PATTERNS, DETERMINANTS, AND WELFARE EFFECTS OF AGRICULTURAL AND LIVELIHOOD DIVERSIFICATION AMONG SMALLHOLDER FARMERS 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

2015

ABSTRACT

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Market-oriented economic reforms are now at least 20 years old in most of Sub-Saharan Africa (SSA). Prior to these reforms, most economies were fettered with far-ranging limits on investment, private sector trade, and other initiatives, and on the free movement of agricultural products over space. Kenya is a prime example of these earlier policies, with limits on maize marketing, agricultural inputs marketing and dairy marketing restrictions that were lifted through the reforms. Over this same time, urban populations and rural population densities have increased dramatically, further broadening the scope for trade. How have farm households responded to radically different economic environment?

Using a five-period panel data from Kenya collected between 1997 and 2010, this dissertation investigated the patterns, determinants and welfare effects of agricultural and livelihood diversification among smallholder farmers in rural Kenya. Even though determinants of smallholder diversification in Sub-Saharan Africa have been investigated, results have been mixed, and few studies have used longer panel data or incorporated weather uncertainty in the analysis. There is also knowledge gap concerning the welfare effects of smallholder diversification on household welfare indicators. This thesis uses a conceptual model relating household diversification of economic activities to the process of agricultural transformation.

The first essay examines the patterns and trends in smallholder livelihood diversification in rural Kenya and how these vary across types of households and spatially. The findings suggest that

Kenyan smallholders are still relatively diversified, suggesting that agricultural transformation in Kenya may still be in initial stages, despite key policy reforms of the 1980s and 2000s.

The second essay uses Fixed Effects Regression methods to investigate the key drivers of smallholder agricultural and livelihood diversification in the presence of weather uncertainty, and how these drivers differ among groups of rural households. Findings show that at higher rainfall stress levels, households adopt diversification as a strategy to mitigate the effects of drought diversification to mitigate against the adverse effects of drought. The study further shows that the least endowed households are most sensitive to these weather effects. Furthermore, smallholder diversification varies inversely with the distance to extension service.

The third Essay uses the Dynamic Panel Data method to investigate the effects of smallholder diversification on three measures of rural household welfare, namely, income, maize security, and wealth. The findings show that smallholder diversification can be used as a mitigating strategy against weather effects on household welfare. Furthermore, there are differential effects between groups of households.

To Rachel, Nicole, and Glenn Johnson

ACKNOWLEDGEMENT

First, I would like to express my utmost gratitude to my advisor Prof. David Tschirley for his support of my Ph.D. study at Michigan State University, and for his mentorship, and motivation His valuable guidance both before and during the Ph.D. program helped me during research and writing process and enabled me to complete the study. Besides my advisor, I would also like to sincerely thank members of my advisory and dissertation committees: Prof. Eric Crawford, Prof. Songqing Jin, Prof. Robert Richardson and Prof. Mathieu Ngouajio. Their comments were very valuable, insightful and thought-provoking. Special appreciation to Prof. Jin for his immense support and his help with the modeling and econometrics.

I would also like to thank the faculty and staff of the Department of Agricultural, Food and Resource Economics (AFRE), Michigan State University, especially the Graduate Chair Prof. Scott Swinton for timeless advice, support and guidance while navigating the Ph.D. study. A number of AFRE and Economics faculty were instrumental in the success of my study: Prof. John Staatz, Prof. Robert Myers, Prof. Roy Black, Prof. Brent Ross, Prof. David Schweikhardt, Prof. David Weatherspoon, Prof. Jeffery Wooldridge, Prof. Jack Meyer, Prof. Peter Schmidt, and Prof. Gary Solon. My special gratitude to Prof. Thomas Jayne and the entire AFRE Food Security Group for immense support and opportunity to be engaged in research while studying.

My sincere thanks to the leadership of Egerton University and the department of Agricultural Economics and Business Management for facilitating study leave to pursue my Ph.D. study, and for all the support I received while studying. I would like to sincerely thank Vice Chancellor Prof. James Tuitoek for his enormous support. My gratitude also goes to the past and present

leadership and staff at Tegemeo Institute of Agricultural Policy and Development. Specifically, I'd like to thank Dr. James Nyoro for his mentorship and support while at Tegemeo

I would also like to acknowledge and appreciate the scholastic and emotional support I received from my fellow student cohorts Dr. Ramziath Adjao, Dr. Nathalie Me-Nsope, Dr.Uchook Duangbootsee, Dr. Rie Muraoka, Dr. Helder Zavale, Prof. Jordan Chamberlain Dr. Vivek Pandey, Ms. Keneilwe Kgosikoma, Mr. Chewe Nkonde and Ms. Benchamaphorn Sombatthira among others. My special gratitude goes to my friend Prof. Milu Muyanga and his family for being there for me and with me through it all. I truly value all the support, encouragement and everything you did to me and my family.

