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Land Access, Land Rental and Food Security: Evidence from Kenya

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Constrained access to land is increasingly recognized as a problem impeding rural household welfare in densely populated areas of Africa. This study utilizes household and parcel level data from rural Kenya to explore the linkage between land access and food security. We find that a 10% increase in operated land size would increase household total food consumption per capita, cereal consumption per capita, non-cereal consumption, and home produced food consumption by 2.6%, 2.1%, 2.7% and 5.4%, respectively. We also find that land rental is the dominant mechanism that poor rural farmers use to access additional land for cultivation. However, the levels of long-term land investment and land productivity are significantly lower for rented parcels than for own parcels even after household fixed-effect and parcel level observed characteristics are controlled for. Furthermore, land rental markets do not allow farmers to fully adjust their operated land size to their desired level.



1 Introduction

Despite the considerable efforts by national governments and the international community to reduce food insecurity and improve nutrition over the years, food insecurity and malnutrition still persist worldwide. For example, 1.4 billion people lived on less than \$1.25 a day, the international poverty line in 2005 (Chen and Ravallion, 2008). And according to FAO (2010), 925 million people suffered from food insecurity in 2010.¹ While the largest number of under-nourished people is in Asia and Pacific (578 million), Sub-Saharan Africa has the highest incidence of under-nourishment where 30% of its total population (roughly 239 million people) suffers from chronic hunger, compared to 16% in Asia and Pacific. Furthermore, Sub-Saharan Africa is the only region where the number of malnourished children has increased in the past 10 years (Ezzati et al., 2002). The number of underweight children is very large and malnutrition is the major cause of child death in Sub-Saharan Africa (UN SCN, 2004; Black et al., 2003). The situation of African women and children is particularly serious, as well as the situation among female teenagers who receive less food than their male counterparts in the same households (Albert, 2012).

These problems of food insecurity are likely to be exacerbated in densely populated and poverty-stricken areas of Africa where the arable land frontier has been exhausted, and where farm sizes are small and declining due to increased population pressures and sluggish structural transformation processes (Jayne et al., 2014). This situation characterizes many areas of rural Kenya (Muyanga and Jayne, 2014). In such settings, many land-constrained rural households rely on land markets as an important means for increasing their access to land (Holden et al., 2009; Yamano et al., 2009; Jin and Jayne, 2013). However, the potential of land rental markets to support poor households' ability to improve their access to food is poorly understood. This study is motivated by the need to more accurately understand the potential of land rental markets to improve rural households' access to land and their food security status.

While there are many studies of land access with focus on the determinants of land rental market participation in numerous countries, the relationship between land access and food

¹ According to FAO, food security is defined as having physical and economic access to sufficient safe and nutritious food for people to meet their dietary needs and food preferences for a healthy and active life (Pinstrup-Anderson 2009).

security has not been well explored in the literature. This study relies on the combination of parcel level data and panel household data covering 713 rural Kenya households from 2004 and 2007 to explore the relationship between land access and food security. Specifically, our analysis aims to achieve the following three objectives: (1) to assess and quantify the relationship between operated land size, household income and food consumption (a proxy for food security); (2) to use the parcel level data from households that cultivate both owned parcels and rented parcels to compare land productivity and investment differences between these two types of parcels; and (3) to investigate the extent to which households are able to access the optimal amount of operational land size² through land rental markets.

Our descriptive and econometric analyses yield several important findings. First, we find a strong positive relationship between land access and food security. A 10% increase in operated land size would increase household total food consumption per capita, cereal consumption per capita, non-cereal consumption, and home produced food consumption by 2.6%, 2.1%, 2.7% and 5.4%, respectively. Second, we find that land rental is the single most important mechanism that land-poor households use to access additional land for cultivation. However, our analysis also highlights considerable concerns with the performance of rental markets in Kenya. We find that land productivity of rented parcels is significantly lower than owned parcels and farmers tend to apply less organic fertilizer to rented land than to own land. Furthermore, land rental markets are not able to allow farmers to achieve the optimal amount of operated land size, as suggested by the fact that tenants rented in 67% of the amount of land they would like to rent in and landlords rented out in 50% of the amount of land they would like to rent out.

The organization of this paper is as follows. Section 2 reviews the literature on the performance of land rental markets in developing areas and in Kenya. Section 3 presents our estimation strategy. The data used in this research is discussed in Section 4, followed by descriptive statistics. Section 5 discusses estimation results. Finally, Section 6 summarizes the major findings and draws policy implications.

² The optimal amount of operational land size is defined as the land size which would maximize value of output per unit of land given the level of the household's labor and other resources under the assumption of perfect land markets.

2 Background

2.1 Land Rental and Sales Markets in the Presence of Market Failures

If all markets function perfectly and farming technology exhibits constant return to scale, the initial endowment of land would not matter in terms of production efficiency because land-labor ratio would be equalized across all households through market equilibration (Feder, 1985; Bardhan and Udry, 1999). Even if there is no land market, efficient outcomes could be achieved as long as other factor markets function perfectly. However, there is ample evidence pointing toward imperfection of rural factor markets in developing areas (De Janvry et al, 1991; Binswanger and Rosenzweig, 1986). One of the reasons why factor markets do not function well in developing areas is the presence of high monitoring costs of hired labor, which makes farmers prefer to use family labor rather than hired labor on their farms. When labor and other factor markets do not function well, households with surplus labor (or other excess assets relative to land) can benefit from acquiring additional land. Land sales and land rental markets are therefore potentially important means for enabling land-poor households to improve agricultural production efficiency when labor market fails to function perfectly (Deininger, 2003).

There are several reasons why land rental markets may achieve these gains for poor rural households more effectively than land sales market. First, land purchases require a much greater up-front payment than renting land. Hence, land rental markets are more accessible for farmers, especially poor farmers facing credits constraints (Hayami and Otsuka, 1993). Second, rental payment sometime can be paid after harvest, which makes renting land by poor farmers possible (Jin and Deininger, 2009). Third, rental markets are more flexible in terms of duration. Finally, rental markets are less risky than sales markets. Distress sale is an example that farmers sold land at a very cheap price to cope with emergency conditions and they ended up losing the land forever (Rawal, 2001; Gaspart et al., 2007). These considerations partially explain why land sales markets are generally much less active than rental markets in Africa (Holden et al., 2009). For the same reasons, rental markets are widely promoted by the Government of Kenya (Government of Kenya, 2007, paras 162 and 163) and many other developing countries (Deininger, 2003).

