SMALLHOLDER AGRICULTURE IN THE CONTEXT OF INCREASING POPULATION DENSITIES IN RURAL KENYA

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

Agricultural, Food and Resource Economics – Doctor of Philosophy

2013

ABSTRACT

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Smallholder farmers constitute the bulk of agricultural producers in sub-Saharan Africa and majority of them are poor. Based on sub-Saharan Africa's land endowment, an agricultural-led growth strategy has been touted as solution for reductions in poverty in this region. However, recent studies cast doubts on the land abundance hypothesis. Each day, the Africa smallholders' landholding and access shrink as population density rises. Despite these mounting population related challenges, analysts have pointed out that sub-Saharan Africa still has the potential to revitalize smallholder agricultural productivity for reduced poverty and hunger if appropriate policies are pursued. They cite the example of the smallholder-led broad-based Asian green revolution that contributed greatly to rural poverty reduction in that region to argue their case.

The first essay investigates the potential for similar forms of inclusive agricultural growth using Kenya as a case study. The study specifically investigate whether formal and informal land institutions in Kenya are making it possible for a broad-based smallholder led agricultural growth process as enjoyed in much of Asia. In Kenya, there has been a policy thinking that agricultural and land reforms supported by adequate government budget allocation have the potential to underpin a revitalized system of smallholder production especially in areas where land sizes have become too small. This Essay uses three sources of data, namely: a panel data spanning 13 years, cross-sectional medium scale farmers' survey data, and qualitative data from focus group discussions.

Several consistent findings are as follows: First, diminishing land sizes have become a binding agricultural production constraint in the densely populated regions of the Kenya. Second, the majority of medium-scale farmers, defined as using between 5-50 hectares for agricultural purposes, owned on average over two times more land than they were using for agriculture, implying a high degree of land owned for speculative purposes and/or an inability these farmers to make productive use of the land they owned. Majority of medium scale farmers are either current or former public sector employees; and acquired their land from savings from non-farm, largely urban jobs; only a minority were primarily engaged in agriculture prior to achieving medium-scale farming status.

The second essay examines how rising population pressure affects smallholders' production, commercialization and household incomes. Using data from five panel surveys on 1,169 small-scale farms, econometric techniques are used to determine how increasing rural population density is affecting farm household behavior and livelihoods. The estimation strategy deals with the potential endogeneity of population density in input demand and output supply equations using a two-stage control function approach.

The overall picture emerging from this essay is that land is becoming an increasingly constraining factor of production and that smallholder agriculture farming practices in the areas of high population density are distinctly more land-intensive. Inputs and output agricultural intensification, household incomes and smallholder commercialization rise with population density up to about 600-700 persons per km^2; beyond this threshold, rising population density is associated with sharp declines in agricultural intensification and commercialization.

For my family
Esther, Annette and Tedd
For my mother
Katuvee wa Muyanga
In the memory of my late father
Muyanga wa Mbindyo

ACKNOWLEDGMENTS

Many people contributed to the success of this work, but owing to space limitations, I will only mention a few. First, I deeply thank my major professor and my dissertation committee chair, Thom Jayne. Thom has not only been my professor, but a mentor and friend. You added the final and the most important weft in the weaving of my academic basket. Using Isaac Newton's words I can only say this: "if I have seen further it is by standing on the shoulders of giants". I also admire your sixth sense. You know when the student needs a push, needs a break, and above all you are able to guide students to discover and develop their potential. I would also like to acknowledge the contributions and feedback from the rest of my examination committee members, Eric Crawford, Robert Myers, Songqing Jin and the late David Campbell. Dr. Campbell was able to go through my drafts, sometimes from the hospital bed, and to participate in my dissertation defense regardless of his failing health. Dr. Campbell died a week after my defense. Dr. Jennifer Olson, his colleague in Geography Department, told me that my defense was the last thing he did professionally. What an honor? David, you confirmed to me that a true warrior does not give up what he loves. You fought a heroic fight; you served as a role model for how to walk a lonely path with style, grace, dignity and honor. R.I.P David.

Thanks are due also to Scott Loveridge, Scott Swinton, and Debbie Conway, for assistance in matters of administration and to Linda Beck who usually came to my rescue whenever my laptop slowed down or failed. Many thanks to the land research group, Jake Ricker-Gilbert, Rui Benfica, David Mather, Nick Sitko, Derek Headey and Jordan Chamberlin from whom I learned a great deal. Jordan you did a wonderful job in extracting the GIS data and generation of maps used in this dissertation. To Margaret Beaver and the Tegemeo Institute (Egerton University) family, thanks for your help with the survey data collection and handling.

I had been warned that a PhD journey would be long and lonely, but this wasn't the case with friends and colleagues like Adam Lovgren, Miltone Ayieko, Jordan Chamberlin, Ramzi Adjao, Tim Hodge, Keneilwe Kgosikoma, Nathalie Me-Nsope, Rie Muraoka, Chewe Nkonde, Assistou Ouedraogo, Vivek Pandey, Alexandra Peralta, Christina Plerhoples, Fang Xia, Dale Yi, Helder Zavale and Raul Pitoro. I acknowledge the gifts of time that the Kenyan friends and families in Lansing bestowed on me and my family. The Ayiekos, the Chotis, the Onyanchas, and the Ododas, just but to mention a few. Thank you for your support and encouragement.

Special thanks to my mother, Jemimah Katuvee. She took the responsibility of raising us singlehandedly when our father passed on to glory in October 1991. She relentlessly toiled the family farm to produce food and a surplus, *Kambaland's* scorching sun and unreliable rainfalls notwithstanding, to cater for our education needs. I would like to thank my brothers and sisters, Ngala, Kataa, Monica, Mwanzia, Mwikali and Aphia, for their continued support. Many thanks to my in-laws Ben Kavale and Susan Mwanzia, and family for your love, prayers and encouragement. To my late sister, Janet Kasumuni, the journey that you initiated in January 1978 when enrollment me as a first grader in Kyatune Primary School has come to an end, barely four monthly after you unexpectedly departed. I wish God gave you some more days to witness the end of the journey. For those who did not receive a mention, I say *ASANTENI sana*.

My wife Esther, my daughter Annette, and son Tedd deserve and merit my deepest gratitude. For the five years of the PhD journey I had been an absent husband and father but their affection to me never vanished. Thanks for your endless love, support and understanding.

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KEY TO ABBREVIATIONS

2SLS	Two stage least square
ADC	Agricultural Development Corporation
AEZ	Agro-ecological zones
APE	Average partial effect
CAN	Calcium Ammonium Nitrate
CF	Control Function
CI	Confidence Interval
CIPEV	Commission of Inquiry into the Post Election Violence
CLB	Community Land Board
CPI	Consumer price index
CRE	Correlated random effects
DAP	Di-Ammonium Phosphate
DHS	Demographic and Health Surveys
DLB	District Land Board
FAO	Food and Agriculture Organization
FE	Fixed effects
FEWS	Famine Early Warning System
FGD	Focus group discussion
FIML	Full information maximum likelihood
FIQI	Fisher-Ideal Quantity Index

GIS	Geographic Information System
GPS	Geographic Positioning System
GRUMP	Global Rural-Urban Mapping Project
ha	Hectare
HCCI	Household crop commercialization index
HDCI	Household dairy commercialization index
HLPCI	Household livestock products commercialization index
HPMZ	High potential maize zone
IV	Instrumental variable
kg	kilogram
km	kilometer
KNBS	Kenya National Bureau of Statistics
KSh	Kenya Shilling
LCB	Land Control Board
LDSB	Development and Settlement Board
LGP	Length of the growing period
LQI	Laspeyres Quantity Index
MSU	Michigan State University
NCPB	National Cereal and Produce Board
NLC	National Land Commission
NLP	National Land Policy
NPP	Net primary productivity

OLS	Ordinary least square
PQI	Modified Paasche Quantity Index
RE	Random effects
SE	Standard error
SSA	Sub-Saharan Africa

CHAPTER 1: BACKGROUND

1.1 Introduction

Reducing poverty and hunger have been a critical policy concern in most of the sub-Saharan African countries for the past half-century. Governments and development agencies have experimented with a series of alternative approaches for addressing poverty. Yet, poverty still remains pervasive. In 2005, more than 40 percent of Sub-Saharan Africa's population was estimated to be below the poverty line (World Bank, 2006). Based on sub-Saharan Africa's natural resource endowment, an agricultural-led growth strategy has been touted as the only way for rapid and sustained reductions in poverty in this region. Africa has for a very long time been considered a continent with vast open lands where population pressures are rarely felt (Bilsborrow, 1987; Wood, 2003). As early as 1900, the population density of sub-Saharan Africa was estimated at 4.4 persons per Sq. Km, contrasted with 38.2 for South Asia, and 62.9 for Europe (Herbst, 2000). This implied that the continent is characterized by high land-to-labor ratios[1] (Fenske, 2010). These historical facts have persuaded the proponents of agricultural-led growth to argue that sub-Saharan Africa should pursue a development strategy more like that of a "land-abundant" America than that of a "land-scarce" Asia (Wood and Mayer, 2001).

This early literature on land abundant Africa continues to inspire the thinking that land is easily and cheaply accessible in this region. Recently, Fischer and Shah (2010) reported that sub-Saharan Africa has about 202 million hectares of the 446 million hectares of uncultivated arable

[1] Hopkins (1973) argued that because of the high land-labor ratios, wealth and power in Africa was traditionally measured in terms of "men" rather than in "acres". Consequently, the pre-colonial authorities were keen to attract more people with whom to subdue nature; strangers could acquire land indefinitely for token payments (Austin, 2009).

land in the world. Similarly, the region is reported to possess an enormous yield gap in staple grains (Fischer *et al.*, 2009; Deininger and Byerlee, 2011; Deininger *et al.*, 2011). Consequently, this land-abundant-Africa thesis has set a platform for a renewed interest in what has been referred to as the “unutilized” land in sub-Saharan Africa triggered by the rising demand for food and fuel as well as the prevailing extreme weather events (Hertel, 2011).

However, recent turn of events cast doubts about the land abundance hypothesis and the viability of an agriculture-led development strategy in Africa. First, population densities in this region are much higher than they were some two centuries ago. Evidence exist showing that there has been a gradual and a steady decline in mean farm size as rural population growth has outstripped the growth in arable land over the past 50 years. A substantial fraction of Africa’s rural population lives in relatively densely populated areas where land scarcity is likely to preclude an extensive dimension of agricultural growth (Jayne and Muyanga, 2012). Data from Columbia University’s Global Rural-Urban Mapping Project indicate that the proportion of the rural population living in areas exceeding 250 persons per km^2 is of similar or greater magnitude in Nigeria, Rwanda, Burundi, Uganda, and Malawi, which together with Kenya account for roughly 35 percent of sub-Saharan Africa’s total population. As a result of the growing population densities, about half or more of Africa’s smallholder farms are estimated at or below 1.5 hectares in size with limited or no potential for area expansion (Jayne et al., 2003).

Second, even in countries characterized by low population densities and high aggregate land endowments, there are inequalities in land access at the household level. For example, studies have found that despite high aggregate land endowment in Northern Mozambique, land access inequalities at the household level persist (Marule, 1998; Bruck and Schindler, 2009). The region has the highest and fastest-rising rate of population growth and the distribution of people across the continent is quite uneven. Consequently, to infer that the region has no problems of rural land shortage would be quite wrong (Shipton and Goheen, 1992).

The third way in which times have arguably changed since the nineteenth century is that a high proportion of farmers perceive that it is not possible for them to acquire more land through customary land allocation procedures (Jayne et al., 2009). For example, in the densely populated areas of Kenya, a considerable proportion of young men are start their families without inheriting any land from their parents, forcing them to either commit themselves to off-farm employment, buy or lease land (Yamano et al., 2009). Landholding sizes have become so small to an extent that further subdivision is not feasible.

What do such small landholding sizes in the context of increased inaccessibility to land and limited off-farm employment opportunities mean for feasible poverty reduction strategy in Africa? First, evidence shows the role of smallholder-led agricultural strategy in households' food insecurity and poverty reduction. For example, the Asian green revolution was a small farm phenomenon; over 80 percent of farms in India, Bangladesh, Indonesia, China, Japan and Viet Nam are less than two hectares (Johnston and Kilby, 1975; Mellor, 1995). This revolution was broad based and contributed greatly to rural poverty reduction in these Asian countries. For agricultural-led growth process to substantially reduce poverty, it must be inclusive such that a large percentage of the smallholder population is able to participate in the process in order to achieve the linkage effects/multipliers associated with structural transformation (Jayne et al., 2003; Vollrath, 2007). Smallholders tend to spend their incomes on locally produced goods and services, therefore stimulating the rural non-farm economy and creating additional jobs. A fundamental element of the structural transformation process is smallholder commercialization -- a transition from subsistence to market-oriented patterns of production and input use.

Smallholder commercialization refers to a cycle in which farmers intensify their use of productivity-enhancing technologies on their farms, achieve greater output per unit of land and labor expended, produce greater farm surpluses, expand their participation in markets, and ultimately raise their incomes and living standards. While there has been general consensus of the need to improve smallholder agricultural production in Africa, little attention has been devoted to understanding whether agricultural and land institutions and policies in this region are compatible with land allocation patterns capable of generating broad based inclusive agricultural growth as was achieved in much of Asia.

Second, evidence demonstrates the efficiency advantages of smallholder family owned farms over large farms (Schultz, 1964; Hayami and Otsuka, 1993; Binswanger et al., 1995; Vollrath, 2007; Hazell, 2011). The defining feature of family farms is the reliance on family labor instead of hired labor. Small farm owners reside on the farm, manage the farm themselves, and are aided by other family members who do not need a lot of supervision to work (Binswanger-Mkhize et al., 2009). Consequently, of low cost of family labor and labor supervision, family farms usually exhibit labor-intensive production practices (Hazell et al., 2010). This is the main reason why family farms are considered more efficient than large farms. Even though it is more difficult for family farms to access input and output markets, financing, technical assistance, and information compared to larger farms, empirical studies have shown that such disadvantages are offset by the advantages in terms of labor incentives (Binswanger-Mkhize et al., 2009). Moreover, such disadvantages can be countered if small farmers coordinate their efforts through marketing and credit cooperatives (World Bank, 2005). Nevertheless, in the recent years there are some pessimist undertones that still question the feasibility of smallholder-led agricultural growth in Africa (Collier, 2008, 2009; Collier and Dercon, 2009).

Currently, it is not at all clear how a smallholder-led agricultural strategy must be adapted to address the limitations of very small and declining farm sizes and increasingly reduced prospects of land accessibility in the densely populated areas that are dependent on rain-fed production systems with only one growing season per year. While the African smallholder farmer has endured for years with unpredictable markets and weather conditions, there is no greater challenge to his ingenuity and resilience than these challenges associated with the mounting human population pressure. While there is broad acceptance of the need for improved smallholder agricultural productivity and commercialization in sub-Saharan Africa, there is significant debate about how to most effectively achieve it. Agricultural growth can be achieved through either the intensification of production on existing land, or by bringing more land into cultivation, or some combination of the two. The question then becomes, which should be the priority focus for governments and development partners?

This dissertation is motivated by the need to identify and evaluate the available development strategies for the increasingly densely populated countries of sub-Saharan Africa. Policy issues to be addressed revolve around investigating how smallholders are coping with shrinking farms sizes; identifying potential ways of improving smallholder access to land; examining whether most farms are becoming, or have already become, “too small” to generate meaningful production surpluses and participate in broad-based inclusive agricultural growth processes given existing on-shelf production technologies; and examining whether there is scope for agricultural intensification.

The dissertation is divided into two essays as follows. The first essay is entitled *Smallholder Land Access in Kenya: Are smallholders farming themselves out of near-landlessness?* This essay seeks to examine how, in the absence of major non-farm employment growth and limited outmigration to urban areas, the current formal and informal land institutions are playing out in facilitating smallholder access to land. The essay analyses the current and potential modes of land acquisition in Kenya to assess the feasibility of achieving smallholder productivity growth through improved land access. The study is inspired by two factors. First, the recent literature indicating that Africa is characterized by landholding inequalities -- manifesting as land underutilization on large farms and major constraints on farm income stemming from land constraints in densely populated smallholder areas -- making redistributive land reforms a potentially attractive strategy for improved smallholder land access. The second factor motivating this study is the increasing number of medium scale (emergent) farmers in many African countries over the last decade. Yet, the processes behind their growth have remained unclear. Is this growth driven by farmers who began their farming careers as smallholder now transitioning to a larger scale of production through the capital and assets accumulation; a precursor to the inclusive agricultural-led structural transformation? Or is the growth driven by land institutions and policies that encourage investment in land acquisitions by individuals from non-agricultural employment sector signaling elite land capture? All these questions are addressed in this study.

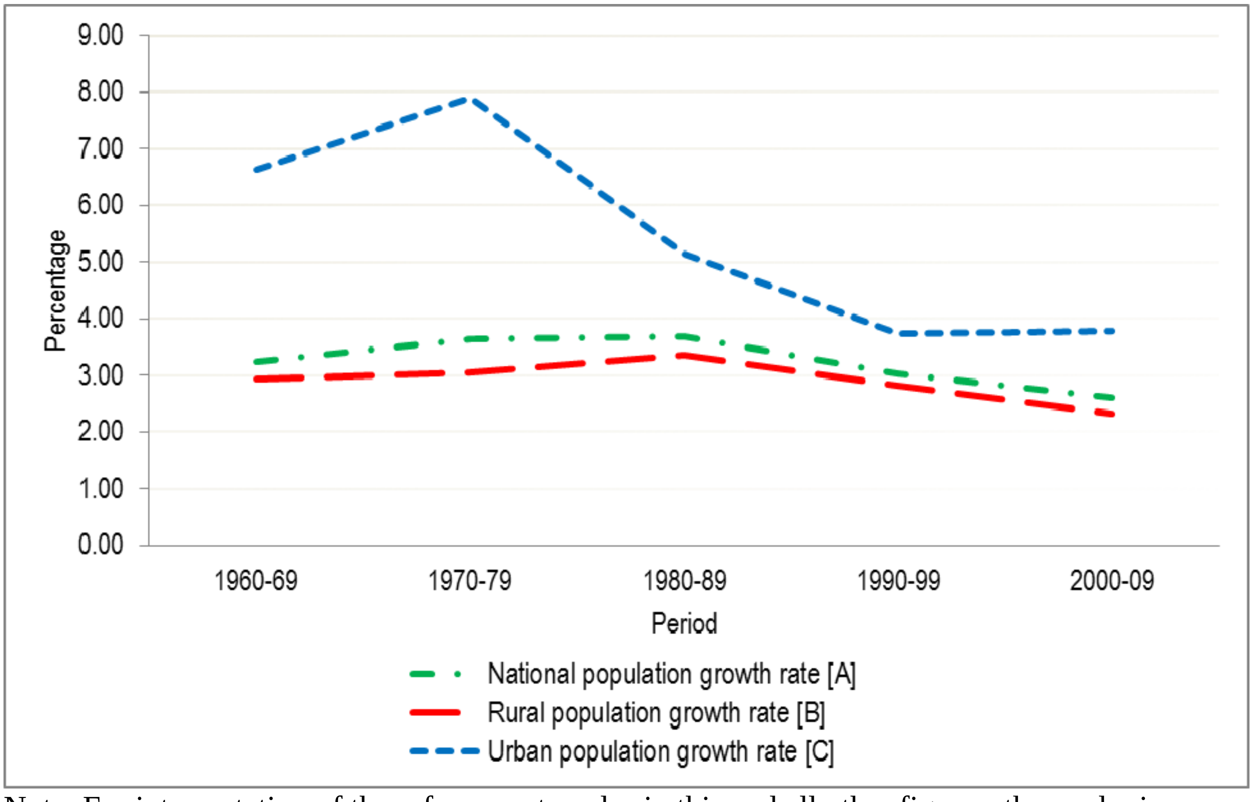
The second essay is entitled *Effects of human population density on smallholder agricultural production and commercialization*. This essay assesses the impact of rising population densities on input demand, output supply, household income, and smallholder commercialization. The overarching objective of this study was to examine how rising population pressure affects smallholders' production, commercialization and household incomes. The study is motivated by the need to understand the nature and magnitude of emerging land constraints in African agriculture using Kenya as a case study. Using data from five panel surveys on 1,169 small-scale farms over the 1997–2010 period, we use panel econometric techniques to determine how increasing rural population density is affecting farm household behavior and livelihoods. The estimation strategy deals with the potential endogeneity of population density in input demand and output supply equations using a two-stage control function approach.

To my knowledge, there has been very little recognition of the potential challenges associated with increasingly densely populated and land-constrained areas of rural Africa. Nor has there been sufficient discussion of how institutions and policies relating to land access would need to be modified to achieve inclusive smallholder-led agricultural growth leading to rural poverty reduction.

Kenya is a useful case study to examine these issues, given that it is one of the more densely populated countries in the region and may therefore provide an advance picture of the dynamics that other countries in the region are likely to be experiencing in the not too distant future. The country covers an area of approximately 582,646km^2, comprising 97.8 percent land and 2.2 percent water surface (Republic of Kenya, 2009). Of the land area, only 16 percent is classified as medium to high potential. The remaining land is mainly arid or semi-arid. Figure 1.1 presents the population growth while Table A1.1 shows the population densities in the original 41 districts in Kenya. While population growth rate has declined and stabilized at about three percent (Figure 1.1), the population density has more than tripled increasing from an average of 19 persons per square kilometer in 1969 to about 66 persons per square kilometer in 2009 (Table A1.1). Table A1.2 presents the 20 percent most densely populated districts in the country.

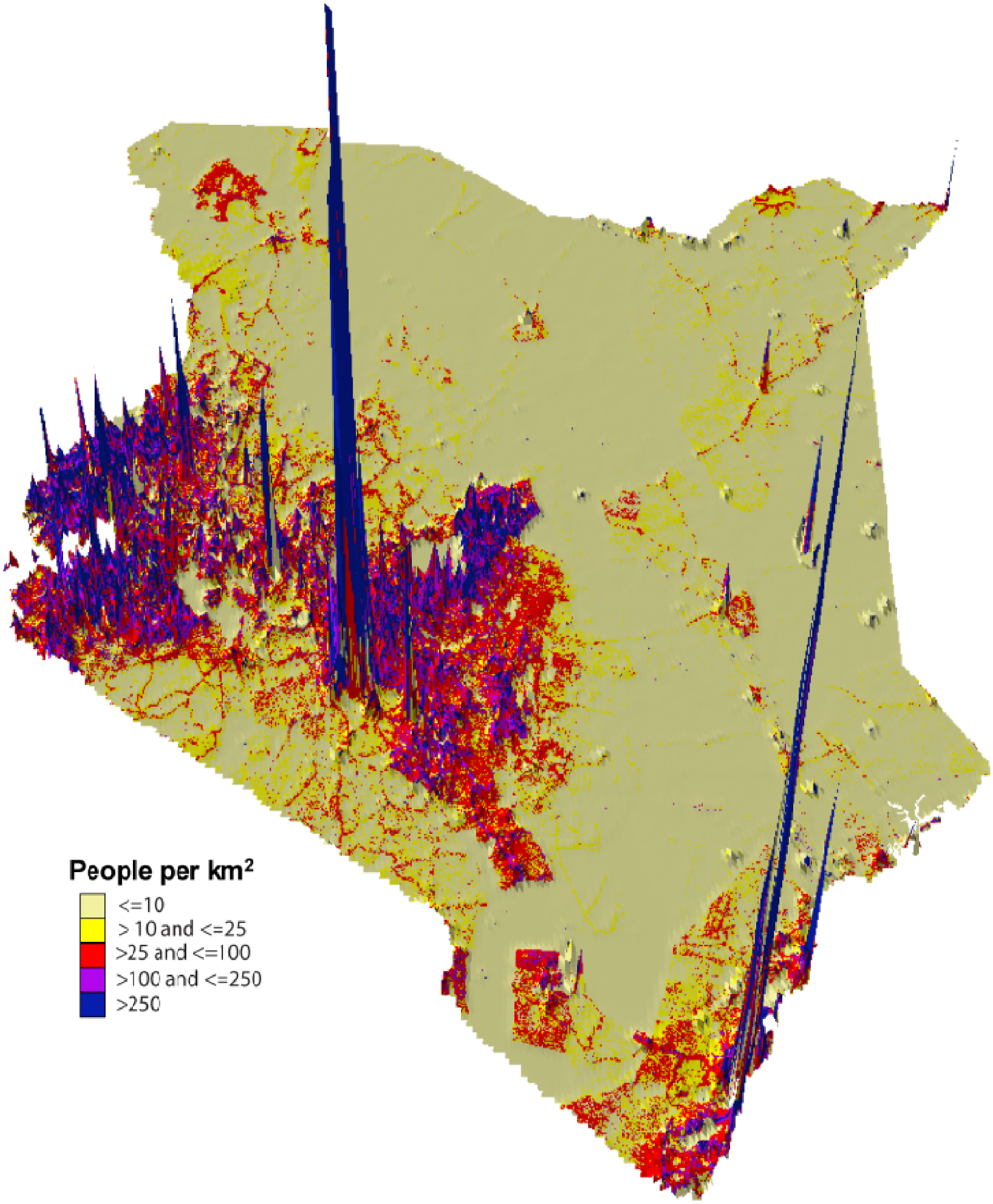
It is important to note that some of the districts, especially in the agricultural high potential regions, are more densely populated than Nairobi was in 1969. Over half of Kenya's rural population lives in areas exceeding 250 persons per square kilometre (Figure 1.2). Cultivated average land per person in agriculture has declined from 0.462 hectares in the 1960s to 0.219 hectares in the 2000-08 period. A similar picture emerges from comparisons in mean farm size within the small-scale farming sector over time. A nationally representative survey of Kenya's small-scale farm sector in 1977 carried out by the Central Bureau of Statistics reports mean farm size ranging across provinces from 2.10 to 3.48 hectares. By contrast, mean farm size in Egerton University's nationwide surveys from 1997 to 2010 show mean farm size to be 1.86 hectares per farm; these longitudinal surveys show a decline in farm size even within that 13-year period.

Figure 1.1: Population growth rates in Kenya



Note: For interpretation of the references to color in this and all other figures, the reader is referred to the electronic version of this dissertation
Data sources: [A] World Bank: http://data.worldbank.org/indicator/SP.POP.GROW ; [B] World Bank: http://data.worldbank.org/indicator/SP.RUR.TOTL.ZG?page=5; and [C] United Nations, Department of Economic and Social Affairs: http://esa.un.org/unpd/wup/index.htm

Figure 1.2: Population density in Kenya



Source: Longabaugh, S. 2008. LandScan High Resolution Global Population Data Set copyrighted by UT-Battelle, LLC, Oak Ridge National Laboratory.

1.2 Key findings

1.2.1 Smallholder Land Access in Kenya: Are smallholders farming themselves out of near-landlessness?

The results point to four key findings. First, the qualitative results from the focus group discussions indicate that access to land is becoming a binding agricultural production constraint in the densely populated regions of the Kenya. Even in the areas considered relatively land abundant like in the lowlands regions, land sizes are swiftly declining due to mounting population pressure. Not only are household farms shrinking in densely populated regions, soil fertility is also rapidly deteriorating due to nutrients mining and degradation associated with reduced fallows. Land conflicts among neighbors and siblings over boundaries and contested inheritances are on the rise due to increasing land scarcity. Increasing land scarcity is also triggering increased incidences of fraudulent land deals as a result of poorly drawn land sale agreements and proliferation of fake land title deeds consequently increasing transaction costs in land markets.

Second, the qualitative data show that the customary land inheritance from parents and land sales and rental markets still remain the most important ways through which smallholder farmers get access land in rural Kenya. The results indicated that there are not unallocated lands and/or common grazing lands in both the low and highly densely populated areas. These customary land transfer practices from parents to male children have led to land subdivisions resulting in tiny landholding especially in the land constrained regions of the country. The land subdivision problem is likely to be compounded by the new constitutional requirement providing for equal treatment of children regardless of gender as far as inheritance of family assets is concerned.

Third, while migration out of densely populated areas is considered a potential avenue to ease land pressure in the land constrained regions, the results show outmigration trends are very low. Rural to rural migration requires financial ability which the smallholder farmers facing land constraints are lacking. Migration is also being inhibited ethnicity and cultural factors. While attachment to ancestral lands limits outmigration, access to land in most of the regions in Kenya is tied on one's ethnic identity. The ethnicity problem was further aggravated by the 2008 post-election tribal land conflicts. Limited non-farm employment opportunities also impede rural to urban migration in Kenya. It is important to mention that in most cases the migrating individuals still retain hold of the land they own in the previous locations. Consequently, outmigration is not easing land scarcity pressure in the densely populated areas of the country.

Fourth, the empirical results from the medium scale farmers' survey show that majority of them used lateral entry into medium-scale farming status. They attained their current farming status by acquiring land from savings from non-farm, largely urban jobs; only a minority was primarily engaged in agriculture prior to achieving medium-scale farming status. A big proportion of them owned on average over two times more land than they were using for agriculture, implying a high degree of land owned for speculative purposes and/or an inability of farmers in this size category to make productive use of the land they owned. In terms of crop productivity, the agricultural entry group seems to be more productive than the lateral entry counterpart. Another interesting finding is that these emergent farmers are generally more productive in terms of total production and production per hectare compared to the smallholder farmers. This study, therefore, suggests that it is primarily individuals with the economic and political capital conferred through public sector jobs that are able to navigate the land administration system to access land.

1.2.2 Effects of population density on smallholder agricultural production and Commercialization in rural Kenya

The overall picture emerging from these results so far is that land is becoming an increasingly constraining factor of production and that smallholder agriculture farming practices in the areas of high population density are distinctly more land-intensive. Consequently, there is a rising strain on rural livelihoods in the densely populated rural areas due to land pressures and declining farm sizes. Inputs and output agricultural intensification, household incomes and smallholder commercialization rise with population density up to about 600-700 persons per km^2; beyond this threshold, rising population density is associated with sharp declines in agricultural intensification and commercialization. For example, the intensity of purchased inputs use increase with population density up to about 600 persons per km^2 and declines after that point. Crop and farm production intensification increase with population density up to about 700 persons per km^2 and thereafter fall. Household aggregate income and non-farm income increase with population density reaching a maximum level at 600 persons per $km^{2.}$

The empirical results also show that smallholder farmers allocate more of their shrinking land to non-maize crop and sell a greater proportion of their production as population density increases. The proportion of land allocated to non-maize crop increases with population density up to about 870 persons per km^2 and declines afterwards. Household crop commercialization as measured by the proportion of marketed crop output also increases with population density reaching a maximum at about 620 persons per km^2 and declines thereafter. It seems farmers alter production patterns to make the best out of their shrinking land resource by switching to high value enterprises such as production of fresh fruits and vegetables, dairy and poultry products.

These results indicate that smallholder landholding sizes are gradually declining in Kenya as in much of sub-Saharan Africa. Currently about 14 percent of Kenya's rural population resides in areas exceeding the 600 persons km^2 population density threshold. Another 20 percent of the rural population is fast approaching this threshold. The results also show that increased access to input markets, passable roads and other physical infrastructural facilities considerably influence the degree of smallholder production and commercialization.

APPENDIX

Table A1.1: Kenya's population density by province and districts

		Density (population/sq. Km)					% change in density since 1969			
		1969	**1979**	**1989**	**1999**	**2009**	**1979**	**1989**	**1999**	**2009**
KENYA		19	27	45	49	66	41	141	162	253
Province	Old District									
Nairobi		733	1,184	1,906	3,083	4,515	62	160	321	516
Central		127	178	294	283	333	40	131	122	162
	Kiambu	151	218	378	442	569	44	150	192	276
	Kirinyaga	147	197	330	309	357	34	125	111	143
	Muranga	227	331	543	376	397	46	139	65	75
	Nyandarua	55	72	125	148	184	32	130	171	237
	Nyeri	108	146	215	198	208	35	99	83	92
Coast		11	16	29	30	40	42	152	163	252
	Mombasa	1,129	1,559	2,992	3,039	4,292	38	165	169	280
	Kilifi	24	34	59	65	88	40	142	169	261
	Kwale	25	35	56	60	79	40	126	141	216
	Lamu	4	7	12	12	16	89	231	224	353
	Taita Taveta	6	9	15	14	17	33	124	123	157
	Tana River	1	2	5	5	6	82	280	257	374
Eastern		12	18	27	30	37	43	115	143	197
	Embu	63	93	76	159	183	47	20	151	189
	Kitui	11	15	27	27	33	35	137	139	195
	Machakos	50	72	120	118	139	45	141	137	180
	Meru	65	91	122	155	177	39	87	136	171
	Marsabit	1	1	2	2	4	87	190	239	548
	Isiolo	2	3	6	6	13	44	224	235	588
North Eastern		2	3	4	8	18	52	84	292	840
	Garissa	1	3	4	9	14	100	143	508	866
	Mandera	4	4	5	10	39	11	46	164	980
	Wajir	2	2	3	6	12	62	82	270	668

Table A1.1 (cont'd)

		Density (population/sq. Km)					% change in density since 1969			
		1969	**1979**	**1989**	**1999**	**2009**	**1979**	**1989**	**1999**	**2009**
Nyanza		168	218	365	348	432	29	117	107	156
	Kisumu	192	231	405	386	464	20	111	101	142
	Siaya	151	188	315	284	333	24	108	88	120
	South Nyanza	115	159	249	245	325	38	117	114	184
	Kisii	305	392	687	654	790	29	126	115	159
Rift Valley		12	18	35	38	55	47	190	216	353
	Baringo	15	19	33	37	50	26	122	149	243
	Keiyo/Marakwet	53	49	89	94	122	(7)	69	79	132
	Kajiado	4	7	17	19	31	73	345	373	700
	Kericho	97	128	221	172	299	32	128	78	209
	Laikipia	7	14	30	34	42	102	331	384	500
	Nakuru	39	70	160	158	214	80	312	308	451
	Nandi	72	104	197	201	261	43	172	177	260
	Narok	7	12	28	30	47	68	303	328	580
	Samburu	3	4	7	7	11	11	102	106	222
	Trans Nzoia	50	104	210	231	328	109	320	363	558
	Turkana	2	2	3	7	12	(14)	33	173	418
	Uasin Gishu	57	90	173	186	267	57	203	226	368
	West Pokot	9	17	32	68	56	92	260	658	522
Western		160	221	387	404	522	38	142	153	226
	Bungoma	114	166	312	334	453	46	174	193	298
	Busia	118	176	315	326	439	49	167	175	271
	Kakamega	218	288	486	501	618	32	122	129	183

Source: Republic of Kenya. Kenya National Bureau of Statistics, Kenya Population and Housing Census Reports (various).

Table A1.2: The 20 percent most densely populated districts in Kenya (new districts)

Province	New District	Rural population	Rural area (sq. km)	Density	Rural area prop.
Western	Emuhaya	135,723	134	1,011	0.77
Western	Hamisi	148,259	156	948	1.00
Western	Vihiga	96,535	104	931	0.52
Nyanza	Kisii Central	283,117	336	844	0.93
Nyanza	Gucha	364,460	444	821	0.96
Nyanza	Manga	87,859	111	789	1.00
Nyanza	Nyamira	263,201	338	779	0.85
Central	Githunguri	128,643	167	772	0.96
Nyanza	Gucha South	146,307	193	760	0.94
Nyanza	Masaba	142,987	193	739	0.64
Western	Kakamega South	104,669	144	729	1.00
Nyanza	Kisii South	54,969	78	701	0.62
Western	Butere	229,635	345	667	0.97
Western	Mumias	241,072	429	562	0.73
Western	Kakamega Central	203,513	371	549	0.88
Western	Bungoma South	314,145	579	543	0.87
Western	Bungoma West	209,286	388	540	0.87
Western	Bungoma North	222,573	421	529	0.75
Western	Bungoma East	168,063	327	513	0.81
Western	Kakamega North	200,276	424	473	0.99
Central	Kiambu East	45,074	100	449	0.53
Central	Gatundu	208,784	477	438	1.00
Western	Busia	283,514	650	436	0.95
Nyanza	Kuria East	81,833	188	435	1.00
Western	Lugari	271,700	642	423	0.96
Central	Murang'a South	321,310	763	421	0.74
Western	Teso South	111,762	278	403	0.93
Western	Teso North	72,818	183	399	0.70
Nyanza	Kisumu West	137,975	352	392	0.98
Rift Valley	Trans Nzoia West	238,854	622	384	0.83

Data source: Republic of Kenya, 2009 National Population Census Data

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CHAPTER 2: SMALLHOLDER LAND ACCESS IN KENYA: ARE SMALLHOLDERS FARMING THEMSELVES OUT OF NEAR-LANDLESSNESS?

2.1 Introduction

Smallholder farmers constitute the bulk of agricultural producers in sub-Saharan Africa. They constitute more than 70 percent of the farming community in this region and majority of them are poor (World Bank, 2007; Wiggins et al., 2010). Based on sub-Saharan Africa's natural resource endowment, an agricultural-led growth strategy has been touted as solution for reductions in poverty in this region. For example, Africa has been considered a continent with vast open lands (Bilsborrow, 1987; Wood, 2003). However, recent studies cast doubts on the land abundance hypothesis (Jayne and Muyanga, 2012). Each day, the Africa smallholder landholding shrinks as population density rises (Ellis, 2005). The land resource is not only shrinking but also degrading as a result of reduced fallows (Niasse, 2011).

The rising population growth represents both production opportunity and constraint to smallholder farmers in this region. On one hand, the increasing population signifies growing demand for food and high food prices thus creating "pull" for increased smallholder production. On the other hand, it results in diminishing farm sizes that may render many smallholders incapable of responding to the expanding food markets. Evidence shows that there has been a gradual decline in mean farm size as a result of population growth that has outstripped the growth in arable land over the past 50 years (Jayne and Muyanga, 2012). As a result, a substantial fraction of Africa's rural population lives in relatively densely populated areas where land scarcity is likely to preclude an extensive dimension of agricultural growth.

Despite these mounting population related challenges, analysts have pointed out that all is not lost. It is still believed that the sub-Saharan Africa region has the potential to revitalize smallholder agricultural productivity for reduced poverty and hunger if the appropriate policies are pursued. The Asian green revolution, for example, was a small farm phenomenon; over 80 percent of farms in India, Bangladesh, Indonesia, China, Japan and Viet Nam are less than two hectares. This broad based agricultural growth in these countries contributed greatly to rural poverty reduction (Johnston and Kilby, 1975; Mellor, 1995). While there has been general consensus of the need to improve smallholder agricultural production in Africa, little attention has been devoted to understanding whether agricultural and land institutions and policies in this region are compatible with land allocation patterns capable of generating broad based inclusive agricultural growth as was achieved in much of Asia.

This study therefore investigates the potential for similar forms of inclusive agricultural growth using Kenya as a case study. The study specifically investigates whether land institutions and policies in Kenya are making it possible for a broad-based smallholder led agricultural growth process as enjoyed in much of Asia. In Kenya, there has been a policy thinking that agricultural and land reforms accompanied by increased government budget support have the potential to underpin a revitalized system of smallholder production especially in areas where land sizes have become too small. Thus, the Vision 2030 (Republic of Kenya, 2008) and the National Land Policy (Republic of Kenya, 2009) proposes a range of agricultural and land reforms aimed at revitalizing smallholder agriculture in Kenya.

The study is inspired by two factors. First, the recent literature indicating that Africa is characterized by landholding inequalities -- manifesting as land underutilization on large farms and major constraints on farm income stemming from land constraints in densely populated smallholder areas -- making redistributive land reforms a potentially attractive strategy for improved smallholder land access (World Bank, 2002). van de Brink et al. (2006) points out that countries that have been least successful in reducing rural poverty (e.g. Brazil, Colombia, Guatemala, and South Africa) are characterized by highly unequal landownership and substantial public investments in large-scale farming. Evidence shows that two comparable countries in all other aspects can lead to dramatically different development trajectories if they started with initial inequality in household landholdings (Deininger and Squire, 1998; Deininger and Olinto, 2000; Acemoglu et al., 2001; Deininger, 2003). For that reason, in countries where farmland is unequally distributed, land redistribution from the most landed and inefficient users, in some cases the state, to the land-poor groups is been touted as a feasible strategy in combating food insecurity and poverty (Lipton, 2009). However, as Binswanger-Mkhize et al. (2009) observes, disagreements usually persist concerning land redistribution approach: should it be state-led or beneficiary-led? The mechanisms for land acquisition -- should it be confiscation, expropriation, negotiation, or market purchase? Who should be the beneficiaries of land redistribution? Who should pay for the reforms? In this connection, the study aims at examining as to whether the current institutions and policies have been successful in facilitating smallholders' access to land, and if not, how they can be improved. Are the intergenerational land transfers, land markets, and government land allocation practices enabling smallholders' access to land?

The second factor motivating this study is the increase in the number of medium-scale (emergent) farmers in many African countries over the last decade. This refers to farmers cultivating between 5 to 20 hectares of land. In Zambia for example, while the overall population of smallholders has increased by 33.5 percent, the number of farmers cultivating between 10 and 20 hectares has grown by 103 percent (Sitko et al., 2013). Another encouraging feature of this group is that their overall production is also increasing. Yet, the processes behind the medium scale farmers' growth have remained unclear in many countries. Is this growth driven by farmers who began their farming careers as small-scale farmers, cultivating less than 5 hectares of land and now transitioning to a larger scale of production through the capital and assets accumulation? If this is the case, is this a precursor to the inclusive agricultural-led structural transformation that Johnston and Kilby (1975) and Mellor (1976) hypothesized? Or is the growth driven by land institutions, policies and public spending patterns that encourage investment in land acquisitions by individuals from non-agricultural employment sector? The factors driving the growth of this class of farmers and their implications is a pertinent policy puzzle that this study intents to unravel.

Consequently, the study attempts to provide answers to the following questions:

1. How are households in densely populated areas responding to shrinking farm sizes? What are the potential modes of increasing smallholder land access in these areas and what are the challenges associated with these modes if any?
2. How do land policies influence land distribution through direct government land allocations and operations of the land markets? Do land allocations and land markets help address the emerging smallholder land constraints or do they facilitate the landed group acquire more land leading to landholding concentration among the large scale farmers?
3. Are households facing diminishing landholding sizes seeking to, and in a position to, migrate to relatively more land abundant regions, urban areas or quitting farming altogether? If so, what are the facilitating factors and if not what are the

impediments? Are “push” or “pull” factors the more important impetus for emigration from rural areas?

4. Are households facing diminishing landholding sizes perceive agriculture as a viable livelihood option in the future and especially for their children? If farming is not an option in the future, what are their envisaged livelihood strategies?
5. What are the characteristics of the medium-scale farmers in Kenya? What modes of land acquisition did they embrace to build up their landholding scale to the current levels? Is their growth driven by a process of smallholder capital accumulation and investment into area expansion? Or is driven by land acquisitions by individuals from non-agricultural employment sector? How is the medium-scale farmers using their land and how is their land productivity compared to that of the smallholders?

By understanding the various processes by which these households acquired their land, we can gain insights into the future distributional effects of existing land allocation policies in Kenya and their impacts on various national policy objectives, such as poverty reduction, equitable rural development, and household food security.

The rest of the essay is organized as follows: the second section presents an overview of land issues in Kenya; the third section presents the conceptual framework while the fourth section presents data sources. Data analysis methods are presented in section five. Section six presents the results while the seventh section discusses policy implications and concludes.

2.2 Historical background of land issues and policies in Kenya

This section reviews literature on land issues and policies that are relevant to smallholder farming system in Kenya. First we discuss the history of the land issues, popularly known to as the *land question*, post- and pre-colonial land policies and the challenges encountered under these policy regimes up to the introduction of the new National Land Policy (NLP) in 2009. Then we conclude by discussing the elements of the NLP.

2.2.1 The history of the land question in Kenya

The land question in Kenya stems from the colonial administration's expropriation of land for establishment of settlement schemes for the settlers at the beginning of the twentieth century. The colonial administration alienated land, often through compulsory acquisitions (Kanyinga, 2009). Before the arrival of the settlers, a stable and flexible structure of access and control of land was in place. Since the expropriation and alienation of land had to be based on law, a legal framework was established to promote further alienation and protect what had already been acquired. The colonial administration introduced the Crown Lands legislation in 1902 which stipulated that the Crown had original title to land that had been acquired (Okoth-Ogendo, 1991; Syagga, 2010). This legislation also established the "scheduled" areas, the fertile highlands, for white settlers and reserves for "natives". The reserves were mostly in the marginal and relatively non-productive areas. Mamdani (1996) refers to this action as the creation of "citizens" (settlers) and "subjects" (natives). The effect was that Africans became tenants of the Crown, with no more than temporary occupation rights to land (Okoth-Ogendo, 1991).

As Kanyinga (2009) explains, the White Highlands were about three Million hectares of which about half of that constituted high potential land suitable for cash crop farming and the remaining was appropriate for large scale livestock farming. Farm sizes averaged between 400 and 800 hectares in the highlands and above that in the pastoral areas. The White Highlands occupied about six per cent of the country and shared between 3600 white families. Since about 68 per cent of the country is remote and unsuited for farming, the remaining 26 per cent of the country's land that is considered arable was shared by about six million Africans.

This new development changed completely the African indigenous systems of land acquisition and control. Rather than the clan or kinship networks, individual families evolved as the important medium of acquiring land (Okoth-Ogendo, 1991; Bruce and Migot-Adhola, 1994; Verma, 2001). As Kanyinga (2009) explains, the Native Reserves were characterized by congestion and landlessness as human population continued to grow. This new land system and the boundaries introduced by the colonial administration could not allow free rural-to-rural migration to ease population congestion, a practice that was common before the arrival of the settlers. Land productivity also reduced significantly due to overuse and overgrazing. The colonial administration paid no attention to the congestion in the reserves. This is because the congestion triggered mass migration into the highlands by the landless in search for wage labor thereby providing the settler economy with cheap labor.

The continued neglect of the African reserves and the harsh economic conditions prevailing in these areas resulted in political unrests that were later addressed in a reform program introduced in 1956. The colonial government came up with a "Plan to Intensify the Development of African Agriculture in Kenya", popularly known as the *Swynnerton Plan*, named after then Assistant Director of Agriculture who designed it (Swynnerton, 1955). The *Plan* introduced land consolidation, adjudication and registration process. The plan sought to change the system from the collective control of land to a more individualized system by giving individuals control of their individual holdings. It removed the legal racial barriers in ownership of agricultural land and undertook to promote land purchase by Africans. The *Swynnerton Plan* was formalized by the Native Land Tenure Rules of 1956.

Even though on the surface the reforms looked like a plan to increase the native Africans' access to land, the colonial government had different underlying objectives altogether (Wasserman, 1976. ; Okoth-Ogendo, 1991; Bruce and Migot-Adhola, 1994; Kanyinga, 2000 and 2009; Anderson, 2005). First, the plan aimed making the natives busy in their farms and thus divert their attention from participating in the growing peasant uprising, the *Mau Mau* rebellion. Second, the plan aimed at creating a stable new class of wealthy African farmers and political leadership that would cooperate with the colonial governments in opposing the peasant uprising. To ensure that the land rights granted through the *Native Land Tenure Rules of 1956* were not disturbed, the *African Courts (Suspension of Land Suits) Ordinance* was passed in 1957 to bar all litigation regarding land (Syagga, 2010). These rules were later incorporated into the *Native Lands Registration Ordinance of 1959*. A new clause was included in these rules that declared that the first registration was not to be challenged even if the land had been obtained fraudulently. At the household level, only five persons could be registered as owners of any parcel of land and holding trust for the other members of the family (Syagga, 2010). In most cases only the male head of household was registered as owner of the land. As a result of this, the male headed could mortgage or even sell the land without recourse to other members of the family. Women and children were effectively excluded from controlling land.