My special gratitude to the University SDA Church, East Lansing church family under the leadership of Pastor David Shin. Thank you all for the prayers and spiritual and emotional support, and for strengthening our faith. Special appreciation my friends Bill and Geri Wilson for their steadfast love and prayers, and for opening their home to my family. I'd like to thank the Onyanchas, the Chotis, Zodwa Mcunu (Zulu Lady), the Dakas, the Ndovies, the Langenis, Jay and Nancy Crawford, the Burlingames, Vallery Bellas, Raymonde Balthazar, the Brooks, and the Boyce's among others.

Last but not least, I would like to thank my family who stood by me throughout the whole program. I want to thank my dear wife Prof. Rachel Ayieko, for her unwavering love, emotional support, and encouragement. I am also grateful to my children Nicole and Glenn, for all they had to go through while Rachel and I were students. They were our inspiration and motivation. I also appreciate the support I received from my siblings. Finally, my parents toiled so hard for my success but were not able to see the ultimate end. Thank you so very much for all the sacrifices.

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KEY TO ABBREVIATIONS

ABBREVIATION	KEY TO THE ABBREVIATION
2SLS	2-Stage Least Squares method
AEZs	Agro-ecological zones
CDF	Cumulative Density Function
CRE	Correlated Random Effects method
FAO	Food and Agriculture Organization
FD	First-Difference method
FE	Fixed Effects method
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
HCDA	Horticultural Crop Development Authority
IMF	International Monetary Fund
IV	Instrumental Variable
KALRO	Kenya Agricultural and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KCC	Kenya Cooperative Creameries
KDB	Kenya Dairy Board
KENFAP	Kenya National Federation of Agricultural Producers
KFA	Kenya Farmers Association
KMC	Kenya Meat Commission
KNFU	Kenya National Farmers Union

ABBREVIATION	KEY TO THE ABBREVIATION
KSA	Kenya Sugar Authority
KTDA	Kenya Tea Development Authority/Agency
NCPB	National Cereal and Produce Board
NIB	National Irrigation Board
OLS	Ordinary Least Squares method
PBK	Kenya Pyrethrum Board
RE	Random Effects method
SAPs	Structural Adjustment programs
SSA	Sub-Saharan Africa

CHAPTER 1

PATTERNS AND TRENDS OF CROP, AGRICULTURAL AND LIVELIHOOD DIVERSIFICATION AMONG SMALLHOLDER FARMERS IN RURAL KENYA

1.1 Introduction and study rationale

In many developing countries, agriculture has remained the main source of livelihood for many rural households. In Kenya, for example, the sector directly contributes 25% of the Gross Domestic Product (GDP) and a further 27% through linkages with other sectors of the economy. About four-fifths of the country's population reside in the rural areas and rely on agriculture for their livelihoods. In addition, nearly nine in ten poor households live in rural areas, where food insecurity and poverty are main challenges (Government of Kenya, 2009). Nearly 80% of farmers in Kenya are smallholders, who are faced with a myriad of challenges ranging from production to access to markets. Sound policies are therefore necessary to support this large group of farmers.

Given agriculture's importance to the economy, the Kenyan government has often pursued agricultural and livelihood diversification policies aimed at increasing rural incomes, eradicating rural poverty, and achieving rural and national food security. Major agricultural policy reforms in Kenya took place in the 1980s and 2000s, and were intended to open up the markets and thus spur growth in the agricultural sector (Odhiambo, Nyangito, & Nzuma, 2004).

Development theory suggests that in the absence of well-functioning markets, households produce mainly for self-sufficiency and the agricultural sector are mainly small-scale, with most households engaging entirely or primarily in the production of a range of staple foods for home consumption. However, as markets become available and households participate in both input and output markets, and as countries experience high population densities coupled with

urbanization and income growth, the agricultural sector is expected to undergo a transformation process (Timmer, 1988), a process by which individual farms shift from a largely diversified, subsistence-oriented production, towards more-specialized production that is oriented towards the market (Staatz, 1999).