2.2 Empirical Evidence on Land Rental Markets

For the past decade or so, land rental markets have been actively studied although there is considerably more evidence to draw upon from South and East Asia than from Africa (Holden et al., 2009). A few highly consistent and important findings have emerged from the large number of studies covering a large number of countries. First, with few exceptions, land rental markets have been found to be a major way -- if not the only way -- for enabling land-poor households to access land (Jin and Deininger 2009 and Kimura et al. 2011 on China, Deininger and Jin 2008 on Vietnam; Deininger et al. 2008 on India, Pender and Fafchamp 2001, Deininger et al. 2008, and Gebregziabher and Holden 2011 on Ethiopia, Migot-Adholla et al. 1994 on Ghana; Holden et al. 2006 on Malawi; Yamano et al. 2009, and Jin and Jayne 2013 on Kenya; Andre and Platteau 1998 on Rwanda; Deininger and Mpuga 2009 on Uganda). Second, land rental markets are generally found to enhance farm productivity. (Jin and Deininger, 2009; Deininger and Jin, 2008, Deininger et al., 2007; Deininger and Mpuga, 2009; Jin and Jayne, 2013). Third, many studies identified the presence of significant transaction costs associated with participating in land rental markets. When uncertainty and imperfect information prevails, transaction costs such as search costs to identify suitable tenants and agency costs to avoid moral hazard problem in land use by tenants could lead imperfections in land rental market (Binswanger and Rosenzweig, 1986; Bardhan, 1989). In this regard, past studies found that the existence of the transaction costs typically does not allow farmers to fully adjust their operated land size to the optimal level (Skoufias, 1995; Deininger, Ali and Alemu, 2008; Yamano et al., 2009; Kimura et al., 2011).

2.3 Land Rental Markets in Kenya

Unlike many countries in Africa, Holden et al. (2009) point out that both land sales and rental markets are allowed in Kenya. Rural households' participation in rental markets appears to be rising. Less than 10% of rural households rented land in several districts in Kenya in the late 1990s (Wangila, 1999). However, Yamano et al. (2009) find that 17.9% households rented land in 15 districts in Kenya in 2004. Jin and Jayne (2013) show that the proportion of households renting in land increased from 18% to 20% from 1997 to 2007 in 24 districts in Kenya. The data used in this study (which is a panel of the 2004 data used by Yamano et al. (2009) in their

analysis) showed that 22.3% of households rented in land in 2007, suggesting that the proportion of households renting in land increased by 5% in 3 years.

The Government of Kenya's National Land Policy (2007) states that "the potential to provide access to land to those who are productive but own little or no land" and also says that government should "encourage the development of land rental markets while protecting the rights of smallholders by providing better information about transactions to enhance their bargaining power" (Government of Kenya, 2007, paras 162 and 163). Given the fact that the Kenyan government takes a positive stance to promote land rental markets and that a significant proportion of Kenya farmers are participating in land rental markets, it is important to understand how well the current land rental markets are functioning in terms of allowing farmers to access additional land for agriculture and the ensuing effects on household income and food security.

3 Estimation Strategy

To estimate the effect of operated land size on crop production, income, and consumption based on household level panel data, we specify the following reduced form

$$Y_{ilt} = \alpha_i + \beta_1 Land_{ilt} + \beta_2 X_{ilt} + \beta_3 Loc_l + \beta_4 D_t + \beta_5 Loc_l * D_t + \varepsilon_{ilt} \quad (1)$$

where Y_{ilt} is one of eight output variables of interest (total food consumption per capita, total cereal consumption per capita, total non-cereal consumption per capita, amounts of purchased food per capita, amounts of home produced food per capita, value of crop production per capita, net crop income per capita which is the difference between value of crop production and all paid costs associated with crop production, and net total income per capita which is the sum of net crop income, net livestock income, wage income, net income from self-owned business and transfer income such as remittances and pensions) of household i in location l in time t .³ $Land_{ilt}$ is operated land size. X_{ilt} is a vector of household control variables including household size, total value of assets, household head's age, a dummy for female head, and a dummy for head with primary education, D_t is a year dummy variable which seizes time trend, Loc_l is location dummies which capture the time-invariant regional characteristics, and $Loc_l * D_t$ is a vector of interaction terms between a year dummy and location dummies that are expected to capture time-

³ Location is the administrative unit in Kenya. There are 86 locations in the sample data

specific regional shocks. α_{il} is a household fixed effect that captures household farmer management ability, household risk preferences, unmeasured household wealth, and so on, that are correlated with operated land size and production/food consumption. The existence of α_{il} would cause OLS estimates to be biased and inconsistent. To purge α_{il} , we take advantage of household panel data and estimate equation (1) using a panel fixed effect estimation approach (or first-differenced estimation approach).⁴ This is equivalent to estimating the following equation:

$$Y_{ilt} - \bar{Y}_{il} = \beta_1(Land_{it} - \bar{Land}_{il}) + \beta_2(X_{ilt} - \bar{X}_{il}) + \beta_4(D_t - \bar{D}) + \beta_5(Loc_l * D_t - \bar{Loc}_l * \bar{D}) + (\varepsilon_{ilt} - \bar{\varepsilon}_{il}) \quad (2)$$

where \bar{Y}_{il} , \bar{Land}_{il} , and \bar{X}_{il} are the mean values over the two time periods for the corresponding variable. In equation (2), household fixed effect (α_{il}) has been dropped. β_1 is the key parameter of interest to be estimated.

However, even after α_{il} is purged, the existence of possible time varying unobservables and the reverse causality issues (i.e., income level could also affect a rural household's ability to access to operational land size) could still lead to biased and inconsistent OLS estimates of equation (2). To obtain consistent estimates, we also estimate equation (1) by an instrumental variable (IV) approach based on pooled cross sectional household data. Operated land area in year t is instrumented by inherited land area (accumulative prior to time t) because land inheritance is likely to be correlated with operated land size but unlikely to affect the outcome variables of interest directly except through its effect on operated land size. The reason why IV estimation of equation (1) instead of IV estimation of equation (2) is adopted is that there are very few households who inherited land between the two rounds of survey (only 20 of households did so).

To examine the yield and input use intensity differences between own and rented parcels based on the parcel level data in 2007,⁵ we use the following reduced form:

$$Yield_{ij} \text{ or } Input_{ij} = \gamma_i + \delta_1 Rent_{ij} + \delta_2 Z_{ij} + \epsilon_{ij} \quad (3)$$

⁴ Given that the panel data covers two time periods, the fixed effect and first-differenced estimation approaches give the same estimation results.