Numerous settlement schemes and land purchase programs were initiated but none of them was successful addressing the problem of the native Africans' landlessness (Atieno-Odhiambo, 1995; Ogot, 1995; Anderson, 2005; Syagga, 2010). For example, in 1960 a Land

Development and Settlement Board (LDSB) was established to oversee resettlement schemes for some 20,000 families through a 7.5 million sterling pounds facility from the World Bank (Syagga, 2010). The scheme further offered credit facilities to Africans wishing to purchase farmland in the White Highlands. It intended to buy some 240,000 acres in the White Highlands, subdivide them into 100-acre parcels and distribute them to a select group of Africans who would farm alongside the whites (Kanyinga, 2009; Syagga, 2010). During the independence negotiations, this resettlement scheme program was transformed to the *Million-Acre Settlement Scheme* funded by the World Bank and the British government aimed at a rapid transfer of the departing European settlers farms to the emerging class of African elites. The transfers were on a willing-seller/willing-buyer basis and the loans could only be given to those who were financially able to pay on cash basis or in installments (Leo, 1989).

The Million-Acre Settlement Scheme came to a close in 1971. By this time, about 1.25 million acres had been used in resettlement exercise (Syagga, 2010). Since then, no other settlement program of such a scale has been initiated to address the unequal distribution of land. As Syagga (2010) notes, politicians and the colonial government loyalists, as well as wealthy businessmen managed to acquire thousands of acres through these settlement programs consequently creating a new class of African elites. As all these studies show, these programs led to elite capture helping only the already landed class to acquire more land. Besides the beneficiaries of the Million-Acre Settlement Scheme, there were some individuals who bought land through either tribal-based land-buying companies or through private transactions mainly by former European farms' laborers and forest workers who used their savings to buy land from departing Europeans settlers (Leo, 1989).

The post-independence years witnessed the grabbing of public land by politically well-connected personalities as documented in the Report of the Commission of Inquiry into the Illegal/Irregular Allocation of Public Land, popularly known as the *Ndung'u Report* (Republic of Kenya, 2004).Granting of rights to public land tended to favor the political elite and was basically in exchange of political support. This saw a lot of public land, both *alienated* and *unalienated*, and trust land unlawfully shift into the hands of elites and members of politically influential ethnic groups (Republic of Kenya, 2004). Many large government *alienated* land, for example the Agricultural Development Corporation (ADC) farms that were previously used for seed production and livestock breeding, were sub-divided and allocated to the political elites. As the Ndung'u Report (Republic of Kenya, 2004) elucidates, about 90 percent of the originally 60,000 acres of land owned by ADC was allocated to politically well-connected people such as politicians, judges, lawyers, and influential businessmen. The land was first illegally converted into settlement schemes under the guise of settling the landless and subsequently illegally allocated to the economic and political elites. Most of these allocations were undertaken after the introduction of multiparty democracy in 1991 and thus were basically meant for buying political patronage. The interests of the landless and the near landless smallholder farmers were ostensibly ignored in favor of the so called "politically correct" individuals' and their networks (Republic of Kenya, 2004). The Ndung'u Commission conservatively estimated the public land that was allocated illegally at about 246,964.79 hectares. Since the post-independence Constitution of Kenya has a provision aimed at protecting private property rights, this provision was ironically extended to protect lands acquired unlawfully.

Both pre- and post-independence skewed land allocation and land grabbing processes resulted in a number of individuals and families owning large tracts of idle land amidst dwindling smallholder landholding. The processes also fueled ethnic tension particularly against the Kikuyu community that significantly benefitted from the settlement scheme programs and the tribal-based land buying companies. For example, the Judicial Commission of Inquiry into Tribal Clashes in Kenya (Akiwumi Commission) report (Republic of Kenya, 1999) and the Commission of Inquiry into the Post Election Violence (CIPEV) (Waki Commission) report (Republic of Kenya, 2008) indicate that the Kalenjins in many occasions, and especially during general elections years, have attempted to flush out Kikuyus from what they regard as their (Kalenjin) ancestral land. While the Constitution of Kenya provides for the liberty of individuals to own land anywhere in the republic, such liberties do not seem to exist on the ground.

2.2.2 The post-colonial land policies and administration

The colonial legacy continued to cast its shadow over the post-colonial Kenya. The immediate independence governments retained the same colonial land policies and institutions despite recognizing inequitable distribution of land issue as a major post-independence challenge. There was no motivation to change the colonial land policies. These policies seamlessly served the selfish interests of the new landed Kenyan ruling elites, just as they did to the departing white settlers. Legal framework governing land was a collection of very many incoherent colonial statutes and the land administration was highly centralized. The result was a long history of inefficient and ineffective land administration and governance system. Consequently, this led to insecurity of tenure, excessive land fragmentation, disparities in land ownership, injustices in land distribution, landlessness, environmental degradation, proliferation of urban informal settlements, and poverty among others (Republic of Kenya, 2009).

Before the enactment of the new land policy in 2009, land ownership was classified into three major categories: *private (freehold) land*, *government (public) land*, and *trust (communal) land*. The private land made up about 20 percent of the country's land. The land under this category was either individually or collectively owned and was registered in the name of an individual or a company. Most of the high-potential agricultural land has already been adjudicated and registered as freehold. Collective freeholds include group ranches established under the Land (Group Representatives) Act of 1968. Private land was created from either government land or trust land through registration following the laid down legal procedures. Approximately 10 percent of Kenya's land is under government ownership (Table A2.1). It comprises two sub-categories, *unalienated* land (land which had not been leased or allocated) and *alienated* land (land which had been leased to a private individual or corporate body, or which had been reserved for the use of a government entity, or which has been set aside for another public purpose). Under the old land policies, it was only the President who had the right to allocate *unalienated* government lands; the President was allowed by law to delegate the powers to the Commissioner of Lands. The President or the Commissioner of Lands had no powers to allocate *alienated* land. The remaining 70 percent were trust lands (Table A2.2). Trust lands were held by County Councils on behalf of local communities, groups, families and individuals in accordance with applicable African Customary Law. Trust land could only be moved from the communal to private ownership through the formal adjudication processes.

The inefficient land administration coupled with declining and disparities in landholding and the perceived large farm inefficiencies brought the land issues into sharp focus and subsequent calls for land reforms during the 1990s. The land administration and management framework was highly centralized, complex, and bureaucratic. The framework was characterized by limited access to land information due to poor record keeping; lack of transparency in its operations; and weak and ineffective mechanisms for fair, timely and affordable land disputes resolution system. Among the most critical land reform issue were (and still remains) the inequitable distribution of land rooted in what has been popularly referred to as “historical injustices”. While the modes of land access were primarily through inheritance and the market, access to public land through direct government allocation became a major political patronage instrument (Republic of Kenya, 1999; Republic of Kenya, 2008).

The perceived large farm inefficiencies, also contributed to the call for land reforms in Kenya. The land reforms protagonists highlighted underutilization of land, particularly the large farms, leading to low agricultural productivity in the context of a high poverty and food insecure country. Most of these large farms are held under the 999-year leases granted to some political elites immediately after independence in 1963 (Bruce, 2009).

The efficiency of the land sales and rental markets also came under the spot light. It has been argued that efficiently functioning land markets have the potential to provide land access to households owning little or no land. Persistence of insecure land tenure systems coupled with information asymmetry, political interference, bureaucratic inefficiencies, corruption and land speculation by the political elite was perceived to slow down land market operations (Republic of Kenya, 2009). As mentioned at the beginning of this section, most of the land in Kenya is held under the trust lands (customary) system. The land reforms activists argued that economic growth required the transformation of customary land tenure to private ownership system; either individual or group ownership system. This would in turn permit the development of a large impersonal land market that would eventually lead to distributive efficiency in land use. To prove their point, they made reference to the impressive post-independence intensification and commercialization of agriculture in the highlands that they attributed to land registration that took place in the early independence days. However, doubts have been raised concerning the distributive efficiency of land markets in Kenya. The country is seemingly highly ethnically fractured and that land conflicts and tenure insecurity have persisted even in areas where land registration was accomplished many years ago (Republic of Kenya, 1999; Republic of Kenya, 2008). While the “official” land registration is supposed to confer undisputable land ownership rights, the authenticity of the past land titling process and the issued title deeds has remained questionable; paradoxically within the government itself. The Standard, a local daily newspaper, quotes a Kenya Government Cabinet Minister in charge of Lands and Settlement, Amos Kimunya, publicly proclaiming that “a title deed is just but mere piece of paper” (Mutua, 2005).

The unavailability of agricultural land has also linked to the existence of the unproductive marginal lands in the northern parts of the country. These areas lack the requisite infrastructural facilities and services to boost agricultural productivity and thus have rendered unattractive. The land reforms debate centered around putting in place an enabling infrastructure and services for agriculture and livestock development such as passable roads, research, extension services, finance, marketing, agro processing, rural electrification and farmers’ training centers.

2.2.3 The National Land Policy

To address the concerns raised in the foregoing sub-section, the government came up with the National Land Policy (NLP) (Republic of Kenya, 2009). The NLP, nested in the new constitution (Republic of Kenya, 2010), provides a new overall framework and defines the key measures required to address the land administration and access issues. The new land policy designates all land in Kenya in three distinct categories: *public land, community land,* and *private land*. A detailed description of what land lies under each category and how it is supposed to be administered is found in Table A2.3. The policy advocates for the following landholding overarching principles: (1) equity; (2) non-discrimination; (3) efficiency; (4) productivity; and (5) sustainability. These include measures to eliminate discrimination, ethnic and gender, in land access; land taxation to curb inefficient land use and idle land holding and hoarding tendencies; resolution of historical injustices; improvement of tenure security; efficient utilization of marginal lands; and efficient land markets.

To implement the National Land Policy, the Government has set up three key land management institutions: the National Land Commission (NLC), the District Land Boards (DLBs) and Community Land Boards (CLBs) (Republic of Kenya, 2009; Daily Nation, 2013). The NLC is an independent constitutional body responsible for land administration functions and serves as the manager of all public land. The NLC primary task is to provide the public infrastructure and support for property rights and markets in land. The mandates of the NLC include, holding title to and manage public land on behalf of the Government; establish and maintain a register of all public, private and community land in the country; exercise the powers of compulsory acquisition and development control on behalf of the government and local authorities; and to collect and manage all land tax revenues except those that are collected by district-based authorities. The NLC is mandated to conduct investigations into the "historical land injustices" and recommend appropriate redress. The NLC will execute its mandates through DLBs, and CLBs. The DLBs are agents of the NLC at the district level and are accountable to the NLC in the performance of their functions. They consist of democratically elected community representatives and supported by officers appointed by NLC. Community Land Boards (CLBs) constitute the third tier of a devolved land administration and management. As a break from the past where the community lands (customary lands system then) were held and managed by County Councils on behalf of local communities, the CLBs are mandated to administer and manage land held under the community land category. Just as the DLBs, the CLBs are composed of democratically elected community representatives and supported by officers appointed by NLC. The elected members of CLBs are people ordinarily resident in an area as determined by the DLBs in consultation with the affected communities and membership criteria is expected to consider ethnic diversity, gender and socio-political dynamics.

Next, we discuss some of the key features of the new land policy and some of the likely challenges the policy is bound to encounter. While the new policy has reformed the way community lands are managed and administered, it is not clear whether the policy will allow the community land ownership system to evolve over time to private (individual, family or group) ownership (Bruce, 2009). The policy is also unclear about the need to reform the community (customary) land system, a system that is known to be bedeviled by corruption (authoritarianism and non-transparency) and gender and ethnic based land access discrimination.

The policy calls for the recovery of public land acquired irregularly and establishment of a Land Title Tribunal to determine the legitimate ownership. Article 68 of the new Constitution of Kenya requires Parliament to enact a law that will "enable the review of all grants or dispositions of public land to establish their propriety or legality". It proposes establishment of a legal and institutional framework to facilitate the returning land back to the original owners or, where this is not possible, providing original owners with compensation. Historical land injustices are to be resolved using mechanisms such as restitution, resettlement, reparation, and compensation of historical injustices and claims. A number of issues have been raised concerning the tackling of the historical land injustices. It is important to note that land initially acquired illegally may have changed hands and now in possession of innocent buyers; in some cases, smallholder farmers. There are fears that what constitutes a redress of first generation injustice to one group may constitute a second generation injustice to another group.

Concerning the resettlement of the landless, the policy does not suggest how to overcome challenges encounted in the past resettlement programs. As discussed earlier on, the past resettlement programs ended up “settling” the political elites and their networks instead of the deserving landless or near landless groups (Ogot, 1995; Anderson, 2005; Syagga, 2010). It is important to note that empirical evidence indicates that well-targeted land redistribution programs have a direct impact on poverty reduction (Binswanger-Mkhize et al., 2009). As Bruce (2009) suggest, the government should also consider the option of setting up a fund to facilitate the landless or those in need of resettlement to purchase land from the open markets. This will lead to scattered patterns of resettlement rather than concentrated patterns that may lead to ethnic tensions and land conflicts later. The concentrated patterns of resettlements of one community in what is considered other ethnic group’s territory to a large extent contributed to the 2008 post-election violence in Kenya (Kniss, 2010). In Uganda, similar consequences resulted when the Bakiga migrants from densely populated southwestern Uganda purchased land in Buganda as a group (Muhanguzi, 2008; Kato, 2009).

The new policy proposes to facilitate the commercialization of land rights to make land market operations more efficient and effective and to institute a regulatory framework for land rental markets. Land registries will be decentralized to facilitate and promote land market operations in community land ownership system. Increased security of land tenure and the development of land market is hypothesized to allow those who have more land than they need to lease it to others thus increasing distributive efficiency. However, as discussed in the next section, land markets rarely lead to redistribution of land access from large to smallholders in countries where there is a highly unequal distribution of land (Deininger et al., 2004). Land markets alone cannot be counted on to redistribute land from large landowners to the landless or near landless smallholders (Binswanger-Mkhize et al., 2009).

To address land fragmentation problem, the policy suggests setting up of economically viable minimum landholding sizes for various agroecological zones and regulation of the manner in which any land may be converted from one category to another. According to this policy, measures will be put in place to determine the appropriate land sizes according to use and productivity in each zone and to provide incentives to stimulate voluntary readjustment of landholding sizes. However, the implementation of this proposal will not be easy task. First, a blanket minimum land size for all agricultural enterprises in a given zone is not practical. For example, land considered too small for maize production may be enough for large scale poultry or vegetables production. Secondly, this requirement may drive the already small parcels out of the registry especially when subdivided to sizes way below the set standards.

With regard to access to public land, the policy suggests a comprehensive review of public land allocation procedures to determine the appropriate amount of land to be allocated to individuals depending on intended use and agro- ecological zone. Concerning the active long land leases, especially the 999-year leases, mechanisms will be established for the surrender of leases going beyond 99 years in exchange for shorter leaseholds. Closely connected to this, the new policy prohibits non-citizens from holding freehold interests in land. Several questions still linger about this long term lease conditions. Are they meant to curb the pervasive unproductive use of land under leaseholds? What is the purpose of the long term leases? Are they meant to foster foreign direct investments and/or technology transfer? If so, then the appropriate lease length should be enterprise specific depending on the level of investment and the duration the investors need to recoup their costs and earn returns on their investment. If the land policy concern is improving smallholder access to land, then the government should consider allocating the land released from the long term leases to the landless and near landless groups. The policy should also put in place incentives to entice leaseholder who have more land than they need to sub-lease some of their land to others.

To facilitate the efficient utilization of land and land-based resources, the policy calls for the establishment of appropriate land taxation system to discourage land speculation. The goal is the provision of appropriate incentives and sanctions to ensure that land owners use their land productively and sustainably. The main shortcoming to this proposal is that it fails to conceptually define what constitutes “productive and sustainable” use in various agroecological zones and enterprises.

The policy puts in place measures to curb land allocation malpractices and elite capture. It also takes away some powers from some state organs such as the Presidency and the Ministry of Lands and transfers them to others bodies such as the National Land Commission and Communal Land Boards. The policy points out clearly that that it will not be possible for every person to own land and that the government will facilitate secure access to land for the citizens through other means, such as leasehold mechanisms. However, the policy certainly leaves many hard decisions to legislators and implementers preparing key legislations to support the implementation of the policy and the Land and Environment chapter of the new constitution.

2.3 Conceptual framework

In this section we develop a framework to analyze the processes behind the smallholder and medium scale farmers' land access in Kenya. Distributions of land and land access in any society in Africa are the outcome of complex historical and geographical processes, and hence, it should not be surprising if the processes fail to conform to any known economic theory. Farm households acquire and exercise rights to obtain and maintain access to land or they lose these rights through multiple paths: as members of social groups or networks, through labor and investment, and through purchase (Shipton and Goheen, 1992; Berry, 1993). To explore the various avenues that households use to access land and how successful they have been in improving smallholder access to land, a framework proposed by de Janvry and Sadoulet (2001) is used. According to this framework, pathways through which households can access land fall into four categories: (1) Intra-family transfers such as inheritances, *inter-vivo* transfers, and allocation of plots to specific family members; (2) access through community membership and community open access resource; (3) access through land sales and rental markets; and (4) access through non-coercive policy interventions such colonization schemes, decollectivization and devolution, and land market-assisted land reform (Figure A2.1). As de Janvry and Sadoulet (2001) point out, each of these avenues is a potential object of policy interventions to improve land access and use efficiency for the smallholders facing shrinking farm sizes.

Historically, family access to land depended on their membership and good standing within a particular group exerting control over the land. Kinship and ethnic adherence along with status, gender and seniority determined access and use rights (Berry, 1989; Migot-Adholla and Bruce, 1994). However, with growing human population densities and the ensuing land squeeze land access through within community transfers is becoming less and less feasible.

Most farm households in sub-Saharan Africa gain access to land through intra-family transfers. Even in countries where land markets are well developed, access to land through inheritance remains fundamental. The transfer of land from parents to children takes place when children marry (*inter-vivo*) and form new productive units or when parents age and eventually die (*post-mortem*) (de Janvry and Sadoulet, 2001; Muyanga et al., 2010). Land transfers from parents to children depend on the number of potential recipients of the parents' assets. For this reason, factors such as the number of male (female) children of the parent's family in patrilineal (matrilineal) inheritance systems may influence current households' landholding. In polygamous families, land is shared equally between wives regardless of their number of children.

Some groups, notably women and children, have in many communities been excluded from land inheritances processes in sub-Saharan Africa (Cooper, 2008). Females land user rights most often come through their ties to kin and husbands and are contingent on marriage (Berry, 1993; Smucker, 2002). A senior wife may have stronger rights than a junior wife. A woman's rights may increase with the length of marriage or with number of children and the rights may end with divorce, with widowhood, with failure to have sons (Gray and Kevane, 1999). As Gray and Kevane (1999) further point out, transfer rights are usually limited for women -- they cannot designate an heir, sell land, or lend land to others. Traditionally, females have no claim on parental assets (Garg and Morduch, 1998; Morduch, 2000). Unmarried daughters stayed with the parents but are not entitled to land allocation. In some cases unmarried daughters are allocated land for farming purposes only, not to own; and are required to surrender the land back to the parents or brothers upon marriage. Since in most African societies individuals are considered adult after marriage, unmarried daughters remain "children" and thus required to continue to "eat from their mother's pot". However, nowadays girls born without male brothers are being allocated the parents' land in some communities.

With diminishing land sizes, access to land via family lineage and community membership is giving way to individualization of property rights and to access to land via land sales and land rental markets (Pinckney and Kimuyu, 1994; Place and Migot-Adholla, 1998; Holden, et al. 2009). Land markets have the potential to improve households land access and production efficiency by equilibrating land and non-land factor ratios across farms (Deininger, 2003). However, in practice the outcomes of land markets in achieving these objects remain under researched especially in sub-Saharan Africa. The achievement of the positive land markets outcomes may be thwarted by credit market imperfections, high transaction costs, government regulations, and ethnicity and cultural related constraints. If land markets are characterized by high transaction costs and credit markets imperfections, farmers' ability to access land from participating in the land markets is directly correlated with their wealth and land endowment (Deininger and Jin, 2008). In such cases, land markets lead to transfer of land from land-constrained to land-abundant households (Andre and Platteau, 1998; Zimmerman and Carter, 1999; Kranton and Swamy, 1999).

There have been relatively few studies of the performance and impact of land markets in sub-Saharan Africa (Holden et al., 2009). Land markets, and particularly land rental markets, have recently been found to be widespread in sub-Saharan Africa, especially in the more densely populated areas where land is relatively scarce and highly fragmented. In some countries such as Ethiopia and Mozambique, land sales are prohibited by the law while in Kenya, both land sales and rental markets are legal and active. In Kenya, land sales transacting parties are required to seek approval from the Land Control Board (LCB) for private owned land (registered) and approval from the government provincial administrators (chiefs) for customary owned land (land held without title deeds). Evidence shows that between 10 and 20 percent of households in rural Kenya rent-in land (Wangila et al., 1999; Yamano et al., 2009; Jin and Jayne, 2013). As Jin and Jayne (2013) observe, land purchases require a much greater up-front payment than renting land and thus may not work for credit constrained smallholder farmers. However, the practice of deferring a part or full rent payment until after harvest facilitates smallholders' participation in land rental markets (Jin and Jayne, 2013).

A study by Yamano et al. (2009) found out that both land sales and land rental markets improve equity and efficiency among smallholders in Kenya. More recently, Jin and Jayne (2013) established that land rental markets transfer land from less efficient to more efficient smallholders and also improve access to land for households with relatively small farms. However, they found that the overall income gains accruing to households with the smallest farms from renting were insufficient to pull a substantial proportion of rural households out of poverty. In general, there is still little evidence Africa on how land rental and sales markets play out in Africa and whether facilitate land transfer from the landed group to the land-poor groups. Are the smallholders able to generate surpluses, accumulate more land and farm themselves out of smallholder farming and poverty into medium scale and subsequently into large commercial farming? This is a puzzle this study is set to unravel.

Socio-political capital and networks are also important factors explaining access to land in certain situations. Access to public and community land or the ability to navigate through bureaucratic land market systems is concentrated in the hands of those with socio-political capital and networks conferred through public sector employment. For example, Jayne et al. (2008) show that households in which the male head is related by blood to the local headman have an average of 0.4 hectares more land than other households in Zambia's smallholder farming sector. In other situations, elites manipulate the decision-making arena and agenda to obtain most benefits (Beard and Phakphian, 2009; Bruck and Schindler, 2009). Elite capture is a function of four factors, namely: disparate access to economic resources, asymmetrical social positions, varying levels of knowledge of political protocols, different education attainment and employment status (Platteau, 2004). As earlier pointed out, the pre-and post-independence settlement schemes meant to settle the landless and public land grabbing in Kenya ended up benefiting the political elites such as chiefs, politicians, and provincial administrators and their associates (Republic of Kenya, 2004; Kanyinga, 2009; Syagga, 2010).

Governments can improve smallholder access to land in a number of ways. In some other situations, governments have intervened to improve the functioning of land markets but obviously with mixed results. Instruments such as taxes on idle land have the potential to shift land from the landed but less efficient users to the more efficient but landless or near landless groups. In post-apartheid South Africa, market-based land reforms implemented by the government to address the racial unequal distribution of agricultural land on "willing-seller willing-buyer" basis inadvertently ended up promoting new black elite entry into commercial farming at the expense of the land-poor smallholders (Lahiff and Cousins, 2005). Lahiff and Cousins (2005) point out that this approach is likely to succeed if accompanied by complementary interventions such as investment in infrastructure, availability of new technologies, reorientation of agricultural research and extension services towards the smallholders, and establishment of smallholder credit programs. Binswanger-Mkhize et al. (2009) argues that when poor people are given good farmland and adequate post- settlement support, they are likely to lift themselves out of poverty.

In situations where the state owns land that is unutilized or underutilized, the government can institute transparent and orderly procedures for land allocation to land-poor smallholders (Munshifwa, 2002; Stambuli, 2002). In situations where state-sponsored redistributive land reforms have been carried out, the results have been mixed. For example, in Zimbabwe, while studies show that 68.2 percent of the land went to land-poor, development commentators and media argue that the process was marked by gross violation of individuals' property rights and that the beneficiaries of the process were the political elites (Scoones et al., 2010).

The government can also raise value of underutilized or unutilized but agriculturally potential land improved public investments in physical infrastructure. This approach was successfully pursued by southern Rhodesia and Zimbabwe starting in the 1970s with its "growth point" strategy in the Gokwe area, once cleared of tse tse flies (Govereh, 1999). As Govereh explains, key public investments in this once abandoned but agro-ecologically productive area induced rapid migration into Gokwe from heavily populated rural areas, leading to the "white gold rush" of smallholder cotton production in the 1980s. Investments that increase land economic value include investments in road infrastructure, schools, health care facilities, electrification and water supply, and other public goods required to induce migration, settlement, and investment in these currently under-utilized areas.

2.4 Methods and data sources

2.4.1 Empirical models and estimation strategy

In this section, we present econometric models to be estimated. The objectives of this exercise are twofold: first, to understand the factors determining the entry pathway into the medium-scale farming status, and second to understand the correlates of the medium-scale farmers' input use intensities and productivity. In evaluating the determinants of medium farmers' outcomes and the influence pathways into medium scale farming have on agricultural productivity, a model that can be employed is the following:

$$\ln y = X'\beta + \delta I + \varepsilon \tag{2.1}$$

where y is the medium scale farmers' agricultural production outcome (landholding, and input use and output supply intensities) of interest, X is a vector of exogenous characteristics, and I is a dummy variable *(I* = 1 if the individual followed agricultural led pathway in to medium scale farming and 0 if entered laterally). This approach, however, might yield to biased estimates because it assumes that pathways into medium scale farming are exogenously determined. Some unobserved characteristics that influence the probability to follow a particular pathway could also influence farmer's agricultural production outcome. Pathway into medium scale farming may be based on individual self-selection. Farmers that follow agricultural pathway may have systematically different characteristics from the farmers that entered into medium scale farming laterally. Unobservable characteristics of farmer and their farm may affect the pathway choice and the production outcome, resulting in inconsistent estimates in specification (2.1). Similarly, pathway choice into medium scale farming should not be assumed to have an average impact over the entire sample of medium scale farmers by way of an intercept shift only. Pathways into medium scale farming should be allowed to influence other covariates' coefficients in the farmers' production outcome equations.

This motivates the use of an endogenous switching regression model (Lee, 1978; Maddala, 1983; Willis and Rosen, 1979). Endogenous switching model accounts for both endogeneity and sample selection issues and allows interactions between pathway into medium scale farming and other covariates in the input demand and output supply functions. The model consists of pathway into medium scale farming equation and medium scale farming outcome of interest equation. The pathway part is estimated using a standard limited dependent variable method while the production outcome equation is estimated separately for each group (agricultural and lateral entry) conditional on pathway into medium scale farming. The endogenous switching model is specified as follows:

$$I_i^* = Z_i\gamma + \mu_i\,,\quad I_i = \begin{cases} 1 & if \quad I_i^* > 0 \\ 0 & otherwise \end{cases} \qquad \text{Selection equation} \qquad (2.2)$$

$$\ln y_{1i} = X_i\beta_1 + \varepsilon_{1i} \;\; if \;\; I_i = 1 \qquad \text{Regime 1} \qquad (2.3)$$

$$\ln y_{2i} = X_i\beta_2 + \varepsilon_{2i} \;\; if \;\; I_i = 0 \qquad \text{Regime 2} \qquad (2.4)$$

where I^* is latent variable for pathways into medium scale farming and I is its observable counterpart (equals one if household used agricultural pathway and zero if entered medium scale faming laterally), Z is a vector of observed farm and non-farm characteristics determining pathway into medium scale farming, and μ is random error term. The vector Z contains unit as its first element and variables that are hypothesized to influence pathways into medium scale farming status namely, household demographic factors such as the age, gender and education attainment of the household head, household size; landholding when the family started farming, and number of years in the current location. As shown in the conceptual framework, family history is a good predictor of channels that households follow to increase landholding and consequently build their production scale. The family history factors relate to the characteristics of the father to the initial household head. They include the amount of land he owned before subdivision, his level of education, whether he's alive or not and whether he held community leadership position. The type of non-farm job also matter. Individual holding public offices or community leadership position have both the social capital and political clout that enable them to acquire land (Bruck and Schindler, 2009). In this model, household's social capital is captured by the household's duration in the current location and participation in public as well as private employment. Land attributes variables include the distance from the plot to the nearest water and motorable road; land location (in the region whether household head was born or outside); and mode of land acquisition and land tenure status. Variables extracted from various geographic information system sources were plunged in to control for land quality in the location where the household is situated. These include the length of the growing period, net primary productivity, elevation and slope. District dummies are also included to capture remaining local fixed effects as well as the survey respondent dummies.

Separate endogenous switching models (equations 2.2 to 2.4) are estimated depending on how the dependent variable in equations (2.3) and (2.4) is defined. First, y is defined as the household land access (land owned and land rented in) and the area under crops; second, intensity of fertilizer application per hectare cultivated; and third as crop production per hectare cultivated and controlled (owned and rented-in). It is important to mention that medium-scale famers grow an array of crops on one land plot each season and the crop grown vary widely across agroecological zones. Consequently, it becomes imperative to aggregate the crop outputs in some manner. To do this, a modification of the Fisher-Ideal index (Figure A2.2) suggested by Mason (2011) is used. The vector of explanatory variable (X) for the landholding estimation contains unit as the first element, maize price, fertilizer prices, distance to infrastructure facilities and markets, household demographic variables, household land attributes and agricultural potential of the location where the household is located. Data on other output and input prices (such as wages and land rental rates) was not collected during the survey.

An efficient method to estimate endogenous switching regression models is by full information maximum likelihood (FIML) estimation (Lee and Trost, 1978; Lokshin and Sajaia, 2004). The FIML method simultaneously estimates the selection equation and the regression equations to yield consistent standard errors. For the endogenous switching model identification, there should be at least one explanatory variable in the first stage selection equation that is not included in the second stage regression (Maddala, 1983). In this case, some variables that are hypothesized to influence the pathways into medium scale farmers include households' head participation in non-farm employment activities and some household historical factors.

2.4.2 Data sources

The study uses data from various sources. The first data set came from a survey involving about 200 medium scale farmers in Kenya. Medium scale farmers in this study are defined as farmers cultivating 5 to 50 hectares of land. Based on field experience, this group has little in common with large-scale commercial farmers in terms of farm size, access to finance, input application rates, and farm management strategies. The aim of the survey was to get insights into the characteristics of the medium scale farmers, how they achieved their current scale of operation, and how efficiently they are utilizing their land. With help of Ministry of Agriculture officials, the Kenya 47 counties were first stratified into five broad categories depending on farming systems and agroecological characteristics. Since the focus of the survey was medium - scale farmers, four counties (Bungoma, Trans Nzoia, Uasin Gishu, and Nakuru) were randomly selected from the containing the highest concentration of this type of farmers. With help of local

Ministry of Agriculture officials in the selected counties, lists of farmers operating between five and 50 hectares in each county was complied. Owing to costs and logistic reasons, only two to four divisions in each county were included. The 200 households for interviews were selected randomly from the selected divisions (Table A2.4). The survey instrument[2] captured information both at the household and land parcel level including, household characteristics and history, farming patterns, agricultural production, household incomes and asset, and land parcel features.

The 200 medium-scale farmers' survey instrument captured the geographic positioning system (GPS) coordinates of each household (Figure A2.3). This made it possible to compliment the survey data with land and soil quality variables data extracted from various geographic information systems (GIS) sources. These variables extracted from the GIS sources included the length of the growing period (LGP) (Fischer et al., 2000); net primary productivity (NPP) (Zhao et al., 2005); and elevation (meters above the sea level) and slope (measure of steepness -- degrees), both from Wilson et al. (2007). The LGP and NPP are useful indicators of agricultural potential.

The second data source is the nationwide Egerton University/Tegemeo Institute Rural Household Survey, a panel dataset tracking roughly 1,300 small-scale farm households in 5 survey waves over the 13-year period from 1997 to 2010. The sampling frame for the panel was prepared in consultation with the Kenya National Bureau of Statistics (KNBS) in 1997. Subsequent surveys were conducted in June of 2000, 2004, 2007 and 2010. Over these 5 panel surveys, 1243 household were able to be consistently located and surveyed. For this analysis, households in the coastal region of the country were excluded because farming is found to

[2] Survey instrument available here: http://aec.msu.edu/fs2/kenya/Land_Access_in_Kenya_Study_Instrument_Final_2012.pdf

account for a relatively small share of household incomes. This leaves a balanced panel of 1146 households surveyed consistently in each of the five years. The surveys collect information on demographic changes, movements of family members in and out of the household since the prior survey, landholding size, land transactions and renting, farming practices, the production and marketing of farm products, and off-farm income-earning activities[3]. This data set was used for three main purposes. First, the data is used analyze how smallholder landholding sizes evolve over the panel period. Second, the data is used to examine if land markets lead to equitable land distribution in rural Kenya. The household landholding Gini index is computed for each panel survey to examine whether inequality in landholding is reduced through smallholder households' participation in land sales and rental markets during the 13 years panel period. Third, the 2010 survey data from the districts where the medium-scale farmers' survey was conducted is used to compare the medium scale farmers and smallholders in terms of landholding, land use and farm productivity.

The household level data is complemented by focus group discussions (FGDs) information collected in the densely populated and land constrained regions of the country (Table A2.5). The objective of the FGDs was to get insights into smallholders' perceptions of the increasing land constraints, their coping mechanisms, emerging nonfarm income earning opportunities, outmigration trends, and households' future outlook[4]. The FGDs consisted of between 12 and 15 participants. All the FGDs were similar in composition and included male and females, young and old farmers and local leaders.

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[3]Each of these surveys instruments, which contain the details of the types of information collected and used in this study, can be viewed and downloaded at http://www.aec.msu.edu/fs2/kenya/index.htm.

[4]Checklist available here: http://aec.msu.edu/fs2/kenya/FGDs_Checklist.pdf

2.5 Results

2.5.1 Descriptive results

As a prelude to the econometric models, descriptive results from the medium-scale farmers' survey and the smallholder panel survey data are reported. The analysis is enriched by qualitative data from the focus group discussions. The descriptive results are organized in four major categories reflecting the major study questions, namely: (i) Emerging land constraints with increasing population densities; (ii) Modes of land access and associated challenges; (iii) Out migration trends in the densely populated areas; (iv) Future prospects of the households in the densely populated areas; and (v) Characteristics of the emerging medium-scale farmers.

(i) Emerging landholding constraints with increasing population densities: Access to land emerged as a key factor limiting agricultural production in the densely populated regions of the Kenya. Generally, household landholding sizes have declined across the country. Table 2.1 shows that the average landholding in rural Kenya stands at about 2.6 hectares which translates to about 05 hectares per adult equivalent. Household landholding sizes range from a high of 4.62 hectares in the high potential maize zone to a low of 1.08 hectares in the densely populated Western Highlands. It was reported in the FGDs that it is impossible for persons starting families in the densely populated highland areas to access more land either through inheritance from their parents, or through land markets. Even in the areas considered relatively land abundant like in the lowlands, land sizes are swiftly declining due to mounting population pressure. Besides the growing population densities and the ensuing land subdivisions, distress land sales as a result of pressing family financial needs (e.g. education and medical costs) and conversion of agricultural land at close proximity to urban centers to residential plots are also gradually contributing to declining agricultural land problem.

Table 2.1: Households mean landholding sizes (hectares)

	Survey year			
	2000	2004	2007	2010
Eastern Lowlands	2.30	2.31	2.36	2.40
Western Lowlands	1.64	1.64	1.66	1.68
Western Transitional	2.87	2.89	2.89	2.91
High Potential Maize	4.62	4.64	4.67	4.69
Western Highlands	1.08	1.08	1.09	1.10
Central Highlands	1.24	1.24	1.24	1.26
Marginal Rain Shadow	2.22	2.20	2.20	2.23
Overall	2.59	2.60	2.62	2.64

Source: Tegemeo Institute Rural Household Surveys.

Not only are household farms shrinking in densely populated regions, a decline in soil fertility has also been experienced. It emerged from the FGDs that the declining soil quality is attributable to soil nutrients mining without adequate replenishment due to mono cropping, over cropping and relay cropping; soil erosion/degradation occasioned by heavy rains; deforestation; and use of unsuitable fertilizers as well as poor soil conservation practices among households. The use of wrong fertilizers and continued use of non-organic fertilizer types have exacerbated the soil quality problems in some areas. It was reported that most of the farm households do not carry out soil testing to establish the suitable fertilizer types for their soils. Continued use of non-organic fertilizer types was associated with increasing soil acidity. Application of Di-Ammonium Phosphate (DAP) and Calcium Ammonium Nitrate (CAN) fertilizers for a long period contributes to increased acidity resulting in stifled crop yields.

Results from the FGDs also showed that land conflicts and disputes among neighbors and siblings are on the rise with declining land sizes. Land conflicts relate to boundary disputes with neighbors and contested land inheritances among siblings. Inheritance related disputes are common especially in situations where land parcels are not registered or are registered in the name of a deceased parent or grandparent. Cases of land conflicts occasioned by returning siblings who have been away in search of non-farm employment but now would want to revert to farming are also on the raise as a result of increasing non-farm employment opportunities scarcity. Land scarcity is also associated with increased incidences of fraudulent land deals due to poorly drawn land sale agreements and fake land title deeds.

(ii) Modes of land access and their success in fostering increased smallholder landholding: Two major land access channels where reported, namely: (1) inheritance from parents; and (2) land sales and rental markets. It emerged from the FGDs that, unlike about three decades ago, there are no unallocated lands and/or common grazing lands available in both the low and highly densely populated areas. Some cases of households accessing land through government allocations were reported in the North-Rift region. Most of this land was trust land, including settlement scheme land purchased by government at independence for the settlement of smallholder farmers; land acquired through illegal excisions of forestland, national parks, game reserves, wetlands, riparian reserves and other protected lands; and Agricultural Development Corporation (ADC) land. Results from the FGDs indicated these land allocations only benefited economic and political elites and not the landless or the near landless smallholder farmers.

We next discuss the major land access modes in more detail and how they have evolved in the context of the increasing human population densities next. Land inheritances from parents emerged as the most important way in which household heads acquired land. Parents are required by the African customary laws to bequeath sons who get married and are starting families with land regardless of landholding sizes. These customary land transfer practices have led to land subdivisions resulting in tiny landholding especially in the land constrained regions of the country. The land subdivision problem is likely to be aggravated by two new developments. First, unlike in the traditional African society where only sons inherited land from their parents, some communities are now allocating land to unmarried daughters. Second, the new Land Policy (Republic of Kenya, 2009) provides for equal treatment of children regardless of gender as far as inheritance of family assets is concerned. This provision is also entrenched in the new constitution promulgated in August 2010 (Republic of Kenya, 2010). Consequently, women are now entitled to land inheritance from their parents, married or not. It was reported that the implementation of the new law is bound to introduce a new dimension of family land conflicts as married women return to their parents to claim their land entitlements.

Even after parents to children land transfers, it was reported in the FGDs that the title deeds in most cases remain in the parents' names due to a bureaucratic and costly land transfer process prevailing in the country. Cases in which the land title deeds are in the names of deceased parents or grandparents were also reported. It is important to note that transfer of title deeds involving deceased persons is even more complicated, costly, and time consuming process in Kenya. In some other situations, to circumvent the costly land transfers process, siblings agree to register their land inheritance in one of the sibling's name. This practice has however resulted in increased cases of land conflicts among siblings and/or siblings' offsprings with time as land scarcity becomes a binding constraint.

The other major avenue through which households acquire land is through participating in land sales and land rental markets. Results from the focus group discussions indicate that land rental and sales markets are available in the low and medium densely populated areas. The markets are even becoming more vibrant with land scarcity as population density increases. With land scarcity, land has acquired value and is systematically replacing livestock as the primary indicator of wealth in rural Kenya. Consequently, land values have steadily increased over time due to high demand arising mounting population pressure. Land sale prices are almost three fold in relatively densely populated than in medium and low populated regions. For example, a hectare of high quality land costs KSh900 thousand in Bungoma County (medium density county) and about KSh3 million in Vihiga County (high density county).

Like in other countries, land markets are characterized by high transaction costs in Kenya. Transaction costs include the search cost of finding a willing seller, the right type of land, and at the right location. For example, cases of individual looking for land to buy and could not find the quality of land they were interested in were reported in the FGDs. Transactions costs are also being amplified by the proliferation of fraudulent land sales and fake title deeds as buyers have to incur additional costs to verify the authenticity of the land registration documents.

While it emerged that inter-community land transactions were allowed as long as the sellers and buyers agree and the land parcel was dispute-free, side interviews with opinion leaders revealed that some communities are less receptive to buyers from other communities. It emerged that people facing land constraints are now becoming less inclined to buying land outside what is considered “their ancestral territory”. This situation was exacerbated by the ethnic-based land conflicts that rocked some parts of the country following the 2008 election outcome. It was mentioned in some FGDs that background checks on the buyers are carried out to avoid allowing in criminals elements and outdated/outlawed cultural practices such as illicit liquor brewing and female circumcision. Ethnicity related land markets limitations were also reported in the demand (buyers') side too.

Land rental markets are active in all regions with agriculturally arable land. Just like the land buying markets, rental prices have been on the increase in the last ten years. It emerged from the FGD that a hectare of good quality land ranges between KSh12000 and KSh25000 in the highly densely populated regions and between KSh7000 and KSh15000 in the medium densely populated regions. Households seeking to rent in land in most cases are required to pay the rent upfront before the start of the farming season. The demand for rental land in the high and medium populated areas is so high that in some areas (e.g. Nakuru County), farmers interested in renting in land are required to pay two to three years before the cropping season. While there are no ethnic-based discriminations in land rental markets, in some situations, the government administrators (chiefs) are involved in overseeing land rental agreements.

How successful are the land sales and rental markets in reducing landholding inequalities among the smallholder farmers? To answer this question, we use the 13 year Tegemeo Institute Panel data. We compute the Gini index of smallholder landholding after first factoring in land sales and buying transactions only (Table 2.2) and second when we factor in land sales and buying transaction and land rented in (2.3) over the panel period. The results generally show that land selling and buying does not significantly reduce landholding inequality among the smallholders. Landholding inequality as indicated by the Gini index actually increased 0.51 to 0.52 even though the difference is not statistically significant at 95 percent level (Table 2.2).

Table 2.2: Gini indices of households' landholding by agro-regional zones

	Survey year											
	2000			2004			2007			2010		
	Gini	[95% CI]		Gini	[95% CI]		Gini	[95% CI]		Gini	[95% CI]	
Eastern Lowlands	0.38	[0.33	0.43]	0.38	[0.33	0.43]	0.38	[0.33	0.43]	0.38	[0.34	0.43]
Western Lowlands	0.36	[0.32	0.40]	0.37	[0.32	0.41]	0.38	[0.33	0.42]	0.38	[0.34	0.43]
Western Transitional	0.38	[0.33	0.42]	0.38	[0.33	0.43]	0.38	[0.33	0.42]	0.38	[0.33	0.42]
High Potential Maize	0.52	[0.48	0.55]	0.52	[0.48	0.55]	0.52	[0.48	0.56]	0.52	[0.48	0.56]
Western Highlands	0.37	[0.34	0.41]	0.37	[0.33	0.41]	0.38	[0.34	0.42]	0.38	[0.34	0.42]
Central Highlands	0.39	[0.36	0.42]	0.39	[0.36	0.42]	0.39	[0.36	0.42]	0.39	[0.36	0.42]
Marginal Rain Shadow	0.43	[0.33	0.53]	0.43	[0.33	0.53]	0.43	[0.33	0.53]	0.43	[0.34	0.53]
Overall	0.51	[0.49	0.54]	0.51	[0.49	0.54]	0.52	[0.49	0.54]	0.52	[0.49	0.54]

Source: Author's calculation from the Tegemeo Institute Rural Household Surveys.

Table 2.3: Gini indices of households' land access by agro-regional zones

	Survey year											
	2000			2004			2007			2010		
	Gini	[95% CI]		Gini	[95% CI]		Gini	[95% CI]		Gini	[95% CI]	
Eastern Lowlands	0.38	[0.33	0.42]	0.38	[0.34	0.43]	0.38	[0.34	0.43]	0.38	[0.33	0.43]
Western Lowlands	0.36	[0.32	0.41]	0.37	[0.33	0.41]	0.37	[0.32	0.41]	0.38	[0.33	0.43]
Western Transitional	0.39	[0.34	0.44]	0.38	[0.33	0.42]	0.37	[0.32	0.42]	0.37	[0.33	0.42]
High Potential Maize	0.55	[0.50	0.60]	0.51	[0.47	0.55]	0.51	[0.47	0.55]	0.51	[0.48	0.55]
Western Highlands	0.38	[0.34	0.42]	0.38	[0.34	0.42]	0.38	[0.34	0.42]	0.37	[0.33	0.41]
Central Highlands	0.38	[0.35	0.41]	0.42	[0.35	0.48]	0.38	[0.35	0.41]	0.39	[0.36	0.41]
Marginal Rain Shadow	0.42	[0.32	0.52]	0.42	[0.31	0.52]	0.41	[0.31	0.50]	0.40	[0.31	0.49]
Overall	0.53	[0.50	0.57]	0.51	[0.48	0.53]	0.51	[0.48	0.53]	0.51	[0.48	0.53]

Source: Author's calculation from the Tegemeo Institute Rural Household Surveys.

Similarly, smallholder landholding inequality does reduce when we further factor in land rentals by households (Table 2.3). Information on land rented out by households in each survey was not available. However, since the sample consists mainly of smallholder farmers who are assumed to be land constrained and thus not engaged in renting out land activities. Table 2.3 shows that even land rental markets appear to have increased land inequality in 2000; they somehow improved smallholder land access equality in 2007 and 2010.

The overall land inequality declines from a Gini index of 0.52 to 0.51 in these two years. Consequently, the general conclusion is that land sales and rental markets are not reducing landholding inequality among the smallholder farmers. These findings are confirmed by information elicited from the FGDs that showed the following: first, it is mostly individuals with non-farm employment who want to get into farming/settle or medium/large scale farmers interested in expanding their scale of production who can afford to buy or lease land at the prevailing rates. Second, increasing cases of distress land sales and rentals especially in the densely populated areas. Some households are selling or renting out their much needed land to meet pressing family financial needs such as educations fees and medical expenses. All these factors combined indicate that land sales and rental markets may not only be unsupportive of the land constrained smallholder but also exacerbating their situation.

(iii) Out-migration trends in the densely populated areas: Out-migration is perceived to be a potential avenue to ease land pressure in densely populated and land constrained regions. While no permanent outmigration was reported in the low densely populated areas, results from the FGDs indicate the high densely populated areas are experiencing low but growing trends in out-migration. The village out-migration rate of people aged 15 years and over was estimated at about one percent. In Vihiga and Bungoma counties for example, some households were reported to have relocated permanently to the neighboring but relatively land abundant counties of Busia and Trans Nzoia. A few cases of households migrating permanently to the coastal lowlands and the neighboring country, Uganda, were also reported. Seasonal out-migration trends are also insignificant in the high densely populated regions.

What factors force/facilitate households or households' members to consider migrating to other areas? FGDs identified diminishing land sizes followed closely by land related conflicts as as the major "push" factors. In some cases, households with exceedingly small landholding sizes were reported to have sold their land and moved out in search of bigger land parcels in relatively land abundant areas[5]. The most important out-migration facilitating factor was financial ability while the limiting factors include attachment to ancestral lands and insecurity and inter-community land related conflicts, especially following the 2008 post-election violence. With regard to the 2008 post-election violence, scholars and development commentators associate its occurrence with longstanding inter-community disputes over land rights and land inequalities (Kniss, 2010). Essentially, most of the out-migration cases reported in the densely populated areas were basically intra-community and not inter-community.