The ubiquity of smallholder farming means that many governments must find a way to make it productive if farmers are to get out of poverty. This is often achieved through policy reforms. Government policies and programs have also been shown to influence the agricultural transformation and farm-level diversification/specialization. In Punjab, for example, Singh & Sidhu, (2004) showed that policy shifts that favored the introduction of high-yielding wheat and rice varieties in the 1960s resulted in a sharp decline in crop diversification and the emergence of wheat-rice specialization. The agricultural policy reforms initiated in the 1980s and 1990s (commonly referred to as Structural Adjustment Programs (SAPs)) by the World Bank and the International Monetary Fund (IMF) in Africa, were designed to spur growth in agriculture towards a more transformed sector (Odhiambo et al., 2004). In the presence of sustained population growth, urbanization, and income growth witnessed in many developing countries, and the associated increased availability and lower cost of food in markets, these policy reforms were expected to have ushered in agricultural transformation and the specialization that it implies.

While there exists well-documented evidence in Asian countries (Delgado & Siamwalla, 1997; Pingali, 1997; Timmer, 1997), there is agreement by researchers that agricultural transformation has not occurred in Africa to the magnitude experienced in Asia (McMillan & Headey, 2014). In Kenya, for example, questions abound regarding whether the policy reforms have elicited the anticipated agricultural transformation. For example, has there been empirical evidence of a

decline in smallholder household diversification that is expected to accompany agricultural transformation, either at the crop, agricultural and livelihood level, and, can these changes be linked to the policy reforms of the 1980s and early 2000s? What are the patterns of smallholder crop, agricultural and livelihood diversification over time nationally and regionally, and what share of rural smallholder households have diversified or specialized between 1997 and 2010? Furthermore, what are the characteristics of households that have become more specialized?

The overarching objective of this study is to examine the patterns and trends in rural livelihood portfolios and how these patterns and trends vary across types of households as well as spatially. The study examines the trends and patterns of the household crop, agricultural and livelihood diversification between 1997 and 2010, a period when many agricultural policy reforms took place. Specifically, the study:

a) Examines the empirical patterns and trends of farm-household diversification with respect to crops, broader agriculture (including livestock), and still broader livelihoods following the policy reforms in Kenya.
b) Investigates the empirical pattern of crop, agricultural and livelihood diversification over time nationally and regionally and estimate the share of households (i) diversifying, (ii) remaining the same and (iii) specializing.
c) Describes the characteristics of households that have diversified, remained the same or specialized over the study period.

The rest of the chapter is organized as follows. The next sub-section presents the study objectives, followed by a discussion of the conceptual model that explains the relationship between agricultural transformation and smallholder diversification and provides a linkage between farm-level household diversification, agricultural production, and economy-wide food

consumption. Section 1.2 discusses the agricultural transformation in Asia and lessons learned while Section 1.3 presents a summary of agricultural policy reforms in Kenya. A brief discussion of the expected patterns and trends is also presented. Methods and data sources for the study are discussed in section 1.4 while the study results are presented in section 1.5. Finally, Section 1.6 presents the discussion of findings and policy implications of the study.

1.2. Agricultural transformation process: Conceptual framework

A few important distinctions can be made regarding smallholder diversification. First, diversification can be economic or spatial. Economic diversification refers to diversification in economic activities at different levels of the economy, while spatial diversification, on the other hand, is diversification in economic activities over distinct units in space (such as village, county or agro-ecological zone) (Kimenju & Tschirley, 2008; Timmer, 1988, 1997). Singling out economic diversification, three distinct levels can be identified: at the overall economy, agricultural sector and farm household. A clear specification of the level at which economic diversification is analyzed is, therefore, important. Finally, at the farm household level, diversification can be analyzed at three levels: crop diversification (diversification in crop agriculture); agricultural diversification, which is diversification in the broader agricultural (crop and livestock) activities; and, livelihood diversification including crop, livestock, and non-farm activities.

A number of studies have examined the linkages between agricultural transformation, commercialization and diversification, and showed that during the pre-transformative stages of agricultural transformation process, when households produce mainly for subsistence, households tend to be highly diversified (Delgado & Siamwalla, 1997; Kurosaki, 2003;