⁵ We only use 2007 data because 2004 data does not have the parcel characteristics variables.

where $Yield_{ij}$ is either value of crop production per acre of land or net crop income per acre of land of parcel j belonging to household i , $Input_{ij}$ is input use intensity variable (either the amount of organic fertilizer or that of chemical fertilizer per acre of land), $Rent_{ij}$ is a dummy variable for land ownership (equal to 1 for rented parcels, and 0 for owned parcels), Z_{ij} is a vector of parcel characteristics including steepness, irrigation condition, and distance to homestead, and γ_i is a household level fixed effect capturing unobserved household level factors that simultaneously affecting farmer's productivity/input use intensity and household's tendency to rent land (e.g., farming skills, access to technology, and wealth). We note that OLS estimation of δ_1 will be biased because γ_i is correlated with $Rent_{it}$ (or $E(c_i|Rent_{it}=1) \neq 0$). To deal with this, we take advantage of the fact that all the households who rented in land also happen to own land, so we can use the owner-cum-tenants subsample to perform within-household estimation to eliminate γ_i , an approach that is widely adopted in parcel-level analysis (Shaban, 1987; Jacoby and Mansuri, 2009; Deininger et al. 2013). The fixed effects model of (2) could be written as follows:

$$(Yield_{ij} - \overline{Yield}_i) \text{ or } (Input_{ij} - \overline{Input}_i) = \delta_1(Rent_{ij} - \overline{Rent}_i) + \delta_2(Z_{ij} - \overline{Z}_i) + (\epsilon_{ij} - \overline{\epsilon}_i) \quad (4).$$

A second source of bias is that $E(\epsilon_{ij}|Rent_{ij}=1) \neq 0$; in fact, it is argued in the literature that the rented parcels are generally of lower quality than owned ones (Jacoby and Mansuri 2009). We include all the main parcel-level variables collected in the survey (e.g., irrigation, distance, and steepness) to control parcel heterogeneity. Without being able to fully control for the unobserved factors, our land productivity estimate can be regarded as an upper bound (i.e., if the bias could be eliminated the coefficient estimate would be smaller). A third estimation challenge stems from the fact that a large number of households that do not apply organic or chemical fertilizer. To account for the zero value of fertilizer or organic manure and the time invariant heterogeneity, we adopt the semi-parametric trimmed LAD approach (Honore, 1992) to estimate a fixed effect Tobit model for the input use regressions.

Finally, we adopt a switching regression to estimate the extent to which farmers are able to adjust their operated land size to the optimal level through participating in land rental markets based on cross sectional household level data in 2007. Following Skoufias (1995) and Deininger

et al. (2008), the switching regression with three rental participation regimes can be specified as the following:

$$y_i = \begin{cases} -\alpha_{out} + \beta_{out}L_i + \gamma_{out}Z_i + \varepsilon_i & \text{if } \varepsilon_i < \alpha_{out} - \beta_{out}L_i - \gamma_{out}Z_i \\ 0 & \text{if } \alpha_{out} - \beta_{out}L_i - \gamma_{out}Z_i \leq \varepsilon_i \leq \alpha_{in} - \beta_{in}L_i - \gamma_{in}Z_i \\ -\alpha_{in} + \beta_{in}L_i + \gamma_{in}Z_i + \varepsilon_i & \text{if } \varepsilon_i > \alpha_{in} - \beta_{in}L_i - \gamma_{in}Z_i \end{cases} \quad (5)$$

where y_i is the amount of net land area leased-in; subscript *out* and *in* denote the rental market participation status of household i with negative net area leased-in and positive area leased-in, respectively. Households who rented-in lands have positive y and those who rented-out lands have negative y . In our sample, there is one household who rented-in and rented-out lands at the same time and this household was omitted from this estimation. L_i is household's land endowment (the key variable of interest); Z_i is a vector of household characteristics including land endowment (e.g., ownership of bullocks, labor endowment, value of total assets, household head age, number of dependents, average number of owned steep land parcels, average number of owned irrigated land parcels, average distance from homestead to owned land parcels); α_{in} and α_{out} are the constant terms and β_{in} and β_{out} are the coefficients on land endowment, γ_{in} and γ_{out} are vectors of other coefficients to be estimated. The coefficients of land endowment (β_{in} and β_{out}) are the key coefficients of interest. The magnitude of these coefficients allows us to test whether and to what extent land rental allows households to optimally adjust operated land size. Specifically, a fully functioning rental market without transaction costs would imply β_{in} equals to -1 and β_{out} equals to 1. So to test whether $\beta_{in} = -1$ (or $\beta_{out} = 1$) is to test whether the rental market allows tenants (landlords) to rent-in (rent-out) the amount of land they would like to rent in absence of transaction costs. A detailed description on the derivation of the hypothesis can be found in Skoufias (1995). Equation (4) is estimated by maximum likelihood estimation (MLE). In the programming of MLE, first, it divides samples in two groups, one with 0 or positive values of net land leasing-in and another with 0 or negative values of it and then starting values for the iterations are provided. Then, single censored Tobit regressions in two sub-samples are applied.

4 Data Source and Descriptive Evidence

4.1 Data

The household- and parcel-level data used in our analysis are from a survey called RePEAT.⁶ The data is jointly collected by the National Graduate Institute for Policy Studies (GRIPS), the World Agroforestry Center, and Tegemeo Institute of Agricultural Policy and Development. The RePEAT survey is based on the survey conducted by the Smallholder Diary Project (SDP)⁷ that collected data from more than 3,300 households randomly from communities in the Central, Rift Valley, Nyanza, and Western, and Eastern provinces in Kenya (Yamano, Otsuka, and Place, 2011). In 2004, the RePEAT survey randomly selected 99 sub-locations and 10 households from each of the selected sub-locations, which results in a sample of 934 households. The second round of the RePEAT survey was conducted in 2007. Due to budget constraints, 23 sub-locations in Eastern province were dropped in 2007. The survey targeted 773 households but interviewed 718 households in 76 sub-locations (the attrition rate is 7.1%). Since 5 households were not engaged in Agriculture, the panel sample used in this study has 713 households. The RePEAT survey includes detailed household information on agricultural activities (cropping, raising livestock and growing trees), land (land tenure, land acquisition, parcel characteristics), demographics, education, assets, salary, expenditure, consumption and so on. Household and parcel level data are used for both descriptive and econometric analysis. Land parcels used for analysis are agricultural farm land grown with grains, vegetables, fruits, commercial, and all other crops. Net total income is computed as the sum of net crop income, net livestock income, wage income, net income from self-owned business and transfer income such as remittances and pensions. Each net income is computed as gross income minus costs. The household food consumption is measured by total food availability which is composed of home-produced food consumption (the difference between value of total food production and value of total sale of food production), home-produced dairy consumption (difference between value of total production and value of total sale of dairy products), and purchased food consumption (total

⁶ RePEAT is Research on Poverty, Environment, and Agricultural technology and survey projects in Ethiopia, Kenya, and Uganda founded by GRIPS and Foundation for Advanced Studies on International Development (FASID).

⁷ The SDP is a project jointly by the Ministry of Livestock Development and Fisheries, the Kenya Agricultural Research Institute, and the International Livestock Research Institute (ILRI).

expenditure on all food items). The food consumption is classified into total food consumption, cereal consumption, non-cereal consumption (meat, vegetables, fruits, dairy products, fish, etc.). Each category is further differentiated by sources – either from home production or from market purchase. All consumptions are measured in value term. To eliminate outlier issues in outcome variables, values were winsorized at the 99th percentile.