Besides the land search related permanent migration, there is also the rural-urban migration especially by the youth in search of non-farm employment. However, as reported earlier in this section, due scarcity in non-farm employment opportunities in the urban centers, individuals facing land constraints are opting to remain in the rural areas and to derive their livelihoods from the tiny pieces of land they inherited from parents.

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[5] It was reported in some FGDs that some households commit a large portion of the proceeds from their land sale to other family needs and eventually end up buying even smaller land pieces than the ones they sold or even end up landless.

It is important to mention that most of the time the migrating households or people still retain the land parcels owned in the previous locations. This is because of number of reasons. First, in Africa people revert to farming upon retirement from non-farm employment. In some cases, holders of salaried employment either continue farming their land or lease it out. For example, an urban consumption surveys conducted by Tegemeo Institute in 2003 and 2009 indicated that over 50 percent of the sample reported to have received farm produce from their own farm located in the rural areas in the month prior the day of the interview. As mentioned elsewhere in this section, with proliferation of fraudulent land transactions some individuals engaged non-farm employment opt not to lease their lands. Second, the fear of the unknown and the desire to be buried close to ones kinsmen when they eventually die. As one of the respondents put it, "conditions allowing, our people (kinsmen) prefer staying close to one another while alive and even in death". Consequently, to a large extent these out-migrations, whether permanent or temporary, are not helping in easing land scarcity pressure in the densely populated areas.

The FGDs results indicate that areas near growing urban centers (districts and divisional headquarters) are also experiencing high in-migration by the upper and middle income urban elites. This group is buying agricultural land and converting it into urban plots for building residential homes. The field survey team came across a farmer who owns 1500 acres of agricultural land along Eldoret to Kitale road but is now sub-dividing the land into one acre residential plots for sale. The conversion of agricultural land to residential plots has been on the rise following the continued sub-division provincial administration units and creation of new headquarters that started in 2002.

The low densely populated areas are experiencing low in-migration. The in-migrating people consist mainly of the urban middle income group looking for relatively cheap land to settle upon retirement from non-farm jobs. These include the nurses, teachers and other government employees working in these areas. These people have worked in these areas for long and hence have built the necessary social capital to enable them live comfortably with the locals. Very few of them are coming from the agricultural land deficit regions. The low population density regions are not agriculturally high potential areas and have poor infrastructural facilities thus not attractive to individuals in searching for land for agricultural production purposes.

(iv) Future prospects of the households in the densely populated areas: How do we expect farming practices and livelihoods to evolve in the next decades especially in the densely populated areas? In the extremely high densely populated regions, most of the people predict that there will be no land to farm in the next 10-20 years. There will be more kitchen gardening and more residential plots. Some people expect a possibility of land consolidation. As land sizes become extremely small, siblings may consider selling their tiny pieces to one of them and relocating (conditionings allowing) to land abundant regions or urban centers. Some respondents predicted a possibility of mass exodus by the landless to small and large urban centers. Already in some areas the landless have moved and settled in urban slums in the nearby small urban centers.

Land extensive crops such as sugar cane are gradually disappearing in the medium populated areas. Respondents expect increased land intensive enterprises such as horticulture (high value crops grown in green houses) and dairy production (zero grazing). As land sizes diminish, people expect a shift towards short maturing and high yielding crops; relay cropping; and increased use of modern technologies in agricultural production.

It was also reported that offsprings of smallholders in the extremely densely populated areas are unlikely to have livelihoods as good as those led by their parents if they rely solely on farming. This is likely to be caused by land scarcity and emerging climatic challenges. For the future generation to lead lives as good as the current generation, the current generation will need to invest more in education of their offsprings to enable them secure non-farm employment. The future generation must embrace modern technology farming-- actually, a consensus emerged in all FGDs that education for the children is not only important for securing good paying non-farm jobs but also necessary for adoption of modern intensive farming technologies.

While crop and livestock farming continue to be the main economic activities in the rural areas, there are some emerging off-farm economic activities in the rural and small urban centers. These activities include sale of second hand clothes (*mitumba*) within the villages; cellphone money transfer services (*M-Pesa*); cellphone repairing and battery charging; buying of old household items -- scrap metal; bicycle passenger transport (*boda-boda*) services; repairing and hawking of household utensils (*mali-mali*); haircut and salon services; artisan jobs/*jua kali* – welding, carpentry and masonry; and washing of clothes for other families. It is important to note that these emerging informal non-farm income generating activities are basically "poverty jobs" that individuals, and especially the youth, are being pushed into by increasing land constraints. These jobs are characterized by insufficient social protection and thus increased vulnerability to poverty.

(v) Characteristics of emerging medium-scale farmers: In this section, we present the descriptive analysis of the medium scale household survey data. The aim is to highlight the distinguishing features between households that followed agricultural-led path and those that pursued lateral entry path into medium-scale farming status. In the survey instrument, households were asked to indicate the primary source of capital used to enter into medium-scale farming status. Based on the responses from this question, the sample was divided into two mutually exclusive analytical groups, namely: (1) Those that used capital from non-farm sources to attain medium-scale farming status, hereafter referred to as “lateral entry”; and (2) Those that used capital generated from farming as the main vehicle for expanding their scale of production into medium scale farming, hereafter referred to as “agricultural entry”.

The results show that majority (59%) of the households used lateral entry into medium-scale farming status (Table 2.4). This group starting farming owning about 14 hectares of land and have managed to build up their landholding threefold to about 38 hectares. About half of the lateral entry group started farming with landholding of about 5 hectares or less. The agricultural entry pathway group owned about 18 hectares of land when they started farming. This group has managed to more than double their mean landholding sizes to 42 hectares. Out of this agricultural entry group, only about 38 percent of them started farming with 5 hectares or less.

Table 2.4: Landholding by entry pathway into medium-scale farming

Entry into medium-scale farming		Started farming owning <=5ha			Started farming with > 5ha			Overall		
		Mean	N	%	Mean	N	%	Mean	N	%
Agricultural entry	Initial (ha)	1.89	31	16	27.62	51	26	17.89	82	41
	Current (ha)	26.83			54.86			42.40		
Lateral entry	Initial (ha)	2.03	58	28	25.89	60	30	14.16	118	59
	Current (ha)	33.11			42.91			38.33		
Total	Initial (ha)	1.98	89	44	26.69	111	56	15.69	200	100
	Current (ha)	30.27			48.60			40.22		

Source: MSU/Tegemeo Institute Medium Scale Farmers’ Household Survey.

The results show that households that pursued the lateral entry pathway were headed by relatively younger individuals who had higher education attainment and were less likely polygamous compared to the households that followed agricultural entry pathway. The average age of heads in the lateral entry group was 62 years compared to 65 years in the agricultural entry group. A sizeable proportion of households that used lateral entry pathway were headed by persons who had post-secondary education (47%) compared to only 18 percent among the households that followed agricultural entry pathway.

Households that followed agricultural entry pathway into medium scale farming have spent relatively more years in farming compared to those that followed a lateral entry pathway (Table 2.5). The results also show that just a few household heads were born in their current location of residence. Only about six percent of the lateral and 15 percent of the agricultural-led entry household heads were born in the location in which they are current farming. This finding suggests that migration may be a prerequisite to improved access to land and production scale expansion. As mentioned earlier on, some migrating households still maintain land, especially land acquired through inheritance, in areas where they were born. The results show that about 17 and 26 percent of the agricultural and lateral entry groups, respectively, still own land in the areas where they were born. This is an indication that sometimes migration may not be helpful in easing land pressure in densely populated areas.

The survey also elicited information on whether the household heads were engaged in any other non-farm income earning opportunities such as business or salaried non-farm employed. The results also show that a large proportion of the medium-scale household heads were/had been involved in some form of non-farm business (Table 2.5). This included about 52 percent among the agricultural entry category and 42 percent in the lateral entry group. A major distinguishing feature between households that followed agricultural entry and those that entered medium-scale laterally was participation in non-farm employment.

Table 2.5: Household demographic characteristics and historical information

	Agricultural-led Growth Pathway			Lateral Entry in Emergent Farming		
Variables	mean	[95% C.I]		mean	[95% C.I]	
Household head age (years)	65.29	[63.01	67.58]	62.34	[59.21	65.46]
Male household heads (prop.)	0.77	[0.68	0.86]	0.81	[0.73	0.88]
Household size	6.41	[5.73	7.10]	6.92	[6.31	7.52]
Head's marital status (prop.)						
single	0.26	[0.18	0.34]	0.26	[0.16	0.35]
monogamous	0.60	[0.51	0.69]	0.70	[0.59	0.80]
polygamous	0.14	[0.07	0.20]	0.05	[0.00	0.10]
Household head's level of education (prop.)						
informal	0.12	[0.05	0.19]	0.07	[0.02	0.11]
primary	0.43	[0.32	0.54]	0.24	[0.16	0.32]
secondary	0.27	[0.17	0.37]	0.22	[0.14	0.30]
post-secondary	0.18	[0.10	0.27]	0.47	[0.38	0.57]
Prop. of heads born in the area	0.15	[0.07	0.22]	0.06	[0.02	0.10]
Prop. owning land where they migrated from	0.17	[0.09	0.25]	0.26	[0.18	0.34]
Years in farming	34.76	[32.07	37.44]	27.78	[18.98	35.26]
Prop. of heads have/had business	0.52	[0.41	0.63]	0.42	[0.33	0.51]
Prop. of heads have/had non-farm job	0.17	[0.09	0.25]	0.84	[0.77	0.91]
Non-farm job employer (%)						
no other job	0.83	[0.75	0.91]	0.16	[0.09	0.23]
civil servant	0.12	[0.05	0.19]	0.57	[0.48	0.66]
private sector	0.05	[0.00	0.10]	0.27	[0.19	0.35]
Duration in non-farm job (years)	3.27	[1.39	5.15]	17.14	[15.03	19.25]
Father to initial household head attributes:						
Had non-farm job (prop.)	0.33	[0.23	0.43]	0.38	[0.29	0.47]
Had some formal education (prop.)	0.35	[0.25	0.46]	0.40	[0.31	0.49]
Still alive (prop.)	0.06	[0.01	0.11]	0.14	[0.07	0.20]
Land before subdivision (ha)	94.68	[40.85	148.50]	45.06	[22.89	67.23]

Source: MSU/Tegemeo Institute Medium Scale Farmers' Household Survey.

A large proportion (84%) of the lateral entry group was/had been in non-farm salaried employment. On average, this group had spent about 17 years in non-farm employment. Out of this group, about 68 percent of them held government-related jobs. Conversely, only 14 heads out of 82 (17%) in the agricultural entry pathway group was/had been in salaried employment.

Table 2.5 also presents retrospective information about the characteristics of the father to the initial household head. The results show that a sizeable proportion of the households were headed by persons whose fathers had some formal education, held non-farm jobs, and had a large landholding before subdivision. Essentially, the amount of land held by the father to the initial household head was a major distinguishing feature between households entry into medium-scale farming pathway. Fathers to the household heads who had pursued agricultural-led pathway had more than double (95 hectares) landholding sizes compared to fathers to lateral entry household heads (45 hectares). A sizeable proportion of households whose fathers to the initial household head was still alive appeared to have followed the lateral entry pathway.

In Table 2.6, some more descriptive features on landholding attributes by entry to medium-scale farming pathway. Most of the medium-scale farmers acquired their land through purchases from land markets. The lateral entry group significantly obtained much more land (85%) through purchases compared to the agricultural-led group (64%). Conversely, the agricultural entry category obtained comparably more land from inheritances from parents compared to the lateral entry group. Households were asked to indicate the proportion of their land that is located in the district where they were born and the proportion that is owned with title deed (Table 2.6). While most of the sampled households had more land in their district of birth, the agricultural led group had comparably much more (90%).

Table 2.6: Household landholding attributes

Variable	Agricultural-led Growth Pathway mean	[95% CI]		Lateral Entry in Emergent Farming mean	[95% CI]	
Prop.of land acquired through purchases	0.64	[0.54	0.74]	0.85	[0.77	0.92]
Prop. of land acquired through inheritance	0.36	[0.26	0.46]	0.15	[0.08	0.23]
Prop. of land in the district of birth	0.90	[0.85	0.95]	0.75	[0.72	0.78]
Proportion of land owned with title	0.59	[0.49	0.70]	0.79	[0.72	0.86]
Proportion of land acquisition by decade:						
1969 or earlier	0.29	[0.21	0.37]	0.06	[-0.04	0.16]
1970 through 1979	0.24	[0.17	0.31]	0.18	[0.09	0.27]
1980 through 1989	0.20	[0.13	0.27]	0.20	[0.12	0.28]
1990 through 2000	0.18	[0.11	0.25]	0.32	[0.25	0.39]
2000 or later	0.09	[0.05	0.13]	0.25	[0.19	0.31]

Source: MSU/Tegemeo Institute Medium Scale Farmers' Household Survey.

Perhaps the most interesting observation is that a sizable proportion (25%) of the lateral entry group had managed to acquire land outside the region where they were born. Similarly, most of the sampled households owned their land with title deeds. The lateral entry group held relatively a larger proportion (79%) of their land under title deeds compared to 59 percent among the agricultural entry pathway group. This implies that the lateral entry group managed to either access land that was already registered or overcome land registration bureaucracies to get their land parcels registered.

The results also show that while the agricultural-led pathway group accumulated much of their land before 1980 while the lateral entry pathway group accumulated their land gradually and much of it from year 1990 onwards (Table 2.6). This indicates that the agricultural entry group perhaps used the land markets in the early years when land was still abundant or benefited, either directly or indirectly, from the immediate post-independence government land allocation schemes. The lateral entry group land accumulation seems to have driven by their high social, economic and political capital derived from higher education attainment and non-farm employment jobs especially in the public service sector. Also, it is apparent that this group accumulated most of their land in the 1990s period. This coincides with the introduction of competitive politics (multiparty democracy) and thus there is a possibility this group benefited, directly or indirectly, from political patronage related government land allocation discussed in section 2.2. The lateral entry group land accumulation can also be explained by the settling public service employees who were retrenched following the structural adjustment programs (SAPs) related public service reforms in the 1990s period.

Next, we discuss land use and crops productivity characteristics of the two groups (agricultural-led and lateral entry). Agricultural crop productivity is defined and the net value of crop outputs (after netting out fertilizer, seed and, land preparation, and hired labor costs) per unit of land. We break each of the two groups into two categories based on landholding: 5 to 25, and 25 to 50 hectares (Table 2.7). The results show that area under crop among the medium scale farmers is an increasing function of landholding with the two medium-scale entry groups putting almost the same proportion of their land under crop. The proportion of land under crop to total household landholding appears to be a decreasing function of landholding. A more complete presentation of these relationships is revealed when we look at the non-parametric regressions results. Figures 2.1, (a) and (b), show the non-parametric regression relationship between cultivated land on the y-axis and household landholding on the x-axis. The results show that area under crop is an increasing function of the household landholding. Figures 2.2, (a) and (b), show the relationship between the proportion of land cultivated over total landholding on the y-axis and household landholding on the x-axis.

Table 2.7: Medium-Scale Farmers' landholding and productivity

	agricultural entry			lateral entry			Overall		
	5-25 ha	25-50ha	mean	5-25 ha	25-50ha	mean	5-25 ha	25-50ha	mean
N	56	26	82	95	23	118	151	49	200
Landholding (ha)	18.62	69.99	42.40	14.39	81.84	38.33	16.17	75.53	40.22
Area under crop (ha)	11.53	35.33	22.55	8.62	38.95	19.38	9.84	37.02	20.85
Prop. of area under crop	0.62	0.50	0.53	0.60	0.48	0.51	0.61	0.49	0.52
Crop production ('000KSh)/ ha owned	82.32	78.20	80.41	65.04	96.55	76.22	72.30	86.79	78.17
Crop production ('000KSh)/ ha cultivated	132.03	136.71	134.20	100.50	161.82	122.26	113.75	148.47	127.82
Fertilizer use ('000KSh)/ha cultivated	12.13	12.16	12.14	11.91	11.27	11.68	12.01	11.74	11.90
Fertilizer use (kg)/ha cultivated	261.49	265.69	263.43	257.79	243.99	252.89	259.35	255.53	257.80
Landholding (ha) / tropical cow*	0.42	0.89	0.64	0.57	1.25	0.81	0.51	1.06	0.73
Livestock value ('000KSh)/ha owned	97.41	76.10	87.55	145.70	44.51	109.79	125.40	61.31	99.44

Source: MSU/Tegemeo Institute Medium Scale Farmers' Household Survey. Note: * Conversion using livestock grazing equivalent scales (FAO, 1987).

Figure 2.1a: Area cultivated by land size –overall

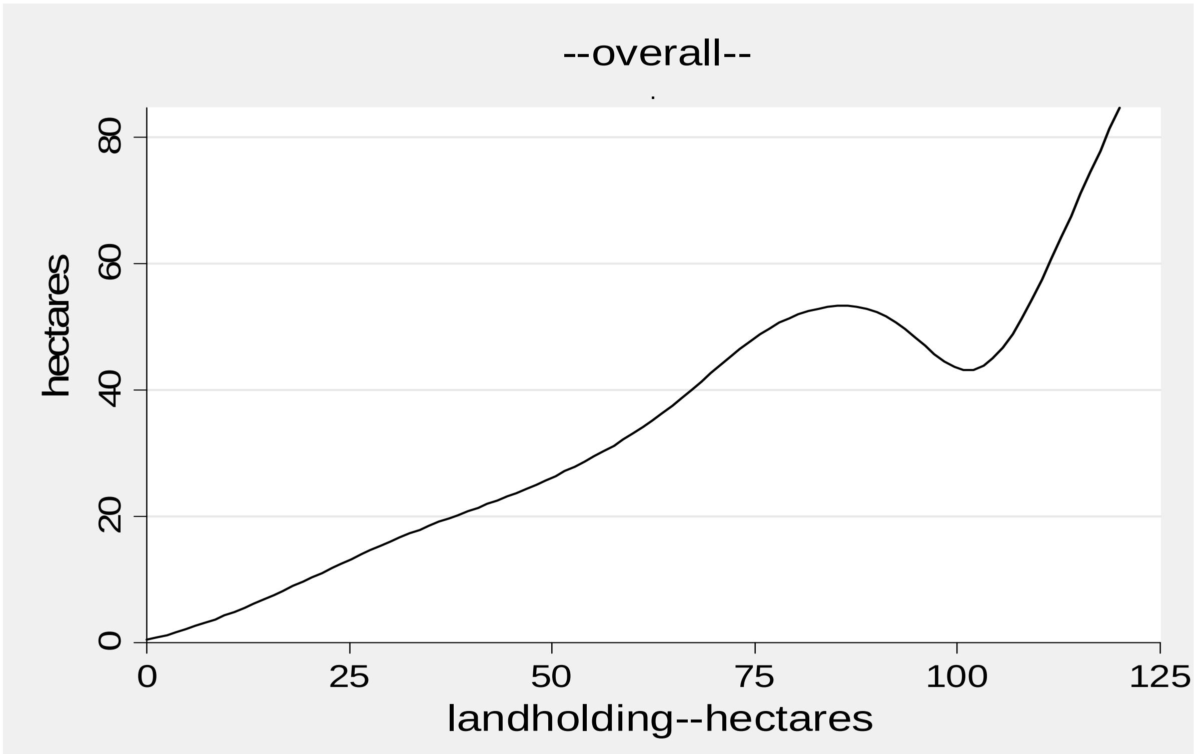


Figure 2.1b: Area cultivated by land size –by growth pathways

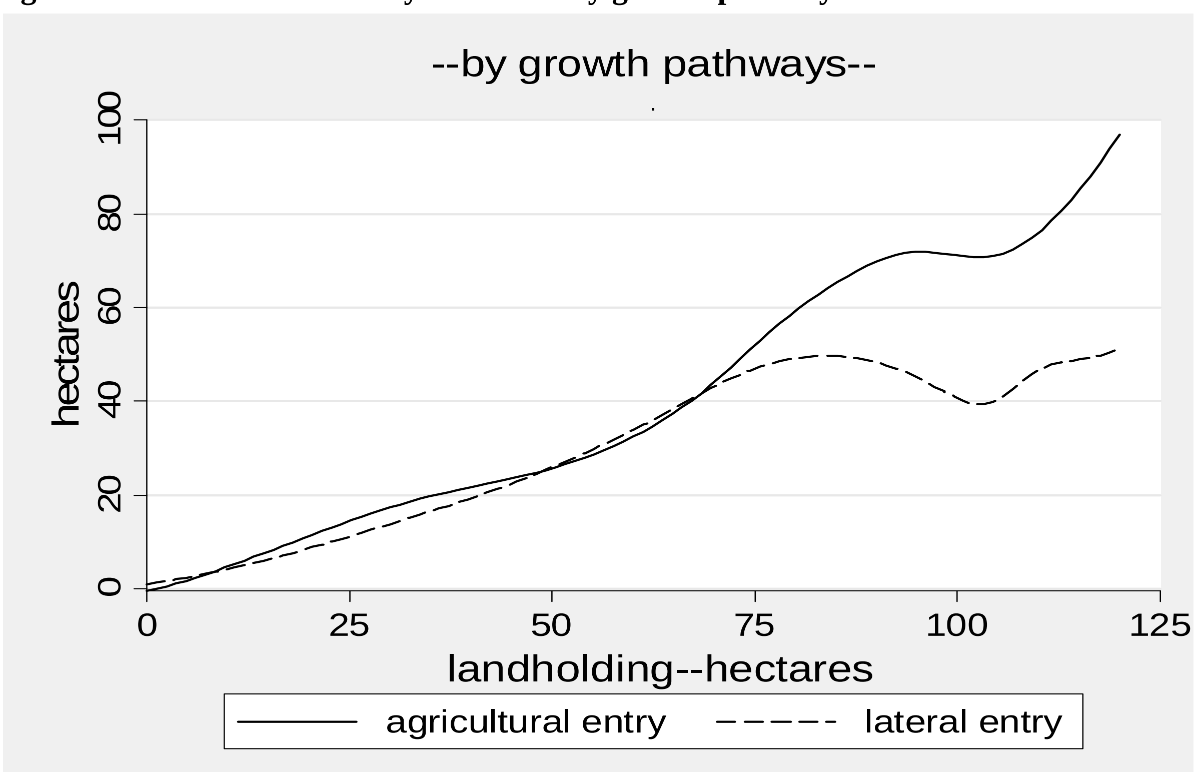


Figure 2.2a: Proportion of area cultivated--overall

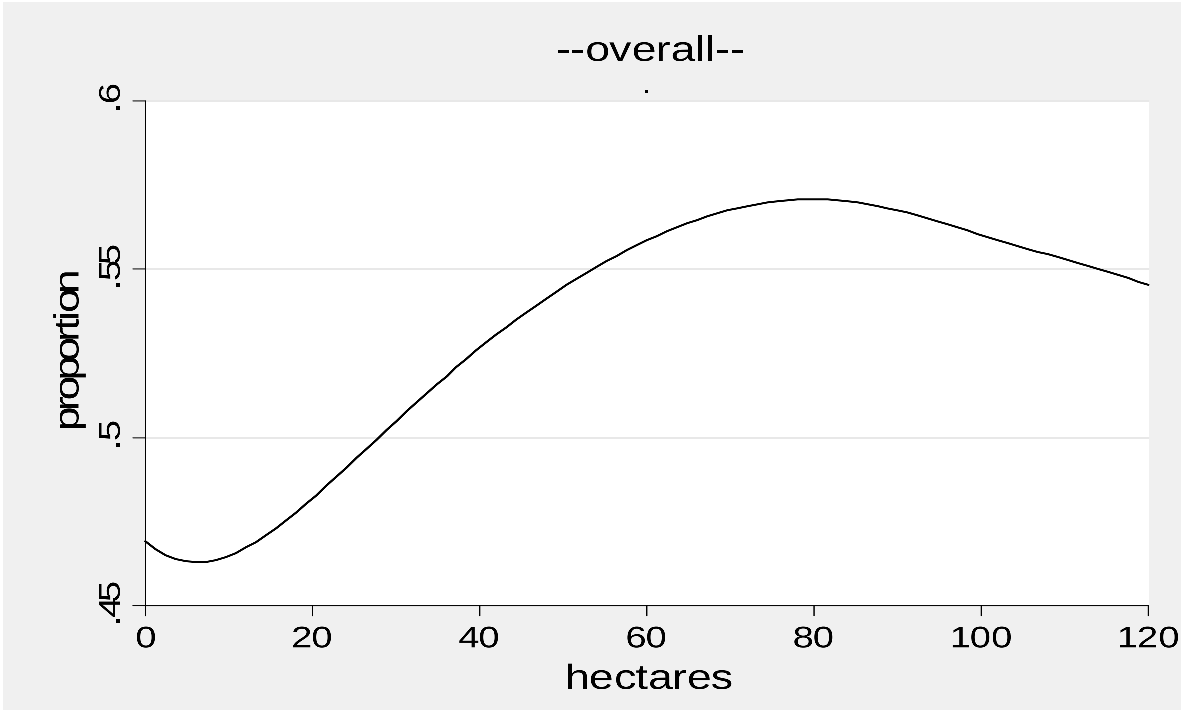
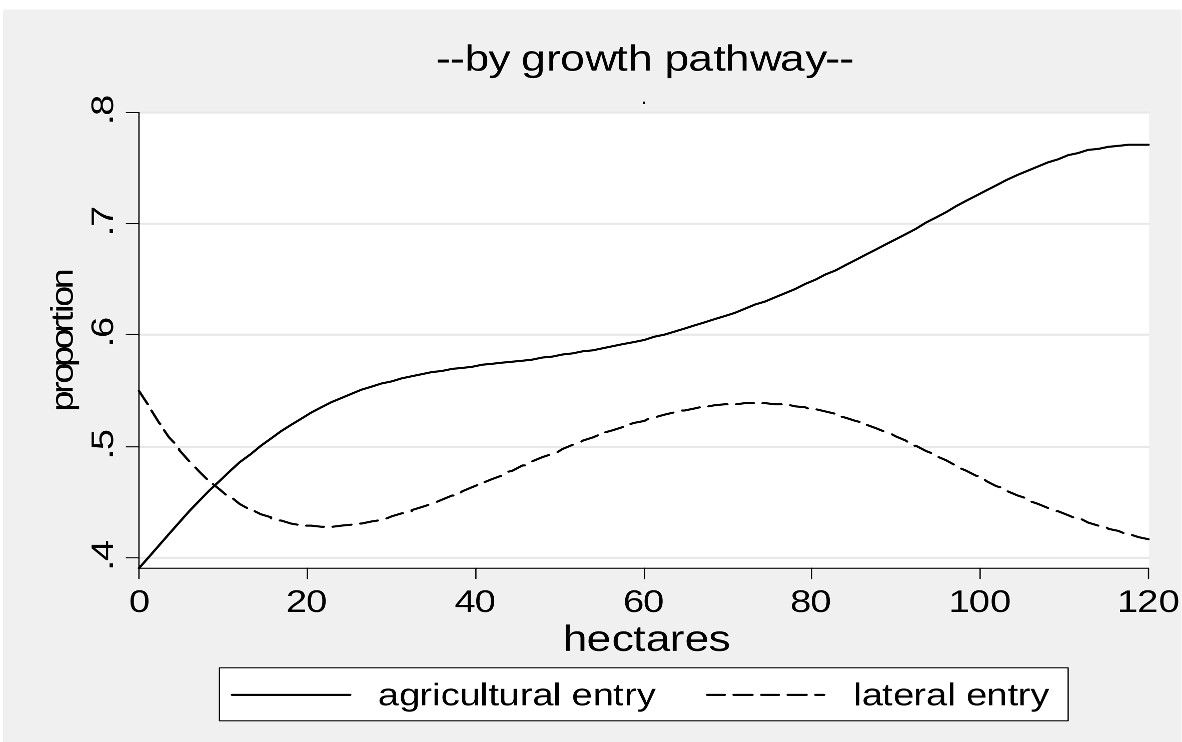


Figure 2.2b: Proportion of area cultivated—by growth pathways



The results show that the proportion under crop declines with household land holding up to about 15 hectares (25^{th} percentile) and thereafter increases reaching a maximum at around 75 hectares (Figure 2.2a). However, when we break down the analysis by the pathways used to achieve medium-scale status a different picture emerges (Figure 2.2b).

The proportion of land under cultivation is an increasing function of household landholding sizes for the agricultural entry group. For the lateral entry group, the relationship between proportion under crop and landholding is a non-linear cubic function. Proportion of area under crop decreases with landholding up to about 25 hectares (75^{th} percentile), thereafter, it increases reaching a maximum at about 75 hectares. The proportion of land under crop never goes beyond 0.50 in this group. It seems while the agricultural entry group is keen to bring most of the land they access under cultivation, the lateral entry group is either holding land for speculative motive and/or for use at a later date.

While fertilizer application rates per hectare cultivated do not seem to vary much household landholding sizes in Table 2.7, the non-parametric regression results reveal a different picture (Figures 2.3 a & b). The intensity of fertilizer uses (y-axis) increase with household landholding size (x-axis) among the medium-scale farmers up to 30 hectares (after the 75^{th} percentile) (Figure 2.3b). Beyond this landholding, the relationship almost flattens out. The same relationship is replicated when we do the analysis by the pathways into medium-scale farming status (Figure 2.3b). The intensity of fertilizer use increases, but at a decreasing rate, with landholding in both groups with the lateral entry group application rates being consistently below the agricultural entry group up to the 99^{th} percentile of the distribution.

Figure 2.3a: Fertilizer use per hectare cultivated – overall

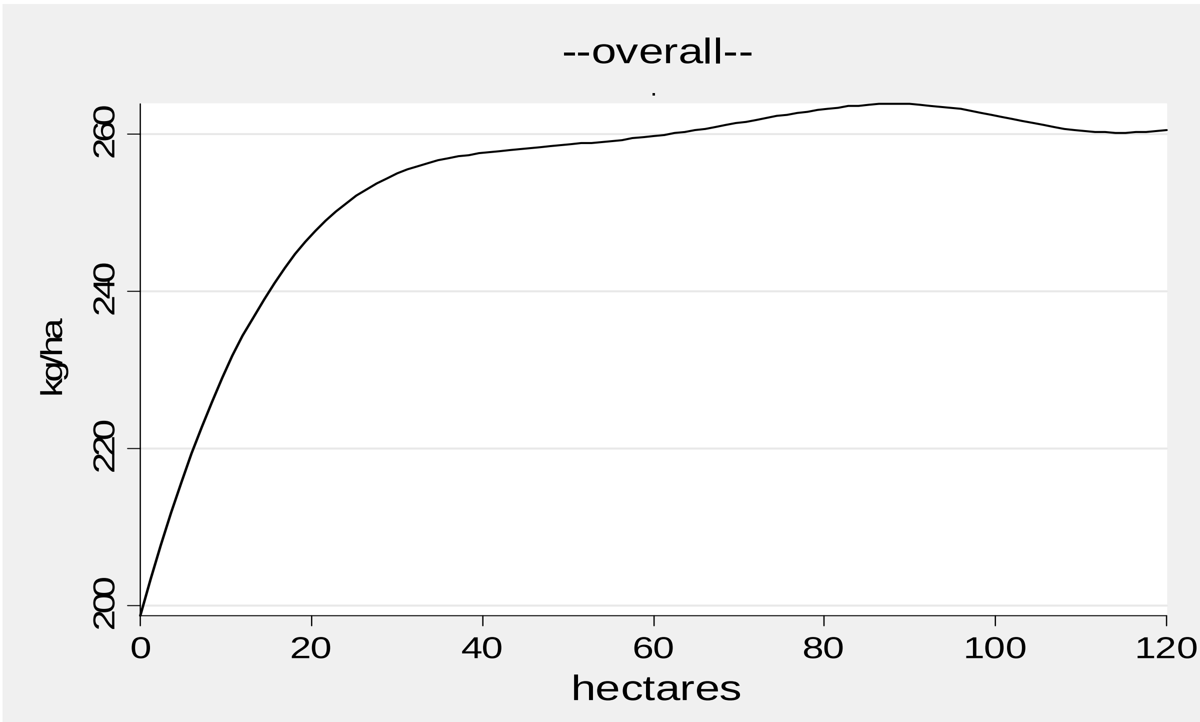
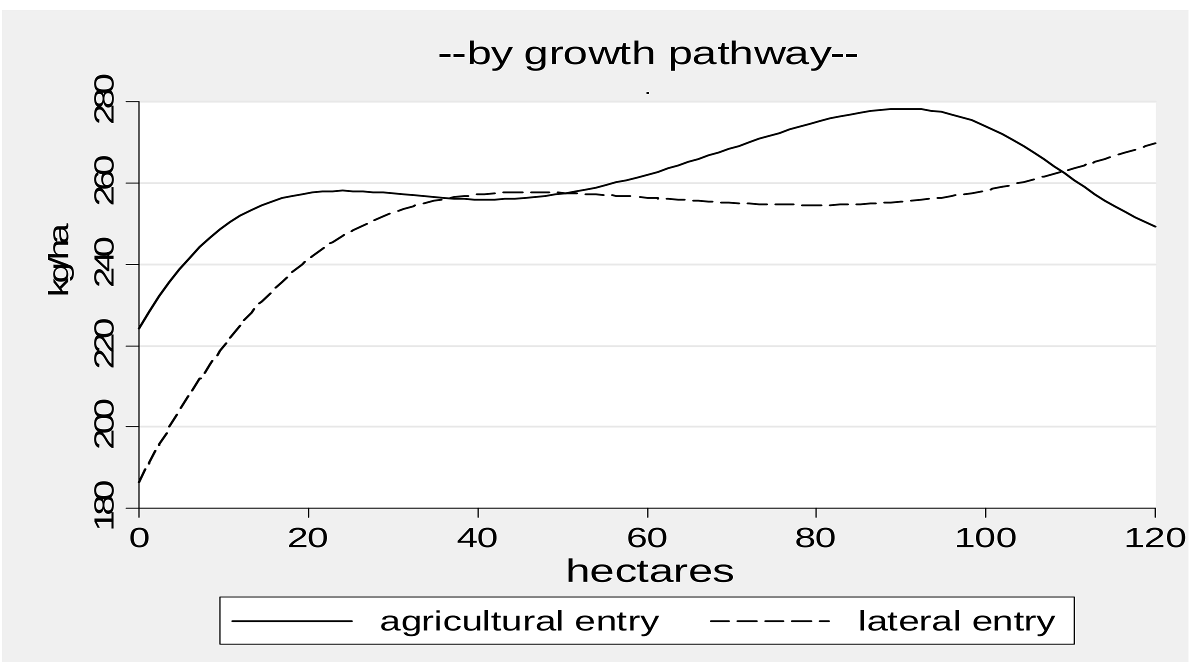


Figure 2.3b: Fertilizer use per hectare cultivated -- by growth pathway



In terms of crop productivity, the results also show that net crop production per unit of land is somehow an increasing function of landholding sizes (Table 2.7). This result is surprising. However, it should be noted that this is a bivariate analysis finding and that crop productivity will be a subject of further analysis using econometric methods. The agricultural entry group seems to be more productive than the lateral entry counterpart.

The agricultural entry group is producing on average KSh80 thousand per hectare owned (KSh134 thousand/ per hectare cultivated) while the lateral entry group is producing KSh76 thousand (KSh122 thousand). A more complete presentation of these relationships is revealed when we look at the non-parametric regressions results. Figures 2.4, (a) and (b), show the non-parametric regression relationship between values of crop production on the y-axis and household landholding on the x-axis. The results show that crop production is an increasing function of the household landholding in the entire sample and by the entry into medium-scale farming pathways subsamples. Figures 2.5, (a) and (b), show the relationship between crop production values per hectare owned y-axis and household landholding on the x-axis. The results show that the crop productivity first declines with landholding size reaching a minimum at about 10 hectares and increases thereafter (Figure 2.5a). A different picture emerges when we break down the sample by the pathways into medium-scale farming status (Figure 2.5b). While crop productivity increases with land among the agricultural entry group, among the lateral entry group, it first declines reaching a minimum at about 30 hectares (after the 75^{th} percentile) and thereafter goes up.

Figure 2.4a: Value of crop production -- overall

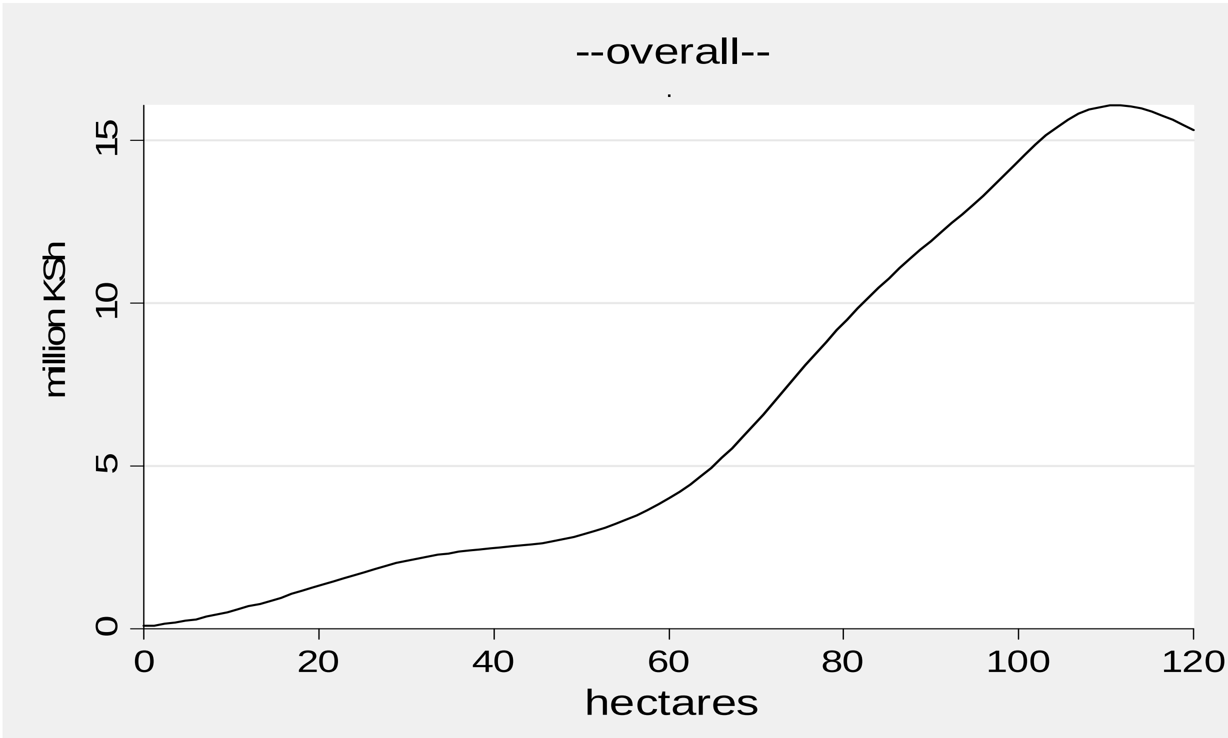


Figure 2.4b: Value of crop production – by growth pathway

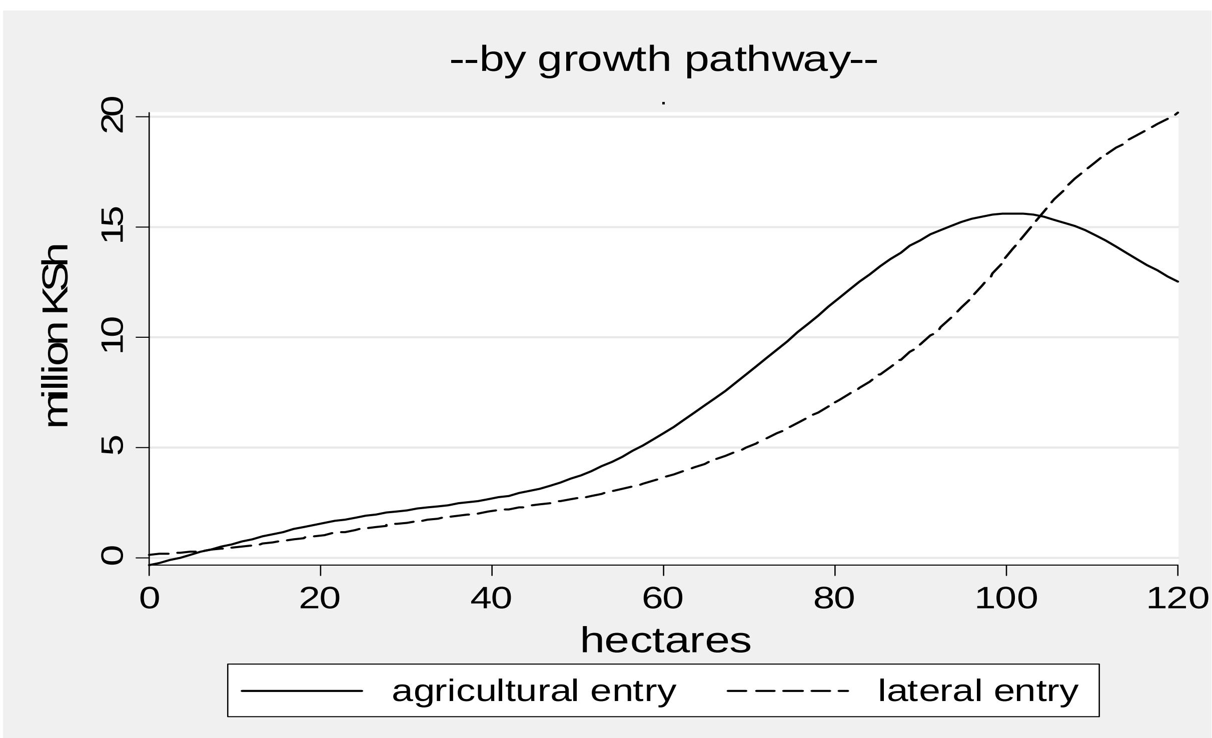


Figure 2.5a: Value of crop production per hectare owned-- overall

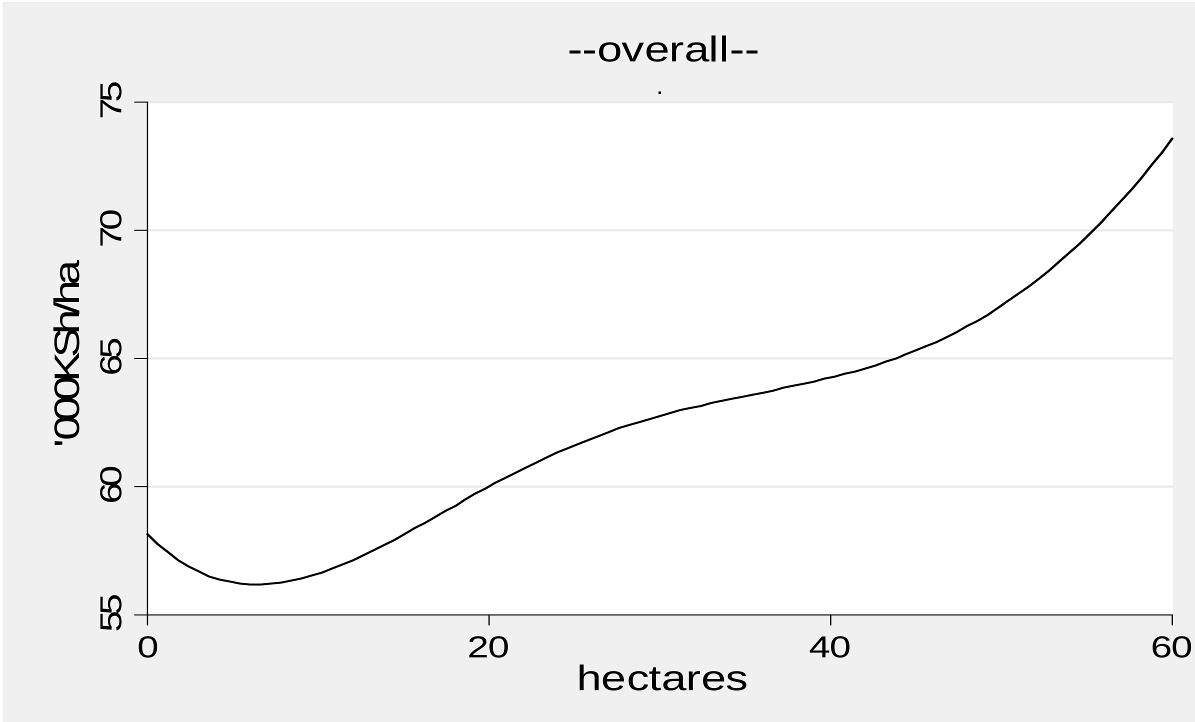
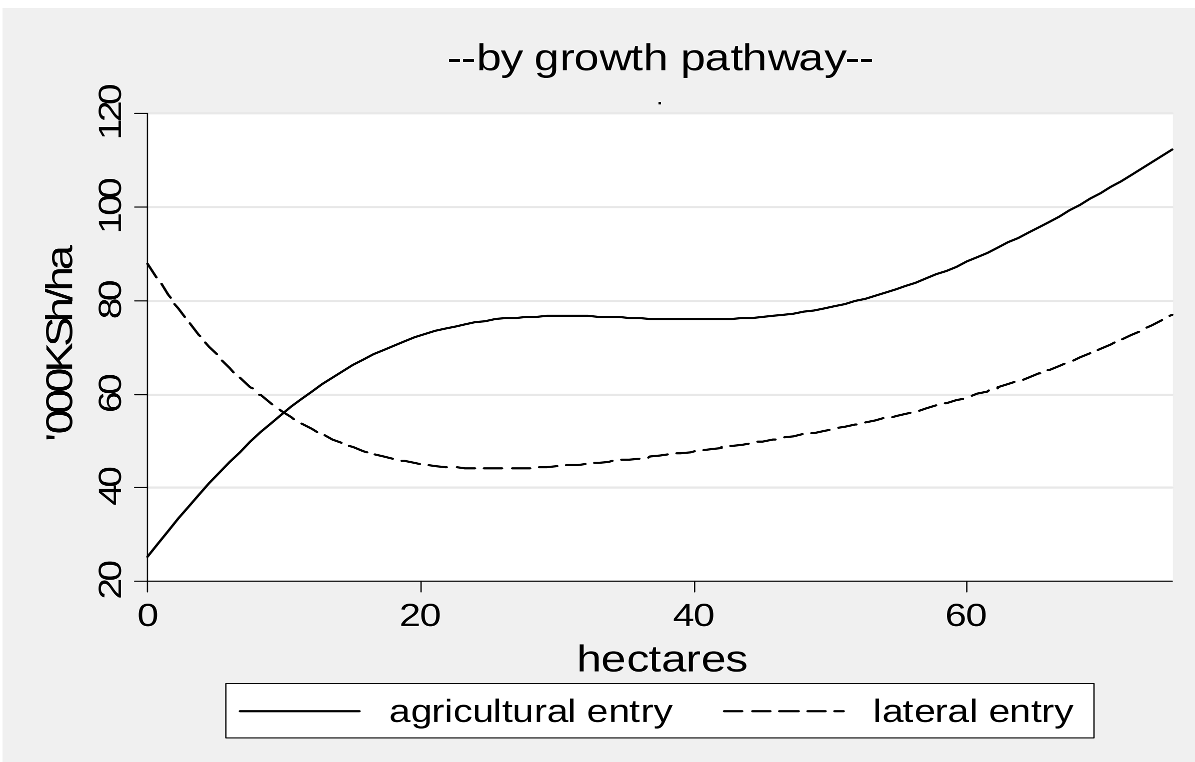


Figure 2.5b: Crop of production per hectare owned – by growth pathway



Figures 2.6, (a) and (b), show the relationship between crop production values per hectare cultivated y-axis and household landholding on the x-axis. The results show that the crop productivity first decline with landholding size reaching a minimum at about 35 hectares and thereafter increases (Figure 2.6a). While crop productivity increases gradually with land among the agricultural entry group, among the lateral entry group, it first declines reaching a minimum at about 30 hectares (after the 75th percentile) and thereafter gradually picks up.

