavior is a complex and multidimensional process which can be explained by three paradigms identified by Adesina and Zinnah (1993) namely the innovation-diffusion-adoption paradigm, the economic constraint paradigm, and the adopter perception paradigm. The role of access to information in the process of technology adoption is explained by innovation-diffusion paradigm. Here extension services play a key role in ensuring the potential end users can be shown it is rational to adopt the new technology. In addition, information costs are involved in the acquisition of new technology and the learning process itself (Wollni *et al*., 2010). Factors such as resource endowments that affect the profitability of the innovation fall under the economic constraint paradigms which determine the observed adoption behavior. Lack of access to capital or land could significantly constrain adoption decisions by different groups. The additional costs associated with adoption result often from higher input and labor requirements of the new technology or practice. Lastly the adopter perception paradigm stresses the role of perceptions and attitudes in the decision making process of the farmer.

The decision to apply an agricultural technology is a function of the net benefits that the farmer expects to gain from adoption as compared to non-adoption of a technology or practice. Since farmers in SSA face various constraints, we do not expect them to optimally adopt the technologies that maximize their profits. Some of these constraints include, slow diffusion of new technologies in rural areas which makes different groups to adopt the new technologies at different times. Some technologies are expensive and access to credit is poor in most of the smallholders' environment. These and other gender specific constraints have slowed down adoption of the technologies that have been shown to increase productivity and farm incomes in the long run.

Besley and Case (1993) provide a brief review of the empirical approaches on modeling agricultural technology adoption studies. They argue that cross-sectional studies are limited in exploring the adoption process but they may provide useful insights into the farm and farmer characteristics associated with ultimately accepting the new technology. Farmers are faced with technology adoption alternatives that they may adopt in a mix that deal with their production constraints. In addition, their choice of technologies today may be partly dependent on earlier technology choices. In this regard, recent studies have started to recognize that conditional on the adoption decision, farmers do consider bundles of technologies that maximize their utility of profit (Dorfamn 1996; Moyo and Veeman 2004; Marenya and Barrett 2007; Yu *et al*. 2008). The benefits realized when several technologies are adopted simultaneously in a plot may exceed the benefits realized when each one is adopted separately.

Given that we investigate several technologies, we will allow for interdependence of the technologies since farmers simultaneously adopt these technologies as substitutes, compliments or supplements. Because the adoption decisions are simultaneously chosen by the farmers and the error terms of the adoption decisions maybe correlated, we use a multivariate probit (MVP) specification. MVP allows for systematic correlations between choices for the different technologies. A positive correlation of the errors terms means the technologies are compliments while negative correlations of the errors terms imply the technologies are substitutes. For example, a source of positive correlation is the existence of unobservable household-specific factors that affect choice of several technologies but are not easily measurable such as indigenous knowledge. If correlation exists, simply estimating the technology adoption equations independently will generate biased and inefficient estimates of the standard errors of the model parameters for each technology (Greene 2008), inducing incorrect inference as to the determinants of technology adoption. Also, Dorfamn (1996) observed that univariate modeling (the estimates of separate probit equations) excludes useful economic information contained in interdependence and simultaneous adoption decisions. Hence, the MVP estimator corrects for this problems by allowing for non-zero covariance in adoption across technologies (Marenya and Barrett 2007).

Another approach would be to use a multinomial discrete choice model with seven discrete choice variables where the choice set is made up of all possible combinations of the technologies adopted ($2^7 = 128$ available alternatives). Since, we end up with many alternatives (128 alternatives); estimating a multinomial logit (MNL) or multinomial probit (MNP) model becomes very challenging. The shortfall of this approach is that interpretation of the influence of the explanatory variables on choices of each of the seven original separate technologies is very difficult. Another shortfall is that it is not possible to test if the technologies are compliments or substitutes using the multinomial discrete choice model. Thus, this study uses the MVP specification to overcome the shortfalls of using the separate probit equations and multinomial discrete choice estimators.