4.2 Modes of Land Transfer

Table 1 shows the relative importance of various means by which Kenyan households acquire additional lands in 2003 and 2006. While purchased parcels accounted for only 7 of households' operated parcels in 2003 and 2006, the number of rented parcels was 63 in 2003 and 50 in 2006, respectively. In addition, 8 parcels in 2003 and 7 parcels in 2006 were inherited or gained through other channels. This indicates that land rental markets were a much more important source of land acquisition than any other channels. The average size of purchased parcels during the two periods was 1.28 acre, larger than the average of rented parcels (0.81 acre). Overall, land rental is the most important way by which farmers access additional land for cultivation on a year-to-year basis.

Table 1 Frequency of households' acquisition of land parcels, by mode of acquisition

Mode of acquisition	Average	2003	2006
Purchased			
Number of parcels	7	7	7
Mean area (acres) per parcel	1.28	0.84	1.73
Rented-in			
Number of parcels	57	63	50
Mean area (acre)	0.81	0.79	0.84
Inherited or other			
Number of parcels	7.5	8	7
Mean area (acre)	1.34	0.95	1.74

4.3 Land Access and Household Characteristics

Table 2 describes household characteristics in 2007 for four groups according to their land access status: those who rented-in land, those who rented-out land, those who were autarkic and those who purchased land between 2004 and 2006. The simple tabulation reveals a number

of interesting insights with regard to land access. Households who purchased land during 2004 and 2006 were most resource-endowed households among groups. They have the largest number of household size and working age household members. The percentage of households with heads having completed primary education and who owned bullocks are also the highest. And most of all, the average total value of assets of this group is the highest in all groups. And as noted before, the number of households purchasing land is very small (only 20 out of 713 households). Hence, access to land through land purchase is only used by very few wealthy households.

Table 1 Household characteristics by land rental market status in 2007

Rental status	All	Rent-in	Rent-out	Autarkic	Purchased land during 2004-06
Land owned (acres)	4.2	3.3	9.2	4.0	4.2
Household size (# of people)	6.1	6.4	6.3	6.0	6.9
Number of working age members (15-64)	3.3	3.5	3.4	3.2	4.3
Number of dependents*	2.6	2.6	2.8	2.6	2.5
Household head's age	58	56	56	59	47
% of female-headed HHs	0.23	0.16	0.31	0.25	0.05
% of heads completing primary education	0.39	0.50	0.27	0.35	0.80
% of HHs with bullocks	0.20	0.25	0.17	0.18	0.40
Total value of asset (KSh)	83,628	89,304	110,482	71,485	262,230
Total value of livestock (KSh)	47,639	59,171	43,706	44,073	52,860
Number of Observations	713	158	52	483	20

Table 2 also shows that land rental markets also tend to transfer land from households with higher land-labor ratio (on average, 2.7 acre per working age member) to those with smaller land-labor ratio (0.94 acre per working age member). Land rental markets also tend to transfer land from female-headed households to male-headed households and also from households without a bullock to those with at least one bullock. The share of heads having completed primary education is higher for those renting in land than those renting out land. This may suggest that, for individuals with at least a primary education, the marginal return to labor may exceed that in non-farm sectors where casual labor and low-skill jobs predominate. Farming may also be a source of income diversification for educated Kenyans.

4.4 Land Access, Production, Income and Food Security

Table 3 and 4 presents descriptive findings on a relationship between land access measured as operational farm size and households' agriculture income, and food security by dividing households into 4 quartiles based on land size in 2007. Table 3 shows a clear and consistent positive relationship between operational land size and value of crop production per capita, net crop income per capita, and net total income per capita. Net crop income is defined as the value of all crop production minus costs associated with crop production, and net total income is a summation of net crop income, net livestock income, non-farm income and transfer income such as remittance and pension. Each net income is computed as gross income minus costs. Total value of crop production and net crop income for the top quartile of households are more than double those of households in the bottom quartile. These differences in farm production are consistent with differences in net total income by farm size, even though a significant share of household income is derived from non-farm activities.

Table 2 Household incomes by operated farm size category in 2007

Operational farm size quartile ^a	1 st (smallest)	2 nd	3 rd	4 th (largest)	Average
Value of crop production (KSh/capita)	7,779	9,696	15,428	24,319	14,275
Net crop income (KSh/capita) ^b	7,036	8,602	13,491	20,840	12,467
Net total income (KSh/capita) ^c	31,547	40,195	42,361	66,170	44,952

^a Operational farm size includes rented land.

^b Net crop income is defined as the value of all crop production minus all paid costs associated with crop production.

^c Net total income is computed as the sum of net crop income, net livestock income, wage income, net income from self-owned business and transfer.

Table 3 Household food security status by operated land size category in 2007

Operational farm size quartile ^a	1 st (smallest)	2 nd	3 rd	4 th (largest)	Average
Total food consumption(KSh/capita) ^b	14,081	14,916	16,013	20,978	16,484
Total cereal consumption (KSh/capita) ^c	4,103	4,478	4,764	6,383	4,927
Total non-cereal consumption(KSh/capita)	11,916	12,910	13,757	17,473	14,000
Total food consumption from own production (KSh/capita)	7,159	8,409	9,586	13,905	9,747
Value of food purchased (KSh/capita)	6,912	6,488	6,283	6,646	6,588

^a Operational farm size includes rented land.

^b Total food consumption includes cereal consumption and non-cereal consumption (meat, vegetables, fruits, dairy products, fish, etc.).

^c Total cereal consumption includes maize, millet, rice, wheat, sorghum, oats, barely, and simsim.

The data also show a robust and positive relationship between land access and food consumption. As Table 4 shows, households who belong to the highest operational land quartile consumed the highest value of total food, cereal, non-cereal and self-produced food. Among all the food categories, the largest source of the difference is food consumption from own production. For example, food consumption from own production for the top quartile household is almost double of that at the bottom quartile. On the other hand, there is very little variation in value of purchased food across quartiles. The results suggest that the main contribution of land access to rural households' food security status is through their own farm production.