Even though data on livestock production (milk, meat, hides/skins, eggs, etc.) was not collected, data on household livestock holding and the estimated value was collected. Using the scales developed by the Food and Agriculture Organization’s Tropical Livestock Unit (FAO, 1987), all livestock are converted into tropical cow equivalent based on livestock grazing equivalence. This is meant to help in comparing how the agricultural and lateral entry groups are using their uncultivated land in livestock production. Subsequently, in terms of livestock holding, the results show that the agricultural entry group is using on average 0.64 hectares per tropical cow compared to 0.81 hectares by the lateral entry group. In terms of livestock values, the agricultural-led group is supporting lower livestock value (KSh88000) per uncultivated hectare compared to the lateral entry group (KSh109000) (Table 2.7).

To examine the distinguishing features between medium and smallholder farmers in terms of land use and agricultural productivity, we present some smallholder agricultural production characteristics in Table 2.8. Smallholders are defined as households farming five hectares and below. As mentioned in the data sources section, the smallholder data came from the same locations as the medium-scale data. While the medium-scale farmers’ data was collected in 2012, the smallholder data was collected in 2010.

Figure 2.6a: Value of crop production per hectare cultivated -- overall

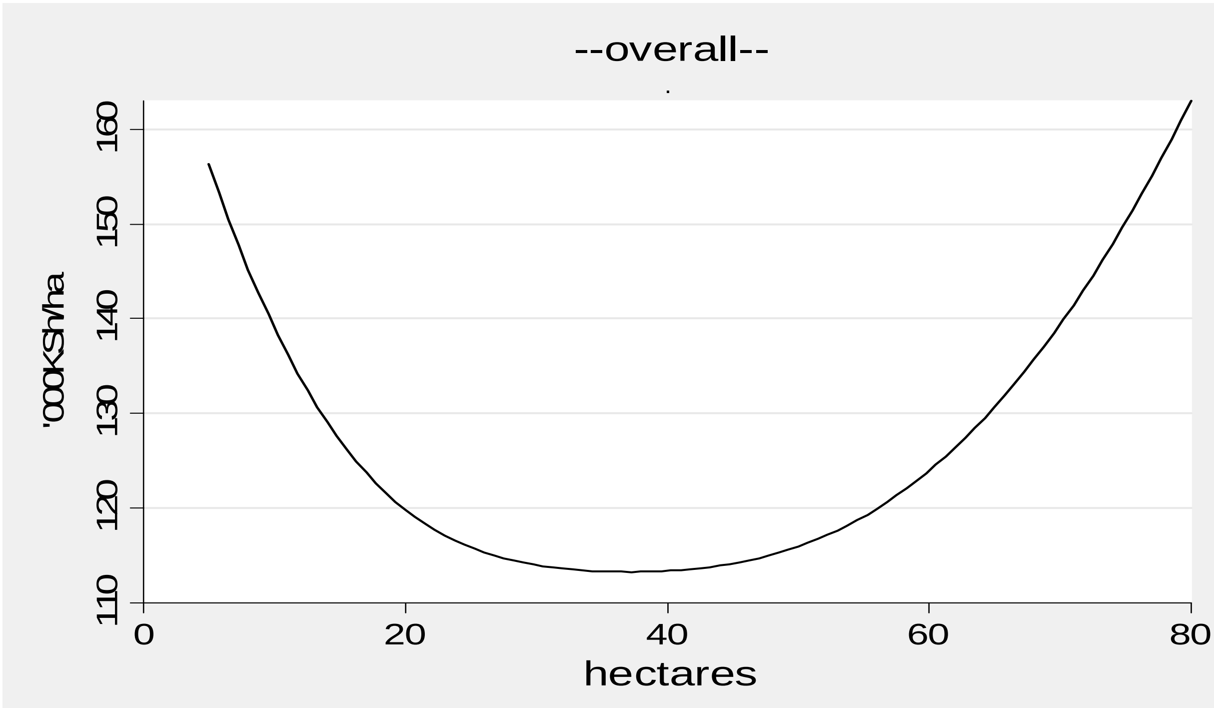
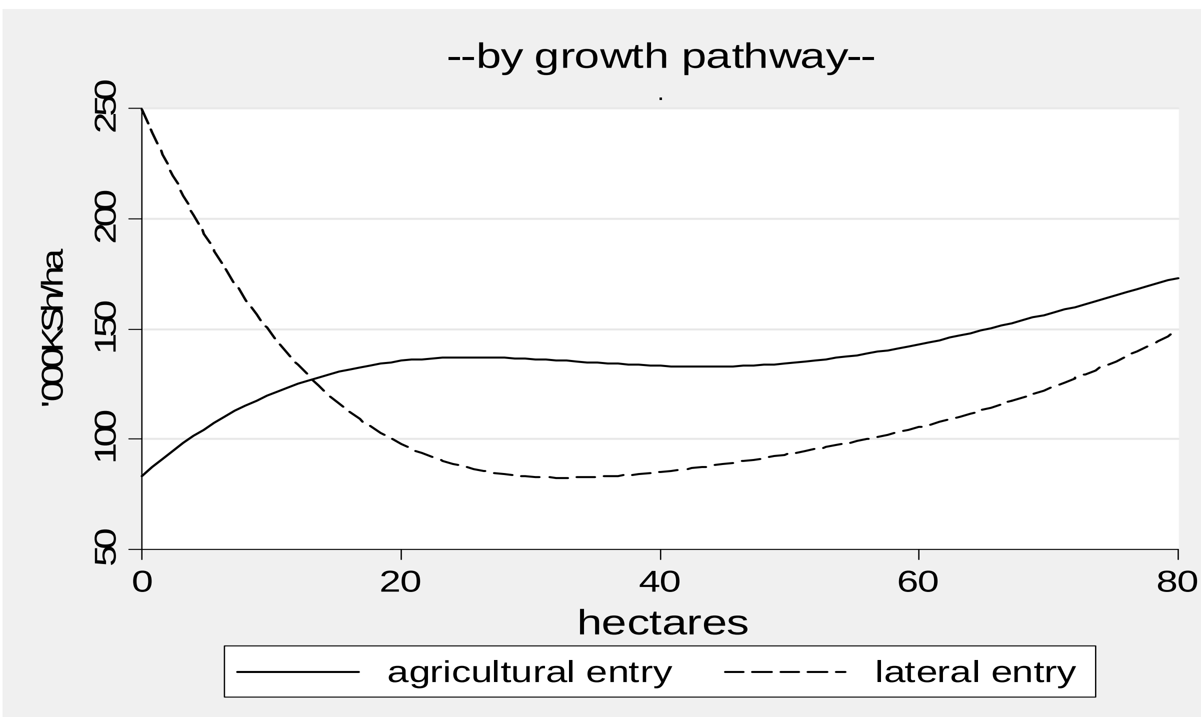


Figure 2.6b: Crop production per hectare cultivated -- by growth pathway



Thus, the smallholder crop productivity figures are inflated using the consumer price index (CPI) developed by Kenya National Bureau of Statistics to make them comparable to the medium-scale farmers' figures. The smallholder sample is also broken down four categories based on landholding (0 – 1; 1 – 2; 2 – 3; and 3 – 5 hectares) to examine how land productivity changes with landholding sizes (Table 2.8). In terms of area under crop, compared to medium-scale farmers, the smallholder farmers are putting a larger proportion (0.69) of their land under crop. Just as in the medium-scale farmer case, proportion of land under crop is a declining function of landholding with households holding less than one hectare putting all their land under crop.

Table 2.8: Smallholder farmers' landholding and productivity by landholding categories

	0<ha<=1	1<ha<=2	2<ha<=3	3<ha<=5	overall
N	66	83	51	36	236
Landholding (ha)	0.59	1.36	2.37	3.99	1.76
Area under crop (ha)	0.55	1.15	1.51	2.23	1.22
Prop. of area under crop	0.93	0.84	0.64	0.56	0.69
Crop production ('000KSh)/ ha owned	104.46	59.76	53.22	64.20	63.55
Crop production ('000KSh)/ ha cultivated	112.32	71.18	83.50	114.87	91.77
Fertilizer use ('000KSh)/ha cultivated	9.40	9.10	9.58	8.93	9.22
Fertilizer use (kg)/ha cultivated	159.08	153.63	163.10	152.22	156.46
Landholding (ha) / tropical cow*	0.02	0.11	0.36	0.75	0.26
Livestock value ('000KSh)/ha owned	1,420.64	299.94	139.13	76.56	158.17

Source: Tegemeo Institute Rural Household Surveys. Note: * Conversion using livestock grazing equivalent scales (FAO, 1987).

In terms of crop productivity, surprising the smallholders are less productive than the medium-scale farmers. The smallholders are producing on average KSh64 thousand per hectare owned (KSh92 thousand/ per hectare cultivated) compared to KSh78 thousand (KSh127 thousand) among the medium-scale farmers. The results also show that crop productivity is a decreasing non-linear function of landholding sizes. Crop productivity seems to be very high among households owning one hectare and below. Crop productivity per hectare owned declines with landholding reaching a minimum at about 2-3 hectares and increases thereafter. Similarly, productivity per hectare cultivated declines with landholding reaching a minimum at about 1-2 hectares and increases thereafter.

In terms of fertilizer application rates, the smallholder farmers seem to applying comparably more fertilizer per hectare cultivated. The smallholders apply about 258 kilograms of fertilizer per hectare compared to 157 kilograms by the medium-scale farmers. Likewise, it seems smallholders are spending more (KSh12000) on fertilizer per hectare cultivated compared to the medium-scale farmers (KSh9000). This difference could be attributable to higher fertilizer application rates among the smallholders and economies of scale experienced by medium-scale farmers due to bulk fertilizer purchases.

Turning to livestock production, results show that the smallholders are using their uncultivated land more productively compared to the medium-scale farmers. The smallholders are using on average 0.26 hectares (Table 2.8) per tropical cow compared to 0.73 hectares by the medium-scale farmers (Table 2.7). It is clear from Table 2.8 that the use of uncultivated land on livestock productivity declines as household land increases.

In Table 2.9, we present household descriptive statistics on income and asset wealth tabulated by the two broad entry pathways into medium scale farming. Even though there appear to be some differences between these two aggregate group's incomes and asset wealthy, the difference are not statistically significant at 95 percent level. The only distinguishing feature between these two groups is in terms of the main source of incomes. While all the households in the sample derive most of their incomes from crop income, the households that followed lateral entry pathway are deriving a sizeable proportion (34%) of their incomes from non-farm sources.

The households that used agricultural pathway are only obtaining about 19 percent of their income from non-farm sources. When you consider incomes derived from salaried employment, the households that used lateral entry pathway are obtaining more than double from salary compared to those households that pursued agricultural led entry pathway. It is important to mention that data on livestock income was not captured in this survey.

Table 2.9: Household income and assets

	Agricultural-led Growth Pathway			Lateral Entry in Emergent Farming		
Variable	mean	[95% CI]		mean	[95% CI]	
Aggregate income-‘million KSh	2.84	[1.77	3.91]	2.62	[1.17	4.07]
Crop income-‘millions KSh	2.62	[1.57	3.68]	2.30	[0.89	3.71]
Non-crop income-‘000KSh	217.18	[147.98	286.38]	323.11	[236.20	410.02]
Income from business-‘000KSh	134.36	[74.66	194.07]	123.42	[70.82	176.03]
Income from salary-‘000KSh	82.81	[45.67	119.96]	199.68	[129.94	269.43]
Crop income/total income prop.	0.81	[0.72	0.84]	0.66	[0.64	0.74]
Non-farm/total income prop.	0.19	[0.16	0.28]	0.34	[0.26	0.36]
Total assets- 'million KSh	30.5	[21.70	39.30]	32.00	[22.40	41.60]
Land- ‘million KSh	25.7	[17.70	33.60]	28.00	[18.90	37.00]
Non-land assets--'million KSh	4.84	[3.64	6.04]	4.05	[3.15	4.94]
Agric. equipment and other assets-‘million KSh	4.06	[3.04	5.09]	3.38	[2.59	4.17]
Livestock- 'million KSh	0.78	[0.54	1.01]	0.66	[0.50	0.82]
Land asset/total assets prop.	0.81	[0.78	0.84]	0.83	[0.81	0.86]
Livestock/total assets prop.	0.03	[0.03	0.04]	0.03	[0.03	0.04]
Ag. equipment/total assets prop.	0.15	[0.13	0.18]	0.14	[0.12	0.16]

Source: MSU/Tegemeo Institute Medium Scale Farmers’ Household Survey.

2.5.2 Econometric results

This section summarizes the econometric estimation results from the methods described in section 2.4.1. While the model for each outcome variable is estimated jointly using FIML estimator, the selection equation estimation results are presented first followed by the outcome equations results. Given that the same explanatory variables were used in the estimation of the selection equation in all endogenous switching models and that there were no marked differences in the selection equations' results in all models, only the result from the estimation of the first outcome of interest (land access) are reported. It is important to mention at the onset that the correlation coefficients (ρ) between the pathways into medium scale farming and the outcome of interest in the agricultural and lateral entry equations in all the models are both positive and statistically significant (Tables 2.11-2.15). This result confirms that an endogenous switching regression model is the appropriate model for this analysis.

(i) Pathways into medium-scale farming selection equation estimation results: The estimates of the correlates of pathways into medium scale farming are presented in Table 2.10. The dependent variable is a binary variable: agricultural entry is represented by "one" while lateral entry is represented by "zero". Only variables' marginal effects are presented. The results show that the following characteristics influence pathways into medium scale farming: (1) household demographics; (2) household head participation in non-farm employment; (3) household historical factors (the initial household head father's attributes); and (4) land holding characteristics and soil quality.

The age of the household head and family size influence pathways into medium scale farming. An increase in the head's age by an additional year increases the probability of agricultural entry into medium scale farming by 0.03. Similarly, an increase in the number of adult members of the household by one person increases the probability of agricultural entry by about 0.17. While increased household head's age may be capturing farming experience, increased adult household members is possibly capturing labor availability in the family, a variable that was not controlled for directly in the models due to lack of data. Farming experience and labor availability are key factors in agricultural production and thus their role in facilitating agricultural led entry into medium scale farming result is not surprising.

Table 2.10: Selection equation results-- pathways into medium scale farming

Dep. var.:1=agricultural entry; 0=lateral entry	Marginal effects	Std. Err.	P>z
Household demographic variables			
Household head age	-0.033	0.013	0.01
Household head sex (1=male; 0=female)	0.408	0.392	0.30
Number of adult members in the household	-0.166	0.050	0.00
Household head education (base=no educ.)			
_primary	-0.211	0.468	0.65
_secondary	0.489	0.595	0.41
_post-secondary	0.025	0.607	0.97
Participation in non-farm activities			
Head’s years in salaried job	0.007	0.021	0.72
Employer type (base=no salary job)			
_private sector	-0.265	0.056	0.00
_civil service	-0.321	0.064	0.00
Household’s years in non-farm business	0.029	0.014	0.04
Household’s history			
Landholding when started farming (ha)	0.016	0.035	0.08
Household’s years in the current settlement	0.499	0.485	0.30
Father to head’s landholding (acres)	0.109	0.056	0.05
Father to head’s education (1=educated; 0=informal)	0.219	0.303	0.47
Father to head is alive (1=alive; 0=dead)	-0.228	0.068	0.00
Father to head was community leader (1=yes; 0=no)	0.404	0.411	0.33
Land characteristics and quality			
Location (1=region; 0=outside)	0.142	0.052	0.01
Acquisition (1=purchase; 0=inherit)	0.186	0.305	0.54
Tenure (1=title; 0=w/out title)	-0.333	0.348	0.34
Length of growing period	0.041	0.025	0.09
Net primary productivity	-0.005	0.004	0.17
Elevation: meters above sea level	0.004	0.001	0.00
Slope/steepness -- degrees	0.023	0.013	0.08
Number of obs.sigma_1	200		
Log pseudolikelihood	-246.247		

Participation in non-farm employment influences entry into medium scale farming. Using households that relied solely on farm employment as the base, the results show that a change to private sector employment increases the probability of lateral entry by 0.27 while a change to public sector increases it by about 0.32. It is interesting to note that that what mattered most was the non-farm employer type and not the number of years in non-farm employment. Similarly, participation in off-farm business activities facilitates agricultural led entry into medium scale farming. Each additional year in off-farm business participation increases the probability of the household's agricultural entry into medium scale farming by 0.03.

Family history was also found to influence entry into medium scale farming pathways. If the land owned by the father to the initial household head before subdivision increased by one hectare, the probability of the current household to enter into medium farming via the agricultural led pathway increased by 0.11. Similarly, the death of the initial household head's father increases the current household's probability of agricultural entry into medium scale farming by 0.23. This result can be explained in two ways. First, after the death of the father to the initial household head, his land is likely to be inherited by his sons thereby making the beneficiaries agricultural entry pathway into medium scale farming possible. Second, fathers to initial households are assumed to possess high social capital and many networks that they accumulate with age. Social capital and networks are helpful in lowering land market transaction costs (e.g. search costs, access to quality land, and land deals negotiations) and thereby facilitating the current household head's, especially those in non-farm employment, entry into medium scale farming possible through a lateral entry. The results also indicate that the size of initial land owned when the family started farming positively influences the probability of the household's entry into medium scale farming via agricultural led pathway.

Households that followed agricultural led entry accessed most of their land in the location where the household head born while those that entered medium scale farming laterally accessed most of their land outside the locations where the heads were born. Relocation from the area where the household head was born increased the probability of household's lateral entry into medium scale farming by 0.14. This finding implies that for a household to enter medium scale farming laterally, it has to look for land beyond the areas where the household head was born. The results also show that the agricultural entry group somehow had high quality land in terms of length of growing period and land elevation.

(ii) Determinants of medium-scale farming access and area under crop: The results on the determinants of medium scale farmers' land access (owned and rented in) and areas under crops from the FIML estimation are presented in Tables 2.11 and 2.12, respectively. The most important determinants of household land access among the famers who entered medium scale farming through agriculture include the age of the household head; the size of land owned when the household started farming; and the location of the household. An increase in the household head's age by one year increased household land access by about two percent while an increase in the initial landholding by one hectare increased current household land access by three percent.

Among the factors influencing land access in lateral entry subsample include: education level of the household head; landholding when the household started farming, and the distance from the household to the nearest motorable road. Household landholding is a function of the household head's education attainment. For example, a switch from no education to primary education increases household land access by eight percent, while a switch to secondary and post-secondary increases land access by 11 and 14 percent, respectively.

Table 2.11: Results of the endogenous switching model for medium-scale farmers' land access

	Agricultural entry		Lateral entry	
Variables	Coef.	P>z	Coef.	P>z
Household demographic variables				
Household head age	0.017	0.04	-0.004	0.47
Household head sex (1=male; 0=female)	0.262	0.24	-0.104	0.53
Household head education (base=no educ.)				
_primary	-0.255	0.25	0.083	0.00
_secondary	-0.008	0.98	0.111	0.00
_post-secondary	0.114	0.60	0.143	0.00
Number of adult members in the household	0.038	0.18	0.016	0.56
Family history				
Landholding when started farming (ha)	0.032	0.01	0.009	0.00
Household's years in the current settlement	-0.044	0.88	-0.166	0.41
Distance to infrastructure				
Distance to nearest water source	-0.052	0.19	-0.006	0.89
Distance to nearest motorable road	-0.048	0.41	-0.112	0.04
Land characteristics and quality				
Location (1=region; 0=outside)	-0.694	0.08	-0.981	0.05
Acquisition (1=purchase; 0=inherit)	-0.126	0.57	0.050	0.76
Tenure (1=title; 0=w/out title)	0.284	0.18	0.544	0.00
Length of growing period	0.050	0.78	0.070	0.53
Net primary productivity	0.002	0.60	0.003	0.22
Elevation: meters above sea level	0.048	0.58	-0.014	0.01
Slope/steepness -- degrees	-0.028	0.00	-0.029	0.00
County (base=Nakuru)				
_Bungoma	0.477	0.46	0.171	0.49
_Uasin Gishu	1.283	0.00	0.906	0.00
_Trans-Nzoia	0.853	0.13	0.757	0.01
_cons	-2.814	0.52	2.976	0.38
Number of obs.	82		118	
ρ	0.051	0.00	0.344	0.00

Table 2.12: Results of the endogenous switching model for area under crop

	Agricultural entry		Lateral entry	
	Coef.	P>z	Coef.	P>z
Household demographic variables				
Household head age	-0.014	0.03	0.006	0.58
Household head sex (1=male; 0=female)	0.023	0.92	-0.080	0.76
Household head education (base=no educ.)				
_primary	-0.186	0.58	0.025	0.51
_secondary	-0.143	0.72	0.103	0.02
_post-secondary	0.034	0.93	0.094	0.04
Number of adult members in the household	0.059	0.03	-0.006	0.87
Landholding and assets				
Current landholding (ha)	0.014	0.00	0.016	0.00
Own tractor (1=yes; 0=no)	0.603	0.01	0.622	0.00
Input/output Prices				
Price of maize (KSh/kg)	0.023	0.17	0.014	0.05
Price of DAP (KSh/kg)	-0.156	0.53	0.157	0.35
Price of CAN (KSh/kg)	0.253	0.28	-0.184	0.19
Distances to infrastructure and markets				
Distance to nearest ag. input dealer (km)	-0.326	0.00	0.049	0.50
Distance to nearest water source (km)	-0.003	0.96	0.051	0.20
Distance to nearest motorable road (km)	0.068	0.35	-0.098	0.20
Land characteristics and weather				
Acquisition (1=purchase; 0=inherit)	-0.082	0.75	-0.150	0.42
Tenure (1=title; 0=w/out title)	0.404	0.18	0.155	0.47
Length of growing period	0.024	0.22	-0.010	0.96
Net primary productivity	0.024	0.12	0.012	0.04
Elevation: meters above sea level	0.003	0.52	0.005	0.04
Slope/steepness -- degrees	0.030	0.01	-0.008	0.96
Rainfall (mm)	-0.066	0.23	-0.031	0.38
Rainfall stress	-0.301	0.42	-0.367	0.21
_cons	-7.606	0.31	5.669	0.28
Number of obs.	82		118	
ρ	0.304	0.00	0.552	0.02

Similarly, households that entered medium scale farming through a lateral entry had access to registered land and land at close proximity to motorable roads. This implies that the lateral entry group had the social economic capital and connections that enabled them to access land close to infrastructural facilities and to either access registered land or navigate the land registration bureaucracy to get their land registered. Generally, the medium scale farmers were more likely to access land in locations outside the areas where the households' heads was born.

Next, we examine the determinants of medium-scale farming area cultivated (Table 2.12). Only two variables seem to be common determinants of area under crops in the two regression results presented in Table 2.12, namely household land access and tractor ownership. Access to additional hectare of land increases land under crops by about two percent while tractor ownership increases area under crop by about 60 percent. In the agricultural entry group, the other factors that influence area under crop include, the age of the household; household size; distance to the nearest input dealer; and land slope in the areas where the household is situated. A reduction in the distance to the nearest input dealer by one kilometer increases area under crops by about 33 percent in the agricultural pathway subsample. In the lateral entry group, the only other factors influence area under crops include households' heads education attainment; price of maize prevailing in the regional markets are the planting time; and the net primary productivity and land slope in the area where the household is located. A switch in the household head's education from no education to secondary education or post-secondary education increases land under cultivation by about ten and nine percent, respectively. Increase in the price of maize price by a shilling per kilogram increases area under crop by one percent in the lateral entry group.

(iii) Determinants of medium-scale farmers' fertilizer use intensities and crop productivity: The results on determinants of fertilizer use intensity (kilograms applied per hectare cultivated) are presented in Table 2.13. Generally, only ownership of a tractor and maize and fertilizer prices, influence the intensity of fertilizer application. An increase in the price of maize by one shilling per kilogram increases fertilizer use intensity by about two percent in the two pathways into medium-scale farming. Ownership of a tractor increase fertilizer use by about 26 percent among the households that followed agricultural-led pathway and by 27 percent in the lateral entry group. The results also show that an increase in the price of DAP by a shilling per kilogram reduces the fertilizer application intensity by three percent in the lateral entry group.

Next, we turn to crop productivity. Agricultural crop productivity is loosely defined and the net value of crop outputs (after netting out fertilizer, seed and, land preparation, and hired labor costs) per unit of land. The results show that the only common factor influencing medium scale farming crop productivity per hectare owned in the two regressions reported in Table 2.14 are the maize prices prevailing in the regional markets at the planting time and the distances to the nearest agricultural input dealers. An increase in maize price by a shilling per kilogram increases medium scale farmers' crop productivity by about three percent while an increase by one kilometer to the nearest input dealer reduces productivity by about 15 percent. The other factors that influence medium farmers' crop productivity are the price of fertilizer for the lateral entry group and households' location land elevation (meters above the sea level) for the agricultural entry group. An increase in DAP price by one shilling per kilogram reduces crop productivity by about three percent.

Similarly, the only common factors influencing medium scale farmers' crop productivity per hectare cultivated in the two regressions are maize prices and distances to agricultural input dealers (Table 2.15). An increase in maize price by a shilling per kilogram increases crop production by four percent.

Table 2.13: Results of the endogenous switching model for intensity of fertilizer use

	Agricultural entry		Lateral entry	
	Coef.	P>z	Coef.	P>z
Household demographic variables				
Household head age	-0.002	0.75	0.006	0.29
Household head sex (1=male; 0=female)	-0.087	0.58	0.265	0.08
Household head education (base=no educ.)				
_primary	0.027	0.89	-0.104	0.65
_secondary	-0.047	0.88	-0.007	0.98
_post-secondary	0.200	0.66	-0.158	0.52
Number of adult members in the household	-0.016	0.48	0.016	0.55
Landholding and assets				
Current landholding (ha)	0.032	0.81	-0.003	0.19
Own tractor (1=yes; 0=no)	0.255	0.04	0.274	0.05
Input/output Prices				
Price of maize (KSh/kg)	0.016	0.02	0.021	0.01
Price of DAP (KSh/kg)	0.039	0.53	-0.026	0.04
Price of CAN (KSh/kg)	0.004	0.94	-0.016	0.12
Land quality and weather				
Slope/steepness -- degrees	-0.037	0.35	0.012	0.20
Rainfall (mm)	0.020	0.52	-0.012	0.62
Rainfall stress	0.950	0.68	-0.462	0.80
_cons	1.497	0.67	-3.443	0.18
Number of obs.	82		118	
ρ	0.221	0.00	0.545	0.01

However, an increase in the distance to the nearest input dealer by a kilometer reduces crop productivity by about two percent. The other factors that influence crop productivity per hectare cultivated include land tenure, land access, the amount of rainfall and rainfall stress. While crop productivity appears to be higher in registered land parcels in the agricultural entry subsample, crop production is a decreasing function of household land access in the lateral entry subsample.

Table 2.14: Results of the endogenous switching model for crop production per ha owned

	Agricultural entry		Lateral entry	
Variables	Coef.	P>t	Coef.	P>t
Household demographic variables				
Household head age	-0.006	0.44	0.002	0.76
Household head sex (1=male; 0=female)	0.025	0.92	0.203	0.22
Household head education (base=no educ.)				
_primary	0.024	0.91	0.029	0.91
_secondary	0.000	1.00	0.127	0.63
_post-secondary	0.231	0.47	0.362	0.17
Number of adult members in the household	-0.004	0.90	-0.002	0.92
Input/output Prices				
Price of maize (KSh/kg)	0.029	0.01	0.034	0.01
Price of DAP (KSh/kg)	-0.002	0.99	-0.026	0.04
Price of CAN (KSh/kg)	0.054	0.63	-0.033	0.11
Distances to infrastructure and markets				
Distance to nearest ag. input dealer (km)	-0.157	0.10	-0.151	0.04
Distance to nearest motorable road (km)	0.435	0.68	0.318	0.77
Distance to nearest water source (km)	-0.089	0.19	-0.011	0.93
Land characteristics				
Current landholding (ha)	0.130	0.42	0.148	0.28
Tenure (1=title; 0=w/out title)	0.169	0.36	0.210	0.27
Own tractor (1=yes; 0=no)	-0.082	0.49	0.012	0.95
Land quality and weather				
Length of growing period	0.004	0.75	-0.026	0.19
Net primary productivity	0.001	0.55	0.000	0.53
Elevation: meters above sea level	0.005	0.02	-0.003	0.30
Slope/steepness -- degrees	-0.005	0.95	0.012	0.27
Rainfall (mm)	0.017	0.69	0.042	0.15
Rainfall stress	-2.955	0.42	-2.773	0.18
_cons	1.857	0.78	11.708	0.08
Number of obs.	82		118	
ρ	0.350	0.00	0.016	0.01

Table 2.15: Results of the endogenous switching model for crop production/ha cultivated

	Agricultural entry		Lateral entry	
Variables	Coef.	P>t	Coef.	P>t
Household demographic variables				
Household head age	-0.119	0.30	-0.004	0.65
Household head sex (1=male; 0=female)	-0.002	0.99	0.074	0.72
Household head educ. (base=no educ.)				
_primary	-0.234	0.46	0.170	0.62
_secondary	0.015	0.97	0.240	0.54
_post-secondary	0.405	0.41	0.513	0.16
Number of adult members in the household	-0.027	0.47	0.022	0.65
Input/output Prices				
Price of maize (KSh/kg)	0.037	0.02	0.036	0.02
Price of DAP (KSh/kg)	-0.290	0.17	-0.395	0.18
Price of CAN (KSh/kg)	-0.218	0.18	-0.288	0.12
Distances to infrastructure and markets				
Distance to nearest ag. input dealer (km)	-0.017	0.09	-0.192	0.04
Distance to nearest motorable road (km)	-0.729	0.62	1.434	0.31
Distance to nearest water source (km)	0.156	0.19	-0.034	0.81
Land characteristics				
Current landholding (ha)	-0.037	0.14	-0.053	0.01
Tenure (1=title; 0=w/out title)	0.062	0.02	0.077	0.77
Own tractor (1=yes; 0=no)	-0.001	0.67	-0.001	0.85
Land quality and weather				
Length of growing period	0.017	0.25	-0.036	0.14
Net primary productivity	0.019	0.17	-0.010	0.24
Elevation: meters above sea level	0.006	0.10	0.002	0.54
Slope/steepness -- degrees	0.007	0.50	-0.003	0.83
Rainfall (10 mm)	0.002	0.67	0.095	0.03
Rainfall stress	-0.197	0.66	-0.617	0.06
_cons	9.433	0.27	16.789	0.04
Number of obs.	82		118	
ρ	0.386	0.00	0.188	0.01

The expected rainfall increases crop productivity but the expected rainfall shock somehow reduces it among the farmers that entered medium scale farming laterally[6]. Increase in the expected rainfall by 10mm increase crop productivity per hectare cultivated by about ten percent. While increased expected rainfall shocks reduce crop productivity, the coefficient is only significant at ten percent level.

2.6 Conclusions and policy implications

Smallholder farmers constitute the bulk of agricultural producers in sub-Saharan Africa and majority of them are poor. Based on sub-Saharan Africa's land endowment, an agricultural-led growth strategy has been touted as solution for reductions in poverty in this region. However, recent studies cast doubts on the land abundance hypothesis. Each day, the Africa smallholder farming land holding and access shrinks as population density rises. Despite these mounting population related challenges, analysts have pointed out that sub-Saharan Africa still has the potential to revitalize smallholder agricultural productivity for reduced poverty and hunger if appropriate policies are pursued. They cite the example of the smallholder-led broad-based Asian green revolution that contributed greatly to rural poverty reduction in that region.

This study investigates the potential for similar forms of inclusive agricultural growth using Kenya as a case study. The study specifically investigate whether land institutions and policies in Kenya are making it possible for a broad-based smallholder led agricultural growth process as enjoyed in much of Asia. In Kenya, there has been a policy thinking that agricultural

[6] Expected rainfall is defined as a six-year moving average of rainfall prior to the main growing season in survey year, while expected rainfall shock is a six-year moving average of the percentage of 20-day periods during the main growing season with less than 40 mm of rainfall.

and land reforms supported by adequate government budget allocation have the potential to underpin a revitalized system of smallholder production especially in areas where land sizes have become too small.

The study is inspired by two factors. First, the recent literature indicating that Africa is characterized by landholding inequalities making redistributive land reforms an attractive strategy for improved smallholder land access. Using a panel data spanning 13 years and qualitative data from focus group discussions in the land scarce densely populated regions we examine how smallholders are coping with shrinking farm sizes and whether land rental and sales markets and other land access modes have been successful in reducing inequalities in land holding. The second factor motivating this study is the increasing number of medium scale (emergent) farmers in many African countries over the last decade. Yet, the processes behind their growth have remained unclear. Is this growth driven by farmers who began their farming careers as smallholder now transitioning to a larger scale of production through the capital and assets accumulation; a precursor to the inclusive agricultural-led structural transformation? Or is the growth driven by land institutions and policies that encourage investment in land acquisitions by individuals from non-agricultural employment sector signaling elite land capture? Using a survey conducted with a random sample of medium scale farmers in Kenya, we explore the rise in medium-scale farming operations over the 1980-2010 period, how the medium scale farmers achieved their current scale of operation, the underlying interpretation of these findings about the priorities and motivations of governments, and the implications for prospects of broadly-based agricultural development strategies.

The results point to four key findings. First, the qualitative results from the focus group discussions indicate that access to land is becoming a binding agricultural production constraint in the densely populated regions of the Kenya. Even in the areas considered relatively land abundant like in the lowlands regions, land sizes are swiftly declining due to mounting population pressure. Not only are household farms shrinking in densely populated regions, soil fertility is also rapidly deteriorating due to nutrients mining and degradation. Land conflicts among neighbors and siblings over boundaries and contested inheritances are on the rise due to increasing land scarcity. Increasing land scarcity is also triggering increased incidences of fraudulent land deals as a result of poorly drawn land sale agreements and proliferation of fake land title deeds consequently increasing transaction costs in land markets.

Second, the qualitative data show that the customary land inheritance from parents and land sales and rental markets still remain the most important ways through which smallholder farmers gain access land in rural Kenya. The results indicated that there are not unallocated lands and/or common grazing lands in both the low and highly densely populated areas. These customary land transfer practices from parents to male children have led to land subdivisions resulting in tiny landholding especially in the land constrained regions of the country. The land subdivision problem is likely to be compounded by the new constitutional requirement providing for equal treatment of children regardless of gender in family assets inheritance.

Third, while migration out of densely populated areas is considered a potential avenue to ease land pressure in the land constrained regions, the results show outmigration trends are very low. Rural to rural migration requires financial ability which the smallholder farmers facing land constraints are lack. Migration is also being inhibited ethnicity and cultural factors. While attachment to ancestral lands limits outmigration, access to land in most of the regions in Kenya is tied on one’s ethnic identity. Following the 2008 post-election tribal land conflicts, ethnicity is slowly becoming a binding land access constrain in rural Kenya. Limited non-farm employment opportunities are impeding rural to urban migration in Kenya. It is important to mention that in most cases the migrating individuals still retain hold of the land they own in the previous locations. Consequently, outmigration is not helping in easing land scarcity pressure in the densely populated areas of the country.

Fourth, the empirical results revealed that land sales and rental markets do not reduce landholding inequality among smallholder farmers in rural Kenya. With increasing land scarcity, land sale and rental prices have been bid high beyond the reach of the land-poor smallholders. It is mostly the medium and large scale farmers interested in expanding their scale of production and as well as individuals transitioning from non-farm employment into farming who can afford such prices and who have the political and economic capital to navigate through the bureaucracies of land markets to access land.

Fifth, the empirical results from the medium scale farmers' survey show that majority of them used lateral entry into medium-scale farming status. They attained their current farming status by acquiring land from savings from non-farm, largely urban jobs; only a minority was primarily engaged in agriculture prior to achieving medium-scale farming status. A big proportion of them owned on average over two times more land than they were using for agriculture, implying a high degree of land owned for speculative purposes and/or an inability of farmers in this size category to make productive use of the land they owned. In terms of crop productivity, the agricultural entry group seems to be more productive than the lateral entry counterpart. Another interesting finding is that these emergent farmers are generally more productive in terms of total production and production per hectare compared to the smallholders.

This study, therefore, suggests that land is becoming a binding agricultural production constraint especially in the densely populated regions of the country. However, the current land policies and institutions and by extension land markets are not facilitating smallholders facing increasing land constraints access to land. The policies are primarily working for individuals with economic and political capital conferred through off-farm jobs that are able to navigate the land markets systems and land administration bureaucracies.

The new national land policy in Kenya spells out a wide range of measures aimed at eliminating land access discrimination based on gender and ethnicity; land taxation to curb inefficient land use and idle land holding and hoarding tendencies; resolution of historical land injustices; improvement of tenure security; efficient utilization of marginal lands; setting up of economically viable minimum landholding sizes; review of public land allocation procedures; and commercialization of land rights to make land market operations more efficient. The policy however leaves very many hard decisions to legislators and implementers preparing key legislations to support the implementation of the policy. The policy does not suggest how to overcome challenges encounters in the past initiatives aimed at improving land access to the smallholders facing landlessness. Empirical studies have shown that well-targeted land redistribution programs can a positive impact on smallholder land access and poverty reduction. While some smallholder farming systems "pessimists" have argued for smallholders whose farms have become too small to quit farming and pursue non-farm income options, Hazell (2011) and Lipton (2009) opines that the exit of small farms is not a "driver" but a "consequence" of economic growth. Hazell (2011) plainly says: "When economies grow, many small farmers (or their children) leave farming because they can find better paying jobs elsewhere. But consolidating land and pushing small farmers off the land before there are better jobs available simply leads to worsening poverty and unwanted levels of rural-urban migration", (Hazell, 2011).

APPENDIX

Table A2.1: Distribution of government land by use in square kilometers

Region	Forest	Townships	Alienated land	Unalienated land	National parks	Open water	Others	Total
Kenya	9,116	2,831	38,546	28,598	24,067	10,960	2,136	116,254
Nairobi	21	93	225	16	117	-	77	549
Central	2,541	156	1,505	28	900	3	155	5,288
Coast	454	838	15,202	19,979	15,065	563	1,022	53,123
Eastern	1,289	227	3,148	8,397	7,721	4,131	452	25,365
N. Eastern	-	-	-	-	-	-	-	-
Nyanza	-	179	113	1	-	3,480	23	3,796
R. Valley	4,195	1,338	18,353	177	262	2,646	404	27,375
Western	616		-	-	2	137	3	758

Source: Syagga (2009)

Table A2.2: Distribution of trust land that is not available for smallholders

Region	Forest	Townships	Alienated land	Unalienated land	National parks	Open water	Others	Total
Kenya	7,084	1,812	33,397	13,810	3,030		492	59,625
Nairobi	-	-	-	-	-		-	-
Central	9	94	102	-	-		163	368
Coast	63	214	3,881	1,687	-		52	5,897
Eastern	789	546	647	4,203	2,484		244	8,913
N. Eastern	-	396	202	3,142	-		-	3,740
Nyanza	1	285	177	119	-		5	587
R.Valley	5,964	154	28,387	4,659	546		21	39,731
Western	258	123	1	-	-		59,625	389

Source: Syagga (2009)

Table A2.3: Classification of land in Kenya

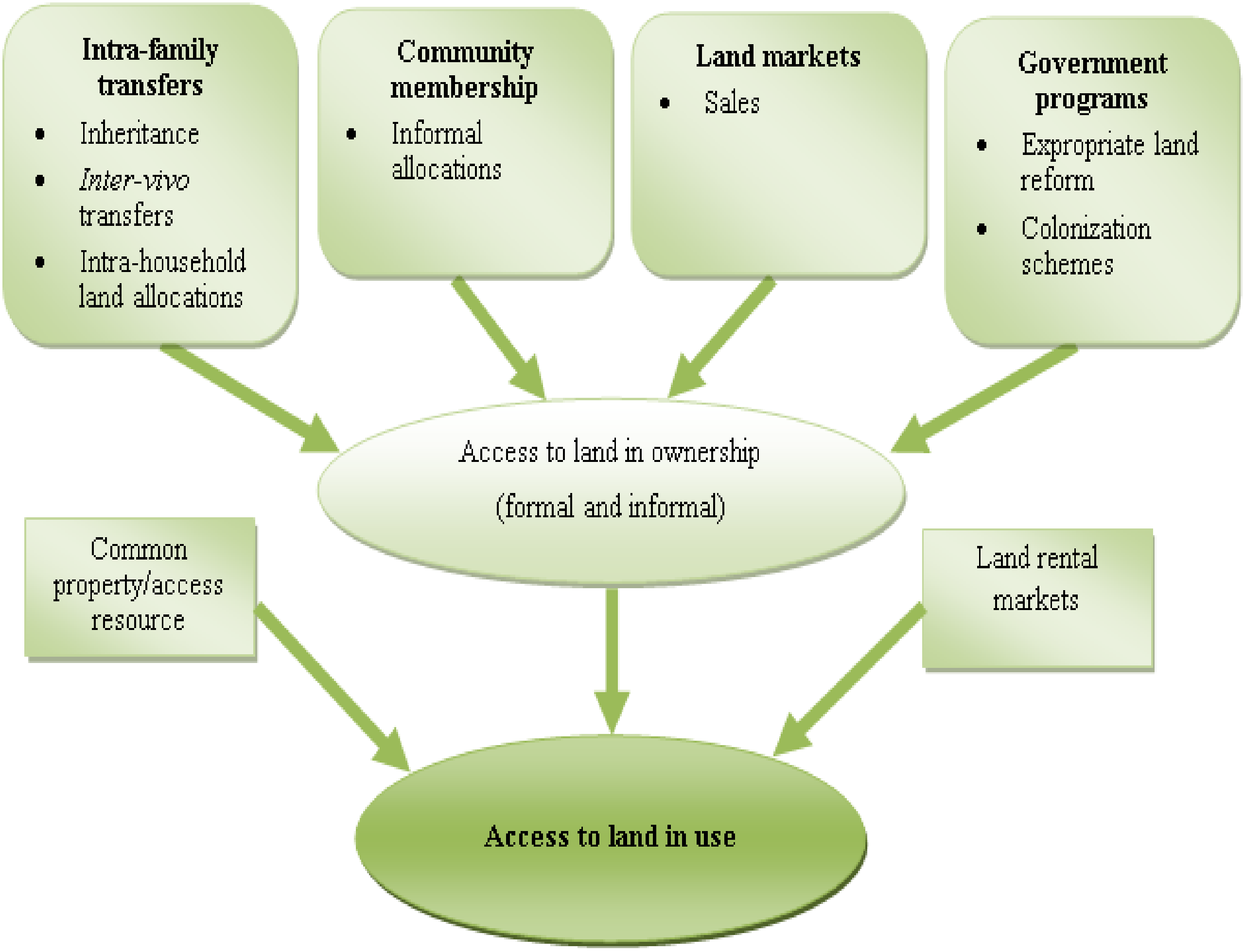
Public Land	**Community Land**	**Private Land**
(1) Public land is— (*a*) unalienated government land; (*b*) land lawfully held, used or occupied by any State organ; (*c*) land transferred to the State by way of sale, reversion or surrender; (*d*) land in respect of which no individual or community ownership can be established; (*e*) land in respect of which no heir can be identified; (*f*) all minerals and mineral oils; (*g*) government forests; (*h*) all roads and thoroughfares; (*i*) all rivers, lakes and other water bodies; (*j*) the territorial sea, the exclusive economic zone and the sea bed; (*k*) the continental shelf; (*l*) all land between the high and low water marks; (*m*) any land not classified as private or community land under this Constitution; and (*n*) any other land declared to be public land by an Act of Parliament— (2) Public land under clause (*a*) clause (1) (*a*), (*c*)**,** (*d*) or (*e*), and clause (1) (b), other than land held, used or occupied by a	(1) Community land shall vest in and be held by communities identified on the basis of ethnicity, culture or similar community of interest. (2) Community land consists of— (*a*) land lawfully registered in the name of group representatives under the provisions of any law; (*b*) land lawfully transferred to a specific community by any process of law; (*c*) any other land declared to be community land by an Act of Parliament; and (*d*) land that is— (i) lawfully held, managed or used by specific communities as community forests, grazing areas or shrines; (ii) ancestral lands and lands traditionally occupied by hunter-gatherer communities; or (iii) lawfully held as trust land by the county governments, but not including any public land held in trust by the county government. (3) Any **unregistered community** land shall be held in trust by **county governments** on behalf of the communities for which it is held.	**I.** Private land consists of — (*a*) registered land held by any person under any **freehold** tenure; (*b*) land held by any person under **leasehold** tenure; and (*c*) any other land declared private land under an Act of Parliament. (1) A person who is not a citizen may hold land on the basis of leasehold tenure only, and any such lease, however granted, shall not exceed ninety-nine years. (2) For purposes of this Article— (*a*) a body corporate shall be regarded as a citizen only if the body corporate is wholly owned by one or more citizens; and **II** (1) There is established the National Land Commission. (2) The functions of the National Land Commission are to — (*a*) manage public land on behalf of the national and county governments; (*b*) recommend a national land policy to the national government; (*c*) advise the national government on a comprehensive programme for the registration of title in land throughout Kenya;

Table A2.3 (cont'd)

Public Land	**Community Land**	**Private Land**
national State organ shall vest in and be held by a **county government** in trust for the people resident in the county, and shall be administered on their behalf by the National Land Commission. (3) Public land classified under clause (1) (*f*) to (*m*) shall vest in and be held by the **national government** in trust for the people of Kenya and shall be administered on their behalf by the National Land Commission. (4) Public land shall not be disposed of or otherwise used except in terms of an Act of Parliament specifying the nature and terms of that disposal or use.	(4) Community land shall not be disposed of or otherwise used except in terms of legislation specifying the nature and extent of the rights of members of each community individually and collectively. (5) Parliament shall enact legislation to give effect to this Article.	(*d*) conduct research related to land and the use of natural resources; (*e*) initiate investigations, on its own initiative or on a complaint, into present or historical land injustices, and recommend appropriate redress; (*f*) encourage the application of traditional dispute resolution mechanisms in land conflicts; (*g*) assess tax on land and premiums on immovable property in any area designated by law; and (*h*) monitor and have oversight responsibilities over land use planning throughout the country.

Source: Condensed by the author from Republic of Kenya (2010)

Figure A2.1: Paths of access to land



Source: de Janvry and Sadoulet (2001) with author's modification

Figure A2.2: Modified Fisher-Ideal Quantity Indices[7]

To aggregate crop production across multiple commodities, we use a modification of the Fisher-Ideal index by Mason (2011), which uses information on the individual household production (kg) and national-level prices of each crop in the crop group. The Fisher-Ideal (FI) index is a combination of two indices, the Modified Laspeyres Quantity Index (ML) and the Modified Paasche Quantity Index (MP) (Diewert 1992; Diewert 1993).

For each crop $j = 1$ to J, we use the national median production quantity as the base quantity in the denominator of both the ML and MP indices. We use the median national-level price in the first year of the Tegemeo panel household dataset (1997) as the base year price, $p_{j,base}$. Thus, changes in the ML index are driven by changes in quantities of each commodity produced over time, as prices do not vary from the base year, nor across households. For p_j in the MP index, we use the national median price for each year. Thus, the MP index allows price variation by year but not across households.

Modified Laspeyres Quantity Index (LQI*)

$$LQI^*_{i,t} = \frac{\sum_{j=1}^{J} q_{i,j,t}\, p_{j,base}}{\sum_{j=1}^{J} q^*_{j,base}\, p_{j,base}}$$

Modified Paasche Quantity Index (PQI*)

$$PQI^*_{i,t} = \frac{\sum_{j=1}^{J} q_{i,j,t}\, p_{j,t}}{\sum_{j=1}^{J} q^*_{j,base}\, p_{j,t}}$$

Fisher-Ideal Quantity Index (FIQI*)

$$FIQI^*_{i,t} = \sqrt{(LQI^*_{i,t} \times PQI^*_{i,t}}$$

[7] Adapted from Mather and Jayne (2011).