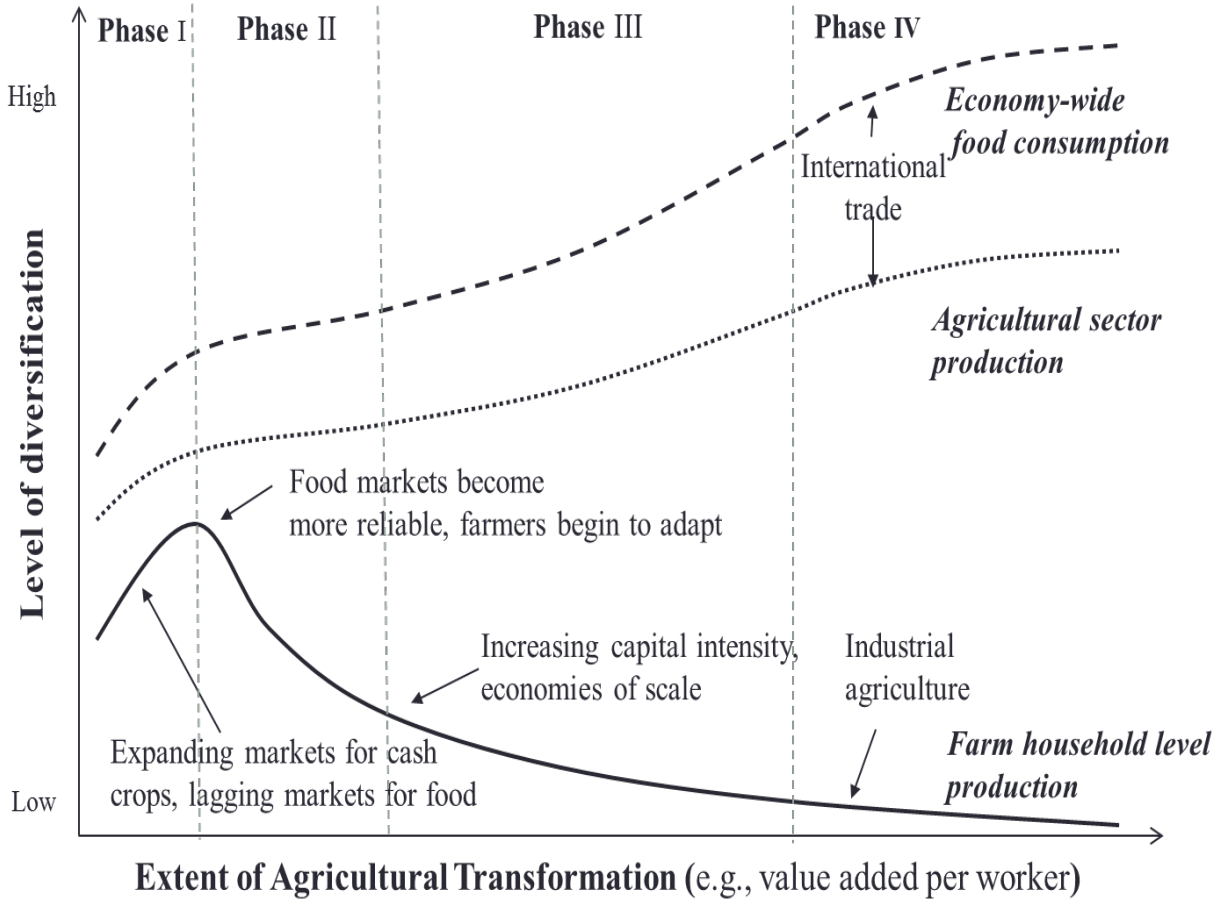
Pattanayak & Nayak, 2003; Timmer, 1997). However, as product and financial markets expand and rural incomes grow, more specialized in their cropping activities, and the agricultural system becomes more commercialized: there is a shift from traditional subsistence production to production for the market. This leads to diversity in marketed products at the national level, accompanied by farm-level and regional specialization (Pingali, 1997; Pingali & Rosegrant, 1995). These patterns were witnessed in the 1970s and early 1980s in Eastern and Southeastern Asian countries (Delgado & Siamwalla, 1997; Pingali, 1997; Timmer, 1997). In Southeast Asia for example, Pingali (1997) showed that economic growth, urbanization and the withdrawal of labor from the agricultural sector led to the increasing commercialization and specialization of agricultural systems.

Thus, a transformed agricultural sector is characterized by households that are more specialized in their agricultural activities, rather than diversified (Timmer, 1997). Two features related to the specialization of economic activities characterize a transformed agricultural sector. First, households increasingly specialize in economic activities in which they can generate the highest returns. Second, spatial distribution of production becomes more concentrated – spatial diversification falls - in accordance with agro-ecological potential and proximity to markets (Staatz, 1999). The degree of the household crop, agricultural and livelihood diversification can, therefore, be used to gauge whether agricultural transformation has occurred in an economy. Agricultural transformation also shifts focus from subsistence agriculture to a more market-oriented production, and this has the effect of diversifying rural livelihoods and improving household food security (Barrett, Reardon, & Webb, 2001; Delgado & Siamwalla, 1997; Timmer, 1988, 1997). Timmer (1988), for example, suggests that, as a country progresses

through the process of agricultural transformation, households move towards specialization into one or a few crops.

A conceptual model illustrating the expected relationship between agricultural transformation and farm-level production, sector-level agricultural production, and economy-wide consumption is displayed in Figure 1.