4.5 Land Tenure Status, Value of Crop Production, Crop Income, and Input Use Intensity

Table 5 compares net crop income and input use intensity between rented parcels and owned parcels using parcel level data in 2007.⁸ The data indicate marked differences in value of crop production and net crop income per acre cultivated area and an amount of organic fertilizer use between the two types of parcels. Value of crop output and net crop income per acre on rented parcels is significantly lower than owned parcels by 28% for value of crop output and by 34% for net income (Kenyan Shieling (KSh) 16,551 vs KSh 23,017 and KSh 13,779 vs. KSh 20,781). Data on organic fertilizer per acre also pointed toward remarkable correlation between

⁸ The results are similar to the 2004 sample. We only report the 2007 data to make it consistent with the econometric analysis. Due to the fact several of the key parcel level characteristics were not collected in the 2004 survey, we excluded 2004 from the regression analysis.

tenure type and incentives to apply organic fertilizer. We find that organic fertilizer use in the rented parcels is less than half the level of that in own parcels (307 kg vs. 687 kg). This is not the case for chemical fertilizer. In fact, the amount of chemical fertilizer per acre is slightly higher in rented parcels than owned parcels (21 kg vs. 18 kg). Agronomy literatures discuss an importance of organic fertilizer application as a strategy used by households to improve the long-run fertility and productivity of their soils (Chikowo et al., 2004; Tittonell and Giller, 2013). It takes a few years of continued organic fertilizer application to reap the full benefits of organic fertilizer use. In contrast, application of chemical fertilizer will reap immediate payoff. It is therefore not surprising that application of organic fertilizer is very different between owned and rented parcels, whereas application of chemical fertilizer is not, because farmers are not incentivized to make the long-term investment when they only use the parcels temporarily and cannot fully recoup the investment.

Table 4 Tenure statuses, value of output per acre, and input use intensity by parcel type in 2007

Tenure status	All parcels	Own parcels	Rented parcels
Value of crop production (KSh/acre)	21,727	23,017	16,551
Net crop income per acre (KSh/acre) ^a	19,395	20,781	13,779
Quantity of organic fertilizer (kg/acre)	614	687	307
Quantity of chemical fertilizer (kg/acre) ^b	18	18	21
Farm size (acre)	1.9	2.1	1.1
Number of parcels	1,241	984	221

^a Net crop income is defined as the value of all crop production minus all paid costs associated with crop production. 0 or negative crop income dummy are included.

^b Quantity of chemical fertilizer is measured in NPK equivalent.

While the simple tabulations presented in the descriptive analysis provide preliminary insights about the relationship between operated land size and household production and food security, and differences in input use intensity and crop income per unit land between rented and owned parcels, we will need to rely on rigorous multivariate econometric analyses to draw inferences about the causal relationships between land access and food security, etc.

5 Econometric Results

This section presents the main econometric results based on equations (2), (3), and (4). We find the econometric results are mostly consistent with the descriptive results presented in the previous section. For example, the econometric results confirm the positive and significant relationship between land access, crop productivity, and food security. Additionally, value of land productivity and an amount of organic fertilizer per acre are significantly lower for the rented parcels than for the owned parcels after the household fixed effect and important parcel level characteristics are controlled for. In addition, the switching regression allows us to gain additional insights about the extent to which households are able to adjust their operated land size relative to the optimal size.

5.1 Land Access and Food Security

Table 6 reports the effect of land access on food consumption that was estimated by panel fixed effect estimation using a panel household data set from 2004 and 2007. The model is in log-log specification, so the coefficients are elasticities. The results are highly consistent with the descriptive findings as the coefficient on operated land size is positive and significant at the 1% level in the case of household total food consumption, total cereal consumption, non-cereal consumption, and self-produced food consumption. The magnitudes of the coefficients on operated land size suggest that a 10% increase in operated land size would increase household total food consumption per capita, cereal consumption per capita, non-cereal consumption, and self-produced food consumption by 2.0%, 3.2%, 1.3%, and 4.1%, respectively. The negative coefficients on household size for all the consumption categories are consistent with the literature that food consumption is associated with considerable economies of scale which describes that expenditure of food consumption per capita of a household with few members is generally more than that of a household with more members (Nelson, 1988; Pradhan and Ravallion, 2000). Total value of livestock is important for total food consumption, non-cereal consumption and own produced consumption, but not for cereal consumption and food purchase, suggesting that wealthier households have more diversified and nutritious dietary patterns.

Table 6 Impact of and access on per capita food consumption (household fixed effect model)^a

Explanatory variables	Log of total food consumption (KSh/capita) ^b	Log of total cereal consumption (KSh/capita) ^c	Log of total non-cereal consumption (KSh/capita)	Log of total food consumption from own production (KSh/capita)	Log of value of food purchased (KSh/capita)
	(1)	(2)	(3)	(4)	(5)
Log of operational farm size (acre)	0.203*** (0.0359)	0.315*** (0.0530)	0.129*** (0.0387)	0.406*** (0.0529)	0.0566 (0.0411)
Log of HH size (residents)	-0.764*** (0.0609)	-0.790*** (0.0933)	-0.785*** (0.0679)	-0.846*** (0.0680)	-0.680*** (0.0986)
Female-headed (=1)	0.0145 (0.0783)	0.0239 (0.130)	-0.0434 (0.0916)	-0.149 (0.0983)	0.0893 (0.112)
Log of head's age	-0.285* (0.150)	-0.368* (0.211)	-0.178 (0.173)	-0.340* (0.197)	-0.103 (0.216)
Head completed primary education (=1)	-0.0835 (0.0571)	0.0199 (0.0869)	-0.105 (0.0667)	-0.173** (0.0829)	0.00160 (0.0770)
Log of value of livestock (KSh)	0.0422*** (0.0125)	-0.00654 (0.0185)	0.0757*** (0.0159)	0.0862*** (0.0185)	0.0137 (0.0158)
Constant	11.75*** (0.626)	11.13*** (0.901)	10.91*** (0.720)	10.72*** (0.821)	10.47*** (0.918)
Observations	1,426	1,426	1,426	1,426	1,426
R-squared	0.583	0.405	0.513	0.454	0.515
Number of HH	713	713	713	713	713

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a Interaction terms between year 2007 and locations, and year 2012 dummy are included in all regressions.

^b Total food consumption includes cereal consumption and non-cereal consumption (meat, vegetables, fruits, dairy products, fish, etc.).

^c Total cereal consumption includes maize, millet, rice, wheat, sorghum, oats, barely, and simsim.

Table 7 reports the estimated effects of land access on food consumption using the IV method. The result of the first stage regression is shown in Table A1, which shows that inherited land size is positively and significantly related to operated land size at 1% level. The coefficients on operated land size are consistent with those of the fixed effect results, as those remains positive and statistically significant for food consumption except for food purchase. The magnitude of coefficients on operated land size suggests that a 10% increase in operated land size would increase household total food consumption, cereal consumption, non-cereal consumption, and home produced food consumption by 2.6%, 2.1%, 2.7% and 5.4%,

respectively, again pointing toward the fact that land access helps improve food security through food availability.