Table A2.4: Medium and large scale farmers survey sample

County	Division	Location	Number of households
Bungoma	Tongaren	Ndalu / Mitua	10
	Tongaren	Ndalu / Mitua	15
	Central	Milima/Mukuyuni	15
Trans Nzoia	Saboti	Kinyoro /Saboti	15
	Waitaluk	Waitaluk	15
	Kwanza	Kaisagat	15
	Kaplamai	Ngonyek farm	13
	Kaplamai	Kaplamai/Sibanga	7
Uasin Gishu	Soy	Soy	15
	Soy	Soy	15
	Moiben	Moiben	15
	Moiben	Karuna	14
	Moiben	Karuna	6
Nakuru	Rongai	Rongai	10
	Rongai	Rongai	5
	Rongai	Rongai	5
	Ngata	Ngata	10

Figure A2.3: Medium and large scale farmers survey sample

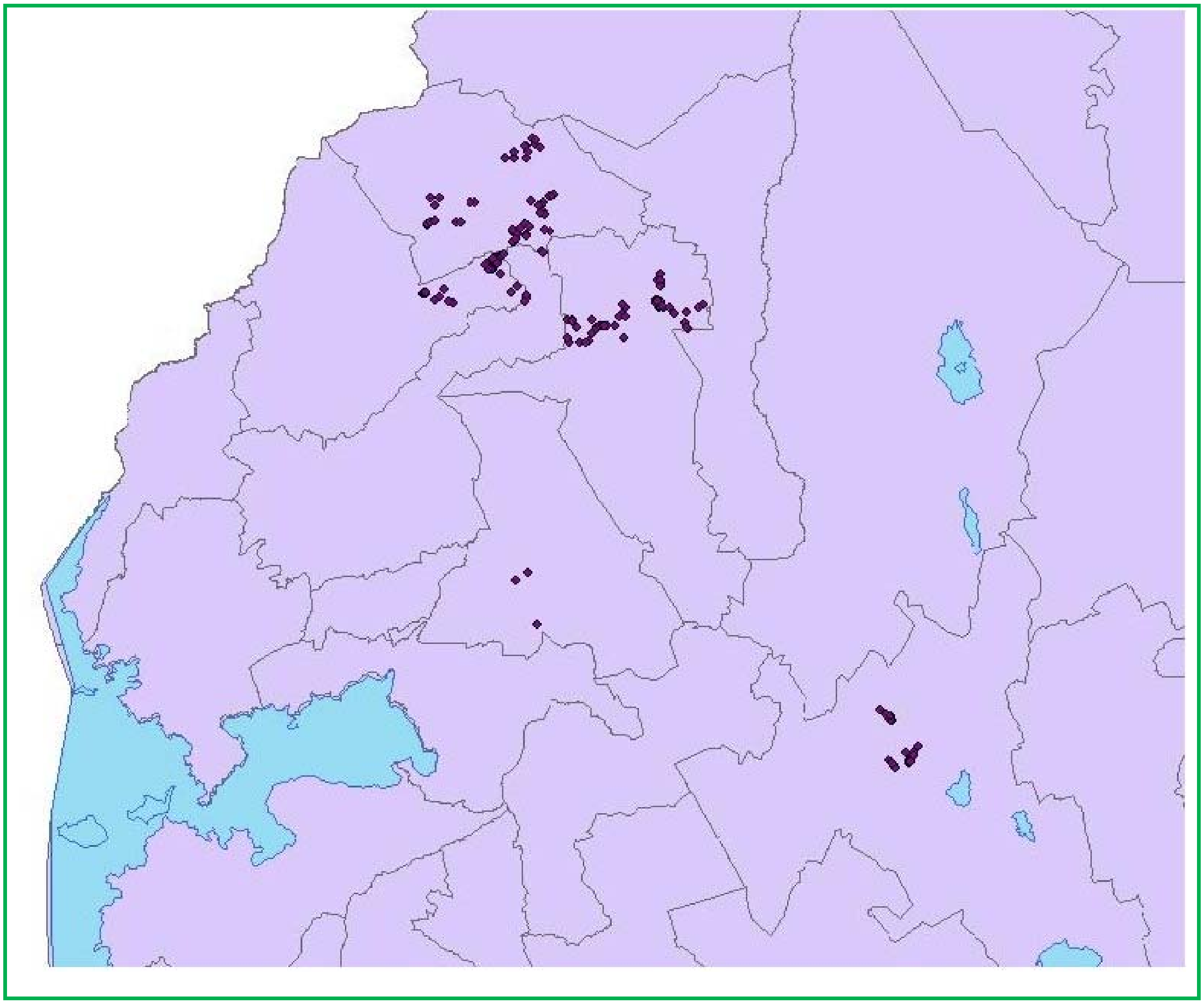


Table A2.5: Focus group discussion sites

District	Division	Location	Sub location	Village	density	Landholding (acres)
Vihiga	Sabatia	North Maragoli	Mulundu	Kigaro	911	2
Kisii	Marani	Mwamunari	Rioma	Emanyi	792	3
Bungoma	Kimilili	Kamukunywa	Nabikoto	Esikweya	786	4
Kakamega	Mumias	Etenje	Musanda	Mukhwenje	659	4
Bungoma	Kanduyi	Bukembe	North Sangalo	Muluhu	616	7
Nyeri	Mukurweini	Muhito	Gatura	Ikiyu	487	3
Nyeri	Mukurweini	Muhito	Gaturia	Gachiriro	804	2
Machakos	Mwala	Mwala	Myanyani	Kandumbo	171	9
Kitui	Chuluni	Mbitini	Katwala	Nzovia	167	10
Uasin Gishu	Ainabkoi	Olare	Kapkeno	Gaiti	161	5
Uasin Gishu	Moiben	Sergoit	Kelji	Kapsking	161	7
Nakuru	Njoro	Ngata	Kirobon	Kapkatet	146	14
Nakuru	Njoro	Ngata	Ngecha	Ngecha B	146	14

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CHAPTER 3: EFFECTS OF POPULATION DENSITY ON SMALLHOLDER AGRICULTURAL PRODUCTION AND COMMERCIALIZATION IN RURAL KENYA

3.1 Background

Reducing poverty and hunger have been a critical policy concern in most of the sub-Saharan African countries for the past half-century. Governments and development agencies have experimented with a series of alternative approaches for addressing poverty. Yet, poverty still remains pervasive. In 2005, more than 40 percent of Sub-Saharan Africa's population was estimated to be below the poverty line (World Bank, 2006). More than 70 percent of the poor live in the rural areas and derive their livelihood from smallholder farming. For this reason, broad based agricultural growth has been widely understood to be the most powerful vehicle for reducing rural poverty and kick-starting broader structural transformation processes (Johnston and Kilby, 1975; Mellor, 1995). Based on green revolution in Asia, growth starting among smallholder farmers has been viewed as having far higher growth 'linkages' than growth in any other sector (Mellor, 1995; Lipton, 2005; Binswanger-Mkhize, 2012). A major feature of the structural transformation processes achieved in other parts of the world such as Asia was *small farm-led* and thus *broad-based* (Johnston and Kilby, 1975; Mellor, 1995). Smallholders tend to spend their incomes on locally produced goods and services, therefore stimulating the rural non-farm economy and creating additional jobs that would lead to diversification out of agriculture and rural-urban transition (Hazell et al., 2010; Bryceson and Jamal, 1997; Ellis, 2005). Consequently, a smallholder-led growth strategy has been touted as having the brightest prospects for rapid and sustained reductions in poverty and hunger in sub-Saharan Africa (Lipton, 2005; World Bank, 2007; Hazell et al., 2007; Bezemer and Headey, 2008; Byerlee and de Janvry, 2009; Haggblade, 2009; Christiaensen et al., 2010; Eastwood et al., 2010; Headey, Bezemer, and Hazell, 2010; Wiggins et al., 2010).

However, the widely held view that agricultural development and structural transformation in sub-Saharan Africa can be achieved by largely replicating the smallholder-led growth processes in Asia have never fully be juxtaposed with salient features of farm structure and trends in land productivity in much of Africa. Evidence for Africa tends to show quite limited land productivity growth in response to rising population density. Unlike in Asia, where land productivity growth was achieved with the aid of extensive irrigation/water control and improved seed varieties, which made high application rates of fertilizer use very profitable, by contrast most of Africa relies on rain-fed production where land productivity growth is challenging because the economics of fertilizer use are much different. As a result of this, most of the agricultural growth in sub-Saharan Africa (SSA) has been based on area expansion, not yield growth, but in many areas of Africa, smallholder farmers are facing increased land constraints.

While land is relatively abundant in some areas, this tend to exist simultaneously with land shortages in more densely populated smallholder areas, reflecting failures in land and labor markets and impediments on migration. Survey evidence consistently shows that farm structure in SSA is highly concentrated. While mean farm size tends to be around 2-3 hectares in most of the region, at least 40 percent of farms are under one hectare, and the marketed surplus and dynamism in smallholder agriculture consistently seems to be confined to 20 percent of the smallholder households or less (Jayne et al., 2003). Increasing rural population density will only lead to smaller farm sizes, and without interventions capable of achieving major and broadly based growth in land productivity, it is not clear how a smallholder-led strategy can kick-start the broad based growth processes required to achieve structural transformation as was experienced in Asia.

Currently, it is not at all clear how a smallholder-led agricultural strategy must be adapted to address the limitations of small and declining farm sizes and increasingly reduced prospects of land accessibility in the densely populated areas that are dependent on rain-fed production systems with only one growing season per year. The overarching issue to be investigated is whether most farms are becoming, or have already become, “too small” to generate meaningful production surpluses and to enable smallholders to participate in broad-based inclusive agricultural growth processes given existing on-shelf production technologies; and whether there is scope for agricultural intensification. Land poverty and landlessness may pose bigger potential problems in African countries because of lack of developed industrial sector to absorb persons squeezed off their lands. In the long run, diminishing land sizes are likely to contribute to hunger, poverty, and perhaps political instability and violence (Gladwin, 1990).

The overarching objective of this study is to model how rising population pressure affects smallholder households’ behavior and outcomes, in particular agricultural incomes, productivity, and commercialization. The study consists of two parts. The first part models how the increasing population density affects smallholder input demand and output supply. It is hypothesized that farm households in the relatively densely populated areas will exhibit declining farm sizes over time that will constrain farm intensification, and thus lower farm productivity and household incomes. The research questions to be explored in this study include:

1. How are the farming and livelihood systems of densely populated and land-constrained rural areas evolving differently than those in relatively land abundant areas?

2. How is increasing population density affecting behavior through (i) diminished landholding sizes; (ii) increasing labor availability per unit of land cultivated; (ii) increasing land sales and rental prices; and (iii) increasing food demand?
3. What is the impact of raising population densities on agricultural productivity?
4. Do the marginal products of fertilizer and other purchased modern inputs vary as a function of population density?

The second part examines the impact of emerging land constraints and rising population density on smallholder agricultural commercialization and the factors that condition these relationships. It is hypothesized that rational farmers in modern agricultural system always try to maximize their net agricultural income from their limited resources. Thus, as land size diminishes due to human population pressure, farmers are expected to use their resources in the best way possible to maximize net returns. For example, with low and stable food crops prices, farmers are expected to rely more on the markets for their food needs and thus able to put a larger proportion of their land entitlement on high value enterprises.

Consequently, the second part of this study examines smallholder diversification in the context of how farmers allocate land among competing crops. Commercialization is examined in the context of farmers' participation in input and output markets. Consequently, we examine how allocation of farmland among alternative crops is adjusting to emerging constraints and opportunities created by increasing population holding other factors constant. Next, we investigate the extent to which increasing human population density influences the degree of smallholder commercialization in rural Kenya. While declining landholding sizes might arguably encourage smallholders to put a larger proportion of their land in food crop production for household subsistence, stable food prices and improved access to markets may by contrast trigger a switch towards agricultural commercialization. When food prices become more stable, smallholder farmers can be hypothesized to follow a comparative advantage production orientation that implies greater reliance on markets for food needs. While increased human population density result in increased food demand, improved infrastructural facilities and market access are hypothesized to enhance smallholder commercialization by triggering production of high value and perishable crops. Consequently, whether and to what extent population growth affects smallholder cropping patterns and commercialization is ultimately an empirical issue, which requires careful econometric analysis.

Since the two study parts derive from the same theory and use the same data and methods, we discuss the conceptual framework, data sources, and econometric methods jointly but present the study results separately. We conclude this section by discussing the study's contributions to the discipline as well as policy implications. With regard to the contribution to the discipline, the study provides an explicit modeling approach for determining the factors explaining farm productivity growth (or lack thereof) and smallholder commercialization within the context of endogenous variables. The incorporation of population density into prices and distances to infrastructure is new. In most of the earlier studies examining the impact of population density on agricultural production in the region, population density, prices and distances to infrastructural facilities are taken as an exogenous (Benin, 2006; Pender and Gebremedhin, 2006; Pender et al., 2006). This study thus shows how to explicitly model input demand and output supply functions where the dependent variables are either continuous or fractional in nature (restricted between zero and one) and in the context of endogenous explanatory variables. The potentially endogenous covariate necessitates the use of the three-stage correlated random effect and control function approaches.

From the policy front, the research comes up with useful policy insights about the future of smallholder agriculture and the viability of a smallholder-led development strategy for densely populated areas with limited potential for area expansion. As the land frontier closes in many countries in many sub-Saharan Africa, smallholder farming areas are confronted by a challenge of increasing agricultural productivity through technical innovation. The results shed light on the validity of the structural transformation process; whether there is a threshold of population density beyond which some other paradigm is needed; and the range of policy parameters that need to be tweaked for it to be successful in Kenya. The study will provide insights into the state of production in the densely populated areas, how productions trends are likely to evolve in these areas in the future, and suggest some institutional and policy measures to be put in place for a feasible smallholder-led development.

3.2 Overview of the effects of population density on agricultural production

The early literature on households' responses to increasing human population pressures came from demographers and anthropologists. This literature posited that households would recognize the need to change their demographic behavior with increasing population pressure. Consequently, households are hypothesized to adopt behavioral changes such as higher age at marriage, increased celibacy, increased contraceptives use and abstinence, and increased abortions of unwanted conceptions (Bilsborrow, 1987). These behavioral changes were congruent with the preventive checks suggested by Malthus (1798). In his book, *The Principle of Population*, Malthus had earlier on pointed out that population growth had the potential to outpace agricultural growth leading to starvation. Later literature found this demographic approach overly narrow in that it neglected the possibility of any economic responses. The framework somewhat assumed fixed supply of natural resources, especially land access, and unchanging methods of production.

The earliest economic conceptualization of the effects of rising population density came from Boserup (1965). Boserup argued that as arable land becomes scarcer relative to population, land is used more intensively. As population grows, societies move through the following stages: (1) forest or long fallow; (2) bush fallow; (3) short fallow; (4) annual cropping; and (5) multiple cropping. In Boserup's framework, agricultural intensification is defined in terms of cropping frequency. The framework postulates a linear switch from long fallows, to shorter fallows, annual cropping and ultimately multiple cropping.

The post Boserup literature introduces a broader conceptual framework to analyze responses to population pressure that combines both demographic and economic factors (Bilsborrow, 1987). Increased population pressure is associated with decreased land holding as a result of fragmentation, spreading the agricultural work thinly resulting in high labor inputs per land unit, reduced fallows, and soil nutrient depletion as a result of high plant nutrients extraction beyond the natural regeneration rates (Drechsel et al., 2001). In response to the increasing population pressure, households innovate to maintain their accustomed standards of living. They not only recognize the need to alter their demographic behavior, but also embrace new production tactics and take advantage of emerging economic opportunities. Bilsborrow (1987) hypothesizes three possible types of responses to human population pressure, namely, (1) demographic, (2) economic, and (3) "demographic-economic". Demographic responses include changes in nuptiality and declines in marital fertility as suggested by Boserup (1965) and Malthus (1798). Increased population pressure within a constrained land environment forces farmers to alter economic production methods, often demanding greater inputs. The economic responses constitute actions such as switching from land-intensive to labor-intensive methods of production; changes in land use patterns, for instance switch from traditional crops to high value crops potentially leading to agricultural commercialization; adoption of modern output enhancing inputs such as inorganic fertilizers and hybrid seeds; and increase in land under irrigation, water availability allowing. By "demographic-economic" response, Bilsborrow (1987) means actions that have both economic and demographic implications such population outmigration, seasonal or permanent, from densely populated areas to less densely populated areas or migration out of agriculture to urban centers.

The theory does not offer much guidance as to which types of responses are more likely in which situations and whether the responses are mutually exclusive -- occurrence of one response precludes the occurrence of others responses. Hopkins (1973) points out that, different responses can emerge in regions which do not show marked variations. Communities with similar demographic characteristics may respond differently to population pressures depending on differences in conditioning variables such as technological elasticities due to differences in soils and climates; differences in work habits; and differences in external influences (Darity, 1980). The conditioning variables help in predicting the likely responses in different situations. Bilsborrow (1987) does an excellent literature review on the probable response types to population pressure, the conditioning variables, and country examples where such responses happened. A summary is presented in Table A3.1. In the remaining part of this section I discuss in greater detail the economic related responses and their conditioning variables.

While a land extensive technique is more productive with low labor input, a land intensive technique is more productive with higher levels of labor (Robinson and Schutjer, 1984). A shift in agricultural production methods is hypothesized to occur gradually as population pressure increases. Lack of opportunities for colonizing new land spur technological change that make possible increases in per capita output. As arable land becomes scarce, it is used more intensively with the help of land-saving inputs courtesy of science and technology, thereby raising agricultural output per unit of land. As Smucker (2002) points out, intensification of agricultural production has been defined and measured in a number of ways. These include total output per unit of land, frequency of cultivation, use of agricultural technologies and implements, and investments in labor-intensive soil and water conservation measures. Binswanger and Ruttan (1978), Hayami and Ruttan (1985), Binswanger and McIntire (1987) and Pingali et al. (1987) explain the agricultural intensification process using the *induced innovation*[8] model of new technologies adoption in response to factor scarcity. Human ingenuity is hypothesized to optimally resolve resource constraints imposed by population pressure if the free markets are allowed to operate freely and appropriate price signals are transmitted to producers (Simon, 2000). Rising population density induces changes in the relative prices of the factors of production. The price of the scarce factor, land, increases relative to the price of the more abundant factor, labor. Prices serve as scarcity signals as well as innovation signals. Farmers facing shrinking landholding innovate by adopting the already on-shelf technologies or developing new technologies to raise land productivity. Innovations may also involve bringing the factors of production together in new ways. Farmers adopt high-yielding and quick-maturing seeds, inorganic fertilizers, pesticides and herbicides as well as reconsidering crop choices.

Intensification also includes crops irrigation, water availability permitting (Zilverber et al., 2010). Adoption of high-value crops or of inputs and irrigation imply labor-intensive

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[8] Although it was Hicks in *The Theory of Wages* (1932) who first discussed the induced innovation, the concept has been used by analysts to explain agricultural development within the context of increasing population pressure.

cultivation techniques that raise output per unit of scarce land. Factor inputs are applied in quantitatively and qualitatively new ways; a new 'curve' of production is developed (Brookfield, 1972). As Blaikie and Brookfield (1987) observes, agricultural intensification in not a linear function; intensification may be limited by environmental thresholds beyond which additional application of inputs to the production process are not tenable. Also, if the hypothesized land-saving induced innovation process is subject to extremely long time lags (McMillan et al., 2011) or does not occur (Krautkraemer, 1994) due to institutional bottlenecks and markets inefficiencies, population pressure is likely to lead to a fall in per capita consumption and lower household well-being; a result that has a *Malthusian effect* flavor.

Research based on in-depth case studies has highlighted situations where population growth has been accompanied by agricultural intensification and improved soil fertility. For example, Tiffen et al. (1994) presents a case study of agricultural intensification in the semi-arid district of Machakos, Kenya. Using several photo pairs (1936 versus 1989) of different parts of the district, Tiffen et al. (1994) contrast the denudated and sparsely populated lands of 1930s with vegetated, intensively farmed and densely populated lands of the 1990s (Figure A3.1). The agricultural intensification occurred alongside a fivefold increase in population density. However, Tiffen et al. (1994) critics argue that the observed changes were facilitated by other factors such as availability of non-farm income and markets due to the district's proximity to Nairobi (the capital city of Kenya), land tenure security (Murton, 1999), and other favorable government policies (Zaal and Oostendorp, 2000; Wiggins, 2012[9]).

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9 "… *Masaku* (Machakos) benefited from higher coffee prices in the 1950s. But why was that? Part is down to the 1954 removal of the pernicious restrictions on small farmers growing coffee, part down to rising world prices; but also very probably owing to public investment in roads that transmitted prices back to the farm gate." Steve Wiggins -- personal communications.

The feasibility of land intensification is dependent on a number of factors. These include the household endowments (physical, human, natural, financial, and social capital); agricultural inputs and outputs pricing policy (price control, subsidies and taxes); agricultural research and development (availability of appropriate technologies); access to programs and services (technical assistance and credit); access to markets and transportation networks (input and output distribution networks); the agricultural potential of the land (soil quality and rainfall); and property rights (Kelly, 2006; Pender et al., 2006). Also, the returns to new technologies and crops must be high; returns required to induce adoption must be relatively higher than those required to sustain the use of current technologies (Dercon and Zeitlin, 2009). Households' demographic characteristics such as education attainment, age and gender of the household head as well community belief systems may also influence technologies adoption[10] (Feder et al., 1985). For example, unresolved policy issues and religious belief systems have constrained the adoption of genetically modified organisms seeds (GMOs) (Hertel, 2011). Household idiosyncratic shocks (such as illnesses and adult mortality) also condition agricultural intensification.

Intensive farming requires new approaches to research and extension, as well as an enabling policy environment. Government policies can make adoption of new technologies a less costly and risky affair particularly for early adopters. While formal land titles are hypothesized to facilitate access to credit and help to prevent land disputes, the impact of land tenure security on land intensification still remains unresolved in the literature (Besley, 1995; Haugerud, 1989; Atwood, 1990; Migot-Adholla et al., 1991; Bruce and Migot-Adholla, 1994). Weather related

[10] However, on the other hand, more educated households may be less inclined to invest in inputs-intensive land investments because the opportunity costs of their labor may be increased by education.

challenges and especially rainfall quantities and its variability are also hypothesized to influence agricultural intensification especially in the rural Africa region where agriculture is rain-fed (McCown et al., 1992).

Believing that there is a link between population density and agricultural intensity does not necessarily imply population density causes agricultural intensification (Darity, 1980). There could be some possible feedback effects prompting potential endogeneity that needs to be addressed in econometric modeling. As Allen (2001) mentions, agricultural intensification caused by other factor may allow the system to support more people thus leading to high population. For example, in Papua New Guinea, Brookfield (1972) encountered intensive practices in situations where there was no population pressure and extensive practices in areas where land was short. Brookfield (1972) points out that innovations may be triggered not only by physical resource scarcities but also by opportunities and government interventions that impinge upon farmers' production decisions. In fact, the need to hasten the process of agricultural intensification through altering market signals has often been the motivation for government interventions. Farmers may change their land use in response to market signals; market incentives can induce farmers to intensify production in the absence of population growth and land shortage. Other factors that are hypothesized to lead to intensified agricultural production include risk management and production for social[11] purposes (Stone, 2001). Even without population pressure, intensive production techniques may be adopted to cope with risk of crop failure and social demands.

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[11]Stone (2001) defines social production as production of goods produced for use by others in ceremonies and rituals such as births, marriages, funerals, and other ritual gathering; a production that he says may seem weirdly "uneconomical" but which earn real social dividends.

3.3 Overview of effects of population density on agricultural commercialization

The structural transformation process has long been considered the main route through which poverty and hunger in Africa would be overcome. A fundamental element of the structural transformation process is smallholder commercialization. What constitutes agricultural commercialization has been a subject of a long standing debate. Smallholder commercialization is defined in terms of smallholder participation in commercial input and output markets, type of crops grown, and the goals of smallholder farmers (Braun et al., 1994; Moti el al., 2009). It is attained when household product choice and input use decisions are made based on the principles of profit maximization (Pingali, 1997). Thus, smallholder commercialization commonly refers to the transition from subsistence to market-oriented patterns of production and input use. The term refers to a cycle in which farmers intensify their use of productivity-enhancing technologies on their farms, achieve greater output per unit of land and labor expended, produce greater farm surpluses, expand their participation in markets, and ultimately raise their incomes and living standards. Agricultural commercialization is also associated with agricultural diversification, because market-oriented crop or livestock production represent diversification away from production of basic food for home consumption.

Commercialization of smallholder agriculture has been touted as an indispensable pathway towards inclusive economic growth, food security and poverty reduction in sub-Saharan Africa (von Braun, 1995; Pingali and Rosegrant, 1995; Timmer, 1997; Moti et al., 2009). This thinking is inspired by a number of reasons. First, since the majority of Africa's population remains engaged primarily in smallholder agriculture, it is difficult to envision any other sector that could trigger mass movement out of poverty other than agriculture. Growth starting among smallholders is suggested to have far higher growth 'linkages' than growth in any other sector

(Mellor, 1995). For the last almost five decades, African policymakers and multilateral institutions such as the World Bank have focused almost exclusively on improved agricultural productivity as the way to reduce wide spread rural poverty in sub-Saharan countries. Second, empirical evidence exists demonstrating that households' income increases as farm resources are shifted from subsistence to commercial agriculture (Kennedy and Cogill, 1987; Bouis and Haddad 1990; von Braun et al., 1994; Dorsey, 1999). Third, with continuously shrinking farm sizes due to human population pressure, subsistence agriculture may not be sustainable in the long run. Consequently, smallholder farmers have to intensify to achieve greater output per unit of land or migrate out of agriculture altogether.

Various indicators of agricultural commercialization have been developed. These indicators reflect how differently authors construe the concept of commercialization. Moti et al. (2009) does any excellent review of these indicators and a summary is available in Table A3.2. At household level, von Braun et al. (1994) suggested three approaches to analyze smallholder commercialization: output and input side commercialization; commercialization of the rural economy; and degree of a household's integration into the cash economy. The first approach measures proportion of agricultural output sold to the market and input acquired from market to the total value of agricultural production. The second approach measures the ratio of the value of goods and services acquired through market transactions to total household income while the third measures the ratio of the value of goods and services acquired by cash transaction to the total household income. Govereh et al. (1999) and Strasberg et al. (1999) developed another indicator of crop commercialization which is a ratio of the gross value of all crop sales per household per year to the gross value of all crop production. Since agricultural commercialization can also be interpreted in terms of how smallholder households diversify away from production of basic food for home consumption to production of market-oriented output, the share of land allocated to non-food crops is also used as a measure of smallholder agricultural commercialization.

Analysts have suggested various factors that are thought to influence smallholder agriculture commercialization (von Braun et al., 1991; Pingali and Rosegrant, 1995; Pender et al., 2006). These factors are grouped into two categories, namely: those that are within the farmer's control (internal) and those that are beyond his control (external). Factors that are beyond the smallholder's control include population growth and demographic changes, technological change, development of infrastructure and market institutions, development of the non-farm sector, rising labor opportunity costs, macroeconomic, trade and sectoral policies affecting prices, development of input and output markets, institutions like property rights and land tenure, market regulations, cultural and social factors affecting consumption preferences, production and market opportunities and constraints, agro-climatic conditions, and production and market related risks. Factors within the smallholder's control include land, labor, physical capital, and human capital. A diagrammatic presentation of the determinants and consequences of smallholder commercialization as per von Braun et al. (1994) is presented in Figure A3.2. While these factors are highly interlinked, in this study, we are interested in examining how changes in human population densities are affecting smallholder commercialization.

While it is postulated that agricultural diversification and commercialization is fundamental part of evolving agricultural development, mounting population pressure is hypothesized to affect it in a number of ways. First, increasing population pressure leads to shrinking farm sizes. Land differs from other agricultural inputs in that its supply is essentially constant and thus its quantity cannot change as price changes (Binkley and McKinzie, 1984).

With limited and diminishing landholding sizes, the existence of various crop production possibilities creates a conflict in land allocation among competing crops. Increased use of land for one crop obviously comes at the expense of others. Early studies argued that as land sizes diminish, farmers allot a major proportion of their land entitlement to food production for self-consumption for family food security (Narain, 1965). Production for self-consumption refers to the production of food grains. Smallholders tend to be highly vulnerable to food price volatility, thus undertake food crop production to cope with risks inherent in agricultural and labor markets (Chavas and Holt, 1990; Pingali et al., 1997; Wehbe et al., 2006; Lin and Dismukes, 2007). Besides, agricultural production in SSA is subject to price and yield uncertainties due to fluctuations in output prices and unpredictable weather conditions. Farming in this region is mostly rain-fed and hence any irregularity in weather has adverse production implications. The production risks are real in SSA because of inexistence of crop insurance schemes to mollify their severity (Dercon, 2002). Consequently, if the risk to food insecurity is high, smallholders are better off devoting a large share of their shrinking land to grow their own food rather than rely on uncertain markets (von Braun et al. 1994; Govereh et al. 1999).

However, if the process of market development contributes to more stable food prices and reduces the wedge between producer and consumer prices, then smallholder may increasingly adopt a more commercialized orientation, involving increased reliance on markets for inputs and outputs. Profit maximization becomes the farm household's new objective function and optimal land allocation depends upon the revenues and costs in its various uses (Binkley and McKinzie, 1984; Pingali and Rosegrant, 1995). Such processes could increase the value of output per unit of land and partially or fully offset the trend toward declining farm size. Thus, the extent to which the shrinking land sizes are affecting cropping patterns and how stabilized/volatile food prices are conditioning the relationship is an empirical question that this study seeks to answer.

Second, the population pressure represents growing demand for food and this effect is likely to be reflected in increasing relative food prices. Changes in these factors are likely to lead to changes in cropping patterns. A high relative price of any crop motivates farmers to grow that particular crop, holding all other factors constant including technology. Since the output prices are observed at a later date, after the production decisions and investments are made, earlier studies have shown that it is the expectations about the future prices that condition farmers' crop choices (Nerlove, 1956; Tegene et al., 1988). Thus, price expectation models, such as the Nerlovian adaptive price expectations model, have been used in agricultural supply response analyses studies. Also, as De (2005) notes, changing output prices may not bring about significant changes in production patterns in the short run. This is associated with biological lags that are typical in agricultural production.

Third, high population density is associated with increased agricultural commercialization due to increased urbanization and improved access to markets. High population density is also associated with urbanization. Urbanization in turn increases demand for marketed agricultural products which tend to increase commodity prices and stimulate agricultural production for the market. High population density is also associated with improved economic infrastructures owing to reduced average cost of infrastructure development (Glover and Simon, 1975; Frederiksen, 1981; Chu, 1997). Improved infrastructure represents enhanced access to agricultural inputs and output markets. Consequently, increased demand for agricultural products and improved access to markets is hypothesized to induce not only agricultural production in general, but the production of high value and perishable products, other factors such as technology and environmental conditions allowing. The high value usually refers to fresh fruits and vegetables and dairy. Subsequently, the extent to which the opportunities presented by the increasing population density, shrinking land sizes notwithstanding, are driving smallholders' commercialization is an empirical issue being pursued in this study.

Fourth, increased population pressures results in land degradation and soil nutrient depletion (Drechsel et al., 2001; Pender and Alemu, 2007). If left unattended, soil degradation will lead to lower agricultural productivity. Households facing shrinking land sizes are expected to increase the use of modern productivity enhancing inputs obtainable from the markets leading to increased smallholder commercialization from the inputs perspective. Consequently, the intensity of use of purchased agricultural inputs as population density increases by the smallholders is an empirical issue that this study examines.

3.4 Conceptual framework

3.4.1 Agricultural household model

Smallholder agriculture systems in sub-Saharan Africa are characterized by semi-commercial farms that produce multiple crops. These systems combine two fundamental units of microeconomic analysis, the household and the firm, that are highly interdependent. As opposed to the purely subsistence systems, in semi-commercial systems some farm inputs are purchased and some outputs are sold in the markets (Table A3.3). To analyze the semi-commercial systems, Singh et al. (1986) proposed a theoretical framework popularly known as the *agricultural household model* that captures the farm household's consumption and production interdependences in a theoretically coherent manner. In this framework, the objective of farm households is assumed to be maximization of expected household utility subject to budget and other resource constraints. Agricultural production either contributes to household’s resource constraint through consumption or through cash generation if farm output is sold at market. Thus, agricultural production is incorporated as part of the household’s budget constraints. Later, de Janvry et al. (1991) extended the original Singh et al. (1986) agricultural household model to include market failures while Omamo (1998) incorporated transactions costs.

In the extended agricultural household model, the household problem is to maximize its utility:

$$\max U = U(X_a, X_m, X_l) \tag{3.1}$$

where the commodities are agricultural goods (X_a), market-purchased goods (X_m), and leisure (X_l). Utility is maximized subject to several constraints, among them: a cash constraint, production technologies for own-farming and nonfarm self-employment activities; exogenous effective prices for tradables; an equilibrium condition for self-sufficiency of farm production; and an equilibrium condition for family labor. First-order conditions of this model give a system of factor supply and demand functions, which in turn allows the estimation of factor inputs and supply functions. Depending on the objective of the study, the dependent variable could defined in terms of quantity of inputs and outputs or the income shares coming from different crops or enterprises.

At the minimum, the theory posits that the desired supply is a function of the expected output price, and supply shift variables such a vector of input prices, and the expected output and input prices of other production possibilities. Since the objective of this study is to examine how human population density affects smallholder agricultural production and income, the immediate next task is to conceptualize how this variable of interest enters the input demand, output supply and income functions. A diagrammatic presentation of how population density influences these smallholder production outcomes is presented in Figure A3.3. Assuming markets are allowed to operate freely and the appropriate price signals are transmitted to producers, escalating population density is hypothesized to affect agricultural production through three fronts, namely, decreasing land holding sizes, increasing labor supply, and increasing demand for food. From the first two fronts, the decreasing land sizes are hypothesized to trigger changes in relative factor prices, consequently triggering changes in the land-labor ratio. The price for the scarce factor (land) is bid high while the price for more abundant factor (labor) declines. From the third front, population growth directly affects the demand for agricultural products by shifting the demand curve for food crops outwards. This shift exerts pressure on food prices thereby inducing a supply response, other factors held constant including internal and external trade, thus putting more pressure on the factor prices.

Relative prices determine how various factors of production are combined in the production process by profit maximizing or cost minimization producers. Prices serve as scarcity signals as well as innovation and adoption incentives for new technologies. According to the "induced innovation" theory, a change in the relative price of factors influence the factor use proportions (Hicks, 1932). A change in the relative prices of factors of production spur innovations aimed at economizing the use of a factor which has become relatively expensive. Since changes in population density influences input demand and output supply indirectly through prices, this process suggests a first stage reduced form regression of output prices on population density variable among other relevant covariates.

However, in a world characterized by market imperfections, factor prices may not fully pick up the effects of the increasing population pressure (Ghebru and Holden, 2009). For example, in many African countries Kenya included, land sales markets are characterized by information asymmetry, enormous transaction costs, government bureaucracy, and ethnicity and cultural constraints. If this is the case, increasing population density may affect landholding sizes and input demand and supply functions in ways that are not fully reflected in market prices. Thus, the existence of inefficient markets suggest a first stage reduced form regression of household landholding on population density among other relevant covariates and the inclusion of population density variable in the estimation of input demand and output supply functions.

As mentioned in Section 3.2, the hypothesized relationship between population density and agricultural intensity does not necessarily imply population density causes agricultural intensification. There could be some possible reverse causality signaling potential endogeneity of the population density variable. Population density drives food production (Boserup, 1965), while food production could also drive population density (Malthus, 1798). Besides, current indicators of land intensification potential and farm size may influence migration which will in turn affect future population density. Households in areas with low potential and/or declining land access may choose to migrate to areas which they perceive to be of relatively higher potential and/or better land access. When confronted by potentially endogenous variable, two methods are available to get around the problem. First is the usual two stage least square (2SLS) instrumental variable method while the second is the control function approach (Wooldridge, 2010). To implement either of the two methods, it requires the availability of at least one instrumental variable (IV); a variable that is correlated with population density but uncorrelated with indicators of land intensification. Consequently, to appropriately model how population density influences agricultural intensification, we will need to estimate a reduced form population density equation using covariates that are hypothesized to influence population growth and at least one plausible IV.

In the remaining part of this section, we conceptualize the drivers of population growth with aim of identifying plausible instruments to be used in the first stage population density reduced form regression followed by conceptualizing how the population density variable enters the prices and landholding equations.

3.4.2 Drivers of human population growth

Economics as a discipline has paid little attention to population studies. The earliest conceptualizations of the drivers of population growth come from demographers and sociologists. Most of these studies have used *demographic transitions theory* to explain the causes and mechanisms behind human population changes over time (Notestein, 1945). The term demographic transition has two primary meanings (Johnson-Hanks, 2008). First, it refers to the historically specific change from high to low rates of fertility and mortality that human populations have undergone since 1750, and second, to a set of theories regarding the causes and mechanisms behind that change. The complementary approach of economists conceptualizes population growth through the various factors influence the demand for children (Bilsborrow and Winegarden, 1985). Economists hypothesize that the demand for children will increase with an increase in the family income and a reduction in the costs of raising them. The supply side is influenced by factors such as the knowledge and use of fertility-regulating methods. These theories are basically household level based and are therefore inadequate in explaining the drivers in aggregate changes in populations densities over time.

Consequently, in this study we will be guided by the demographic transitions theory. According to the demographic transitions theory, as living standards rise and health conditions improve, first mortality rates decline and then, somewhat later, fertility rates decline (Kirk, 1996). People would naturally deploy the advantages of modernity to reduce death rates, but that fertility rates would be stalled by cultural factors that would only slowly give way (Notestein, 1945). Population growth is fuelled by two components: the "demographic momentum", which is built into the age composition of current populations, and changes in reproductive behavior, mortality and migration. As Fischer and Heilig (1997) explain, the 'echo effect' of a high-fertility period in the past creates a demographic momentum that counters reproductive control measures that favor smaller families. No significant changes in fertility are expected to counter the demographic momentum since most developing countries have large rural populations whose fertility is driven by deep-rooted cultural norms and values, and religious beliefs. Fertility rate is loosely defined as the average number of children that would be born to a woman over her lifetime. Other determinants of fertility include age at marriage (or beginning of sexual activity), prevalence and effectiveness of contraception, prevalence of induced abortion, and duration of postpartum infecundability, especially due to breast feeding (Lutz and Qiang, 2002). Speakers of the same language are generally expected to experience fertility transition at the same time (Johnson-Hanks, 2008).

Changes in reproductive behavior include changes in nuptiality and declines in marital fertility as suggested by Boserup (1965) and Malthus (1798). Changes in mother's literacy and infant mortality rates greatly influence fertility rates. Studies have found inverse relationship between mothers' education attainment and family sizes (Fischer and Heilig, 1997). However, better health status of women on the other hand increases fertility rates. The decline in mortality among infants resulting from the spread of modern hygiene and medicine is associated with decreased fertility. Adult mortality declines due to increased life expectancy as a result of diseases eradication or control with the advancement in modern medical technology.

Next, we examine the role of migration in rural population redistribution. As Bilsborrow (2001) explains, resource scarcity or depletion drives human migration. Migration, be it rural to urban or rural to rural, decrease rural density in one area while raising it in others, as rural populations leave areas with scarce resources in search of resources and opportunities elsewhere. At the macro-level, perhaps the leading determinants of migration and displacement of people is caused by scarcity of water and land, conflicts over natural resources, natural hazards and natural disasters (Naude, 2010). Inter-ethnic and political conflicts also influence migration. At the micro-level, factors influencing people's decisions to migrate include differences in economic opportunities and living conditions between origin and destination areas, people’s awareness of those differences, distance to the potential destination, and their ability to move (Bilsborrow and Winegarden, 1985). Under these broad categories come educational levels, and differences in wage rates and living conditions. Cultural factors such as psychological or emotional attachments to family, friends, and community stop people from migrating as well as the government policies such as land tenure system.

3.4.3 Effects of population density on household landholding

In most studies, landholding sizes are generally assumed to be fixed (Zhang et al., 2009). However, the factors that affect landholding size and how landholding size changes with socio-economic circumstances are important issues that have not been fully investigated. Previous studies relating to the size of landholdings have often been centered on community well-being

(Gilles and Dalecki, 1988; Swanson, 1988; Labao and Michael, 1991). Only a handful of them have explicitly examined the impact of increasing population densities on farm land size.

Land in the African context is not just like any other economic commodity (Shipton and Goheen, 1992). Landholding in this region is an outcome of complex historical and geographical processes that may fail to conform to any known economic theory. Consequently, we use previous studies to conceptualize how population density affects household landholding. Households acquire rights to obtain and maintain access to land or they lose these rights through multiple paths such as social groups or networks membership, kinship ties, and through purchase (Shipton and Goheen, 1992; Berry, 1993).

Even in countries where land markets are well developed, access to land through inheritance remains fundamental. Land transfers from parents to children depend on the parent's landholding sizes and the number of potential recipients of the parents' assets. In polygamous families, land is shared equally between wives regardless of their number of children. Females have lesser claim on parental resources (Garg and Morduch, 1998; Morduch, 2000). Females' land access comes through ties to husbands (Berry, 1993; Smucker, 2002). A senior wife has stronger rights than a junior wife. A woman's rights increase with the length of marriage or with number of children and the rights may end with divorce, with widowhood, with failure to have sons (Gray and Kevane, 1999). As Gray and Kevane (1999), transfer rights are usually limited for women -- they cannot designate an heir, sell land, or lend land to others. The growing human population density triggers land subdivisions resulting in tiny landholding pieces. Aging population results in land transfers and parcelization (Gobster and Rickenbach, 2003). Other factors influencing landholding at the household level include agricultural technology and education levels (Shipton and Goheen, 1992).

Historically, family access to land depended on their membership and good standing within a particular group exerting control over the land. Kinship and ethnic (tribe) adherence along with status, gender and seniority determined access and use rights (Berry, 1989; Migot-Adholla and Bruce, 1994). Social capital is also an important factor determining access to land and other assets. Jayne et al. (2008) show that households in which the male head is related by blood to the local headman have more land than other households in Zambia. However, with mounting population densities and the ensuing land squeeze, land access through within community transfers is becoming less and less feasible option.

Land sales markets are becoming crucial in the re-allocation of land (Pinckney and Kimuyu, 1994; Place and Migot-Adholla, 1998; Holden, et al. 2009). If markets are functioning efficiently, access to land though this channel is depended on land sales prices among other factors. With the swelling population densities, land prices have been bid so high rendering this land access channel inaccessible to the land poor. As mentioned earlier, land sales markets in SSA are characterized by many imperfections as a result of factors such transaction costs and ethnicity related constraints. This calls for a direct inclusion of the population density variable in the reduced form household landholding model.

3.4.4 Effects of population density on land rental prices

Though land rent literature is distinct from land price literature, studies have found that farmland price and rent movements are highly correlated and to larger extent land rent is the most widely accepted factor driving farmland price Falk (1991). In this section, we explore the process through which land sales and rental prices are determined and the role increasing population density plays. Just like in other markets, equilibrium prices in the land markets are determined by the forces of demand and supply. In this study, we assume that what we observe and collect data on are the equilibrium prices after the demand for land available for sale or rental purposes is equated with supply and the households' solve their profit maximization problem. Therefore, we model the observed equilibrium prices as a function of the variables that drive the supply as well as demand side of the land sales and rental markets to equilibrium.

Increasing population density directly puts pressure on the supply side of the land markets thereby pushing up prices (Weerahewa et al., 2008). Indirectly, increasing population density represents increasing demand for food and thus mounting pressure on factors of production; land being one of them. From the *Ricardian rent theory*, land prices are highly depended on land productivity (Ricardo, 1821). The higher the quality of land available for sale or rental purposes, the higher the price. Thus, from the supply side of the market, land pieces that are more fertile and closer to the market represent lower cost of production and thus command relatively higher prices. From the demand side, Du et al. (2007) shows land rental rates are a function of the expected market prices. For example, the rental price an individual is willing to pay for a piece of land at the planting time is determined by the expected profitability of the land as reflected in the output's expected market prices at the time of harvest. Land prices are also greatly influenced by development pressure emanating from the nearest urban centers (Shi et al., 1997; Livanis et al., 2006).

3.4.5 Effects of population density on agricultural wages rate

The effects of population density on agricultural wages depend on how population pressure affects the determinants wages, in other words, the demand and supply conditions in agricultural labor market. In this study, we follow previous studies that have attempted to model how agricultural wage rates respond to certain economic and demographic changes. It is assumed that a substantial proportion of the rural population is primarily is dependent on agricultural wage employment, and labor is hardly organized for group bargaining or covered by any wage protection law by the government. Just like the land price case, we assume that what we observe and collect data on are the equilibrium wage after the demand for labor equates with the labor supply. Consequently, we model the equilibrium wage rate as a function of the variables that drive the supply and the demand side of the labor markets to equilibrium.

On the supply side, increasing population density increases the pool of the potential workers. Most of the earlier studies have argued that an increase in the price of agricultural outputs increase the demand for agricultural labor. Khan (1984) explains that increase in agricultural productivity increases wages by stimulating the demand for labor. The effect of increase in crop prices, however, can go either way. On one hand, higher crop prices encourage production and increase the labor demand; on the other hand, these higher prices increase workers' consumption expenditure on food and therefore, induce higher labor supply especially among the landless workers who are net-buyers of food (Boyce and Ravallion, 1991; Ravallion, 1990; Hani, 1996). Thus, the ultimate effect of increase in crop prices is an empirical issue.

The other important nonwage determinants of labor demand are identified as agricultural productivity (in terms of yield per unit of land); the important nonwage determinants of labor supply are food prices, prices of other non-food items that workers consume and their alternative nonfarm sources of income (Ahmed, 1981; Bardhan, 1984; Hossain, 2004; Khan, 1984). Technological factors such as use of labor-saving or land-saving technologies (e.g. fertilizers and tractors) also affect wage rates. The expansion of alternative means of livelihood, including nonfarm employment, which reduces the workers' dependence on land, also increases their real wages (Hossain, 2004). Proximity to urban centers and reduced distances to infrastructural facilities also influence wage rate in two different ways. First, reduced distances to urban centers and infrastructural facilities exposes workers to other nonfarm income earning opportunities thus bidding high the agricultural wage. Thus, trends in labor wage rates may be influenced greatly by wages in the non-farm sector. Second, reduced distances represents reduced agricultural production costs and probably reduced demand for agricultural labor. Thus, the impact of reduced distances on labor is an empirical question.

3.4.6 Effects of population density on agricultural output prices

The theory posits that the input demand and the desired supply are a function of the expected output price and demand and supply shift variables such a population density. Population growth directly affects the demand for agricultural products by shifting the demand curve for food crops outwards. This shift exerts pressure on food prices thereby inducing a supply response that puts pressure on the factor prices, other factors held constant. Due to biological lags in the production, output prices are however not observed at the time the production decisions are taken. It is important to note that we can only observe and collect data on the market equilibrium prices after they are determined by the demand and supply forces. Consequently, we conceptualize how to model the equilibrium price as a function of the variables that drive the supply and the demand of the crops market to equilibrium.