Figure 1. Conceptual model for agricultural transformation and economic diversification



Source: Adapted from Timmer (1988) and Kimenju & Tschirley, (2008)

A country's agricultural transformation process can be divided into four phases depending on the level of diversification. Each phase is determined by, among other factors, a combination of population growth, income growth, market development, and the country's agricultural policy reform process. At the farm household level (Figure 1, lower line), Phase I is characterized by an initial sharp increases in diversification, followed by increasing specialization of individual farm production (Kimenju & Tschirley, 2008; Timmer, 1988, 1997). In this phase, diversification increases, driven primarily by the expanding markets for cash crops and for the sale of food crops. Markets for staple foods show sluggish development compared to cash crops in this phase mainly for two reasons. First, staples have a lower value per weight than cash crops, implying higher relative transactions costs and hence less potential for trade. This tends to restrict the scope of trade in staples relative to higher value cash crops. In addition, while cash crops have markets beyond the local and regional realms, staples are mainly traded locally, and often, investments tend to favor the cash crops. In this phase, the government tends to restrict trade in staple crops because they are at the core of food security. Also, farmers take a long time to trust the availability of food for purchase in rural markets, so while they might sell, they don't want to buy. In addition, the wedge between sales and purchase prices tend to be quite large in the early stages, making it economically to continue producing most of their staple foods. Thus, with a less developed market for staple foods, smallholder farmers in the early stages of the agricultural transformation are likely to become more diversified as they add cash crops and traded livestock products to their portfolio while attempting still to produce all their staple food needs (Kimenju & Tschirley, 2008). Towards the end of Phase I, farm level diversification (bottom line) peaks and then begins a declining trend, ushering in Phase II.

The second phase is characterized by increased reliability of food markets, and farmers beginning to adapt to the changing markets and economic conditions. Two forces are at play in this phase. First, the increased trade and agricultural labor productivity drive household incomes up. Farmers begin to purchase food while pursuing off-income activities. Second, as food markets become more reliable, i.e., as food for purchase becomes reliably available, and the wedge between the purchase and selling prices becomes lower, households find it beneficial and less costly to participate in the market as buyers. Agricultural productivity generates surplus towards the development of the non-agricultural sector (Briones & Felipe, 2013). Taken together, these factors are likely to lead to increased specialization at the farm-level as farmers engage in economic activities for which they have a comparative advantage.

With time, farmers start to become more capital-intensive (Briones & Felipe, 2013; Kimenju & Tschirley, 2008) as the Phase III of the agricultural transformation sets in. Agriculture at this stage is increasingly linked to the rest of the economy due to improved physical (road) and market infrastructure, leading to falling physical marketing and transaction costs. This opens up regions that were erstwhile previously unreachable. Eventually, this phase ushers in the final phase (Phase IV) of the agricultural transformation process, in which agriculture is successfully integrated with the rest of the economy.

Even as individual farm households become more specialized over farmers over the course of agricultural transformation (Phases II–IV), a more diversified production is expected at the agricultural sector level (Figure 1, middle line), driven by rising incomes and changing consumer preferences that allow a more diverse diet. Thus, as incomes and urbanization increase, consumers diversify their consumption beyond staple crops into fresh fruits and vegetables, animal products and processed products, and, broader agricultural production becomes more

diversified than production on individual farms. Also, the economy-wide consumption (Figure 1, top line) becomes more diversified as markets allow for regional and international trade to complement domestic production. Thus, the trajectory for agricultural transformation in developing countries is characterized by more specialization at the farm household level, and a more diversified agricultural sector and economy-wide consumption

1.3 The Asian experience

The transformation of agriculture in Asia appears to have followed the conceptual model presented above. Many East (except China) and Southeast (Malaysia, Indonesia, and Thailand) Asian countries underwent agricultural transformation in the late 1980s. These countries experienced rising agricultural share of GDP relative to that of employment, as the returns to labor in agriculture rose relative to those in the rest of the economy, driven by the exit of labor from the agricultural sector and technology change in agriculture. In addition, there was increasing land and labor productivity relative to developing regions, significant yield improvements, and a shift from low-value commodity mix to high-value products (Briones & Felipe, 2013; Joshi, Gulati, Birthal, & Tewari, 2004). The transformation process was triggered by forces of demand and supply (Pingali, 1997). On the demand side, these countries experienced a rapid increase in incomes that led to diversification in food demand, thereby creating opportunities for commercialized agriculture.