Table 7 Impact of and access on per capita food consumption (household IV model)^a

Explanatory variables	Log of total food consumption (KSh/capita) ^b	Log of total cereal consumption (KSh/capita) ^c	Log of total non-cereal consumption (KSh/capita)	Log of total food consumption from own production (KSh/capita)	Log of value of food purchased (KSh/capita)
	(1)	(2)	(3)	(4)	(5)
Log of operational farm size (acre)	0.261*** (0.0435)	0.210*** (0.0594)	0.267*** (0.0537)	0.544*** (0.0631)	0.00569 (0.0480)
Log of HH size	-0.771*** (0.0248)	-0.715*** (0.0352)	-0.777*** (0.0299)	-0.839*** (0.0371)	-0.644*** (0.0324)
Female-headed (=1)	-0.0685** (0.0315)	-0.0410 (0.0434)	-0.0583 (0.0362)	-0.0641 (0.0459)	-0.0786* (0.0404)
Log of head's age	-0.0814 (0.0547)	-0.124* (0.0724)	-0.0155 (0.0665)	0.0960 (0.0815)	-0.221*** (0.0676)
Head completed primary education (=1)	0.111*** (0.0270)	0.127*** (0.0373)	0.118*** (0.0315)	0.0719* (0.0387)	0.163*** (0.0332)
Log of value of livestock (KSh)	0.0666*** (0.00841)	0.0298*** (0.00979)	0.115*** (0.0104)	0.156*** (0.0121)	0.00304 (0.00912)
Constant	10.54*** (0.271)	9.686*** (0.342)	9.641*** (0.318)	8.013*** (0.376)	10.94*** (0.306)
Observations	1,426	1,426	1,426	1,426	1,426
R-squared	0.660	0.463	0.637	0.655	0.520

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a Interaction terms between year 2007 and locations, and year 2012 and no inheritance dummies are included in all regressions.

^b Total food consumption includes cereal consumption and non-cereal consumption (meat, vegetables, fruits, dairy products, fish, etc.).

^c Total cereal consumption includes maize, millet, rice, wheat, sorghum, oats, barely, and simsim.

Table 8 Impact of land access on production and agriculture income (household fixed effect and IV model)^a

Explanatory variables	Log of value of crop production (KSh/capita)		Log of net crop income (KSh/capita) ^b		Log of net total income (KSh/capita) ^c	
	FE	IV	FE	IV	FE	IV
	(1)	(2)	(3)	(4)	(5)	(6)
Log of operational farm size (acre)	0.708*** (0.0639)	0.829*** (0.0751)	0.682*** (0.0734)	0.800*** (0.0882)	0.334*** (0.0567)	0.442*** (0.0841)
Log of HH size	-0.870*** (0.0721)	-0.915*** (0.0426)	-0.889*** (0.0921)	-0.877*** (0.0512)	-0.796*** (0.0982)	-0.787*** (0.0481)
Female-headed (=1)	-0.207* (0.121)	-0.102* (0.0536)	-0.230 (0.164)	-0.0907 (0.0628)	-0.249* (0.135)	-0.200*** (0.0591)
Log of head's age	-0.202 (0.209)	-0.0230 (0.0928)	-0.495** (0.247)	-0.0242 (0.110)	-0.193 (0.221)	-0.424*** (0.103)
Head completed primary education (=1)	-0.0651 (0.0855)	0.0975** (0.0445)	-0.0105 (0.106)	0.0600 (0.0536)	-0.0821 (0.109)	0.208*** (0.0508)
Log of value of livestock (KSh)	0.0179 (0.0183)	0.0513*** (0.0139)	0.0127 (0.0227)	0.0448*** (0.0162)	0.0397* (0.0205)	0.0887*** (0.0151)
Constant	10.34*** (0.873)	9.054*** (0.430)	11.24*** (1.021)	8.777*** (0.512)	11.48*** (0.902)	11.39*** (0.462)
Observations	1,425	1,425	1,426	1,426	1,426	1,426
R-squared	0.464	0.651	0.595	0.658	0.364	0.498
Number of HH	713		713		713	

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a Interaction terms between year 2007 and locations and year 2012 dummy are included in all regressions and no inheritance dummy is included in all IV regressions.

^b Net crop income is defined as the value of all crop production minus all paid costs associated with crop production.

^c Net total income is computed as the sum of net crop income, net livestock income, wage income, net income from self-owned business and transfer income.

5.2 Land Access, Production, and Income

Table 8 shows the impacts of land access on crop production and household income using household level panel data in 2004 and 2007. As in the case of food consumption, the econometrics results on the impact of operated land size on crop production and income are generally consistent with the descriptive evidence. Like in Table 7, we report results based on both the fixed effect estimation (columns 1, 3 and 5) and on IV estimation (columns 2, 4, 6).

Results from fixed effect model estimation indicate that doubling the operated land size would increase value of crop production per capita by 71%, net crop income per capita by 68 % and net total income per capita by 33%. The IV results also suggest significant and large effect of land access on crop production, net crop income and net total income; doubling the operated land size would lead to 83%, 80% and 44% increase respectively. Results on other variables are also interesting and mostly as expected. For example, female-headed households have significantly lower crop production and net total income. Total value of livestock has consistently positive and significant impact on production and net income in all IV estimations and on net total income in the fixed effect model. This is not surprising as high value of livestock may help household buy more inputs and also provide more organic fertilizer for crop production.

5.3 Land Rental and Value of Crop Output, Crop Income per Acre, and Input Use Intensity

Table 9 reports the estimation results on the impact of land rental on value of crop production and net crop income using parcel level data in 2007. The base models include only land area and dummy for a rented parcel (columns 1 and 3). The base model is expanded by including irrigation dummy, steepness dummy, and distance from home to the parcel (columns 2 and 4). The base model indicates that land productivity is 52% (in the case of the value of crop production per acre) or 50% (in the case of net crop income per acre) less for the rented parcels than for the owned parcels. Adding the parcel characteristics (irrigation, distance to home and steepness) only slightly reduced the coefficients (from 52% to 51%, and from 51% to 49%, respectively, for the case of value of crop production per acre, and for the case of net crop income). Two key explanations for lower land productivity of rented parcels compared to owned parcels. One explanation is related to tenure security. Because rental is informal and more temporary, tenants do not have incentive to invest on the rented land as compared to own land. The other explanation is that parcel quality including soil fertility may be lower for rented parcel than for owned parcels. Lower land productivity on rented parcels in our case is likely to be outcome of the two combined effects. Given the magnitude of differences in value of crop output and net crop income between own and rented parcels and the fact that the differences are only trivially affected by the addition of the observed parcel characteristics, it is suggested that the

large productivity differences between the two types of parcels are unlikely to be solely caused by the unobserved quality difference of parcels.

Table 10 reports the fixed effect Tobit results on input use intensity (i.e., the amount of organic and chemical fertilizer use per acre). Consistent with the descriptive evidence, the coefficient on rented parcels is negative and statistically significant for organic fertilizer but insignificant for chemical fertilizer. Lower level of organic fertilizer on the rented parcels is consistent with the argument that farmers have less incentive to make investment including organic fertilizer on parcels that are less secure. If the unobserved land quality is taken into account in the investment decision, then our results on rented parcels are the lower bound estimate of disincentive effect of tenure insecurity. The negative and significant coefficient on a dummy variable for rented parcels in the organic fertilizer regression (columns 1 and 2, Table 10) further increases our confidence that tenure insecurity is likely to have contributed to lower land productivity of rented parcels as compared to owned parcels.