Smallholder production systems in sub-Saharan Africa are highly diversified and are partially integrated into the markets. This situation presents two challenges in econometric modeling. First, farmers grow a wide array of crops on one land plot each season and crop enterprises vary across agroecological zones making it difficult to obtain a balanced panel data on crop production and the respective prices. Second, prices data is rarely reported for crops produced basically for home consumption without marketed surplus. Since most of the smallholders are partially integrated into markets, it is assumed that their main objective is production for household consumption. If the smallholders can be assured of low and stable maize prices then they can diversify their cropping patterns and produce for the markets; else they produce staples for self-sufficiency. Consequently, it is assumed that the expected price of maize, the main staple crop, is the most important output price determining production decisions among smallholders in rural Kenya.

Following Mason (2011), we use an approach somewhat similar to quasi-rational expectations (Nerlove and Fornari, 1998) to estimate the expected subjective maize price values. We model expected farm-gate maize prices as a function of variables observed by the farmer at planting time. These include wholesale market prices of maize from the nearest regional market, effective NCPB pan-territorial prices, and household and village level characteristics that might affect the maize sale price received by a given household. We do not replicate a price prediction model for each of the non-maize crops as we due to data limitations. Instead, following Mather and Jayne (2012), we use a naïve price expectation for each crop, which is the wholesale price at the nearest regional market prevailing during the planting season. However, because most outputs are regionally tradable and Kenya is at least a semi-open economy, we hypothesize that population density may not have as great an impact on output prices as population density would on prices of non-tradables, such as farmland and labor.

3.5 Data sources

3.5.1 Household longitudinal data

The study mainly draws from the nationwide Egerton University/Tegemeo Institute Rural Household Survey, a panel dataset tracking roughly 1,300 small-scale farm households in 5 survey waves over the 13-year period from 1997 to 2010 (Figure A3.4). The sampling frame for the panel was prepared in consultation with the Kenya National Bureau of Statistics (KNBS) in 1997. Twenty four (24) districts were purposively chosen to represent the broad range of agro-ecological zones (AEZs) and agricultural production systems in Kenya. Next, all non-urban divisions in the selected districts were assigned to one or more AEZs based on agronomic information from secondary data. Third, proportional to population across AEZs, divisions were selected from each AEZ. Fourth, within each division, villages and households in that order were randomly selected. In the initial survey in 1997, a total of 1,500 households were surveyed in 109 villages in 24 districts within eight agriculturally-oriented provinces of the country.

Subsequent surveys were conducted in June of 2000, 2004, 2007 and 2010. Over these 5 panel surveys, 1243 household were able to be consistently located and surveyed. For this analysis, households in the coastal region of the country were excluded because farming is found to account for a relatively small share of household incomes. This leaves a balanced panel of 1146 households surveyed consistently in each of the five years. The surveys collect information on demographic changes, movements of family members in and out of the household since the prior survey, landholding size, land transactions and renting, farming practices, the production and marketing of farm products, and off-farm income-earning activities[12].

Attrition bias is a potential problem in panel data estimations. The average attrition rate between any two consecutive rounds is about five per cent. Jin and Jayne (2013) estimated re-interview models to assess the degree to which attrition could be a problem in this panel data. While the results are not presented here due to space limitation, the authors find that the observed attrition is largely random. Accordingly, no need to worry about selection biases caused by attrition, although efficiency is somehow lost because of a reduced sample size.

3.5.2 Geographic information systems (GIS) data[13]

The household panel survey instrument captured the geographic positioning system (GPS) coordinates of each household. This made it possible to compliment the survey data with geographic information systems (GIS) data on soil quality and more disaggregated data on current and historical population numbers at the villages where the panel households are located. Data on population densities was extracted from the Global Rural-Urban Mapping Project (GRUMP)[14]. To obtain a density (persons/km^2), the GRUMP population estimate was divided by land area suitable for agriculture. The population estimate is the average population count per pixel for all pixels within a 10km radius.

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[12] Each of these surveys instruments, which contain the details of the types of information collected and used in this study, can be viewed and downloaded at http://www.aec.msu.edu/fs2/kenya/index.htm.

[13] Jordan Chamberlin, a colleague and fellow PhD candidate did the GIS data extraction.

[14] See http://sedac.ciesin.columbia.edu/gpw/docs/UR_paper_webdraft1.pdf.

The other variables extracted from the GIS sources included the length of the growing period (LGP) (Fischer et al., 2000); net primary productivity (NPP) (Zhao et al., 2005); and elevation (meters above the sea level) and slope (measure of steepness -- degrees), both from Wilson et al. (2007). The LGP is a useful indicator of agricultural potential. It combines information on temperature and available moisture to determine the length of time crops are able to grow. That is, periods which are too cold or too dry (or both) for crop growth are excluded. LGP is often measured in terms of the number of days experiencing temperatures > 5°C when moisture conditions are adequate for plant growth. The NPP refers to the standing biomass in a given area at a given time. It is typically measured in units of mass / area / time. NPP is sometimes used as an alternative measure of agricultural potential, since it reflects the amount of vegetative biomass growing in a given area (whether cultivated or not).

3.5.3 Regional market maize price and weather data

The study also drew from the monthly wholesale price data for maize and for each of the main food and cash crops collected from regional wholesale markets across Kenya by the Market Research and Information Department of the Ministry of Agriculture. Data on rainfall estimates comes from the Famine Early Warning System (FEWS), which was produced at the level of every 0.1 degree latitude and 0.1 degree longitude. This data interpolates rainfall estimates based on data from rain stations as well as satellite data (such as on cloud cover and cloud top temperatures). The FEWS rainfall estimates were then matched to Tegemeo panel survey households using the GPS coordinate.

3.6 Data analysis methods

3.6.1 Descriptive analysis

As a prelude to the econometric analysis, bivariate descriptive analysis are carried out to examine how various household groupings based on population density of the villages they are located evolve over the panel period in terms of demographic trends, farming patterns, farm production, agricultural commercialization and household incomes. We superimposed the longitude-latitude coordinates of the 109 villages in the Tegemeo survey on the 10km^2 pixel population density estimates from the Global Urban-Rural Mapping Project database for 2009, to obtain population density estimates for each village. Population densities in the sample ranged from 44 persons per km^2 in the case of Laikipia West to 965 persons per km^2 in Vihiga District. We then sort these 109 villages by population density and next stratified them into five equal population density groups, or quintiles. Population densities range from 30 to 147 persons per km^2 in the lowest quintile, 148 to 313 in the second quintile, 315 to 470 in the third quintile, 475 to 655 in the fourth quintile, and 659 to 1135 persons per km^2 in the highest quintile. We then examine how the five groups are evolving differently over the 1997-2010 period in terms of two main features:

i. Farming patterns: changes in farm size, land values, rental rates, land-to-labor ratios, input intensity per unit of land cultivated and cropping patterns. The 2007 survey also contains a module exploring household members' inheritance of land and the amount of land controlled by their parents.

ii. Farm production, assets and household incomes: changes in incomes from crops, animal production, and non-farm income as well as household asset wealth.

iii. Indicators of smallholder commercialization: Land allocation to non-maize crops, non-maize crop production, intensity of purchased inputs use, and value of crops and livestock product sales.

3.6.2 Econometric models

We are interested in measuring the effect of population density on smallholder input demand and output supply, commercialization, and household income. As mentioned in the conceptual framework and summarized in Figure A3.3, three issues must be considered when specifying the econometric models to be estimated: First, population density is likely to influence these variables either *directly* or *indirectly* through its effects on input factor prices and output prices. Second, population density is potentially endogenous in the factor demand and output supply models. Third, while the expected output prices directly influence the output supply, they also influence output supply indirectly through effects on input factor prices. As mentioned earlier on, we use the *control function* approach suggested by Wooldridge (2010) to circumvent the endogeneity problem.

Considering all these three issues suggest the following estimation strategy: (i) first stage estimation of population density model on a vector of covariates where at least one of them is a plausible instrumental variable; (ii) second stage estimation of maize prices model whereby population density enters as a covariate while controlling for its potential endogeneity; third stage estimation of input factor and output supply functions where population density and its residuals from the first stage regression, the expected maize price (predicted maize values from the second stage regression) and input factor prices enters the vector of the covariates. Consequently, we estimate the following models:

First stage: Population density equation

$$D_{it} = H_i \kappa + \varepsilon_{it} \tag{3.2}$$

Second stage: Maize price equation

$$P_{it} = \rho_{01} D_{it} + Z_{0,it}\eta_0 + \theta_0 \hat{\varepsilon}_{it} + c_{0,i} + \mu_{0,it} \tag{3.3}$$

Third stage: Input factor prices, farm size, input demand and output supply equations

$$F_{it} = \rho_{11} D_{it} + \gamma_{11}\hat{P}_{it} + Z_{1,it}\eta_1 + \theta_1 \hat{\varepsilon}_{it} + c_{1,i} + \mu_{1,it} \tag{3.4}$$

$$L_{it} = \rho_{21} D_{it} + \gamma_{21}\hat{P}_{it} + Z_{2,it}\eta_2 + \theta_2 \hat{\varepsilon}_{it} + c_{2,i} + \mu_{2,it} \tag{3.5}$$

$$X_{it} = \rho_{31} D_{it} + \gamma_{31}\hat{P}_{it} + Z_{3,it}\eta_3 + F_{it}(D_{it})\lambda_3 + \tau_3 L_{it}(D_{it}) + \theta_3 \hat{\varepsilon}_{it} + c_{3,i} + \mu_{3,it} \tag{3.6}$$

$$Q_{it} = \rho_{41} D_{it} + \gamma_{41}\hat{P}_{it} + Z_{4,it}\eta_4 + F_{it}(D_{it})\lambda_4 + \tau_4 L_{it}(D_{it}) + \theta_4 \hat{\varepsilon}_{it} + c_{4,i} + \mu_{4,it} \tag{3.7}$$

In the first stage, we estimate the population density equation (3.2). The dependent variable, D, is measured at the village level where the household is located and is defined as the number of persons per square kilometer of the potentially arable land rather than the standard total surface area; H is a vector of the covariates that includes unity as its first element and other variables that influence population growth (population growth momentum, fertility and mortality rates) as identified in the conceptual framework section. The variables include land quality variables (length of growing period, net primary productivity, elevation and slope), village population size in 1950, literacy rates, distances to water source, religious affiliations, contraceptive use, age at first marriage and first intercourse, child mortality, and ethnicity. Most of these covariates are hypothesized to be correlated with population growth variable but uncorrelated with agroecological potential where these households are located, thus plausible instrumental variables.

In the second stage, the maize price model (3.3) equation is estimated. The dependent variable price vector P is the price of maize per kilogram. The vector Z_0 includes unit as its first element, household ownership of means of transport (truck and/or bicycle), distances from the homestead to the nearest infrastructural faculties, level of investment in in storage facilities, maize buyer type, regional maize price at planting time, NCPB maize prices in the previous year, and demographic characteristics of the household head (gender, age, and level of education). In this model and those in third stage, we include population density variable, and its square if necessary, to test for its direct effects on the dependent variable. The null hypothesis for the absence of direct effect is $\hat{\rho} = 0$. The residuals ($\hat{\varepsilon}$) from the first stage population density estimation are also included. The inclusion of the residuals ($\hat{\varepsilon}$) from the first stage population density reduced form regression into the second stage regressions, help in breaking the endogeneity link between the population density variable and the error terms (μ) in the second and third stage models. The null hypothesis $\hat{\theta} = 0$ tests the exogeneity of population density variables in the second and third stage models. While c represents the unobserved time-constant effects, μ represents the unobserved time-varying effects.

In the third stage, four set of models (3.4 to 3.7) are estimated. The dependent variable price vector F_{it} includes land rental rates per hectare for a year, and agricultural wage rate per day. We do not model land sales prices due to data limitations. Besides, as mentioned elsewhere in this paper, land sales markets are characterized by high transaction costs and thus assumed to be inefficient. Consequently, we model household landholding (L) directly. We also do not model fertilizer prices since fertilizer prices are not determined locally but in the international markets. The dependent variables X and Q are defined depending on the study objective. In the first part of the study (effect of population density on smallholder input demand, output supply and income), X represents the intensity of fertilizer and purchased input use per hectare owned while Q represent crop production per hectare owned.

Smallholder production systems in sub-Saharan Africa are highly diversified and are partially integrated into the markets. This situation presents a challenge for modeling in a number of ways. First, farmers grow a wide array of crops on one land plot each season and crop enterprises vary across agroecological zones making it difficult to obtain a balanced panel data on crop production and the respective prices. Second, the wide array of crops produced implies too few degrees of freedom for statistical modeling. Given these circumstances, it becomes imperative to aggregate the outputs in some manner. To aggregate crop production across multiple commodities, we convert crop production into monetary values using prices and modification of the Fisher-Ideal index (Figure A3.5) suggested by Mason (2011). In the second a part of this study, the dependent variables are the indicators of smallholder diversification and commercialization. Consequently, in this study X represents the proportion of land allocated to non-maize crops to the total land owned (input side) while Q captures the proportion of marketed crop production to the total crop production (supply side); that is, the household crops commercialization index (HCCI).

Next we discuss the explanatory variables used in the third stage models. Just as in the estimation of model (3.3), population density variable and its residuals ($\hat{\varepsilon}$) from the first stage regression are also included. We also include the predicted maize prices ($\hat{P}$) from the second stage maize model estimation as a proxy for the farmers' output price expectations. It is important to note that all the vectors Z include unity as the first element. The vector Z_1 include the district mean land holding sizes, land quality variables, distances to infrastructural faculties, naïve expectation of maize and beans prices—prices prevailing in the regional markets at the planting time, survey year and agricultural zone dummies. The vector Z_2 include household demographic variables, (gender, age, education attainment of household head and household size), land holding of the household of the household head's father before sub-division, land holding of the spouse's father before sub-division, household duration in the current location, and tribe and survey year dummies. The vectors Z_3 and Z_4 include land productivity variables (length of growing period, net primary productivity, elevation and slope); expected rainfall and expected drought shocks[15]; fertilizer price; distance to the nearest motorable road; ownership of radio (access to information); household demographic variables (gender, age, and level of education of the household head and household size) among other variables.

[15] These two variables were computed by David Mather. Expected rainfall is defined as a six-year moving average of rainfall prior to the main growing season in survey year, while expected rainfall shock is a six-year moving average of the percentage of 20-day periods during the main growing season with less than 40 mm of rainfall.

The third stage models are estimated as a system using the correlated random effects (CRE) approach (Mundlak 1978; Chamberlain, 1984). The reason as to why we use CRE is because some of the covariates in these models are time constant and thus drop out if fixed effects (FE) estimation approach is used[16]. The CRE approach involves the inclusion of the long-term average of each time-varying variable in the model. However, in the second part of this study, since it involves non-linear models, we estimate the models equation by equation. The dependent variables are essentially fractional response variables; they are continuous strictly between zero and one. Consequently, we use the Fractional Probit estimation method proposed by Papke and Wooldridge (2008).

To compute the total partial effects of the population density on input demand and output supply function we use the following method:

$$\frac{\partial X_{it}}{\partial D_{it}} = \underbrace{\frac{\partial X_{it}}{\partial D_{it}}}_{DIRECT} + \underbrace{\left[\left(\frac{\partial X_{it}}{\partial F_{it}} \times \frac{dF_{it}}{dD_{it}}\right) + \left(\frac{\partial X_{it}}{\partial L_{it}} \times \frac{dL_{it}}{dD_{it}}\right)\right]}_{INDIRECT} \tag{3.8}$$

$$\frac{\partial Q_{it}}{\partial D_{it}} = \underbrace{\frac{\partial Q_{it}}{\partial D_{it}}}_{DIRECT} + \underbrace{\left[\left(\frac{\partial Q_{it}}{\partial F_{it}} \times \frac{dF_{it}}{dD_{it}}\right) + \left(\frac{\partial Q_{it}}{\partial L_{it}} \times \frac{dL_{it}}{dD_{it}}\right)\right]}_{INDIRECT} \tag{3.9}$$

It is also important to mention that since the estimation of the second and third stage models involve generated regressors, standard errors generated by most econometric software for the coefficients are bound to invalid since they ignore the sampling variation in the estimation of

[16] Random effects (RE) also allow the inclusion of time-constant variables. However, the assumption that fixed effect factor is not correlated with the explanatory variables is often not plausible.

the coefficients in the first two steps. Disregarding the sampling error in the generated regressors is likely to underestimate the computed standard errors. Consequently, we use the bootstrap approach with 500 replications to get a valid estimate of the standard errors. Inferences are also made fully robust to arbitrary heteroskedasticity and serial correlation. The results from the input demand and output supply models are presented in the next section.

3.7 Results and discussions

3.7.1 Descriptive results

This initial section discusses bivariate relationships as a prelude to the econometric findings. Table 3.1 presents information on farm size and farming practices by village population density quintiles over the four survey years. The results clearly show that landholding sizes and areas under crop are decreasing functions of the population density. Landholding sizes among the smallholders in the 20 percent most densely populated are roughly one third of those in the 20 percent low densely populated group. Over the 10-year panel period, landholding size in the 20 percent most densely populated villages averaged 1.35 hectares. In the same period, landholding sizes in the 20 percent least densely populated villages averaged 4.25 hectares. The same scenario is replicated when we look at landholding per adult equivalent across the population density quintiles. The areas under cultivation have somehow declined across the population density categories over the 10-year period. The area under crop in the highest density quintile averaged 0.89 hectares and are about half of those in the lowest density quintile. The proportion of farmland under fallow (uncultivated area) has also declined by about 20 percent over time across all the quintiles.

Table 3.1: Farming practices and factor intensities, by pop. density quintile

	Population density quintile	Survey year				Four survey panel	
		2000	2004	2007	2010	mean	95% CI
Family land (hectares)	5 [highest]	1.28	1.22	1.38	1.36	1.35	[1.16 1.55]
	4	1.63	1.62	1.85	1.58	1.68	[1.58 1.78]
	3	2.06	2.13	1.69	1.59	1.89	[1.72 2.05]
	2	2.90	3.23	2.88	2.47	2.99	[2.71 3.27]
	1 [lowest]	3.80	4.46	4.28	3.79	4.25	[3.94 4.55]
Land holding per adult equivalent (hectares)	5 [highest]	0.28	0.29	0.35	0.30	0.31	[0.27 0.34]
	4	0.34	0.37	0.47	0.36	0.38	[0.36 0.41]
	3	0.45	0.50	0.49	0.45	0.47	[0.44 0.51]
	2	0.55	0.61	0.56	0.63	0.59	[0.54 0.65]
	1 [lowest]	0.83	0.96	0.93	0.95	0.92	[0.85 0.99]
Area cultivated in the main season (hectares)	5 [highest]	0.99	0.94	0.85	0.79	0.89	[0.85 0.94]
	4	1.18	1.26	1.22	1.03	1.17	[1.10 1.24]
	3	1.54	1.36	1.16	0.99	1.27	[1.20 1.35]
	2	1.73	1.79	1.54	1.30	1.58	[1.48 1.67]
	1 [lowest]	1.98	1.87	1.74	1.59	1.80	[1.68 1.91]
Labor per hectare cultivated	5 [highest]	6.04	7.15	5.94	6.43	6.39	[5.84 6.94]
	4	4.54	4.12	4.19	4.71	4.39	[4.12 4.67]
	3	5.14	5.18	4.81	4.67	4.96	[4.47 5.46]
	2	3.10	3.19	3.65	3.57	4.49	[2.33 6.65]
	1 [lowest]	3.06	3.11	3.34	3.15	3.16	[2.94 3.39]
Cost of purchased inputs/ha ('000 KSh) -- real	5 [highest]	12.53	12.85	11.32	13.25	12.49	[11.70 13.27]
	4	15.76	17.68	14.72	18.23	16.60	[15.41 17.80]
	3	11.19	13.09	10.67	14.57	12.38	[10.88 13.88]
	2	5.25	10.26	10.52	12.05	9.52	[8.45 10.58]
	1 [lowest]	7.45	7.25	7.47	9.01	7.80	[6.53 9.06]
Land values /hectare ('000KSh)	5 [highest]	-	-	-	703.02	703.02	[541.27 864.78]
	4	-	-	-	633.03	633.03	[359.66 906.40]
	3	-	-	-	723.67	723.67	[479.64 967.70]
	2	-	-	-	626.00	626.00	[276.30 975.70]
	1 [lowest]	-	-	-	271.82	271.82	[103.76 439.87]
Hired agricultural wage labor rate (KSh/ day)-- real	5 [highest]	54.50	57.34	56.45	65.68	58.49	[57.70 59.27]
	4	65.50	77.74	74.07	88.24	76.39	[75.20 77.59]
	3	62.25	63.63	64.88	75.41	66.54	[65.04 68.04]
	2	63.83	76.97	74.49	85.98	75.31	[74.24 76.37]
	1 [lowest]	76.47	80.99	81.41	80.03	79.73	[78.46 80.99]

Source: Tegemeo Institute Rural Household Surveys. Note: Population density quintiles are defined by ranking all households in the surveys by village-level population density and dividing them into five equal groups.

Next, we examine how major agricultural inputs and inputs prices vary across population density quintiles. Family labor, defined as the number of adult equivalents, adjusted to the number of months spent in the household, per hectares of land cultivated, has generally increased over the 13-year period, and is highest in the 20 percent densely populated villages (Table 3.1). Similarly, the 2010 land values were more than twice as high in the three highest population density quintiles than in the lowest density quintile. Information on land values was only collected in the 2010 survey. Results also show that agricultural wage rates in the lowest densely populated villages are 30 percent higher than in the highest densely populated areas (Table 3.1). Capital expenditure, defined as the cost of purchased inputs (cost of fertilizer, seed and land preparation) per hectare seems to be an increasing but non-linear function of population density. It increases with population density from the first (lowest) quintile up to the fourth but declines in the fifth (highest) quintile.

Perhaps the relationships between inputs use and population density are more revealing when we look at the non-parametric regression results. Figures 3.1a and 3.1b show the non-parametric regressions of fertilizer use per hectare cultivated on population density. The fertilizer use intensity increases with population density up to the 75th percentile and declines thereafter. Similarly, fertilizer use is seemingly an increasing function of household labor (Figures 3.2a and 3.2b).