On the supply side, there was increased urbanization leading to labor scarcity at the rural level. This, coupled with diminishing per capita land sizes, meant that subsistence agriculture had to give way to a more transformed sector that could meet the increasing urban food demand (Pingali & Rosegrant, 1995). As the economies continued to grow, subsistence agriculture

became uneconomical, and households increasingly began to rely on markets for their food demand. Also, because of increasing opportunity cost of family labor, households engaged more in off-farm and non-farm economic activities (Pingali & Rosegrant, 1995). These forces, and the changing policy environment that encouraged a market-oriented approach to agricultural growth, and the improved physical and market infrastructure opened up the rural economies to more market opportunities, thereby resulting in more diversified overall agricultural production and consumption, and more specialized regional and farm-level agricultural production.

Thus, the Asian agricultural transformation was largely driven by a supportive policy environment, infrastructure (markets and roads) development and technological improvements. Lessons from the Asian experience suggest that specialization can happen when the economic conditions are right. While some scholars argue that the process of agricultural transformation is a stylized process, its rate differing by continents and countries (Pingali, 1997), others question if the same experience can be replicated in other parts of the developing world (e.g., (Ellis, 2005).

1.4 Kenya's policy reforms and agricultural transformation

Kenyan agricultural policy reforms after independence took a path that can be categorized into two regimes: (i) period of government controls (1964 – early 1980s), and (ii) the period of decontrols (1980s and beyond). The period following independence ushered in a set of policies contained in the *Sessional Paper No. 10 of 1965 on African Socialism and its Implication to Planning in Kenya* (Republic of Kenya, 1965) that provided for government intervention in nearly all agricultural production and marketing. Based on the need for political equality, social justice and human dignity following the end of colonial rule, the key tenets of this policy paper were equitable income distribution, employment creation, and self-sufficiency. Under this

regime, the government determined the crops to promote, and created incentive structures (pricing and marketing) favoring those commodities. Private trade of essential commodities over space was inhibited, and full private provision of agricultural inputs was restricted. State-run organizations were created to support the production and marketing of key commodities and supply agricultural inputs. These included, among others, the National Cereals and Produce Board (NCPB) for marketing maize and other cereals, the Kenya Tea Development Authority (KTDA) for marketing of tea, the Kenya Co-operative Creameries (KCC) for marketing milk, the Horticultural Crop Development Authority (HCDA) for promotion of export horticulture, and the National Irrigation Board (NIB) for promotion of irrigated crops.

Commodity boards were also established to promote the production and marketing of key commodities, including the Cotton Board of Kenya, Pyrethrum Board of Kenya (PBK), the Kenya Sugar Authority (KSA), the Kenya Dairy Board (KDB), and the Kenya Meat Commission (KMC). Several cooperative societies were established to support the procurement of agricultural inputs and marketing of the commodities and these were further affiliated under the Kenya National Farmers' Union (KNFU, later renamed the Kenya National Federation of Agricultural Producers (KENFAP). The Kenya Farmers Association (KFA) was also set up to provide agricultural inputs (Odhiambo et al., 2004). Also, the government heavily supported the investment in agricultural research and extension and production of seed for key commodities and controlled the foreign exchange market. Because private sector participation and commodity flow were limited by government policies, surpluses from one region could not efficiently fill deficits in other regions. Therefore, the ability of farmers to pursue profitable opportunities was restricted (Delgado & Siamwalla, 1997).

Beginning in the early 1980s, the World Bank and the International Monetary Fund (IMF) recommended an array of policies aimed at reducing government controls and encouraging private sector participation. The Structural Adjustment Programs (SAPs) were a set of market liberalization policies reducing price decontrols and promoting private sector participation in the marketing of agricultural products and inputs. In response to these recommendations, the government proposed key policy reforms spelled out in the *Sessional Paper No. 1 of 1896 on Economic Management for Renewed Growth* (Republic of Kenya, 1986), to allow for gradual removal of price controls and market liberalization. In the new proposals, the role of government was to provide an enabling policy and regulatory environment for enhanced private sector participation.

Key agricultural policy reforms during this period included the elimination of nearly all staple price controls, legalization of private trade (both domestic and regional), a more limited role of parastatals in the grain trade, and removal of nearly all input and other price subsidies. For example, maize marketing was fully liberalized in 1994, which paved the way for free movement of maize within the country and regionally. The foreign exchange sector was liberalized in 1998 allowing for flexible exchange rates. Also, the government liberalized the agricultural input market in 2001, which brought changes to the importation and local distribution of fertilizer and other agricultural inputs and resulted in demonstrably greater access among farmers. There has also been increased research and development initiatives aimed at the availability of, and increased access to, high-quality seed and planting materials. The livestock sector was also liberalized between 1988 and 1992, allowing for private processing of milk among other changes (Odhiambo et al., 2004). It has been shown that these reforms have led to greater availability and lower prices of food staples in retail markets (Jayne & Jones, 1997).