Table 9 Impact of land tenure on value of output per acre (household fixed effect model, parcel level data in 2007)

Explanatory variables	Log of value of crop production (KSh/acre)		Log of net crop income (KSh/acre) ^a	
	(1)	(2)	(3)	(4)
Log of operational farm size (acre)	-0.0788 (0.0653)	-0.103 (0.0670)	-0.175*** (0.0483)	-0.196*** (0.0482)
Rented in parcel (=1)	-0.518*** (0.0901)	-0.511*** (0.0921)	-0.495*** (0.0846)	-0.485*** (0.0842)
Steep parcel (=1)		0.00304 (0.142)		-0.0118 (0.132)
Irrigated parcel (=1)		0.897 (0.552)		0.770** (0.385)
Distance to parcel (km)		-0.0258** (0.0110)		-0.0314*** (0.0106)
Log of paid input costs (KSh/acre)	0.0901*** (0.0222)	0.101*** (0.0217)		
Constant	9.055*** (0.133)	9.004*** (0.134)	9.578*** (0.0227)	9.595*** (0.0340)
Observations	1,241	1,226	1,241	1,226
R-squared	0.103	0.139	0.625	0.636
Number of HH	713	712	713	712

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a Net crop income is defined as the value of all crop production minus all paid costs associated with crop production.

Table 10 Impact of land tenure on fertilizer use (household fixed effect Tobit model, parcel level in 2007)^a

Explanatory variables	Organic fertilizer (kg/acre)		Chemical fertilizer (kg/acre) ^b	
	(1)	(2)	(3)	(4)
Log of operational farm size (acre)	61.93 (107.3)	-71.85 (179.4)	-0.447 (0.997)	-1.022 (1.129)
Rented in parcel (=1)	-2,294*** (614.1)	-1,990*** (598.8)	-0.249 (2.413)	-0.297 (2.640)
Steep parcel (=1)		195.7 (568.4)		4.282 (3.288)
Irrigated parcel (=1)		-1,580** (752.1)		7.313 (17.24)
Distance to parcel (km)		-383.0 (233.4)		-0.249 (0.350)
Observations	1,241	1,226	1,241	1,226

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a All regression is estimated by the semi-parametric trimmed LAD approach.

^b Quantity of chemical fertilizer is measured in NPK equivalent.

Table 11 Determinants of net land leased-in (maximum likelihood estimates, 2007 data)

Explanatory variables	(1)	(2)
Leasing-in equation		
Area owned (acre)	-0.723*** (0.115)	-0.673*** (0.138)
Female-headed (=1)	-0.275 (1.352)	-0.320 (1.372)
Own bulls (=1)	6.744** (3.181)	7.674* (3.971)
Log of value of assets (KSh)	-0.0961 (0.581)	0.102 (0.625)
Number of working members (15-64 years of age)	0.317 (0.247)	0.483** (0.247)
Number of dependents (<15 & >64 years of age)	-0.246 (0.253)	-0.125 (0.246)
Head completed primary education (=1)	6.530** (2.860)	6.957** (2.891)
Head's age	0.0963** (0.0459)	0.0939** (0.0442)
Average number of own steeped land parcels	1.763 (1.396)	0.775 (1.368)
Average number of own irrigated land parcels	-0.505 (3.088)	-0.0593 (3.298)
Average distance to own land parcels (km)	3.957*** (1.429)	2.902** (1.171)
Constant	9.291 (12.77)	-0.278 (14.26)
Leasing-out equation		
Area owned (acre)	0.444*** (0.0771)	0.495*** (0.107)
Female-headed (=1)	1.091 (0.786)	1.234 (0.769)
Own bulls (=1)	-2.393*** (0.890)	-3.266*** (0.996)
Log of value of assets (KSh)	-0.633** (0.308)	-0.336 (0.327)
Number of working members (15-64 years of age)	-0.314** (0.142)	-0.315** (0.144)
Number of dependents (<15 & >64 years of age)	-0.175 (0.141)	-0.227 (0.148)

Table 11 (cont'd)

Explanatory variables	(1)	(2)
Leasing-out equation		
Head completed primary education (=1)	-1.478** (0.727)	-1.881** (0.768)
Head's age	0.0294 (0.0228)	0.0236 (0.0245)
Average number of own steeped land parcels	0.410 (0.621)	0.549 (0.600)
Average number of own irrigated land parcels	-2.240 (1.664)	-3.693** (1.679)
Average distance to own land parcels (km)	-0.00719 (0.132)	-0.00958 (0.115)
Constant	47.84*** (12.20)	29.07 (33.78)
District dummies included	No	Yes
Σ	7.016*** (1.25)	6.803*** (1.18)
Log likelihood	-1003.55	-978.94
Observations	712	712

The numbers in parentheses are standard errors adjusted for clustering effect at the village level. ***, **, and * indicate significance at 1, 5, and 10%, respectively.

5.4 Determinants of Net Land Leasing In and Out

Table 11 reports the results for the switching regression of land rental (equation 5) using data from 2007 to show the extent of land rental market imperfection. The base model (column 1) only includes all the relevant household characteristics and the augmented model (column 2) includes both the household characteristics and the district dummies.

First, we look at the lease-in side. If the rental land market functions perfectly, the coefficients of land endowment will be -1 (i.e., $\beta_{in} = -1$ in equation (5)) in columns (1) and (2). However, the coefficients of area owned in renting-in equation are -0.73 for the base model and -0.67 for the augmented model and both coefficients are significantly different from -1 at the 1% significance level. This indicates that land rental markets do not perform perfectly. Tenants who

rented in land only rented in 73% to 67% of the amount of land they would like to rent in in the case of no transaction costs of renting land.⁹

Next, we turn to the lease-out side. If the land rental market functions perfectly, the coefficient of land endowment would be 1 (i.e., $\beta_{out} = 1$ in equation (5)) in columns (2) and (3). However, the coefficients of area owned in lease-out equation are 0.44 for the base model and 0.48 for the augmented model and both coefficients are statistically different from 1 at 1% level of significance. In other words, households who rented out land were only able to rent out 44% to 48% of the amount of land they would want to rent out in the case of no transaction costs of renting land.¹⁰ To put our estimates into a context, farmers in India were found to be able to rented-in (or out) 78% (or 68%) of the amount of land they would desire to rent-in (or out) if there is free of transaction costs of renting while the situation is much more dire in Ethiopia as the corresponding figures are 30% and 21% (Deininger et al., 2008). Thus, the land rental market in Kenya functions at a level that is comparable to that in India but much higher than that in Ethiopia.