Figure 3.1a: Fertilizer expenditure per hectare-overall

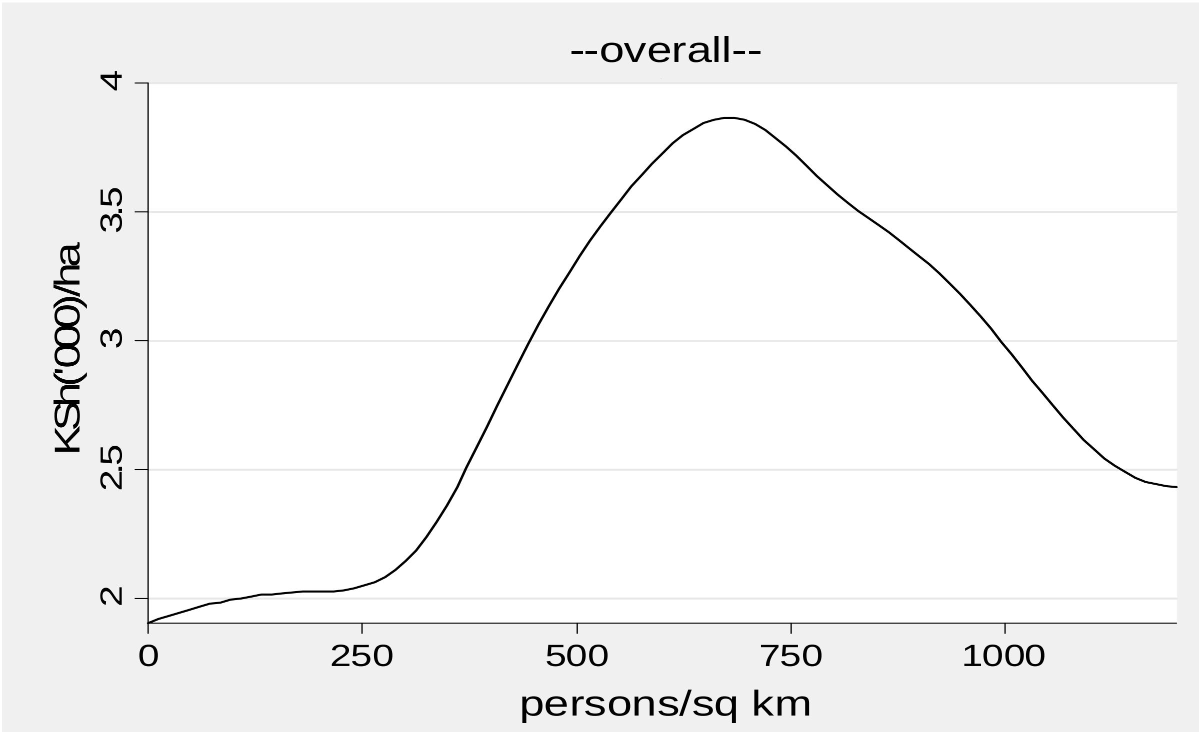


Figure 3.1b: Fertilizer expenditure per hectare-by survey year

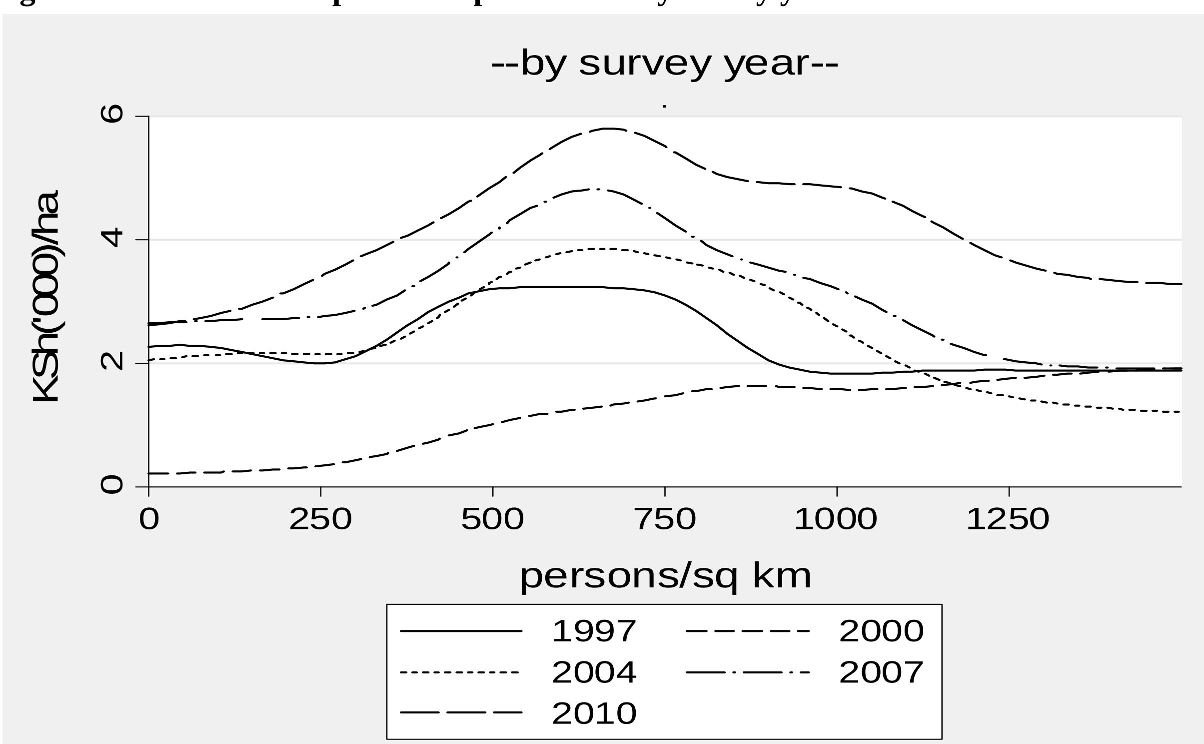


Figure 3.2a: Fertilizer expenditure per unit of labor-overall

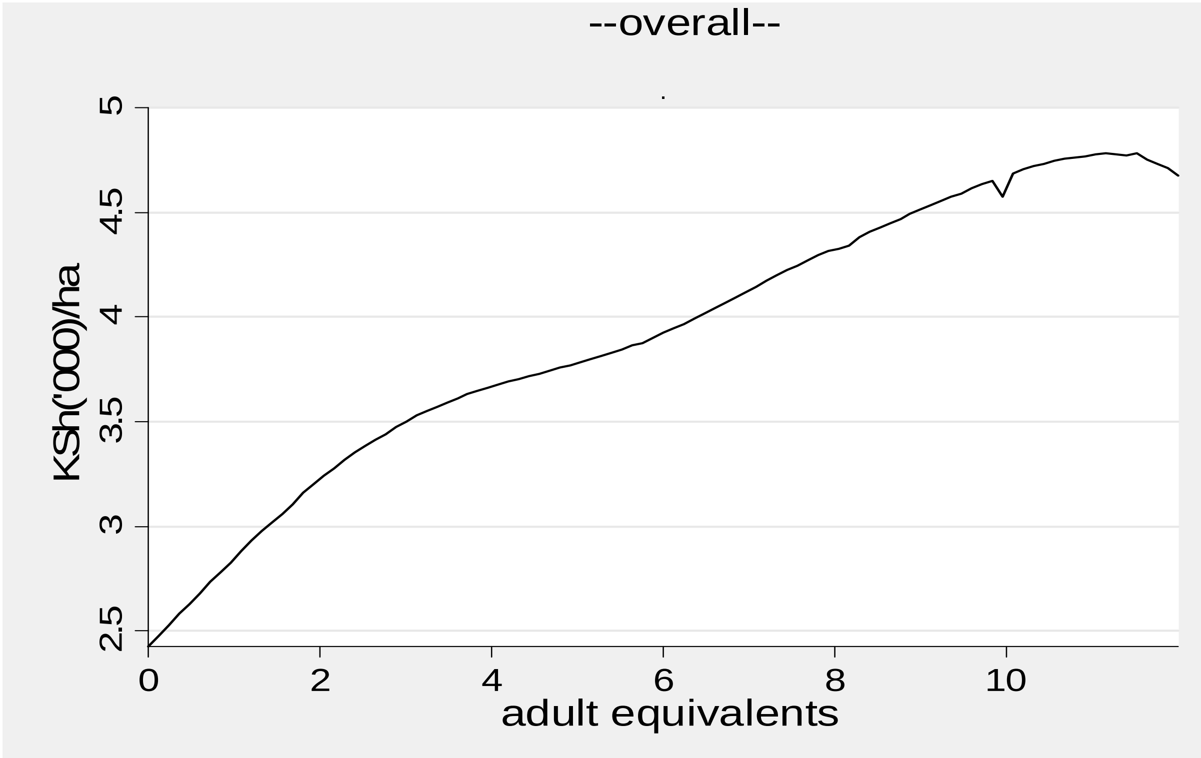


Figure 3.2b: Fertilizer expenditure per unit of labor-by year

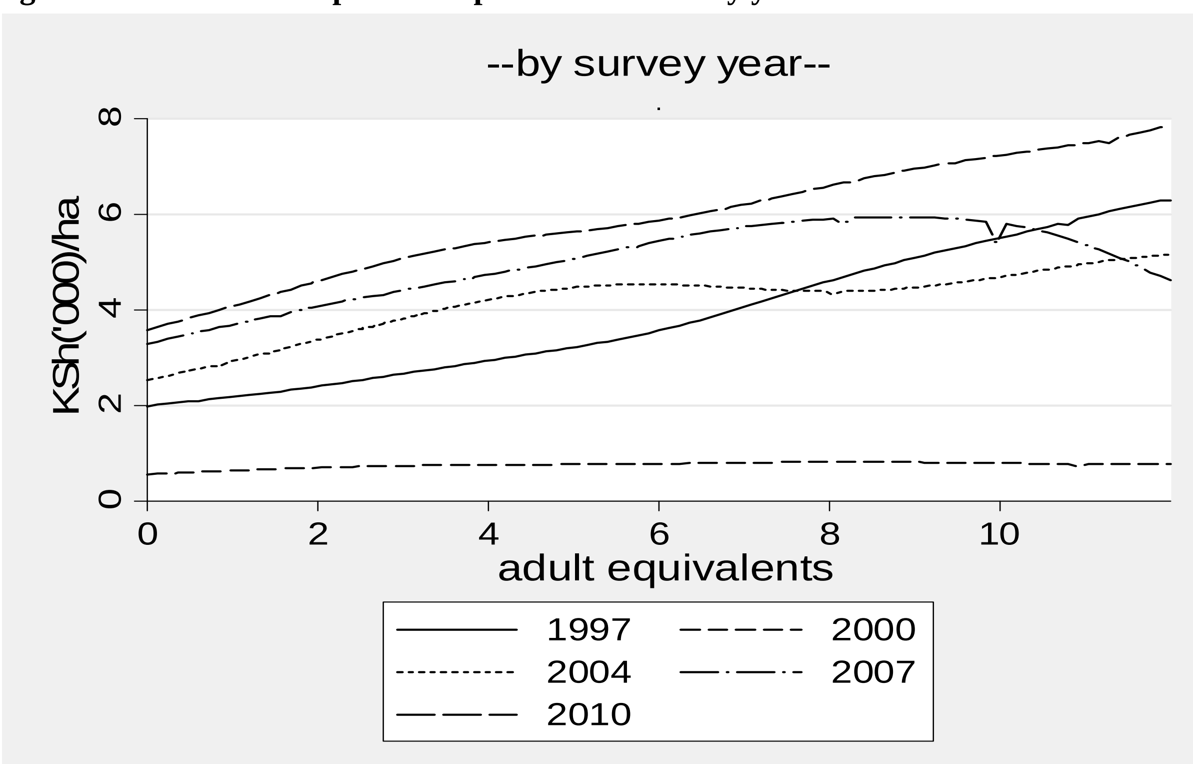


Figure 3.3a: Capital-labor ratio-overall

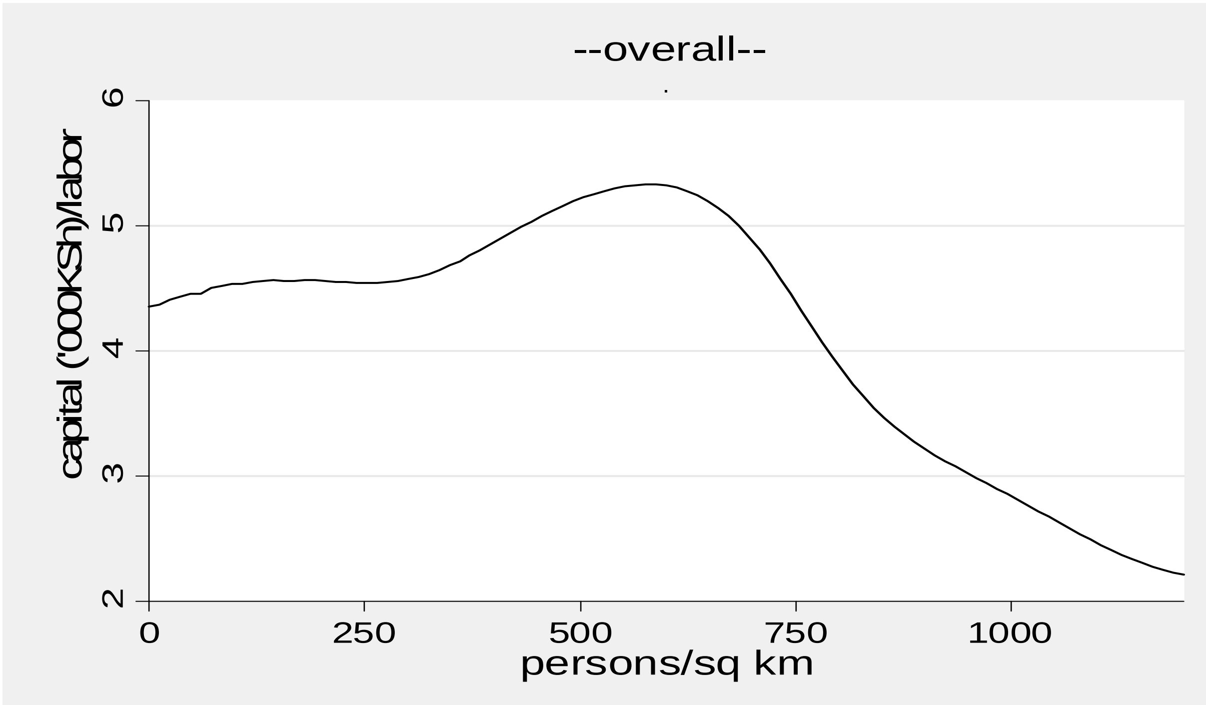


Figure 3.3b: Capital-labor ratio-by survey year

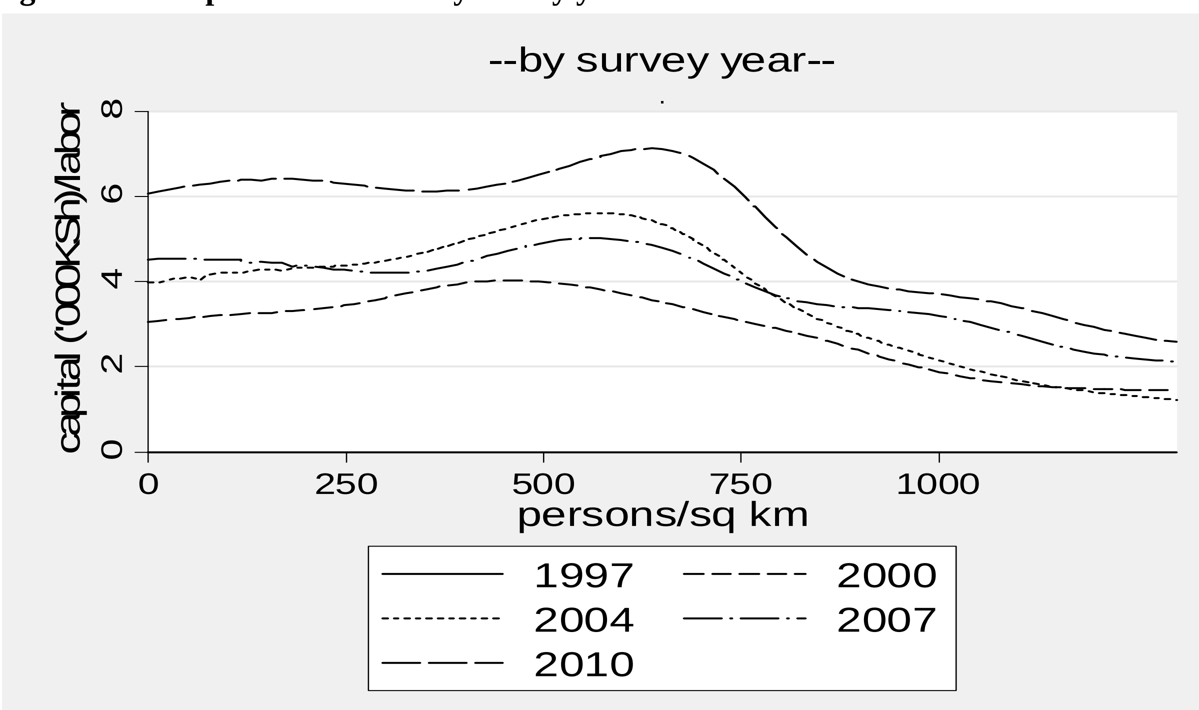


Figure 3.4a: Capital-land ratio-overall

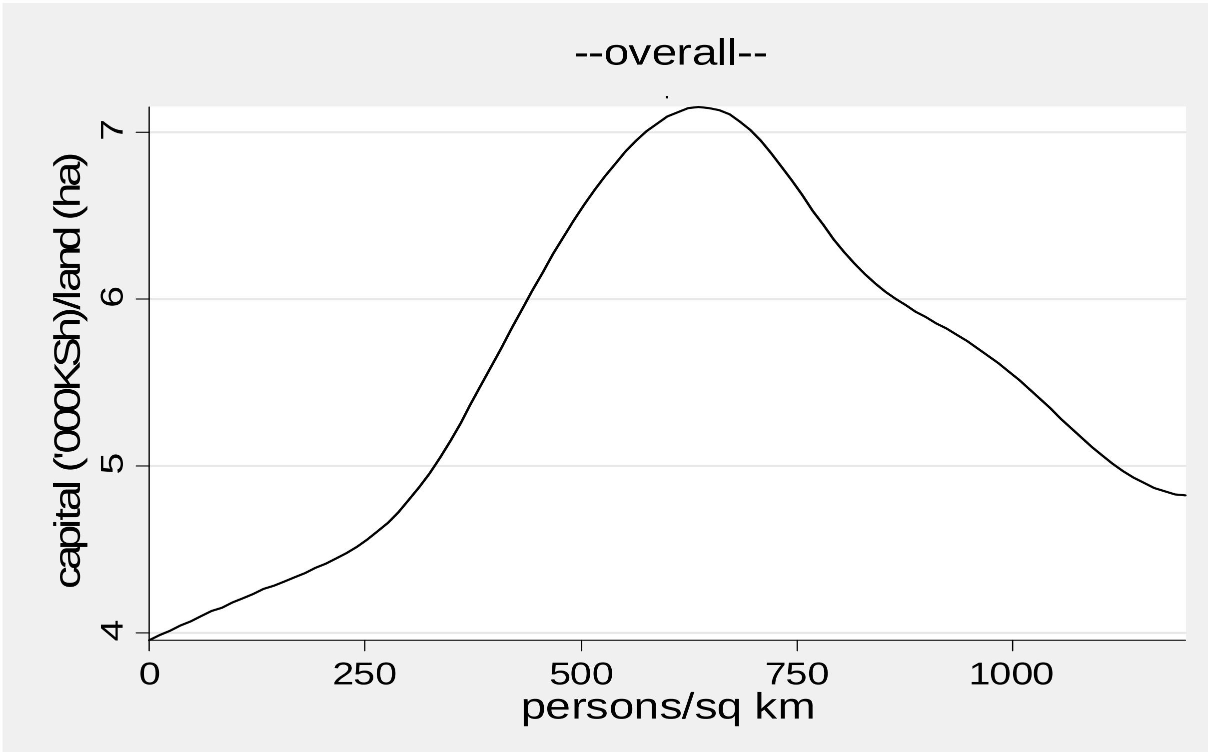


Figure 3.4b: Capital-land ratio-by survey year

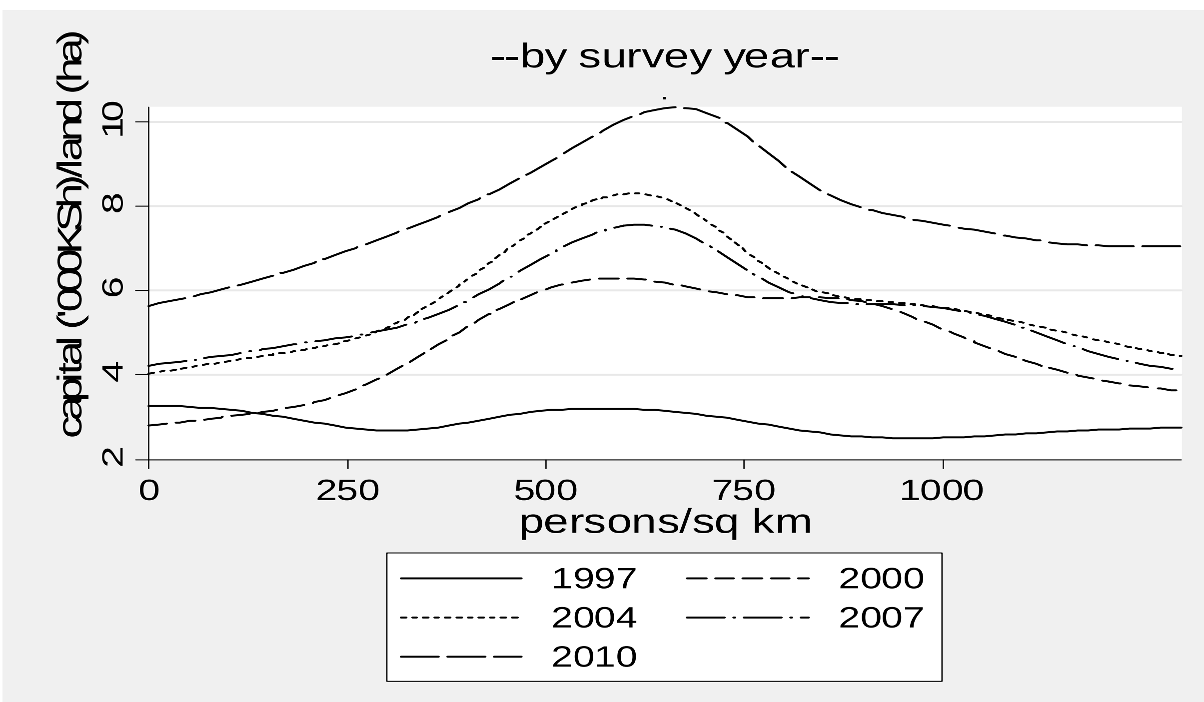


Figure 3.5a: Owned land-labor ratio --overall

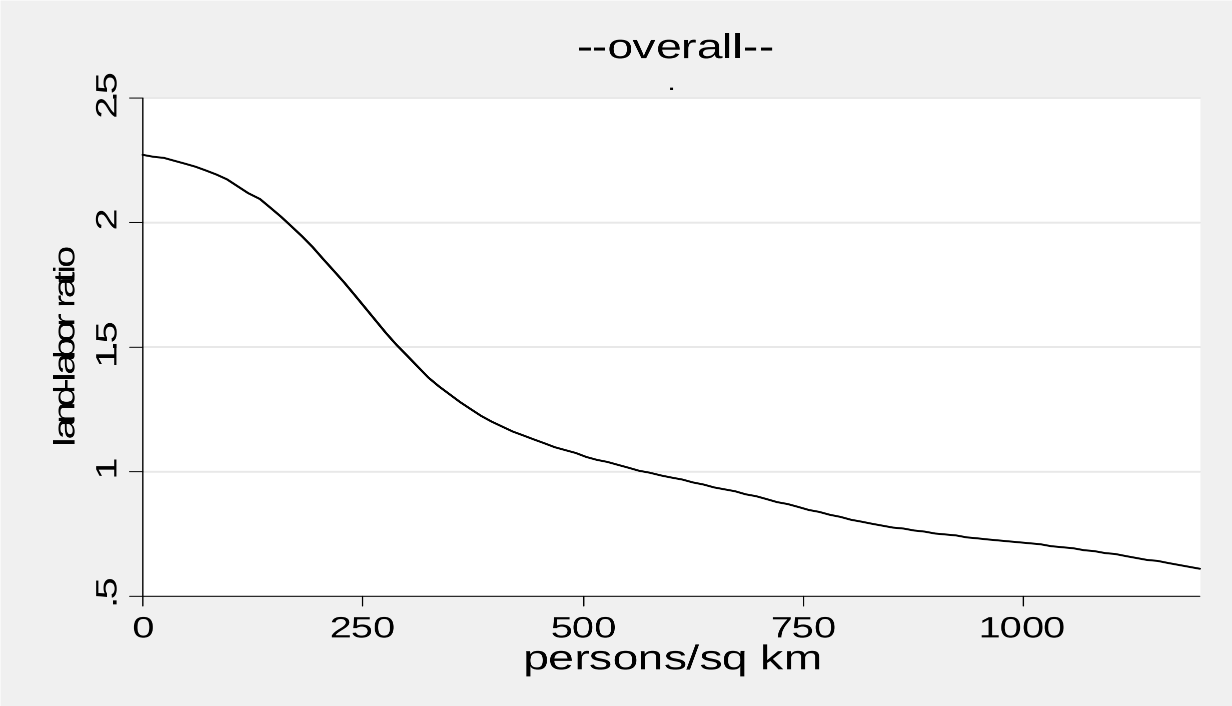


Figure 3.5b: Owned land-labor ratio--by survey year

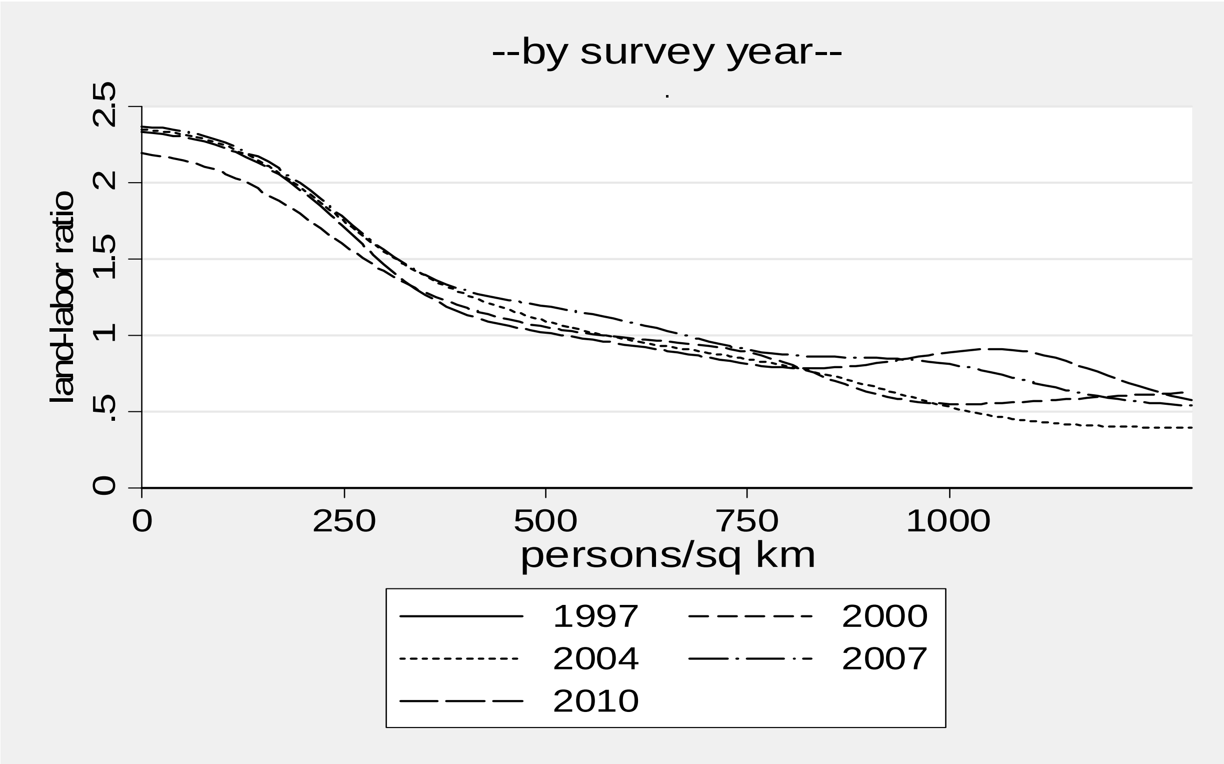


Figure 3.6a: Cultivated land-labor --overall

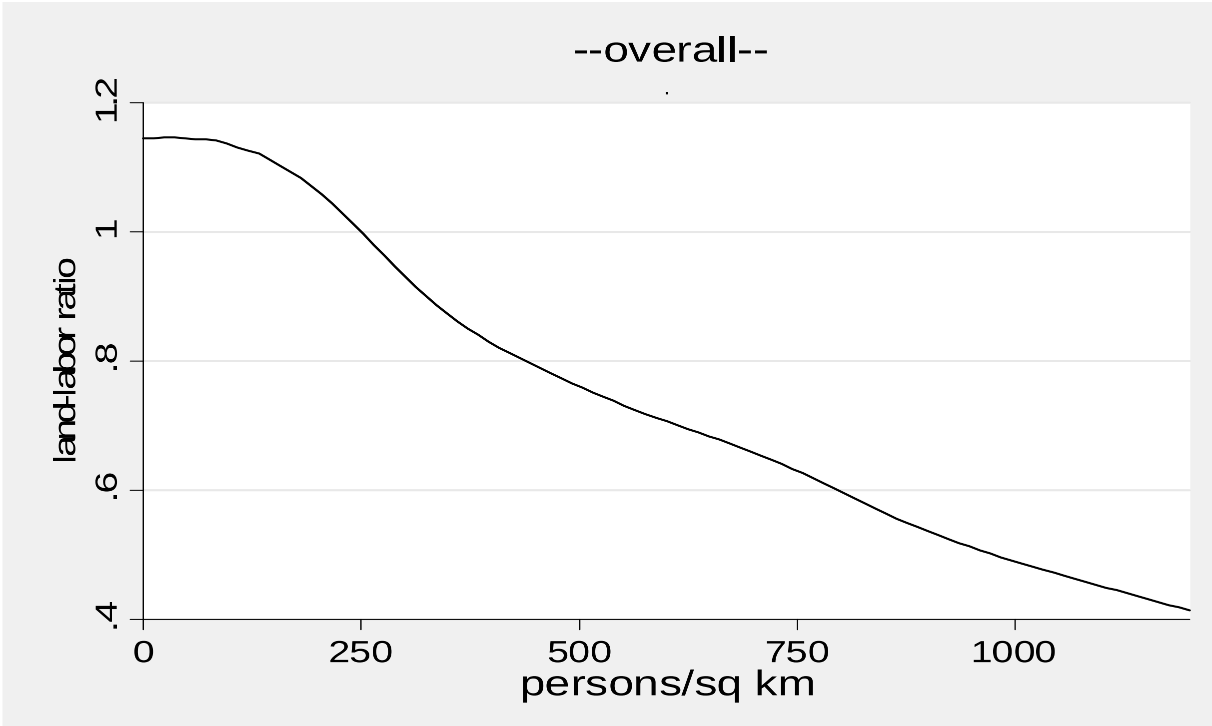
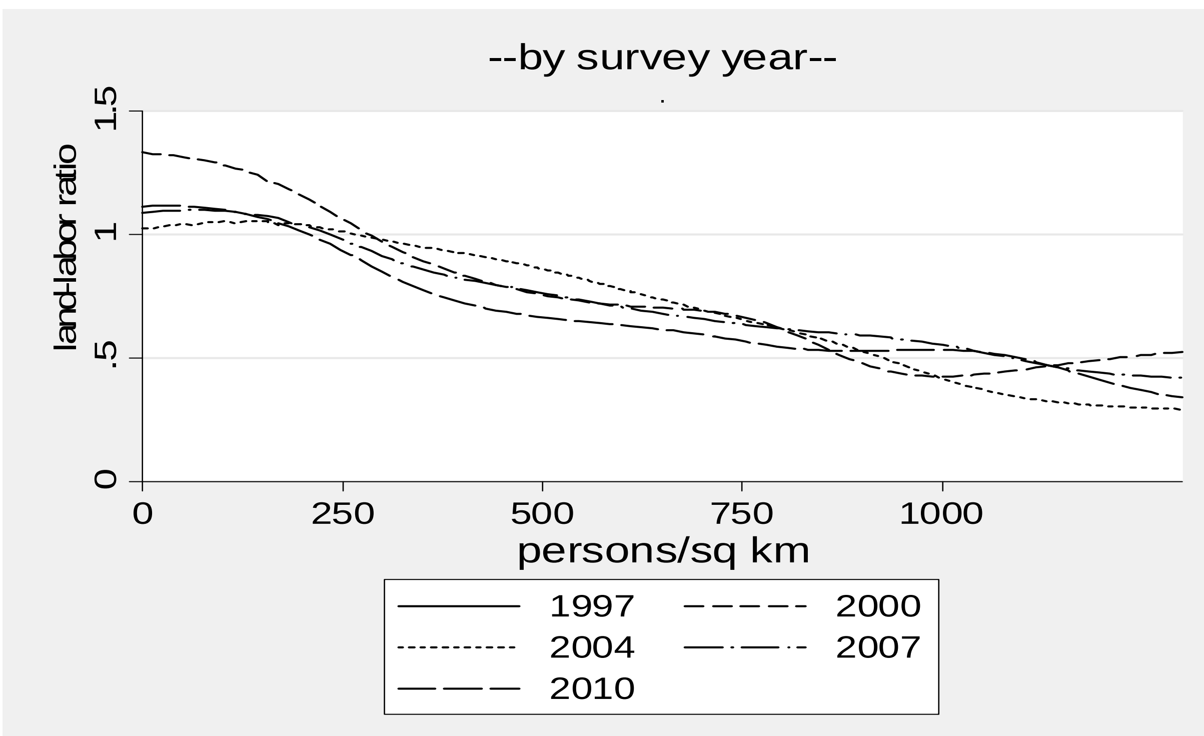


Figure 3.6b: Cultivated land-labor ratio--by survey year



The results also show that households use increasing units of capital per unit of labor as population density increases but up to a certain threshold (75th percentile); thereafter, the capital-labor ratio declines (Figures 3.3a and 3.3b). Figures 3.4a and 3.4b present the non-parametric regression results of capital-land ratio on population density. The results are very similar to those obtained in the capital-labor ratio regressions. Capital-land ratio is an increasing but non-linear function of population density. Last, we present the non-parametric regressions of land-labor on population density. Generally, the results show that the proportion of land, owned or cultivated, to family labor declines with population density (Figures 3.5a to 3.6b).

Table 3.2 presents trends in farm production, income, and asset wealth over the panel period by village population density quintiles. The value of net crop income (gross crop income minus input costs) per hectare or per unit of labor, a measure of partial land productivity, increases with population density up to the fourth density quintile and declines thereafter. This finding confirms the results presented in Table 3.1 and from non-parametric regressions showing that the intensity of labor and purchased inputs use is an increasing function of the population density up to a certain threshold, 531 to 678 persons per km^2, and declines thereafter. Similarly, the value of net farm income (from crops and animal products) per hectare is also a non-linear increasing function of population density. Table 3.2 also shows that off-farm income per adult equivalent is slightly higher for households in the low density areas.

Next, we discuss the value of asset wealth per adult equivalent by population density quintiles (Table 3.2). The list of productive assets consistently collected and valued in each of the four surveys includes but not limited to ploughs, tractors, carts, trucks, spray pumps, water tanks, stores, wheelbarrows, combine harvesters, donkeys and livestock.

Table 3.2: Household income and wealth trends, by population density quintile

'000 KSh -- real	Pop den quintile	Survey year					Five survey panel	
		1997	2000	2004	2007	2010	average	95% CI
Net crop income per hectare	5 [highest]	27.17	51.03	40.47	44.71	44.28	41.53	[37.76 45.30]
	4	27.30	45.13	41.74	45.28	82.71	48.43	[43.65 53.21]
	3	22.35	31.01	31.50	35.65	51.64	34.43	[31.23 37.62]
	2	16.41	18.83	25.59	33.18	36.80	26.16	[23.01 29.31]
	1 [lowest]	17.40	20.00	16.68	14.83	9.48	15.68	[14.02 17.34]
Net crop income per unit of labor	5 [highest]	9.39	22.82	18.72	17.76	16.63	17.06	[14.89 19.23]
	4	11.80	25.46	21.80	22.59	41.31	24.59	[21.55 27.64]
	3	11.56	20.33	17.14	21.17	29.51	19.94	[17.55 22.34]
	2	15.73	16.63	18.28	26.15	31.39	21.64	[16.63 26.64]
	1 [lowest]	14.28	18.97	22.41	16.39	8.60	16.13	[14.28 17.98]
Net farm income per hectare owned	5 [highest]	46.75	74.20	69.57	46.15	47.75	56.88	[49.65 64.12]
	4	44.55	69.20	69.83	46.07	83.81	62.69	[57.63 67.74]
	3	30.71	40.70	45.28	36.33	53.24	41.25	[37.52 44.99]
	2	30.51	29.02	38.28	35.29	40.03	34.62	[30.92 38.31]
	1 [lowest]	25.13	29.26	29.61	16.41	10.21	22.12	[20.05 24.19]
Net farm income per unit of labor	5 [highest]	14.81	31.01	29.08	18.03	17.00	21.99	[18.75 25.23]
	4	18.23	36.31	32.80	22.92	41.72	30.40	[27.19 33.61]
	3	15.10	25.55	23.85	21.45	30.18	23.23	[20.69 25.77]
	2	25.54	24.02	27.73	28.75	34.06	28.02	[22.59 33.44]
	1 [lowest]	19.57	30.08	37.56	19.94	29.70	27.37	[14.52 20.23]
Value of off-farm income per adult equivalent	5 [highest]	7.84	8.45	11.11	10.75	13.24	10.28	[9.08 11.47]
	4	8.75	10.91	16.56	18.54	28.38	16.63	[13.73 19.54]
	3	6.68	8.59	11.85	13.20	15.74	11.21	[9.56 12.85]
	2	8.84	9.82	12.66	12.87	19.14	12.67	[10.73 14.61]
	1 [lowest]	7.88	12.50	13.17	15.95	17.80	13.46	[11.58 15.34]
Value of assets/wealth per adult equivalent	5 [highest]	8.37	7.91	8.49	10.58	8.49	8.77	[7.64 9.89]
	4	11.14	11.06	12.93	21.01	20.47	15.32	[12.47 18.17]
	3	9.06	8.41	12.69	14.37	16.82	12.27	[10.61 13.92]
	2	19.16	13.11	15.82	15.09	20.83	16.80	[14.51 19.09]
	1 [lowest]	22.20	24.20	36.55	38.26	39.10	32.06	[27.68 36.43]
Household aggregate annual income	5 [highest]	16.10	26.95	25.20	25.74	29.36	24.67	[22.56 26.74]
	4	19.10	31.83	38.33	40.09	64.27	38.72	[34.61 42.77]
	3	15.50	24.29	26.78	29.39	37.78	26.75	[24.17 29.25]
	2	22.40	22.45	28.27	30.86	42.98	29.39	[26.04 32.70]
	1 [lowest]	19.00	29.35	35.01	38.15	31.55	30.61	[27.19 34.07]

Source: Tegemeo Institute Rural Household Surveys.
Note: Population density quintiles are defined by ranking all households in the surveys by village-level population density and dividing them into five equal groups.

Recent studies in the poverty literature (e.g. Carter and Barrett, 2006; Krishna et al, 2004) argue that the value of assets more accurately measures wealth than income or consumption, as it is less susceptible to random shocks, and is likely to be a more stable indicator of household welfare. This is especially true in regions where rain-fed agriculture is a major source of annual income and where households rely greatly on their physical assets for their livelihoods. For these reasons, we consider asset holdings to be an important measure of household livelihood, productive potential, and safety net. The results show that the households' asset wealth per adult equivalent has been consistently higher (more than twice) in households located in the low population density areas (Table 3.2). Family size in adults and adult equivalents is almost the same across all five population density quintiles, meaning that asset wealth per household is also substantially higher on average in the low density areas. Conversely, aggregate household income rise with population density up to the fourth population density quintile, and thereafter starts to decline (Table 3.2).

Table 3.3 presents information on smallholder commercialization indicators by population density quintiles over the five survey years. The results clearly show the proportion of land allocated to non-maize crops and the proportion of non-maize crop production are both increasing but non-linear functions of population density. These variables generally increase with the population density up to the fourth population density quintile, and fall thereafter. A quick calculation using the information given in Table 3.3 show that a hectare of land allocated to non-maize crop yields on average about three and four times in the low densely and high densely populated areas, respectively, compared to a hectare allocated to maize crop.

Table 3.3: Smallholder commercialization indices by population density quintiles

	Pop den quintile	Survey year					Panel average
		1997	2000	2004	2007	2010	
Proportion of land allocated to non-maize crop	5 [highest]	0.58	0.64	0.50	0.55	0.56	0.57
	4	0.58	0.72	0.72	0.72	0.65	0.68
	3	0.44	0.54	0.48	0.50	0.46	0.49
	2	0.39	0.34	0.40	0.40	0.41	0.39
	1 [lowest]	0.48	0.53	0.46	0.40	0.44	0.46
Proportion of non-maize crop production	5 [highest]	0.70	0.78	0.69	0.69	0.74	0.72
	4	0.71	0.82	0.81	0.77	0.81	0.78
	3	0.58	0.68	0.66	0.62	0.68	0.64
	2	0.43	0.50	0.53	0.50	0.61	0.51
	1 [lowest]	0.50	0.62	0.52	0.50	0.65	0.56
Maize production (kgs) per hectare allocated to maize	5 [highest]	218.85	213.81	114.49	134.05	105.54	156.65
	4	209.49	280.59	202.13	200.68	175.63	213.53
	3	213.74	135.06	107.87	137.23	102.21	139.69
	2	321.25	123.87	149.72	156.38	88.07	170.92
	1 [lowest]	335.51	122.69	214.08	165.69	59.99	179.16
Non-maize production (kgs) per hectare allocated to non-maize crops	5 [highest]	635.53	698.25	495.18	315.70	420.06	513.85
	4	456.42	366.32	302.54	254.04	354.78	346.15
	3	592.23	425.81	916.92	327.65	827.72	621.76
	2	943.80	492.56	411.88	832.81	538.80	639.14
	1 [lowest]	640.37	638.27	818.48	458.04	636.19	638.27

Source: Tegemeo Institute Rural Household Surveys. Note: Population density quintiles are defined by ranking all households in the surveys by village-level population density and dividing them into five equal groups.

The non-parametric regression results of proportion of land allocated to non-maize crops on population density variable are presented in Figures 3.7 show similar pattern. The area allocated to non-maize crop increases with population density up to about 750persons/km^2 and after somehow plateaus. The same scenario is replicated when we look at the non-parametric regression results of the proportion of non-maize crop production on population density variable; although results are not presented here to save on space.

Figure 3.7: Proportion of area allocated to non-maize by population density

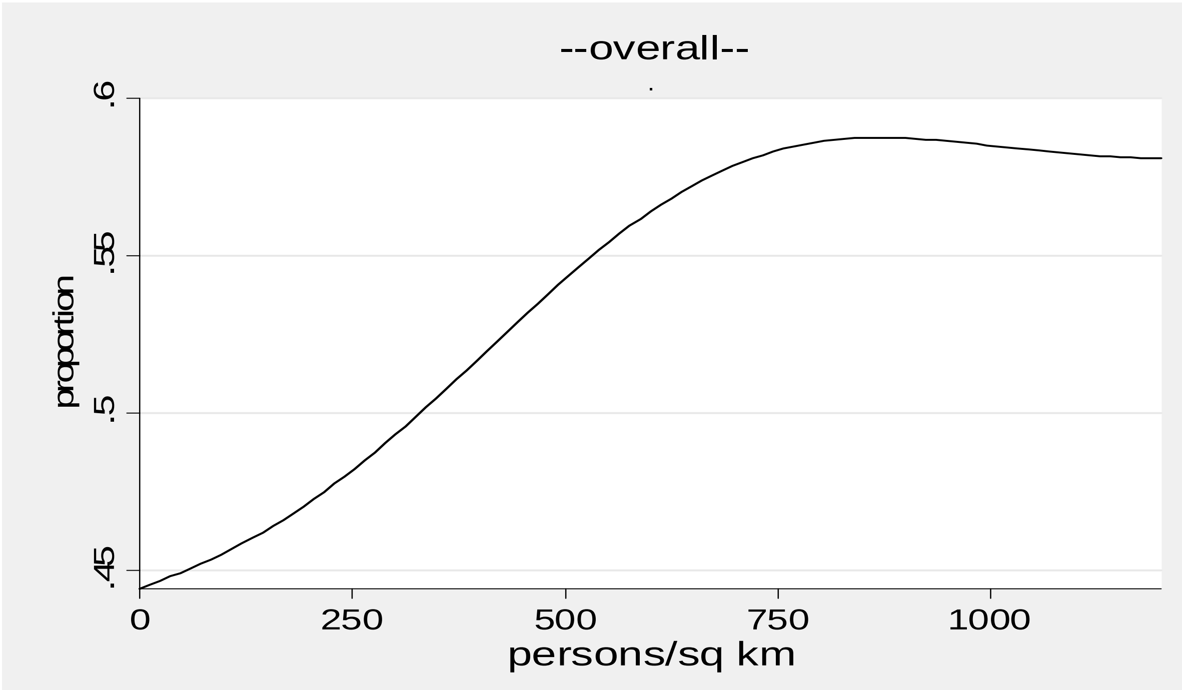


Figure 3.8: Household commercialization index (HCCI) by population density

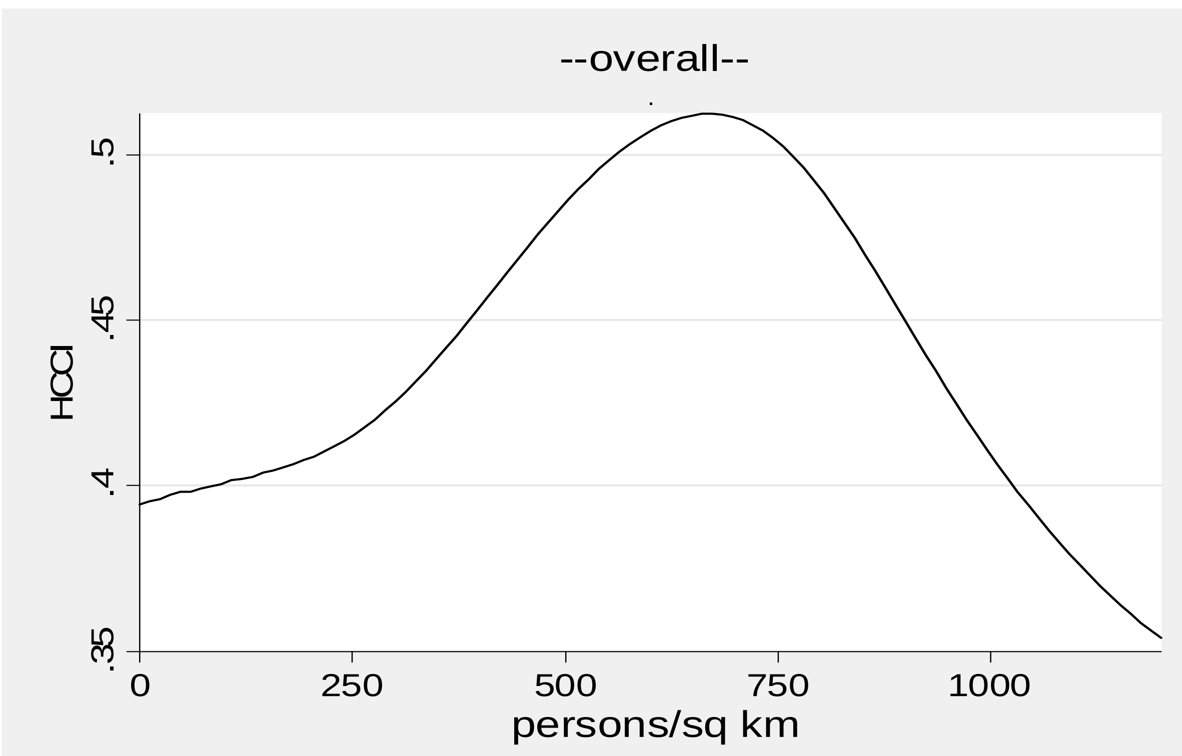


Figure 3.9: Household dairy commercialization index (HDCI) by population density

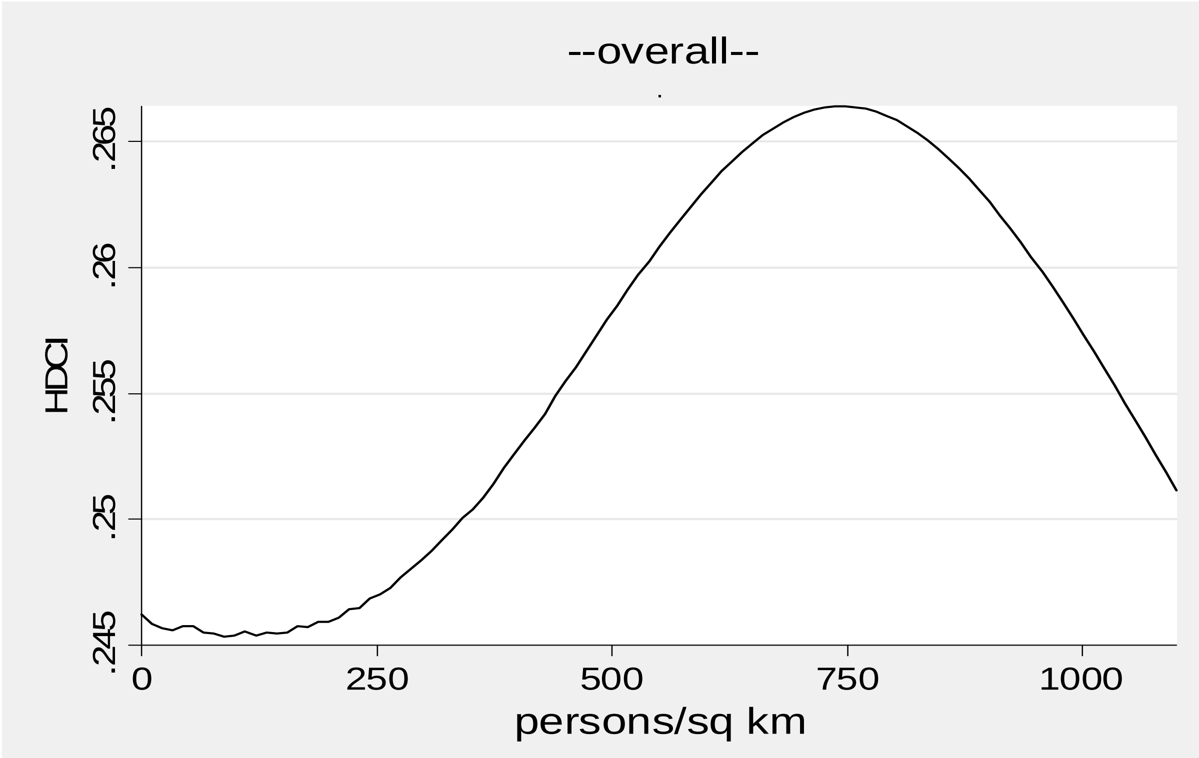
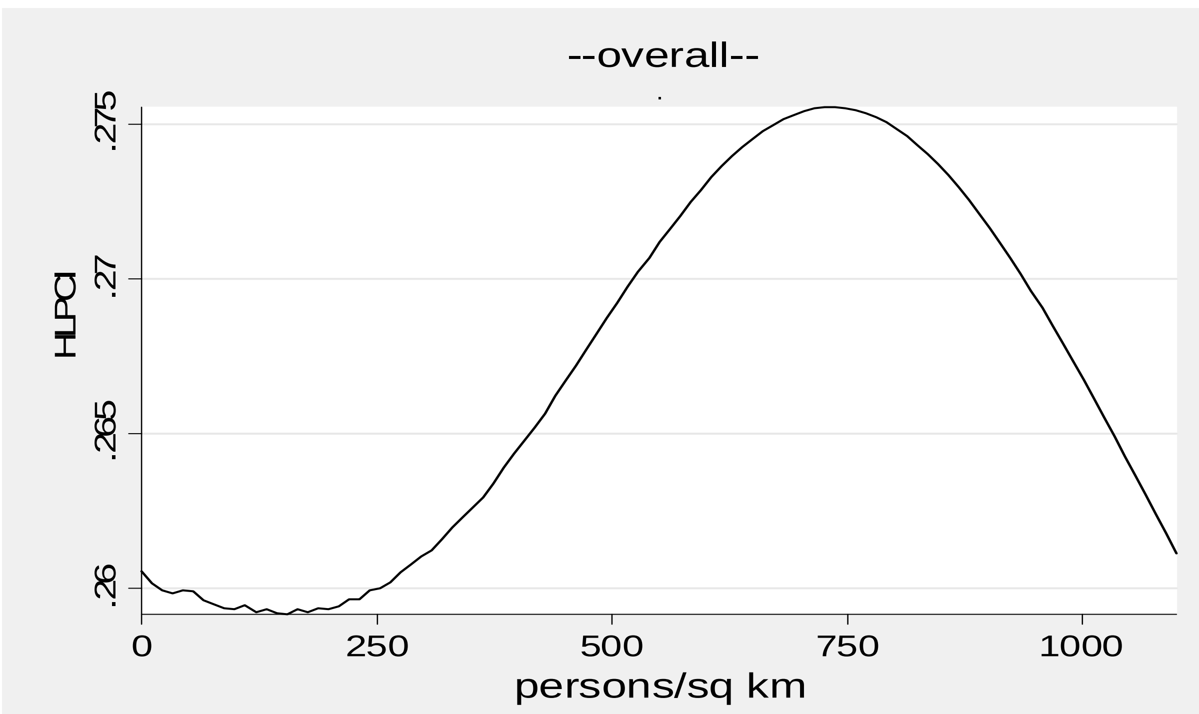


Figure 3.10: Livestock products commercialization index (LPCI) by population density



In Table 3.4 results on household aggregate value of crop and livestock products sales per hectare are presented. Livestock products include milk, eggs, skin and hides, honey, wool and manure among others. We also present dairy products separately since milk constitutes the largest portion of the livestock products. Generally, the results show that crop sales, aggregate livestock products, and milk sales increase with population density up to the fourth population density quintile, and decline thereafter. Similar results emerge when we look at how various indices of smallholder output commercialization relate to population density. These indices include household crop commercialization index (HCCI) defined as the proportion of crop sales value to total crop production value; household livestock products commercialization index (HLPCI) defined as the proportion of the value of livestock products sold to total livestock products value; and household dairy commercialization index (HDCI) defined as the proportion of dairy products sold to total dairy products. The results show that all these indices are positive but non-linear functions of population densities (Table 3.4). The non-parametric regression results show clearly the turning points. The HCCI increases with population density up to about 600 persons per km^2 and drops thereafter (Figure 3.8). Similarly, HLPCI and HDCI are positive but non-linear functions population density with a turning point at about 750 persons per km^2 (Figures 3.9 and 3.10). Clearly, crop commercialization hits its turning point at comparatively lower population density compared to livestock products commercialization.

Table 3.4: Smallholder commercialization by population density quintiles

'000KSh nominal	Pop. den. quintile	Survey year					Panel average
		1997	2000	2004	2007	2010	
Value of crops sales per hectare '000KSh	5 [highest]	18.93	30.77	21.98	28.77	35.07	27.03
	4	18.81	34.31	33.89	44.76	83.84	43.63
	3	15.82	24.59	23.75	29.93	45.12	28.22
	2	11.20	9.98	18.62	26.37	32.93	20.13
	1 [lowest]	13.00	15.57	10.90	9.00	4.45	10.59
Value of livestock product sales per hectare '000KSh	5 [highest]	-	11.17	16.76	10.73	28.65	16.86
	4	-	13.70	18.24	23.22	34.37	22.44
	3	-	4.08	4.54	9.78	16.22	8.63
	2	-	4.35	7.30	9.03	12.78	8.46
	1 [lowest]	-	6.66	7.60	9.82	12.96	9.23
Value of milk sold per hectare '000KSh	5 [highest]	-	10.89	16.41	9.94	25.02	15.60
	4	-	13.37	17.79	22.90	33.74	22.02
	3	-	3.74	4.13	9.68	15.32	8.19
	2	-	3.76	5.54	7.41	9.65	6.66
	1 [lowest]	-	4.72	7.02	8.59	12.71	8.21
Household crop commercialization index (HCCI)	5 [highest]	0.33	0.27	0.33	0.27	0.31	0.30
	4	0.44	0.51	0.51	0.58	0.59	0.52
	3	0.41	0.50	0.43	0.45	0.45	0.45
	2	0.40	0.39	0.43	0.44	0.40	0.42
	1 [lowest]	0.43	0.41	0.44	0.39	0.23	0.38
Household animal commercialization index (HACI)	5 [highest]	-	0.28	0.22	0.25	0.32	0.27
	4	-	0.39	0.43	0.48	0.50	0.45
	3	-	0.22	0.21	0.29	0.39	0.28
	2	-	0.30	0.24	0.31	0.32	0.29
	1 [lowest]	-	0.33	0.33	0.42	0.43	0.38
Household dairy commercialization index (HDCI)	5 [highest]	-	0.27	0.21	0.24	0.30	0.25
	4	-	0.38	0.43	0.47	0.49	0.44
	3	-	0.22	0.19	0.27	0.36	0.26
	2	-	0.26	0.23	0.30	0.30	0.27
	1 [lowest]	-	0.31	0.32	0.40	0.42	0.36

Source: Tegemeo Institute Rural Household Surveys.

Note: Population density quintiles are defined by ranking all households in the surveys by village-level population density and dividing them into five equal groups.
HICI= value of inputs acquired from market/ gross value of crop production
HCCI= gross value of crop sales /gross value of crop production
HACI=gross value of animal product sales / gross value of animal products production
HDCI=gross milk sales / gross milk production

The overall picture emerging from these results so far is that land is becoming an increasingly constraining factor of production and that smallholder agriculture farming practices in the areas of high population density are distinctly more land-intensive. Smallholder farmers allocate more of their shrinking land to non-maize crop and sell a greater proportion of their production. It seems farmers alter production patterns to make the best out of their shrinking land resource by switching to high value enterprises such as production of fresh fruits and vegetables, dairy and poultry products. From another perspective, high population density has been shown to lead to improved economic infrastructures and market access owing to reduced average cost of infrastructure and urbanization (Glover and Simon, 1975). Improved market access enables farmers and increased demand motivates farmers to produce a surplus for the market and to engage in high value and perishable enterprises that are not possible with poor market access. However, these increasing trends in production are experienced up to a certain population density threshold. These bivariate relationships, while providing a fairly consistent picture, do not control for the effects of other variables affecting farm productivity, incomes and asset wealth. However, these relationships do lead to an important hypothesis for more rigorous analysis in the next section.

3.7.2 Econometric results

In this section, we report the econometric results from the input demand, output supply, households' incomes, and smallholder commercialization models estimation. But before that, we present and discuss briefly the results from the first stage population density, second stage maize price estimations, and the key insights from the third stage input prices and landholding regressions. The results on determinants of population density are presented in Table 3.5.

Table 3.5: OLS estimation results for population density

	Log of persons/km^2 of total land [standard]			Log of persons/km^2 of arable land [GRUMP]		
	Coef.	Robust SE	P>t	Coef.	Robust SE	P>t
Length of Growing Period (LGP)	0.004	0.000	0.00	0.004	0.000	0.00
Net Primary Productivity (NPP)	0.001	0.000	0.03	0.002	0.000	0.00
Elevation: meters above sea level	0.002	0.000	0.00	0.001	0.000	0.00
Slope: measure of steepness -- degrees	0.050	0.004	0.00	0.047	0.003	0.00
Estimated population count for 1950	0.026	0.000	0.00	0.015	0.000	0.00
Literacy (1=literate; 0=illiterate) *	-3.351	0.082	0.00	-1.919	0.064	0.00
Distance to water source -km)*	-0.006	0.001	0.00	-0.001	0.001	0.17
Religion (1=Catholic; 0=non-Catholic) *	7.486	0.192	0.00	5.565	0.153	0.00
Women-average age at first birth*	-1.898	0.061	0.00	-1.049	0.049	0.00
Contraceptive use (1=yes; 0=no) *	-0.261	0.120	0.03	-2.602	0.086	0.00
Women: age at first marriage*	-0.503	0.035	0.00	-0.654	0.026	0.00
Women: age at first intercourse*	-0.300	0.007	0.00	-0.142	0.005	0.00
Women: number of children dead*	-5.542	0.101	0.00	-1.544	0.084	0.00
Tribe dummies						
_ethnic_1	6.782	0.144	0.00	2.188	0.113	0.00
_ethnic_2	4.159	0.116	0.00	0.974	0.092	0.00
_ethnic_3	5.081	0.113	0.00	1.986	0.085	0.00
_ethnic_4	4.340	0.083	0.00	1.421	0.064	0.00
_ethnic_5	3.179	0.066	0.00	0.835	0.050	0.00
_ethnic_6	3.404	0.059	0.00	0.337	0.058	0.00
_ethnic_7	5.452	0.153	0.00	2.149	0.117	0.00
_cons	38.411	0.931	0.00	15.985	0.771	0.00
Number of obs	5845			5845		
R squared	0.88			0.89		

Note: * b/1989 DHS available at http://www.measuredhs.com/data/available-datasets.cfm

We run two separate models. In the first model (I) using the standard population density defined as the number of persons per square kilometer of total land, and its square if necessary, and controls for soil quality and climatic conditions. In the second model (II), we use population density defined as the total number of persons per kilometer km^2 of arable land (hereafter referred to as GRUMP population density). As the results shows, all the coefficients are statistically significant and most of them bear the expected signs.

Table 3.6 present the second stage regression of the determinants of the maize prices. The results show that maize prices are a decreasing but non-linear function of population density in the two models. Maize price decrease with population density reaching a minimum at 490 and 787 persons per km^2 in the first and the second models, respectively, and falls thereafter. The average partial effects (APES) indicate that an increase in population density by 100 persons per km^2 reduces maize prices by about one percent in model I and by eight percent in model II. Generally, it seems like maize prices are highest in the maize-deficit low (lowlands) and high densely (highlands) populated areas and are lowest in the medium population density areas, basically high potential maize zones. Even though we had hypothesized that population density may not have as great an impact on maize prices due to trade effects, it seems there are price differentials across regions due to delays in price adjustments, market inefficiencies and transport costs. The other important correlates of maize price include type of maize buyers and the maize prices prevailing at the regional markets at the planting time and National and Cereal Produce Board (NCPB) previous year’s maize buying prices in the region. It is important to mention that the significant coefficient of the residuals from the first stage population density equation implies that population density variable is endogenous in the maize price equation.

Table 3.6: CRE estimation results for producer farm gate maize prices

	Model I			Model II		
Dependent variable: log of maize price/kg (KSh)	Coef.	Bootstrap SE	P>z	Coef.	Bootstrap SE	P>z
Population density (100 pp/sq km) [Standard]	-0.063	0.017	0.00	--	--	--
Population density square	0.006	0.001	0.00	--	--	--
Density (100 pp/sq km) [GRUMP]	--	--	--	-0.139	0.025	0.00
GRUMP density square	--	--	--	0.009	0.001	0.00
Distance to motorable road (km)	-0.002	0.003	0.41	-0.002	0.003	0.53
Distance to tarmac road (km)	0.030	0.093	0.75	0.053	0.092	0.56
Own a truck (1=yes; 0=no)	0.035	0.026	0.18	0.038	0.026	0.15
Own a bicycle (1=yes; 0=no)	-0.005	0.009	0.56	-0.005	0.009	0.59
Own a radio (1=yes; 0=no)	0.010	0.011	0.33	0.009	0.011	0.41
Storage facility-- estimated value (KSh)	0.002	0.002	0.34	0.002	0.002	0.37
Maize buyer type (base=private buyer)						
NCPB	0.092	0.011	0.00	0.087	0.011	0.00
processor	0.136	0.019	0.00	0.158	0.020	0.00
other	0.077	0.009	0.00	0.074	0.009	0.00
Regional maize price/kg - planting time	0.008	0.002	0.00	0.008	0.002	0.00
NCPB previous years buying price/kg	0.011	0.005	0.02	0.013	0.005	0.01
Sex of household head (1=male; 0=female)	-0.004	0.014	0.76	-0.003	0.014	0.81
Age of the household head (years)	-0.036	0.056	0.51	-0.046	0.056	0.41
Education attainment (# of years)	0.001	0.002	0.53	0.001	0.002	0.46
Survey year dummies (base=1997)						
_Iyear_2000	0.103	0.050	0.04	0.095	0.050	0.06
_Iyear_2004	0.160	0.067	0.02	0.188	0.067	0.01
_Iyear_2007	0.125	0.068	0.07	0.180	0.069	0.01
_Iyear_2010	0.547	0.088	0.00	0.617	0.088	0.00
First stage population density residuals	-0.016	0.040	0.69	-0.212	0.058	0.00
_cons	3.367	0.125	0.00	3.106	0.107	0.00
Population den. direct effect (APEs)	-0.006			-0.076		
Turning point: density (pp/sq km)	490			787		
Observations	5845			5845		
Number of households	1169			1169		
R squared	0.53			0.52		

Note: Time averages of time varying variables and region dummies included

As expected, agricultural wage rate is a decreasing but somehow nonlinear function of population density (Table 3.7). Wage rate decreases with population density up to about at 1025 and 1280 persons per km^2 in the first and the second models, respectively, and rises thereafter. It is important to note that these two turning points are way outside the sample population density variable distribution 99th percentile. The APEs show that an increase in population density by 100 persons per km^2 reduces wage rates by about 11 and 14 percent in model I and II, respectively. The significant coefficient of the residuals from the first stage population density equation implies that population density variable is endogenous in the wage equation. Other variables that influence positively agricultural wage rates are reduced distances to infrastructural to roads and infrastructural facilities, and high expected maize prices.

Conversely, land rental rates increase with population pressure (Table 3.8). Land rental rates increase with population density reaching a maximum at about 1040 and 1138 persons per km^2 in the first and the second model, respectively, and drops thereafter. Again these land rental rates turning points are way beyond the 99th percentile of the sample population density variable distribution. The APEs indicate that an increase in population density by 100 persons per km^2 increases land rental rates by about two and six percent in model I and II, respectively. The significant coefficient of the residuals from the first stage population density equation implies that population density variable is endogenous in the land rental equation. Other variables that seem to significantly influence land rates include household landholding as proxied by the district landholding median sizes and the expected maize price. While land rental rates understandably increase with diminishing land sizes, they rise with high expected maize prices.

It appears the rental equilibrium rates are higher if leasers and leaseholders expect high crop prices. Weather conditions and quality of soils in the areas where the households are located as proxied by length of growing period (LGP), net primary productivity (NPP) and elevation also influence land rental rates.

Table 3.7: CRE estimation results for agricultural wage

	Model I			Model II		
	Coef.	Bootstrap SE	P>z	Coef.	Bootstrap SE	P>z
Population density (100 pp/sq km) [Standard]	-0.123	0.018	0.00	--	--	--
Standard population density square	0.006	0.001	0.01	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	--	-0.197	0.021	0.00
GRUMP population density square	--	--	--	0.008	0.001	0.00
Distance to motorable road (km)	-0.008	0.004	0.04	-0.009	0.004	0.01
Distance to tarmac road (km)	-0.004	0.001	0.00	-0.004	0.001	0.00
Distance to health center (km)	-0.002	0.001	0.00	-0.002	0.001	0.01
Distance to electricity supply (km)	-0.004	0.002	0.04	-0.004	0.002	0.05
Expected maize price/kg	0.052	0.006	0.00	0.052	0.006	0.00
Survey year dummies (base=1997)						
_Iyear_2000	0.186	0.020	0.00	0.204	0.020	0.00
_Iyear_2004	0.335	0.023	0.00	0.416	0.025	0.00
_Iyear_2007	0.455	0.019	0.00	0.578	0.026	0.00
_Iyear_2010	0.404	0.058	0.00	0.561	0.058	0.00
First stage population den. residuals	0.020	0.006	0.00	-0.055	0.013	0.00
_cons	3.777	0.080	0.00	3.546	0.083	0.00
Population den. direct effect (APEs)	-0.108			-0.138		
Turning point: pop. den. (pp/sq km)	1025			1280		
Observations	5845			5845		
Number of households	1169			1169		
R squared	0.60			0.62		

Note: Time averages of time varying variables and survey years and region dummies included

Table 3.8: CRE estimation results for land rental rates

	Model I			Model II		
	Coef.	Bootstrap SE	P>z	Coef.	Bootstrap SE	P>z
Population density (100 pp/sq km) [Standard]	0.156	0.009	0.00	--	--	--
Standard population density square	-0.008	0.001	0.00	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	--	0.091	0.018	0.00
GRUMP population density square	--	--	--	-0.004	0.001	0.00
District median landholding (ha)	-0.019	0.007	0.01	-0.030	0.013	0.02
Distance to motorable road (km)	-0.003	0.003	0.33	-0.001	0.003	0.80
Distance to tarmac road (km)	-0.005	0.001	0.55	0.003	0.012	0.82
Distance to water source (km)	0.001	0.001	0.84	-0.004	0.006	0.51
Distance to health center (km)	-0.005	0.001	0.00	-0.003	0.001	0.84
Distance to electricity supply (km)	-0.030	0.010	0.00	-0.031	0.012	0.01
Expected maize price/kg	0.059	0.005	0.00	0.048	0.005	0.00
Length of Growing Period (LGP)	0.014	0.002	0.00	0.014	0.003	0.00
Net Primary Productivity (NPP)	0.001	0.000	0.00	0.001	0.001	0.07
Elevation: meters above sea level	0.004	0.000	0.00	0.005	0.001	0.00
Slope -- degrees	-0.071	0.003	0.00	-0.089	0.004	0.00
Survey year dummies (base=1997)						
_Iyear_2000	-0.036	0.009	0.00	-0.002	0.011	0.88
_Iyear_2004	-0.057	0.020	0.01	0.014	0.026	0.58
_Iyear_2007	0.214	0.019	0.00	0.301	0.025	0.00
_Iyear_2010	-0.067	0.048	0.16	0.130	0.060	0.03
Region dummies (base: central highlands)						
_Izone_3	-0.558	0.059	0.00	-0.398	0.069	0.00
_Izone_4	-0.968	0.029	0.00	-0.984	0.043	0.00
_Izone_5	-0.715	0.030	0.00	-0.780	0.030	0.00
_Izone_6	-0.190	0.033	0.00	-0.195	0.032	0.00
_Izone_7	-0.612	0.032	0.00	-0.566	0.026	0.00
_Izone_9	-0.549	0.054	0.00	-0.646	0.072	0.00
First stage population den. residuals	0.023	0.008	0.00	-0.059	0.013	0.00
_cons	6.184	0.124	0.00	6.243	0.165	0.00
Population den. direct effect (APEs)	0.045				0.021	
Turning point: pop. den. (pp/sq km)	1040				1138	
Observations	5845				5845	
Number of households	1169				1169	
R squared	0.71				0.61	

Note: Time averages of time varying variables included

Household landholding sizes decreases with population pressure (Table 3.9). If population density increases by 100 persons per square km^2, household landholding declines by about nine and 15 percent in the first and the second model. Besides population density, household demographic variables, intergenerational factors, and ethnicity as captured by the household head's tribe also influence household landholding sizes. Household landholding increases with the household head's age and education attainment. Similarly, the more the amount of land the father to the household head or the spouse had, the more the land the current household controls. The significant coefficient of the residuals from the first stage population density equation implies that population density variable is endogenous in the landholding equation.

In the remaining part of this section, we present the key econometric results from the input factor demand, output supply, households' incomes, and smallholder commercialization models estimation. For each model, we run three separate regressions depending on the population density variable used: model I – the standard population density; model II – GRUMP population density; model III – without population density variable. It is important to mention at the onset that the population density variables were found to be endogenous in all the input demand, output supply, household income, and smallholder commercialization models.

(i) Effects of population density on factor input demand: Results presented in Table 3.10 shows that the intensity of purchased inputs use per hectare cultivated increase with population density up to about 400 persons per km^2 and declines after that point. Using the standard definition of population density, an increase in population density by 100 persons per km^2

increases the mean purchased inputs use per hectare directly by about six and indirectly by about one percent.