The basic model is characterized by a set of binary dependent variables (T_i) specified as follows:

$$T_i^* = \beta_{ij} X_j + \varepsilon_i \qquad (1)$$

$$T_i = \begin{cases} 1 \text{ if } T_i^* > 0 \\ 0 \text{ otherwise} \end{cases} \qquad (2)$$

Where i=1…k denotes the type of agricultural technology adopted on a plot. We construct dummy variables for the following technologies: minimum tillage, SWC, maize-legume intercropping, maize-legume rotation, animal manure application, inorganic fertilizer and improved seed varieties (Maize and Legumes). X_j are the control variables which are the same for the different agricultural technologies. β_{ij} is a vector of parameters to be estimated. ε_i are error terms that may be correlated, otherwise, we estimate the univariate probit model (Greene 2008). ε_i are distributed as multivariate normal distribution with zero means, unitary variance and an n×n contemporaneous correlation matrix [$Q = \rho_{ij}$].

In the adoption literature, the variables hypothesized to influence adoption of agricultural technologies includes: human capital (proxy by education and age), gender, agricultural extension services, credit facilities, plot characteristics (soil quality, plot slope, plot size, irrigation investments, etc.), social capital, income, family labor, ownership of properties such as land and household assets, infrastructure, culture and traditional norms (e.g.

Bandiera and Rasul 2002; Wollni et al., 2010, Pender and Gebermedhin 2007; Arellanes and Lee 2003, Asfaw and Admassie 2004; Barrett 2005; Isham 2002; Nyangena 2008). In a literature review by Yesuf and Pender (2005) they found that land tenure; agricultural extension services; access to credit; household endowment of labor, land, physical capital, financial capital and social capital; farm size and access to markets influence adoption/investment in SWC decisions. However they were quick to point out that the empirical evidence is mixed and hence need for more research especially for determinants such as agricultural extension services which are context dependent.

Plot characteristics such as the plot slope, soil quality, irrigation on the plot do increase the likelihood of adopting improved land management strategies. In Honduras, plots with irrigation, plots farmed by their owners and plots with steeper slopes were more likely to adopt minimum tillage among resource-poor agricultural households (Arellanes and Lee 2003). Ownership of properties such as land, livestock, farm equipment and household assets represent the physical capital of the farmer. The wealthier the farmer, the more likely he/she are able to finance and adopt expensive technologies such as fertilizer use and improved seed varieties.

A hypothesis that is often raised in the literature is that Land tenure does influence the adoption of agricultural technologies in two ways. First, we have technologies that yield their benefits to farmers after a long-term (e.g. animal manure application, minimum tillage, SWC) and those technologies that yield their benefit in the short-term (e.g. Fertilizer use, intercropping, crop rotation). The idea is that a better tenure security will increase the likelihood that farmers will capture the returns from the long term investments without threats of evictions (Kassie and Holden 2007). Thus we expect land tenure to positively influence long-term technology adoption but its effects on short-term technologies is ambiguous.

We will use interacted models, in which key policy variable (education, extension services and plot ownership) in the model are allowed to have both a main effect (for both men and women plot managers) and an additive effect for women plot manager. Because those variable will be entered separately and interact with a gender dummy, the model allows us to determine the extent to which the effect of those characteristic differs for women and men in the adoption decisions. The t-statistic on the interacted coefficient provides a simple test of whether that difference is statistically significant. Because the model includes a dummy variable for woman plot manager, it also estimates the effect of gender that is due neither to differences in observed characteristics nor to differences in adoption decisions to those characteristics.

Following the literature we will include the following explanatory variables: age, education (years of schooling), family size, market distance, credit access, participation in farmer's group, number of trader farmer's know in and outside the village, assets ownership excluding livestock (log assets), extension and training services, farm size, expenditure (log per capita expenditure), ownership of livestock (cattle). Plots characteristics include plot size, perceived soil fertility, perceived steepness of the plot, perceived soil depth, and land ownership.

6. Empirical results

We used MVP approach to analyze the data. The regression results are presented in table 2. A likelihood ratio test of the null hypothesis that the correlation coefficients (ρ statistics) are jointly equals zero against the alternative that ρ does not jointly equal zero was carried out. The hypothesis of independence between the error terms is strongly rejected, hence the use of MVP supported by the results. All the technologies under consideration have positive correlations meaning that the agricultural technologies under study complement each other in a plot where they are adopted.