The coefficients on other variables provide further insights on the performance of land rental markets in Kenya. First of all, land rental does allow land-poor households to rent in land from land-rich households as indicated by the negative coefficients of land endowment in the rent-in and positive coefficients of land endowment in the rent-out equations. Similarly, rental markets tend to transfer land from households with less labor to households with more labor, as the coefficients of number of household members whose ages are between 14 years old and 65 years old is significant and negative in the rent-out equation and positive and significant (though only in the expanded model) in the rent-in equation. Consistent with the literature, having a bullock or not is very significant in household's renting decisions, as land rental tends to transfer land from households without a bullock to households with at least one bullock. Additionally, households with heads having completed primary educations are more likely rented-in and

⁹ The average land area of households who rented-in lands is 1.2 hectare. If tenants could adjust rented-in land size fully, which means if $\beta_{in} = -1$, the computed average rented-in land area would become 1.9 hectare for column (2) case.

¹⁰ The average land area of households who rented-in lands is 8.4 hectare. If landholders could adjust rented-out land size fully, which means if $\beta_{out} = 1$, the calculated average rented-in land area would become 18.1 hectare for column (2) case.

rented-out, which is consistent with finding in the descriptive result. This may show that the marginal return to labor for individuals who completed primary education may be higher for farm sector than non-farm sector where low-skilled jobs prevail. Average distance to owned land parcels is positive and significant in the leasing-in model, suggesting households with land that is far away from their homes tend to rent-in land. The negative coefficients for the average number of own irrigated parcels (though significant only in the specification with district dummies) in the leased-out models tend to suggest that households with good quality land are less likely to rent out land.

For robustness check, I also estimated simple probit models to identify determinants of land rental market participation. Results from probit models are reported in Table A2. Except for the working age members in the leased-out model, results on other key variables such as area owned, own bullock dummy, and whether a head completed primary education dummy or not are largely consistent with those from the Tobit switching regression models.

6 Conclusions and Policy Implication

While African governments have devoted enormous efforts to promoting food security, the prevalence of malnutrition and food insecurity is still quite high. Raising farm production and productivity is a top food security strategy for rural households who remain largely dependent on agriculture for their livelihoods. Considerable evidence shows a strong correlation between operated farm size and food production in rural Africa. However, there is no rigorous empirical evidence to shed light on the linkage between land access and food security. It is quite possible that households with relatively small landholding sizes have diversified to a greater extent into non-farm activities and are able to fully offset their lower own farm production with food purchased through their non-farm incomes. We attempt to fill in these knowledge gaps by exploring the relationship between land access and food security using data from rural Kenya in this study.

Our analyses yield three salient findings. First of all, we establish a strong linkage between land access and food security. In general, households with small farms are not able to procure sufficient food through non-farm jobs to achieve comparable levels of food consumption per capita as their relatively land-abundant neighbors. Second, we find that land rental markets

are the most important means available to land-constrained rural households to access additional land for cultivation. Third, regression results show that rental markets perform below their potential. The value of crop production and net crop income are significantly lower on rented parcels than on owned parcels even after parcel characteristics and household fixed effects are controlled for. Consistently, farmers also apply less organic fertilizer on rented parcels than on owned parcels. In addition, farmers are not able to use land rental markets to attain their optimal operated land size. Tenants (landlords) were only able to rent in (out) from 67 to 73% (from 44 to 48%) of the optimal amount of land they would like to rent in absence of transaction costs of renting land.

Therefore, while land rental markets currently play a positive role in promoting household food security in rural Kenya, there appears to be untapped potential for them to play a more important role than they currently do. Policy efforts to improve the functioning of land rental markets may be an under-recognized yet potentially important component of food security and nutrition strategies in rural Kenya, and most likely in other parts of the region. More detailed research on the organization and behavior of land rental markets is needed to identify the specific causes of the apparently considerable underperformance of Kenya's rural land rental markets.

Appendix

Table A1 The first stage regression of Table 7 and 8^a

Explanatory variables	Log of operational farm size (acre)
Log of operational farm size (acre)	0.378*** (0.0222)
Log of HH size	0.101*** (0.0334)
Female-headed (=1)	-0.145*** (0.0419)
Log of head's age	0.0784 (0.0737)
Head completed primary education (=1)	0.113*** (0.0365)
Log of value of livestock (KSh)	0.0811*** (0.00886)
Constant	-0.0431 (0.372)
Observations	1,426
R-squared	0.480

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

^a Interaction terms between year 2007 and locations, and year 2012 and no inheritance dummies are included in the regression.

Table A2 Determinants of land leased-in and leased-out (probit model-marginal effect at mean, 2007 data)

	Leasing-in		Leasing-out	
	(1)	(2)	(3)	(4)
Area owned (acre)	-0.0130** (0.00565)	-0.0160*** (0.00568)	0.00343*** (0.00119)	0.00275** (0.00128)
Female-headed (=1)	-0.0558 (0.0369)	-0.0629* (0.0358)	0.0119 (0.0149)	0.0123 (0.0143)
Own bulls (=1)	0.103** (0.0509)	0.156*** (0.0578)	-0.0299** (0.0142)	-0.0279** (0.0120)
Log of value of assets (KSh)	0.0196 (0.0147)	0.00651 (0.0158)	0.00292 (0.00602)	-0.000108 (0.00603)
Number of working members (15-64)	0.0139** (0.00603)	0.0148** (0.00611)	-0.00241 (0.00246)	-0.00337 (0.00225)
Number of dependents (<15 & >64)	0.00555 (0.00699)	0.00855 (0.00737)	0.00193 (0.00233)	0.000581 (0.00215)
Head completed primary education (=1)	0.0855** (0.0395)	0.0985** (0.0401)	-0.0418*** (0.0131)	-0.0383*** (0.0122)
Head's age	-0.00145 (0.00124)	-0.00129 (0.00128)	-0.00112** (0.000503)	-0.00104** (0.000485)
Average number of own steeped land parcels	-0.0250 (0.0288)	-0.0311 (0.0292)	-0.0169 (0.0128)	-0.00744 (0.0122)
Average number of own irrigated land parcels	0.125 (0.0977)	0.199** (0.0986)	0.00741 (0.0365)	-0.00152 (0.0325)
Average distance to own land parcels (km)	-0.00356 (0.00624)	-0.00284 (0.00584)	-0.0378*** (0.00979)	-0.0268*** (0.00834)
District dummies included	No	Yes	No	Yes
Chi-squared	38.83	60.83	26.89	65.85
Pseudo R ²	0.06	0.09	0.11	0.16
Observations	711	711	711	711

The numbers in parentheses are robust standard errors.

***, **, and * indicate significance at 1, 5, and 10%, respectively.

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