Besides the policy reforms, there has been a relatively steady growth in per capita incomes of 3% per year (growth was lower in the 1990s, but the 1980s were comparable to 2000s). Large and long-term investments in agricultural research through the creation of the Kenya Agricultural and Livestock Research Organization (KALRO, formerly the Kenya Agricultural Research Institute (KARI)) and support to other national agricultural research systems (such as universities) have occurred with the aim of increasing productivity to address the increasing demand occasioned by rapid population growth, urbanization and incomes.

The country's current economic blueprint, the Vision 2030 aims to transform the country into a middle-income economy by the year 2030 (Republic of Kenya, 2007). The Vision emphasizes the importance of agriculture and recognizes that in order to transform agriculture, there ought to be yield increases and smallholder specialization. In addition, the Vision calls for the formulation of land policies that emphasizes the utilization of unutilized lands, infrastructure development and institutional reforms to make it easier to do business.

All these reforms were expected to have set in place the process of agricultural transformation in Kenya. However, the extent to these policy reforms may have influenced agricultural transformation has not been adequately investigated. This study, is, thus an attempt to examine how rural smallholder farmers responded to the policy reforms.

1.5 Methods and data sources

1.5.1 Measuring diversification: The Herfindahl Diversification Index

According to (Gollop & Monahan, 1991), a well-designed index of diversification should have the following three key characteristics. First, it should vary directly with the number of different products produced or economic activities engaged in. Second, it should vary inversely with the

increasingly unequal distribution of products across product lines. Third, it should be bounded between 0 and 1. The Herfindahl Index has been used to measure diversification. The general specification of the index is given in equation (1).

$$D_k = 1 - \sum_{i=1}^{N} \left(S_{i,k}\right)^2 \quad (1)$$

where,

D_k= the Herfindahl Diversification Index for economic unit *k*,

$S_{i,k}$ = to the share of the total income from economic activity *i* for the economic unit k,

$\sum_{\mathrm{i=1}}^{\mathrm{N}} \left(\mathrm{S_{i,k}}\right) = 1$ and,

N = the total number of economic activities.

The Herfindahl Index meets all the conditions above. First, it is bounded between 0 and 1, with 0 indicating complete specialization while 1 implies complete diversification. A household with only one economic activity derives all its income from that activity. As a result, $D_k = 0$, implying complete specialization. As the number of income sources or economic activities for the household increase, the share of each activity in the household income, $S_{i,k}$, declines and the diversification index D_k increases. At the extreme, when there are many economic activities contributing to household income, each with a small share of the total income, D_k approaches 1.

The Herfindahl index is also sensitive to the distribution of the income sources or economic activities (Gollop & Monahan, 1991). For example, for a farm household producing three products each contributing an equal share to the total household income, the diversification index

will be 0.67. On the other hand, if one of these products contributes, say, 90% of the total income while the remaining two each contributes 5%, the diversification index will be 0.19. Thus, the greater the number and the more unequal the distribution of the product shares, the less diversified the income and the lower the diversification index, D_k.

Besides estimating the diversification index, another useful indicator that allows for spatial comparisons is the Cumulative Density Function (Tolley & Pope, 1988). For a real-valued random variable X with a known probability function, the Cumulative Density Function (CDF) describes the probability that X has a value less than or equal to some stated value, x, i.e.,

$$F_X(x) = Prob(X \leq x) \quad (2)$$

According to this theory, F_X stochastically dominates another distribution G_X in the first-order if and only if,

$$F_X(x) \leq G_X(x) \; for \; all \; x, \quad (3)$$

with a strict inequality over some interval. Alternatively, F_X second-order stochastically dominates another distribution G_X if and only if,

$$\int_{-\infty}^{c} F_X(x)dx \leq \int_{-\infty}^{c} G_X(x)dx \;\; for \; all \; c, \quad (4)$$

with a strict inequality over some interval. For this study, CDF plots were produced to compare regional differences in diversification.

1.5.2 Types of household diversification

Three measures of economic diversification were computed: crop, agricultural, and livelihood diversification. Crop diversification was computed from the gross household revenue shares of eight broad crop groups, namely, (i) maize (ii) other cereals (iii) pulses, (iv) roots and tubers, (v) vegetables, (vi) fruits, (vii) industrial and cash crops and, (viii) other crops (e.g., fodder). Agricultural diversification index was computed from the eight crop groups above in addition to four livestock groups, namely, (ix) cattle and cattle products, (x) goats, sheep and pigs, (xi) poultry, and (xii) other livestock/livestock products. Finally, to obtain the livelihood diversification index, four non-farm categories, namely, (xiii) salaried employment, (xiv) informal business, (xv) remittances and (xvi) farm *kibarua* (casual labor on other farms) were added to the agricultural categories above (i to xii).: Gross revenue for each of the categories were computed and used to generate the appropriate Herfindahl Diversification Index for each of the three types of diversification and survey period.