--- Table 2 about here ---

With the exception of animal manure and SWC, we find no gender differences for improved seed varieties, maize-legume intercropping, maize-legume rotation, minimum tillage, and application of chemical fertilizer technologies relative to male managed plots. These finding resonate with past studies that found no significant difference between male- and female farmer in the adoption of chemical fertilizer and improved seed varieties (Doss and Morris 2001, Bourdillon *et al.*, 2002). Women plot managers are more likely to adopt SWC relative to male managed plots. Jointly managed plots are less likely to adopt minimum tillage, but more likely to adopt maize-legume intercropping, and improved seed varieties relative to male managed plots. Our analysis of gender differences reveals that women plot managers are less likely to apply animal manure, though we would have expected animal manure to be cheap and thus more adoption by female poor resource managers. However, one could also argue that animal manure is produced by animals which are owned by male hence lack of manure by female plot manager leads to less adoption. We find that cattle ownership increases the likelihood of animal manure application. Frequent use of manure highlights the crucial role that livestock play in smallholder farming (Waithaka *et al.,* 2007).

Female plot manager who receive extension services are more likely to adopt maize-legume intercropping and animal manure on their plots but reduces their likelihood to practice SWC and fertilizer use relative to male managed plots. However, we find a significant positive influence of extension services on maize-legume intercropping, improved seed varieties, fertilizer use, and minimum tillage with no significant effect on the other technologies. This result supports available evidence on the mixed performance of extension services on technology adoption (e.g. Freeman and Owiti 2003, Chirwa 2005). Results further indicate that household income (proxy by expenditure) seems to favor adoption of inorganic fertilizer, animal manure application and SWC but less likely to adopt maize-legume rotation. Perhaps this is because wealthier farmers can afford to adopt expensive technologies such as inorganic fertilizer.

Plot characteristics are highly significant variable in determining the choice of agricultural technologies. As the plot size increases farmers are more likely to adopt improved seed varieties, maize-legume intercropping, maize-legume rotation, minimum tillage, animal manure and use inorganic fertilizer. Plots with good fertile soil are more likely to adopt improved seeds varieties, fertilizer and animal manure application relative to poor fertile soils. With regard to plot slope, we find that flat sloped plots negatively and significantly influence the adoption of SWC and chemical fertilizer but positively influence the application of animal manure relative to steep slope. On the soil depth, farmers are likely to adopt maize legume rotation, improved seeds and apply inorganic fertilizer on shallow depth soil but less likely to use animal manure relative to deep depth soil. The results show lack of significance for the distance-to-market for inputs such as chemical fertilizer. Similar results were found in western Kenya by Freeman and Owiti (2003) study of fertilizer adoption.

As expected, technologies that yield benefits after a long period such as SWC, and animal manure are more likely to be adopted in owned plots. This is consistent with the finding that better tenure security will increase the likelihood that farmers will capture the returns from the long term investments without threats of evictions (Kassie and Holden 2007). On the other hand, farmers are less likely to apply chemical fertilizer, adopt improved seed varieties, maize-legume intercropping and maize-legume rotation on their own plots. Perhaps this is because farmers prefer to use long-term soil fertility enrichment on their plots and short-term soil fertility intensifications on rented in plots.

We uncover that access to credit is positively and significantly correlated with adoption of SWC, minimum tillage and chemical fertilizer. Family size has significant positive effect on the adoption of SWC but negatively correlated with maize-legume rotation and improved seed varieties. Though with mixed signs, education turns to be negative and significant in determining the choice of maize-legume intercropping and minimum tillage. The results also revealed that older farmers have a lower adoption probability of improved seeds, maize-legume intercropping, maize-legume rotation, minimum tillage and chemical fertilizer. SWC, maize-legume intercropping and Maize-legume rotation are negatively influenced by social capital (participation in farmers groups); we did not find evidence of social capital influencing adoption of the other technologies. We also control for regional variation.