Table 3.9: CRE estimation results for household landholding

log land owned (ha)	Model I Coef.	Model I Bootstrap S.E	Model I P>z	Model II Coef.	Model II Bootstrap S.E	Model II P>z
Population density (100 pp/sq km) [Standard]	-0.087	0.029	0.00	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	--	-0.149	0.040	0.00
Household size	0.026	0.004	0.00	0.026	0.004	0.00
Head's gender (1=male; 0=female)	0.045	0.035	0.20	0.045	0.035	0.20
Age of the household head (years)	0.006	0.001	0.00	0.006	0.001	0.00
Education attainment (# of years)	0.008	0.004	0.06	0.008	0.004	0.06
Land rental rates ('000KSh)	-0.016	0.009	0.07	-0.017	0.009	0.06
Landholding --father of initial head (ha)	0.005	0.001	0.00	0.005	0.001	0.00
Landholding --father of the spouse (ha)	0.002	0.001	0.08	0.002	0.001	0.09
# of years in the current location	0.006	0.003	0.06	0.006	0.003	0.07
Ethnic group dummies						
_Itribe_1	-0.021	0.180	0.91	0.021	0.180	0.91
_Itribe_2	-0.551	0.203	0.01	-0.503	0.204	0.01
_Itribe_3	-0.814	0.286	0.00	-0.563	0.303	0.06
_Itribe_4	-0.438	0.178	0.01	-0.344	0.180	0.06
_Itribe_5	-1.456	0.272	0.00	-1.191	0.288	0.00
_Itribe_6	-1.172	0.274	0.00	-0.742	0.303	0.01
_Itribe_7	-0.736	0.198	0.00	-0.407	0.222	0.07
_Itribe_8	-0.724	0.239	0.00	-0.436	0.258	0.09
_Itribe_9	-0.236	0.286	0.41	0.049	0.296	0.87
First stage population den. residuals	0.001	0.000	0.00	0.001	0.000	0.00
_cons	-0.822	0.220	0.00	-0.834	0.219	0.00
Observations	5845			5845		
Number of households	1169			1169		
R squared	0.68			0.68		

Note: Household ethnicity, time averages of time varying variables, and survey year and agroecological zone dummies included

Table 3.10: CRE estimation results for intensity of cash input use per hectare cultivated

	Model I		Model II		Model III	
Dep. var: Log purchased inputs (KSh)	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.157	0.00	--	--	--	--
Standard population density square	-0.016	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.110	0.00	--	--
GRUMP population density square	--	--	-0.013	0.00	--	--
Expected maize price (KSh/kg)	0.052	0.00	0.399	0.03	0.057	0.00
Land owned (ha)	-0.078	0.00	-0.080	0.00	-0.079	0.00
Wage rate ('00Ksh/day)	-0.027	0.12	-0.035	0.04	-0.037	0.03
Land rental rates ('000Ksh/ha)	-0.017	0.24	-0.017	0.24	-0.011	0.44
DAP price (KSh/50kg)	-0.014	0.00	-0.013	0.00	-0.013	0.00
Distance to motorable road (km)	-0.010	0.14	-0.010	0.15	-0.012	0.09
Distance to tarmac road (km)	-0.010	0.00	-0.010	0.00	-0.010	0.00
Gender of head (1=male; 0=female)	0.058	0.13	0.055	0.14	0.058	0.12
Household size	-0.005	0.34	-0.006	0.28	-0.006	0.27
Age of head (years)	0.003	0.12	0.003	0.11	0.003	0.10
Education attainment of head (# of years)	0.011	0.01	0.011	0.02	0.010	0.02
First stage population density residuals	0.001	0.00	0.001	0.01	--	--
_cons	6.321	0.00	5.609	0.00	5.747	0.00
Direct partial effects	0.060		0.021		--	
Indirect partial effects	0.006		-0.018		0.006	
Total partial effects	0.066		0.003		0.006	
Turning point: pop. density (persons/km^2)	496		439		--	
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included

When we use the GRUMP population density, a similar increase in population density increases the mean intensity of purchased inputs use by about two percent. However, this direct effect is cancelled out by the negative indirect effect of the increasing population density on purchased inputs use through input factor prices and landholding. Besides population density and input factor prices, the other variables associated with increased farm inputs use intensification are reduced distances to roads and high education attainment by the household heads.

Table 3.11: CRE estimation results for intensity of fertilizer use (kgs/ha cultivated)

	Model I		Model II		Model III	
Dep. var: Log fertilizer intensity (kgs/ha)	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.077	0.01	--	--	--	--
Standard population density square	-0.010	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.073	0.05	--	--
GRUMP population density square	--	--	-0.009	0.02	--	--
Expected maize price (KSh/kg)	0.065	0.00	0.971	0.00	0.063	0.00
Land owned (ha)	-0.056	0.00	-0.057	0.00	-0.057	0.00
Wage rate ('00Ksh/day)	0.031	0.17	0.023	0.31	0.025	0.27
Land rental rates ('000Ksh/ha)	0.003	0.90	0.010	0.62	0.006	0.78
DAP price (KSh/50kg)	-0.008	0.04	-0.008	0.04	-0.008	0.04
Distance to motorable road (km)	-0.005	0.10	-0.005	0.10	-0.005	0.11
Gender of head (1=male; 0=female)	-0.003	0.97	-0.002	0.97	-0.003	0.96
Household size	0.004	0.56	0.003	0.61	0.003	0.62
Age of head (years)	0.003	0.21	0.003	0.19	0.003	0.20
Education attainment of head (# of years)	0.010	0.11	0.009	0.15	0.009	0.12
First stage population density residuals	0.009	0.00	0.012	0.00	--	--
_cons	0.425	0.57	-1.341	0.14	0.461	0.52
Direct partial effects	0.008		0.011			
Indirect partial effects	0.004		-0.065		0.004	
Total partial effects	0.012		-0.054			
Turning point: pop. density (persons/km^2)	397		417			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included

Similar results obtain when we consider households' intensity of fertilizer use (Table 3.11). The intensity of fertilizer use per hectare cultivated increase is also a nonlinear increasing function of population density reaching a maximum at about 400 persons per km^2 and declining thereafter. The APEs however show that while increasing population density increases fertilizer use when we use the standard population density variable, using the GRUMP definition population density actually reduces fertilizer intensification.

An increase in the standard population density by 100 persons per km^2 increases fertilizer application intensity both directly and indirectly by about one percent. While increasing population density increases fertilizer use intensities directly when we use the GRUMP population density, the negative indirect effects of the increasing population density through other avenues such as input and output prices crowds out the positive direct effects.

(ii) Effects of population density on factor output supply: Crop intensification defined as crop production per hectares owned increases with the population density up to 710 and 1164 persons per km^2 in the first and second model, respectively, and thereafter drops (Table 3.12). In the first model, an increase in population density by 100 persons per km^2 increase mean crop production per hectare by about 11 percent directly and by two percent indirectly through the effects of increasing population density on prices and landholding sizes. A similar increase in population density increases smallholder crop intensification by 19 percent, directly, and four percent, indirectly, in the second model. A similar picture emerges when we consider intensification defined as crop production per hectare cultivated (Table 3.13). The only differences are that the crop intensification turning points occur at slightly lower population density levels and the APEs are slightly smaller too in this case. Besides population density, and input and output prices, other factors that influence crop production intensification include the amount of rainfall received, ownership of a radio that proxy access to information and to a certain extent capture households asset wealth, and household head's education attainment.

Table 3.12: CRE estimation results for net crop production per hectare owned

	model I		model II		model III	
Dep. var: log crop output kg/ha owned	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.276	0.00	--	--	--	--
Standard population density square	-0.019	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.269	0.00	--	--
GRUMP population density square	--	--	-0.012	0.00	--	--
Expected maize price (KSh/kg)	0.036	0.04	0.052	0.00	0.059	0.00
Land owned (ha)	-0.259	0.00	-0.261	0.00	-0.260	0.00
Wage rate ('00Ksh/day)	0.010	0.53	-0.008	0.62	-0.004	0.81
Land rental rates ('000Ksh/ha)	-0.052	0.04	-0.045	0.08	-0.044	0.08
DAP price (KSh/50kg)	0.000	0.96	0.002	0.72	0.001	0.80
Rainfall '00mm	0.030	0.09	0.032	0.07	0.036	0.04
Rainfall stress	-0.110	0.49	-0.075	0.63	-0.053	0.74
Own radio (1=yes; 0=no)	0.147	0.00	0.145	0.00	0.146	0.00
Distance to motorable road (km)	-0.002	0.65	-0.002	0.58	-0.003	0.54
Gender of head (1=male; 0=female)	0.070	0.28	0.069	0.29	0.072	0.27
Household size	-0.009	0.24	-0.010	0.19	-0.010	0.19
Age of head (years)	0.002	0.49	0.002	0.49	0.002	0.45
Education attainment of head (# of years)	0.014	0.04	0.013	0.07	0.013	0.06
First stage population density residuals	0.027	0.27	-0.077	0.04	--	--
_cons	6.145	0.00	6.258	0.00	3.539	0.00
Direct partial effects	0.105		0.188			
Indirect partial effects	0.022		0.035		0.022	
Total partial effects	0.127		0.223			
Turning point: pop. density (persons/km^2)	710		1164			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	
R squared	0.65		0.65		0.65	

Note: Time averages of time varying variables, naïve expectation, and survey year and agroecological zone dummies included

Table 3.13: CRE estimation results for net crop production per hectare cultivated

	model I		model II		model III	
Dep. var: log crop output kg/ha	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.249	0.00	--	--	--	--
Standard population density square	-0.018	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.233	0.00	--	--
GRUMP population density square	--	--	-0.012	0.00	--	--
Expected maize price (KSh/kg)	0.031	0.05	0.932	0.00	0.059	0.00
Land owned (ha)	-0.053	0.01	-0.054	0.01	-0.054	0.01
Wage rate ('00Ksh/day)	-0.027	0.05	0.013	0.39	-0.014	0.35
Land rental rates ('000Ksh/ha)	-0.052	0.03	-0.045	0.05	-0.045	0.04
DAP price (KSh/50kg)	0.002	0.69	0.003	0.59	0.003	0.56
Rainfall '00mm	0.028	0.10	0.030	0.08	0.034	0.05
Rainfall stress	-0.133	0.37	-0.095	0.52	-0.074	0.62
Own radio (1=yes; 0=no)	0.104	0.01	0.098	0.02	0.103	0.01
Distance to motorable road (km)	-0.002	0.65	-0.003	0.53	-0.003	0.51
Gender of head (1=male; 0=female)	0.011	0.85	0.013	0.84	0.013	0.83
Household size	0.005	0.48	0.004	0.55	0.004	0.58
Age of head (years)	0.003	0.30	0.003	0.24	0.003	0.26
Education attainment of head (# of years)	0.013	0.04	0.011	0.07	0.012	0.06
First stage population density residuals	0.024	0.22	-0.042	0.16	--	--
_cons	6.946	0.00	5.123	0.00	4.657	0.00
Direct partial effects	0.089		0.149			
Indirect partial effects	0.004		-0.062		0.004	
Total partial effects	0.094		0.087			
Turning point: pop. density (persons/km^2)	686		982			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included

The smallholder farm output intensification as measured by gross farm production (crop and livestock) per hectare controlled is also a nonlinear but increasing function of population density (Table 3.14). It increases with population density up to 670 and 1144 persons per km^2 in the first and the second model, respectively, and drops thereafter. Increase in population density

100 persons per km^2 directly increases mean gross farm intensification by eight and three percent directly and indirectly, respectively, in the first model. In the second model, a similar increase in population density triggers a 14 percent (directly) and a four percent (indirectly) growth in smallholder farm intensification.

Table 3.14 CRE estimation results for gross farm production per hectare owned

	model I		model II		model III	
Dep. var: log farm output KSh/ha owned	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.233	0.00	--	--	--	--
Standard population density square	-0.017	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.196	0.00	--	--
GRUMP population density square	--	--	-0.009	0.01	--	--
Expected maize price (KSh/kg)	0.032	0.04	0.040	0.01	0.045	0.00
Land owned (ha)	-0.311	0.00	-0.313	0.00	-0.312	0.00
Wage rate ('00Ksh/day)	-0.057	0.00	-0.040	0.01	-0.044	0.01
Land rental rates ('000Ksh/ha)	-0.010	0.63	-0.003	0.88	-0.003	0.88
DAP price (KSh/50kg)	-0.003	0.55	-0.001	0.80	-0.002	0.72
Rainfall '00mm	-0.005	1.00	0.020	0.88	0.052	0.70
Rainfall stress	-0.013	0.92	0.013	0.92	0.033	0.78
Own radio (1=yes; 0=no)	0.169	0.00	0.167	0.00	0.168	0.00
Distance to motorable road (km)	-0.003	0.75	-0.003	0.70	-0.005	0.58
Gender of head (1=male; 0=female)	0.031	0.56	0.030	0.57	0.032	0.54
Household size	-0.017	0.01	-0.018	0.01	-0.018	0.01
Age of head (years)	0.003	0.21	0.003	0.22	0.003	0.19
Education attainment of head (# of years)	0.011	0.08	0.010	0.12	0.010	0.11
First stage population density residuals	0.036	0.10	-0.005	0.09	0.040	0.00
_cons	7.351	0.00	7.352	0.00	5.395	0.00
Direct partial effects	0.080		0.136			
Indirect partial effects	0.027		0.044		0.027	
Total partial effects	0.107		0.179			
Turning point: pop. density (persons/km^2)	670		1144			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included.

Table 3.15: CRE estimation results for net farm production per hectare owned

	model I		model II		model III	
Dep. var: log farm output KSh/ha owned	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.257	0.00	--	--	--	--
Standard population density square	-0.020	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.183	0.00	--	--
GRUMP population density square	--	--	-0.008	0.03	--	--
Expected maize price (KSh/kg)	0.036	0.04	0.049	0.01	0.053	0.00
Land owned (ha)	-0.288	0.00	-0.291	0.00	-0.290	0.00
Wage rate ('00Ksh/day)	-0.050	0.00	-0.033	0.04	-0.036	0.03
Land rental rates ('000Ksh/ha)	-0.022	0.37	-0.014	0.55	-0.014	0.57
DAP price (KSh/50kg)	-0.013	0.80	0.034	0.95	-0.010	0.98
Rainfall '00mm	-0.003	0.86	0.004	0.98	0.003	0.84
Rainfall stress	-0.215	0.13	-0.175	0.21	-0.161	0.25
Own radio (1=yes; 0=no)	0.122	0.00	0.121	0.00	0.122	0.00
Distance to motorable road (km)	0.004	0.67	0.005	0.60	0.007	0.50
Distance to tarmac road (Km)	-0.001	0.83	-0.001	0.74	-0.002	0.71
Gender of head (1=male; 0=female)	0.067	0.30	0.066	0.30	0.068	0.29
Household size	-0.010	0.17	-0.011	0.13	-0.011	0.13
Age of head (years)	0.004	0.16	0.004	0.15	0.004	0.14
Education attainment of head (# of years)	0.014	0.04	0.013	0.04	0.014	0.05
First stage population density residuals	0.031	0.19	-0.048	0.17		
_cons	7.449	0.00	7.166	0.00	5.357	0.00
Direct partial effects	0.084		0.126			
Indirect partial effects	0.025		0.040		0.025	
Total partial effects	0.109		0.165			
Turning point: pop. density (persons/km^2)	654		1128			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included.

Similar results obtain when we consider farm intensification defined as net farm output per hectare owned (Table 3.15) and per hectare cultivated (Table 3.16). Smallholder farm intensification attain maximum at nearly the same population density thresholds and the APEs are comparable in terms of sign and magnitude. Other important factors that are associated with high farm intensification are household's ownership of radio, smaller household's sizes, and households headed by highly educated individuals.

Table 3.16: CRE estimation results for net farm production per hectare cultivated

	model I		model II		model III	
Dep. var: log farm output KSh/ha cultivated	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.231	0.00	--	--	--	--
Standard population density square	-0.018	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.129	0.00	--	--
GRUMP population density square	--	--	-0.006	0.05	--	--
Expected maize price (KSh/kg)	0.029	0.05	0.045	0.00	0.051	0.00
Land owned (ha)	-0.056	0.00	-0.058	0.00	-0.057	0.00
Wage rate ('00Ksh/day)	-0.071	0.00	-0.056	0.00	-0.058	0.00
Land rental rates ('000Ksh/ha)	-0.024	0.28	-0.018	0.43	-0.017	0.45
DAP price (KSh/50kg)	0.001	0.79	0.003	0.57	0.002	0.62
Rainfall '00mm	0.039	0.79	-0.004	0.98	0.019	0.90
Rainfall stress	-0.199	0.14	-0.158	0.24	-0.143	0.29
Own radio (1=yes; 0=no)	0.085	0.04	0.083	0.04	0.084	0.04
Distance to motorable road (Km)	-0.001	0.95	-0.001	0.84	-0.001	0.80
Gender of head (1=male; 0=female)	0.010	0.86	0.010	0.87	0.011	0.85
Household size	0.005	0.43	0.004	0.52	0.004	0.52
Age of head (years)	0.005	0.04	0.005	0.04	0.005	0.03
Education attainment of head (# of years)	0.013	0.04	0.012	0.06	0.012	0.05
First stage population density residuals	0.035	0.07	0.027	0.02	--	--
_cons	8.231	0.00	7.669	0.00	6.443	0.00
Direct partial effects	0.070		0.083			
Indirect partial effects	0.005		0.005		0.004	
Total partial effects	0.074		0.088			
Turning point: pop. density (persons/km^2)	630		994			
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included.

(iii) Effects of population density on household income: The aggregate household income per adult equivalent is an increasing but a nonlinear function of the standard population density (Table 3.17). It increases with population density reaching a maximum level at 450 persons per km^2 and falls thereafter. The household aggregate income reaches its maximum point at a relatively lower population density threshold compared to that of crop and farm output thresholds. Looking at the APEs, increasing population density generally reduces aggregate household income. An increase in population density by 100 persons per km^2 increases mean household income directly by less than one percent.

However, this positive effect is wiped out by the negative two percent indirectly population density effect transmitted through the influence of population density on prices and landholding. Conversely, household income is a straightforward declining function of the GRUMP population density. An increase in GRUMP population density by 100 persons per km^2 reduces household's mean income directly by four percent and indirectly by three percent.

There are also other important factors that determine the level of aggregate household incomes. These include access to information, distances to input and output markets, and household demographic variables. While ownership of a radio increases household mean income by about 22 percent, increased distances to motorable roads reduce income by about two percent. A switch from male to female headship reduces household income by 21 percent while an additional year in the education attainment of the household head increases household income by about two percent. Relatively smaller households have higher incomes compared to larger ones.

Table 3.17: CRE estimation results for household aggregate income per adult equivalent

	model I		model II		model III	
Dep. var: log income (KSh)/adult equivalent	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.143	0.00	--	--	--	--
Standard population density square	-0.016	0.00	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	-0.037	0.02	--	--
Expected maize price (KSh/kg)	0.022	0.18	0.021	0.20	0.022	0.17
Land owned (ha)	0.190	0.00	0.188	0.00	0.189	0.00
Wage rate ('00Ksh/day)	-0.021	0.14	-0.032	0.02	-0.030	0.03
Land rental rates ('000Ksh/ha)	-0.048	0.01	-0.043	0.03	-0.043	0.02
DAP price (KSh/50kg)	-0.009	0.06	-0.008	0.10	-0.008	0.10
Rainfall '00mm	-0.015	0.27	-0.010	0.45	-0.010	0.46
Rainfall stress	-0.057	0.63	-0.024	0.84	-0.016	0.89
Own radio (1=yes; 0=no)	0.218	0.00	-0.218	0.00	0.219	0.00
Distance to motorable road (km)	-0.018	0.04	0.019	0.02	-0.019	0.02
Gender of head (1=male; 0=female)	0.206	0.00	0.206	0.00	0.207	0.00
Household size	-0.100	0.00	-0.101	0.00	-0.101	0.00
Age of head (years)	0.022	0.93	0.029	0.91	0.032	0.90
Education attainment of head (# of years)	0.023	0.00	0.023	0.00	0.023	0.00
First stage population density residuals	0.068	0.00	0.018	0.59	0.012	0.44
_cons	9.338	0.00	8.738	0.00	9.236	0.00
Direct partial effects	0.003		-0.037			
Indirect partial effects	-0.017		-0.030		-0.017	
Total partial effects	-0.014		-0.067			
Turning point: pop. density (persons/km^2)	450					
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included.

Next we examine the effect of population density on off-farm income (Table 3.18). Surprisingly, the results show that off-farm income per adult equivalents is not a function of population density. Increasing population density only influences off-farm income indirectly through its effects on household landholding sizes.

Table 3.18: CRE estimation results for household off-farm income per adult equivalent

	model I		model II		model III	
Dep. var: log off-farm income (KSh)/ae	Coef.	P>z	Coef.	P>z	Coef.	P>z
Population density (100 pp/sq km) [Standard]	0.012	0.61	--	--	--	--
Population density (100 pp/sq km) [GRUMP]	--	--	0.014	0.73	--	--
Expected maize price (KSh/kg)	-0.015	0.49	-0.013	0.55	-0.013	0.54
Land owned (ha)	0.112	0.00	0.112	0.00	0.112	0.00
Wage rate ('00Ksh/day)	-0.017	0.61	-0.017	0.61	-0.018	0.60
Land rental rates ('000Ksh/ha)	-0.006	0.84	-0.006	0.85	-0.006	0.85
DAP price (KSh/50kg)	0.003	0.68	0.003	0.68	0.003	0.68
Rainfall '00mm	0.025	0.22	0.025	0.22	0.025	0.22
Rainfall stress	0.221	0.20	0.224	0.20	0.221	0.20
Own radio (1=yes; 0=no)	0.122	0.02	0.122	0.02	0.122	0.02
Distance to motorable road (km)	-0.020	0.11	-0.021	0.10	-0.020	0.10
Distance to tarmac road (Km)	-0.001	0.80	-0.001	0.79	-0.001	0.80
Gender of head (1=male; 0=female)	0.418	0.00	0.418	0.00	0.418	0.00
Household size	-0.067	0.00	-0.067	0.00	-0.067	0.00
Age of head (years)	-0.009	0.01	-0.009	0.01	-0.009	0.01
Education attainment of head (# of years)	0.022	0.02	0.022	0.02	0.022	0.02
First stage population density residuals	-0.014	0.62	-0.009	0.84	-0.004	0.85
_cons	10.082	0.00	9.991	0.00	9.796	0.00
Indirect partial effects	-0.010		-0.016		-0.010	
Observations	5845		5845		5845	
Number of households	1169		1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and survey year and agroecological zone dummies included.

An increase population density by 100 persons per km^2 reduces household's mean off-farm income indirectly by one percent in the first model and by two percent in the second model. Generally, it seems household off-farm income is explained more significantly by household's access to information and demographic variables. Ownership of a radio increases household non-farm income by about 12 percent while a switch from male to female headship reduces off-farm income by about 42 percent in the first and second models. Similarly, relatively smaller households, those headed by younger persons and by persons with high education attainment earn more off-farm income.

While it was hypothesized that a variety of off-farm income earning opportunities would emerge as land becomes a binding constraint in the densely populated areas, this doesn't seem to be the case. To the contrary, off-farm income declines with shrinking household farm sizes. While qualitative evidence gathered during the fieldwork showed some evidence of emergence of some new off-farm activities, these activities are very low paying "poverty jobs". The emerging non-farm activities include sale of second hand clothes (*mitumba*) within the villages; cellphone money transfer services (*M-Pesa*); cellphone repairing and battery charging; buying of old household items -- scrap metal; bicycle passenger transport (*boda-boda*) services; and repairing and hawking of household utensils (*mali-mali*).

(iv) Effects of population density on smallholder commercialization: We conclude this section by examining the effects of increasing population density on smallholder diversification and commercialization. The results from the fractional probit regression of the proportion of land allocated to non-maize crop are presented in Table 3.19. The results show that the proportion of land allocated to non-maize crop is an increasing but nonlinear function of population density (first model). The proportion increases with the GRUMP population density up to about 890 persons per km^2 and declines afterwards. This turning point occurs almost at the 90th percentile of the sample distribution. An increase in population density by 100 persons per km^2 increases the mean proportion of area allocated to non-maize crops directly by four percent and by two percent indirectly through the effects of the increasing population density on input factor and output prices and household landholding. A reduction in the expected maize prices by one shilling per kilogram is found to increase the proportion of land allocated to maize by about 0.013 while reduced maize price variability increases share of land allocated to maize.

Table 3.19: Fractional probit estimation results of land allocated to non-maize crop

Dep. var: Proportion of land allocated to non-maize crop	Model I		Model II	
	Coef.	APEs	Coef.	APEs
Population density (100 pp/sq km) [GRUMP]	0.196***	[0.046]	--	--
GRUMP population density square	-0.011***	[-0.003]	--	--
Expected maize price (KSh/kg)	-0.054***	[-0.013]	-0.081***	[-0.019]
Maize price variability	-0.008**	[-0.002]	-0.010***	[-0.002]
Land owned (ha)	-0.018	[-0.004]	-0.018**	[-0.004]
Wage rate ('00Ksh/day)	-0.026***	[-0.006]	-0.385**	[-0.091]
Land rental rates ('000Ksh/ha)	-0.013*	[-0.003]	-0.181**	[-0.043]
DAP price (KSh/50kg)	-0.010**	[-0.002]	-0.011**	[-0.003]
Rainfall '00mm	-0.003		-0.003	
Rainfall stress	-0.230*	[-0.054]	-0.251**	[-0.059]
Own radio (1=yes; 0=no)	0.061		0.055	
Distance to nearest fertilizer seller (km)	0.001		0.001	
Distance to motorable road (km)	-0.009		-0.006	
Household size	-0.012*	[-0.003]	-0.011**	[-0.003]
Age of the household head (years)	-0.001		-0.001	
Head education attainment (years)	0.002		0.003	
First stage population density residuals	0.002**		0.003**	
_cons	6.104**		0.553**	
Direct partial effects		[0.043]		
Indirect partial effects		[0.019]		[0.019]
Total partial effects		[0.062]		
Turning point: pop. density (persons/km^2)	890			
Observations	5845		5845	
Number of households	1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and region and survey year dummies included.

Other variables that influence the proportion of land allocated to non-maize crop include the price of DAP, expected rainfall shock as measured by a six-year moving average of the percentage of 20-day periods during the main growing season with less than 40 mm of rainfall, and household size. While increasing price of fertilizer and rainfall shocks reduce the proportion of land allocated to non-maize crop, relatively large family sizes reduces this proportion.

Table 3.20: Fractional probit estimation results for household crop commercialization

	Model I		Model II	
Dependent variable: HCCI	Coef.	APEs	Coef.	APEs
Population density (100 pp/sq km) [GRUMP]	0.198***	[0.047]	--	--
GRUMP population density square	-0.016***	[-0.004]	--	--
Expected maize price (KSh/kg)	0.011		-0.059***	[-0.014]
Maize price variability	-0.009***	[-0.002]	-0.010***	[-0.002]
Land owned (ha)	-0.029**	[-0.007]	-0.026**	[-0.006]
Wage rate ('00Ksh/day)	-0.030***	[-0.007]	-0.156	
Land rental rates ('000Ksh/ha)	-0.014**	[0.003]	-0.216**	[-0.051]
DAP price (KSh/50kg)	0.004		0.003	
Rainfall '00mm	0.004		0.007	
Rainfall stress	-0.039		0.032	
Own radio (1=yes; 0=no)	0.040		0.038	
Distance to nearest fertilizer seller (km)	-0.006***	[-0.002]	-0.007***	[-0.002]
Distance to motorable road (km)	-0.005**	[-0.001]	-0.013**	[-0.003]
Household size	-0.011		0.001	
Age of the household head (years)	0.004***	[0.001]	0.045***	[0.011]
Head education attainment (years)	0.006**	[0.002]	0.007	
First stage population density residuals	0.059**		0.029***	
_cons	-2.118**		-3.242***	
Direct partial effects		[0.043]		
Indirect partial effects		[0.004]		[0.004]
Total partial effects		[0.047]		
Turning point: pop. density (persons/km^2)	619			
Observations	5845		5845	
Number of households	1169		1169	

Note: Time averages of time varying variables, naïve expectation of other crop prices, and region and survey year dummies included.

From the farm output side, the proportion of marketed crop output as measured by the household crop commercialization index (HCCI) is also found to be a positive but nonlinear function of population density (Table 3.20). The HCCI increases with population density reaching a maximum at about 620 persons per km^2 in the first model, and declines thereafter. An increase in population density by 100 persons per km^2 increases the mean HCCI directly by about four percent and indirectly by less than one percent. The results also show that distances to input and output markets, and infrastructural facilities, and the age and the level of education of the household head influence smallholder crop commercialization. In the first model, crop commercialization appears to be relatively higher among the households headed by older persons, persons with high education attainment, and among households located at close proximity to markets.

What these results imply is that when households expect low and stable maize prices, they are able to put a greater proportion of their shrinking land to relatively high value. But this can only occur up to a certain population density threshold beyond which increasing population density has negative effects to smallholder commercialization. It should also be quickly pointed out that maize is considered a cash crop especially in the high potential maize region of the country.

3.8 Conclusions and policy implications

The overarching objective of this study was to examine how rising population pressure affects smallholders' production, commercialization and household incomes. Using data from five panel surveys on 1,169 small-scale farms over the 1997–2010 period, we use panel econometric techniques to determine how increasing rural population density is affecting farm household behavior and livelihoods. The estimation strategy deals with the potential endogeneity of population density in input demand and output supply equations using a two-stage control function approach. The study is motivated by the need to understand the nature and magnitude of emerging land constraints in African agriculture using Kenya as a case study.

The overall picture emerging from these results so far is that land is becoming an increasingly constraining factor of production and that smallholder agriculture farming practices in the areas of high population density are distinctly more land-intensive. Consequently, there is a rising strain on rural livelihoods in the densely populated rural areas due to land pressures and declining farm sizes. Inputs and output agricultural intensification, household incomes and smallholder commercialization rise with population density up to a certain threshold; beyond this point, rising population density is associated with sharp declines in agricultural input and output intensification.

The empirical results also show that smallholder farmers allocate more of their shrinking land to non-maize crop and sell a greater proportion of their production as population density increases. However, this can only feasible up to a certain population density threshold, beyond which increasing population density reduces smallholder commercialization. It seems farmers alter production patterns to make the best out of their shrinking land resource by switching to high value enterprises such as production of fresh fruits and vegetables, dairy and poultry products.

These results indicate that smallholder landholding sizes are gradually declining in Kenya as in much of sub-Saharan Africa. Currently about 14 percent of Kenya's rural population resides in areas exceeding the 600 persons per km^2 population density threshold. Another 20 percent of the rural population is fast approaching this threshold. The results also show that increased access to input markets, passable roads and other physical infrastructural facilities considerably influence the degree of smallholder production and commercialization.

Generally, these findings suggest that increased access to land will ensure that smallholder facing land size constraints are able to generate agricultural surpluses and consequently participate in agricultural output markets. Strategies to improve rural households' access to land will need to be not only on the country's land agenda, but also its food security and poverty reduction agendas. There is also some scope for promoting equitable access to land through land redistribution reforms to reduce landholding inequalities. A coordinated strategy of public goods and services investments in road infrastructure, schools, health care facilities, electrification and water supply would also be helpful in raising the economic value of arable land in the country that is relatively remote and still unutilized. The study also calls for redoubled public investment in the national agricultural research systems to focus on new farm land-saving technologies and practices appropriate for one-hectare farms or smaller.

APPENDIX

Table A3.1: Responses to population pressure and the conditioning variables

Response	Conditioning variables	Country examples
Demographic responses (e.g. postponed marriage, increase celibacy, contraception use, sterilization, abortions)	Availability of inexpensive modern contraceptives and sterilization; increased women education; women employment opportunities; cultural factors; age at marriage.	Puerto Rico; China; Taiwan
Extensification (more land brought into cultivation), land reforms	Availability of untapped cultivable land; land tenure systems; efficiency of land markets; existing infrastructure (transport and communication); unequal land distribution implying greater potential for land reforms; cultural factors.	Chile; Taiwan
Intensification (hybrid seeds, fertilizer and 'night soils'[17] use); irrigation	Existence of labor-intensive, land-saving technologies; institutional structure (access to credit for purchasing seeds, fertilizer); supply of surface or underground water.	Nigeria; Chile; China; Taiwan; Indonesia; Kenya
Switch from traditional crops; commercialization of agriculture	Soil and climatic conditions; availability of water; proximity to markets; state of physical infrastructure.	Senegal; Nigeria; Indonesia
Off-farm diversification and out-migration [rural-rural; rural-urban; out of the country]	Availability of off-farm rural employment opportunities; favorable macroeconomic policies for urban jobs creation; wide urban-rural wage differential (pull factor); immigration policies; information; education; cultural factors.	Uganda; Nigeria; Chile; Puerto Rico

Source: Summarized by the author from Bilsborrow (1987).

[17] Night soil refers to the use of human excrement collected at night as a fertilizer in China.

Figure A3.1: Photos contrasting Kalama Hills, Machakos District, Kenya

[a] 1936

Source: Norton-Griffiths (2008)

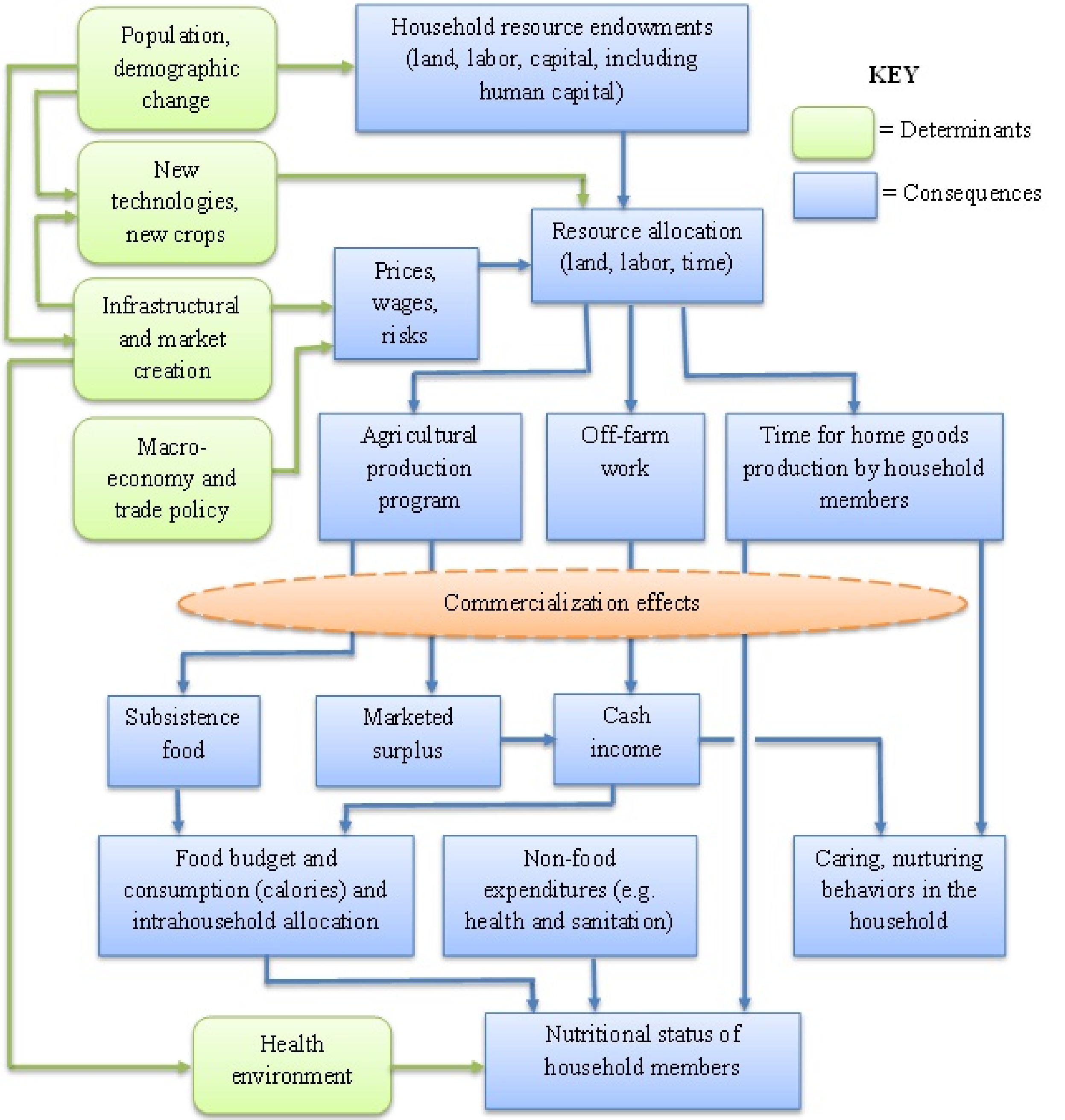
[b] 1989

Source: Norton-Griffiths (2008)

Table A3.2: Indices of agricultural commercialization

Index			Source
Commercialization of agriculture (output side)	=	Value of agricultural sales in markets/ agricultural product value	von Braun et al. 1994; Gabre-Madhin et al. (2007)
Commercialization of agriculture (input side)	=	Value of inputs acquired from market/ agricultural product value	von Braun et al. 1994
Commercialization of rural economy	=	Value of goods and services acquired through market transactions/ Total income	von Braun et al. 1994
Degree of integration into the cash economy	=	Value of goods and services acquired by cash transactions/ Total income	von Braun et al. 1994
Household crop commercialization	=	Gross value of crop sales/ Gross value of all crop production	Govereh et al. (1999); Strasberg et al. (1999); Gabre-Madhin et al. (2007)
Net-market position (sales)	=	sales/(volume of commodities stored at the beginning+ volume of commodities produced during season)	Gabre-Madhin et al. (2007)
Net-market position (purchases)	=	purchases/(volume of commodities stored at the beginning+ volume of commodities produced during season)	Gabre-Madhin et al. (2007)
Specialization	=	Value of purchased agricultural products not produced by household/ Gross value of agricultural production	Gabre-Madhin et al. (2007)

Figure A3.2: Determinants and consequences of smallholder commercialization



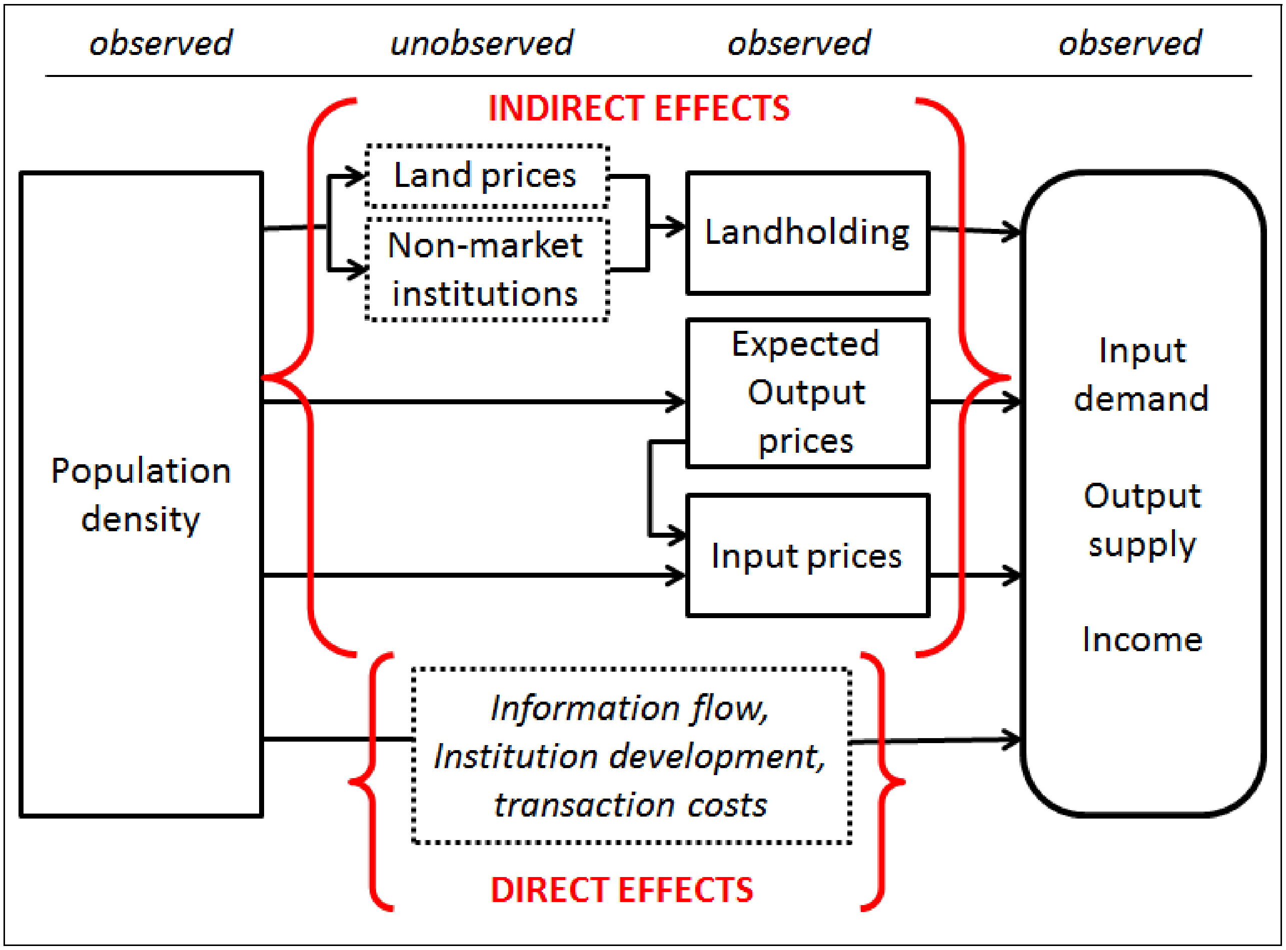
Source: von Braun et al. (1994) with some modification by the author

Table A3.3: Processes in agricultural commercialization

Level of market orientation	Farmers objective	Source of inputs	Product mix	Household income source	Human nutrition	Soil fertility
Subsistence system	Food self-sufficiency	Household generated (non-traded)	Wide range	Predominantly agriculture	Predominantly home produced	Farm yard manure
Semi-commercial system	Surplus generation	Mix of traded and non- traded inputs	Moderately specialized	Agricultural and non-agricultural	Home produced and purchased	Farm yard manure and chemical fertilizers
Commercial system	Profit maximization	Predominantly traded inputs	Highly specialized	Pre-dominantly non-agricultural	Predominantly purchased	Chemical fertilizers

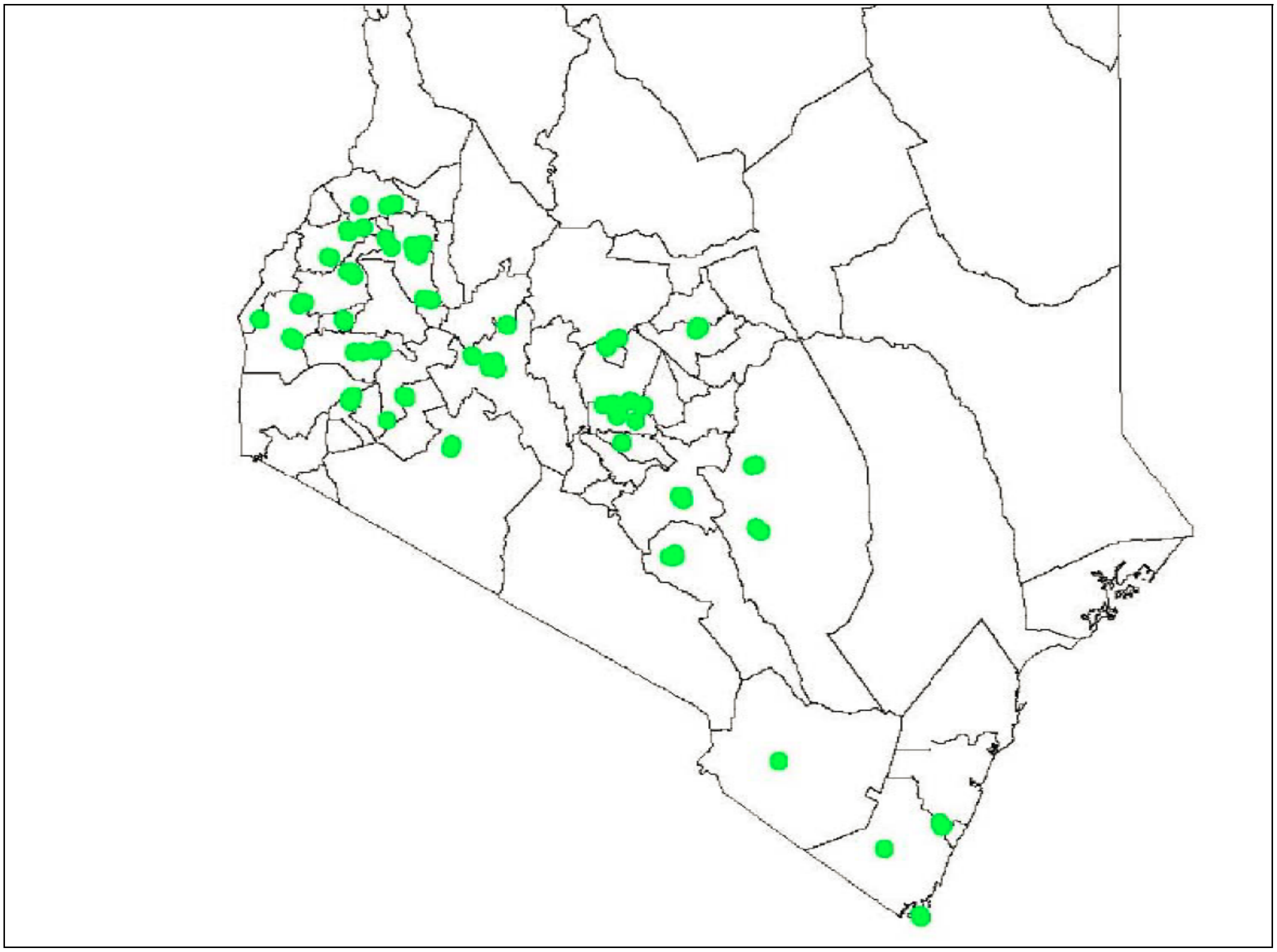
Source: Pingali (2001).

Figure A3.3: Effects of population density on smallholder production and income



Source: Chamberlin (2013)

Figure A3.4: Egerton University/Tegemeo Institute panel data households' locations



Source: Suri, 2005

Figure A3.5: Modified Fisher-Ideal Quantity Indices[18]

To aggregate crop production across multiple commodities, we use a modification of the Fisher-Ideal index by Mason (2011), which uses information on the individual household production (kg) and national-level prices of each crop in the crop group. The Fisher-Ideal (FI) index is a combination of two indices, the Modified Laspeyres Quantity Index (ML) and the Modified Paasche Quantity Index (MP) (Diewert 1992; Diewert 1993).

For each crop $j = 1$ to J, we use the national median production quantity as the base quantity in the denominator of both the ML and MP indices. We use the median national-level price in the first year of the Tegemeo panel household dataset (1997) as the base year price, $p_{j,base}$. Thus, changes in the ML index are driven by changes in quantities of each commodity produced over time, as prices do not vary from the base year, nor across households. For p_j in the MP index, we use the national median price for each year. Thus, the MP index allows price variation by year but not across households.

Modified Laspeyres Quantity Index (LQI*)

$$LQI^*_{i,t} = \frac{\sum_{j=1}^{J} q_{i,j,t}\, p_{j,base}}{\sum_{j=1}^{J} q^*_{j,base}\, p_{j,base}}$$

Modified Paasche Quantity Index (PQI*)

$$PQI^*_{i,t} = \frac{\sum_{j=1}^{J} q_{i,j,t}\, p_{j,t}}{\sum_{j=1}^{J} q^*_{j,base}\, p_{j,t}}$$

Fisher-Ideal Quantity Index (FIQI*)

$$FIQI^*_{i,t} = \sqrt{(LQI^*_{i,t} \times PQI^*_{i,t}}$$

18 Adapted from Mather and Jayne (2011).

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