7. Conclusions

Using smallholders' plot level dataset this study contributes to the still short literature on the role of gender on agricultural technologies adoption. This paper explores the gender differential in the adoption of Maize-legume intercropping, Maize-legume rotation, improved seed (maize and legumes), use of chemical fertilizer, application of animal manure, soil and water conservation (SWC), and minimum tillage (conservation or zero tillage in Kenya. The study uses primary plot level data and household data collected from two agricultural zones: western Kenya region (Siaya and Bungoma districts) and Eastern Kenya region (Meru South, Imenti South and Embu districts) of Kenya. A sample of 613 households and 2851plots are used. The paper tests two hypotheses: are there gender differences in technology adoption; second, are the technologies compliments or substitutes. Both descriptive and econometric methods are employed. Plots are disaggregated into plots jointly managed, plots managed by female and those plots managed by male.

The descriptive results point at women having access to different quality of land as men. We also find significant differences in the ownership of plots and mean plot size with women managing smaller plots. In addition, we observed differences in access to education, cattle ownership, income (proxy by expenditure), salaried employment and ownership of mobile phone between male-and female-headed households. However, there are no gender differences in the access to extension visits, asset ownership excluding livestock and total farm size between the women- and men-headed households.

The econometric results suggest that all the technologies under consideration have positive correlations meaning that the agricultural technologies under study complement each other in a plot where they are adopted. The analysis further shows that gender differential in some technology adoption do exist. Women plot managers are more likely to adopt SWC but are less likely to apply animal manure relative to male managed plots. Jointly managed plots are less likely to adopt minimum tillage and more likely to adopt maize-legume intercropping and improved seed varieties relative to male managed plots. But we find no gender differences for adoption of maize-legume intercropping, maize-legume rotation, improved seed varieties, minimum tillage and application of inorganic fertilizer.

The results of this analysis show that the adoptions of agricultural technologies are strongly influenced by plot characteristics and household factor, suggesting several policy implications. Provision of credit facilities would significantly increase adoption of SWC, minimum tillage and chemical fertilizer. The lack of significance of the distance-to-market for inputs such as chemical fertilizer suggests that there is good access network for these inputs in the study areas. Continued reduction in the cost of accessing farming inputs should be enhanced.

Though older farmers might have more experience with traditional technologies such as animal manure, younger farmers tend to be more innovative, educated and may also have a lower level of risk averseness towards technologies such as maize-legume intercropping, maize-legume rotation, minimum tillage, chemical fertilizer and improved seeds than older farmers. So, efforts to promote maize-legume intercropping, maize-legume rotation, minimum tillage, chemical fertilizer and improved seeds should target younger farmers who would warmly welcome the complimentary role the technologies play in a plot where they are adopted.

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Appendix 1

Tables

Table 1: Descriptive Statistics and variables definitions

	dependent variables	whole sample N=2851		male plot manager (u1) N=892		Female plot manager (u2) N=822		joint plot manager N=1126		t-test for equality of means(u1=u2)	
Variable name	**variable definition**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**t-Value**	**p-value**
mleginter	Maize-legume intercrop(1=yes)	0.355	0.479	0.311	0.463	0.428	0.495	0.337	0.473	5.0852	0
mlegrot	maize-legume rotation(1=yes)	0.405	0.491	0.374	0.484	0.467	0.499	0.385	0.487	3.9016	0
Improved maize	1=Improved, 0=otherwise	0.395	0.489	0.407	0.492	0.375	0.484	0.399	0.490	1.3668	0.1719
improved bean	1=Improved, 0=otherwise	0.409	0.492	0.410	0.492	0.398	0.490	0.418	0.493	0.5267	0.5985
improved seed	1=Improved maize or legumes, 0=otherwise	0.672	0.470	0.672	0.470	0.657	0.475	0.684	0.465	0.6388	0.523
swc	practice soil and water conservation (1=yes)	0.667	0.471	0.619	0.486	0.644	0.479	0.723	0.448	1.0463	0.2956
mintill	Practice minimum tillage (1=yes)	0.046	0.209	0.070	0.255	0.023	0.149	0.044	0.204	4.5508	0
fertilizer	use of fertilizer (1=yes)	0.517	0.500	0.548	0.498	0.461	0.499	0.534	0.499	3.6164	0.0003
manure	use of manure (1=yes)	0.459	0.498	0.502	0.500	0.397	0.489	0.476	0.500	4.4132	0
					plot characteristics						
womanmag	subplot manager (1=woman)	0.289	0.453								
manmag	subplot manager (1=man)	0.314	0.464								
bothmag	subplot manager (1=joint)	0.396	0.489								
Tenure	Owned plot=1; 0=otherwise	0.865	0.341	0.898	0.303	0.860	0.347	0.845	0.362	2.4157	0.0158
plot size	size of the plot in acres	0.806	0.961	0.944	1.410	0.653	0.557	0.806	0.707	5.5315	0
plotdist	Plot distance in walking minutes	7.195	16.715	6.650	15.347	6.453	13.762	8.197	19.504	0.2799	0.7796
goodsoil	plot has good fertile soil(yes=1)	0.316	0.465	0.520	0.500	0.292	0.455	0.174	0.379	9.8277	0

medsoil	plot has moderately fertile soil(yes=1)	0.542	0.498	0.444	0.497	0.482	0.500	0.662	0.473	1.5884	0.1124
poorsoil	plot has poor fertile soil (yes=1)	0.140	0.347	0.036	0.186	0.226	0.418	0.162	0.368	12.2725	0
flatslope	plot has gentle slope (yes=1)	0.469	0.499	0.557	0.497	0.542	0.499	0.345	0.476	0.6177	0.5368
medslope	plot has moderate slope (yes=1)	0.490	0.500	0.411	0.492	0.412	0.492	0.612	0.488	0.0324	0.9742
steepslope	plot has steep slope (yes=1)	0.041	0.198	0.033	0.178	0.047	0.211	0.043	0.203	1.5006	0.1337
shaldepth	plot has shallow deep soil (yes=1)	0.146	0.353	0.128	0.334	0.166	0.372	0.145	0.352	2.2048	0.0276
meddepth	plot has moderate deep soil (yes=1)	0.651	0.477	0.689	0.463	0.573	0.495	0.679	0.467	5.0053	0
deepdepth	plot has deep soil (yes=1)	0.203	0.402	0.183	0.387	0.261	0.440	0.177	0.382	3.9178	0.0001
socio-economic characteristics											
		whole sample (N=613)		**male headed (N=494)**		**female headed (N=119)**					
Variable		**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**	**Mean**	**Std. Dev.**			**t-Value**	**p-value**
gender of hh head	1=female, 0=male	0.194	0.396								
age	age of hh head	50.313	14.762	49.389	14.594	54.151	14.898			3.183	0.002
education	years of schooling	7.380	3.974	8.092	3.629	4.445	4.006			9.632	0.000
hhsize	family size	5.747	2.668	5.978	2.622	4.790	2.658			4.425	0.000
farming	main occupation is farming	0.742	0.438	0.692	0.462	0.950	0.220			5.913	0.000
salary	main occupation is salary employed	0.082	0.274	0.095	0.294	0.025	0.157			2.511	0.012
assets	total value of non-livestock assets	74570.420	185075.000	75768.440	183588.800	69597.140	191836.800			0.326	0.744
expenditure	family expenditure in 12 months	105145.300	209989.200	113748.400	228078.200	69431.650	98823.570			2.072	0.039
extension	receive extension services	0.669	0.471	0.673	0.010	0.653	0.021			0.893	0.372
farmergroup	member of farmers group	0.173	0.378	0.192	0.395	0.092	0.291			2.596	0.010
frmsize	total farm size (ha)	1.199	3.365	1.279	3.723	0.863	0.702			1.193	0.233
cattle	number of cattle	2.439	3.064	2.597	3.247	1.782	2.022			2.620	0.009

phone	owns mobile phone	0.793	0.406	0.828	0.378	0.647	0.480	4.433	0.000
traders	number of traders farmer knows	6.448	5.896	6.681	5.971	5.475	5.492	2.001	0.046
relygovt	household can rely on government during crop failure	0.581	0.494	0.569	0.496	0.630	0.485	1.219	0.224
network	household has relative in leadership positions	0.485	0.500	0.507	0.500	0.395	0.491	2.202	0.028
govtskills	farmers confidence in local government officials including extension officers skills	0.711	0.454	0.702	0.458	0.748	0.436	0.994	0.321
mktdist	walking distance to main market (in minutes)	28.468	28.977	27.906	27.481	30.798	34.529	0.977	0.329
credit	access to credit (yes=1)	0.117	0.322	0.125	0.331	0.084	0.279	1.253	0.211
District dummies									
bungoma	Bungoma district=1	0.245	0.430	0.265	0.442	0.160	0.368		
embu	Embu district=1	0.181	0.385	0.168	0.374	0.235	0.426		
imentisouth	Imenti South district=1	0.165	0.371	0.168	0.374	0.151	0.360		
merusouth	Meru south district=1	0.166	0.373	0.176	0.381	0.126	0.333		
siaya	Siaya district=1	0.243	0.429	0.223	0.416	0.328	0.471		

Table 2: Multivariate probit

VARIABLES	(1) mleginter	(2) mlegrot	(3) impseed	(4) swc	(5) mintill	(6) fert	(7) manure
Household characteristics							
womanmag	-0.190	-0.001	0.109	0.572***	-0.575	-0.159	-0.771***
	(0.200)	(0.213)	(0.224)	(0.218)	(0.399)	(0.215)	(0.237)
womanmedu	0.010	-0.004	0.014	-0.053***	0.038	0.014	-0.003
	(0.014)	(0.015)	(0.015)	(0.015)	(0.032)	(0.014)	(0.015)
womanmowner	0.077	0.059	-0.216	-0.091	-0.119	0.244	0.307*
	(0.160)	(0.168)	(0.190)	(0.167)	(0.294)	(0.176)	(0.184)
womanmext	0.217*	0.069	0.095	-0.265**	-0.186	-0.280**	0.417***
	(0.124)	(0.127)	(0.130)	(0.128)	(0.291)	(0.125)	(0.128)
bothmag	0.123*	0.117	0.123*	0.103	-0.265**	0.028	-0.056
	(0.071)	(0.072)	(0.073)	(0.070)	(0.127)	(0.070)	(0.069)
lnpercaexp	0.043	-0.081**	-0.063	0.150***	-0.021	0.086**	0.136***
	(0.040)	(0.039)	(0.041)	(0.039)	(0.059)	(0.039)	(0.039)
lncattle	-0.122***	-0.091**	0.027	-0.116***	-0.188**	0.055	0.410***
	(0.044)	(0.044)	(0.044)	(0.045)	(0.080)	(0.044)	(0.044)
lnassets	-0.002	0.014	-0.028	-0.050***	0.010	-0.012	-0.041**
	(0.020)	(0.019)	(0.020)	(0.019)	(0.028)	(0.019)	(0.019)
age	-0.006***	-0.007***	-0.011***	0.003	-0.006*	-0.009***	0.000
	(0.002)	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)
hhsize	-0.013	-0.038***	-0.025**	0.054***	-0.034	0.006	0.011
	(0.012)	(0.012)	(0.012)	(0.012)	(0.022)	(0.012)	(0.011)
education	-0.022**	-0.002	-0.011	0.016	-0.026*	0.001	-0.013
	(0.010)	(0.010)	(0.010)	(0.010)	(0.015)	(0.010)	(0.010)
mktdist	0.001	0.001	0.002*	-0.002**	0.002	0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
credit	0.007	-0.102	0.141	0.254***	0.290**	0.216***	0.148*
	(0.083)	(0.086)	(0.088)	(0.091)	(0.124)	(0.081)	(0.083)
farmergroup	-0.145**	-0.252***	-0.043	-0.169**	-0.169	0.029	0.048
	(0.071)	(0.073)	(0.070)	(0.069)	(0.127)	(0.069)	(0.067)
extension	0.127*	0.038	0.116*	-0.025	0.403***	0.271***	0.008

	(0.069)	(0.070)	(0.068)	(0.070)	(0.106)	(0.066)	(0.066)
plot characteristics							
lnplotsize	0.373***	0.344***	0.282***	0.018	0.361***	0.463***	0.060*
	(0.037)	(0.036)	(0.037)	(0.035)	(0.065)	(0.035)	(0.033)
goodsoil	-0.090	0.138	0.313***	0.102	0.205	0.322***	0.182*
	(0.105)	(0.103)	(0.104)	(0.107)	(0.189)	(0.105)	(0.102)
medsoil	-0.075	0.104	0.342***	0.054	0.155	0.164*	0.094
	(0.095)	(0.093)	(0.094)	(0.099)	(0.176)	(0.096)	(0.095)
flatslope	-0.179	0.024	-0.031	-0.721***	-0.151	-0.428***	0.289**
	(0.133)	(0.141)	(0.143)	(0.162)	(0.222)	(0.148)	(0.144)
medslope	-0.126	0.072	-0.134	-0.098	-0.051	-0.473***	0.082
	(0.133)	(0.139)	(0.141)	(0.161)	(0.216)	(0.147)	(0.143)
shaldepth	0.117	0.280***	0.198**	0.057	0.093	0.188*	-0.248***
	(0.099)	(0.097)	(0.100)	(0.101)	(0.174)	(0.098)	(0.095)
meddepth	-0.426***	-0.183***	0.041	0.061	0.022	-0.146**	-0.137*
	(0.069)	(0.070)	(0.072)	(0.071)	(0.121)	(0.070)	(0.070)
ownedplot	-0.360***	-0.251***	-0.306***	0.384***	0.029	-0.298***	0.382***
	(0.098)	(0.093)	(0.101)	(0.091)	(0.141)	(0.094)	(0.095)
District dummies							
bungoma	0.664***	0.295***	0.267***	-0.845***	-0.520**	0.322***	-0.465***
	(0.104)	(0.105)	(0.103)	(0.100)	(0.212)	(0.100)	(0.101)
embu	0.404***	0.460***	0.776***	0.119	0.187	0.644***	0.359***
	(0.091)	(0.091)	(0.093)	(0.088)	(0.137)	(0.089)	(0.089)
merusouth	-0.202**	0.173*	0.775***	0.279***	0.177	0.251***	0.526***
	(0.097)	(0.092)	(0.093)	(0.087)	(0.133)	(0.087)	(0.088)
siaya	1.462***	1.212***	0.190*	0.133	-0.117	-0.017	-0.058
	(0.110)	(0.110)	(0.111)	(0.106)	(0.198)	(0.108)	(0.108)
Constant	0.545	1.211***	1.956***	-0.816*	-0.535	0.486	-1.773***
	(0.442)	(0.450)	(0.457)	(0.450)	(0.661)	(0.431)	(0.438)
Model chi-square	2358	2358	2358	2358	2358	2358	2358
Obs	2637	2637	2637	2637	2637	2637	2637

Robust standard errors in parentheses

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

	Correlation coefficient	**Robust std. Err**	**P-value**
rho21	0.852	0.013	0.000
rho31	0.611	0.028	0.000
rho41	-0.018	0.034	0.598
rho51	0.111	0.050	0.027
rho61	0.568	0.026	0.000
rho71	0.180	0.031	0.000
rho32	0.638	0.024	0.000
rho42	0.008	0.032	0.797
rho52	0.064	0.056	0.251
rho62	0.584	0.024	0.000
rho72	0.186	0.030	0.000
rho43	0.011	0.032	0.733
rho53	0.050	0.054	0.351
rho63	0.488	0.026	0.000
rho73	0.180	0.030	0.000
rho54	0.242	0.058	0.000
rho64	0.067	0.032	0.037
rho74	0.070	0.031	0.026
rho65	0.191	0.044	0.000
rho75	0.126	0.039	0.001
rho76	0.216	0.030	0.000

Likelihood ratio test of rho21 = rho31 = rho41 = rho51 = rho61 = rho71 = rho32 = rho42 = rho52 = rho62 = rho72 = rho43 = rho53 = rho63 = rho73 = rho54 = rho64 = rho74 = rho65 = rho75 = rho76 = 0: chi2 (21) = 2193.38 Prob > chi2 = 0.0000