1.5.3 Estimation and analysis

This study adopted a descriptive approach to examine how diversification at various levels (crop, agricultural or livelihood) varies across households over time and space. The analysis was carried out at regional and household subgroups levels. Households were grouped by gender of household head, quartiles of income, and quartiles of acreage cultivated. Diversification patterns and trends were analyzed, first, for the whole sample, and then, for groups of households and comparisons made for each type of smallholder diversification.

In addition, households were grouped into three categories based on their change in diversification over the study period, namely, whether they had become “more diversified”,

showed no change in the diversification index, or became "more-specialized" [1] over the survey period. Shares of households in each of the categories for relevant type of diversification were computed, and their characteristics were examined. Cumulative density functions (CDF) plots for each of the zones were graphed for each of the three types of diversification to show regional differences in changes in diversification over the study period.

Based on the policy reforms in Kenya that began in the 1980s and continued into early 2000s, and the subsequent economic environment in the country resulting from these reforms, a number of patterns were hypothesized. First, it is assumed in this study that, the policy reforms, together with income growth, urbanization, and population growth, may have ushered in a transformed agricultural sector. With this in mind, the hypotheses made here assume the country has passed Phase I. with higher household incomes, availability of markets and increasing rural population densities, households would increasingly become more specialized in their livelihoods during the study period. Specifically, it was expected that households would move away from food self-sufficiency to relying on the market for household consumption. In addition, household incomes would increasingly be derived from off-farm and non-farm sources.

Second, it was hypothesized that, due to agricultural policy reforms, households would become more specialized at the cropping activity level. Some households, especially those in the country's grain basket, would be more specialized in cereal production. Others, especially those in arid and semi-arid areas, would specialize in livestock production while yet others would be

[1] For purposes of this study, a farm household was considered to be more diversified (less specialized) if its 2007 – 2010 mean index was greater than the 1997 – 2000 mean index by more than 10 percentage points. Similarly, a farm household was categorized as more specialized (less diversified) if its 2007 – 2010 mean index was less than the 1997 – 2000 mean index by more than 10 percentage points. A household with a change of less than or equal to 10 percentage points in absolute terms was considered to have registered no change in its diversification status, hence maintained the status quo.

specialized in industrial crops and other high-value crops. Thus, maize production would be more concentrated in areas that have the comparative advantage of producing maize. Other crops would also follow this pattern.

Third, it was also hypothesized that trends in diversification and specialization would be influenced by population densities. It was expected regions with higher population densities would experience more specialization as labor migrates to the urban centers. In addition, areas close to major urban centers, and areas with better infrastructure and access to services would experience specialization.

1.5.4 Data sources

This study uses the Kenya rural household rural survey dataset collected by Egerton University's Tegemeo Institute of Agricultural Policy and Development. This is a five-wave panel household dataset covering a period of 13 years collected in 1997, 2000, 2004, 2007 and 2010. Each survey had a one-year recall period. Sampling was based on eight (8) distinct agro-ecological zones (AEZs). A total of 24 districts, 39 divisions, and 120 villages were included in the study. The initial sample comprised 1500 households. As of 2010 when the last survey was conducted, the sample was down to 1309, representing an attrition rate of nearly 11% (Table 5). Causes of attrition included household dissolution, migration from the study area, non-contact and refusal to be interviewed. Of the 1309 households that were surveyed in 2010, 1301 participated in all five panel waves. Questionnaire remained fairly stable over the last four surveys, enabling consistent capture of the household and demographic changes over time. A detailed description of the survey design and implementation is found in Argwings-Kodhek (1998).

1.6 Study findings

1.6.1 Household revenue shares

Table 1 displays the smallholder household crop, livestock and off-farm gross revenue shares in Kenya in 1997 and 2010. Over the entire sample, crop income accounted for 45% of the household gross revenue in 2010, compared to 41% in 1997. On the other hand, off-farm and livestock income in 2010 accounted for 36% and 19%, respectively, down from 37% and 22% in 1997. Despite being well below estimates in earlier studies (e.g., (Bryceson & Jamal, 1997; Reardon, 1997), these statistics affirm that crop income is the dominant source of household revenue among the smallholder farm household in rural Kenya, and that long-run crop shares of gross household revenue may have increased between 1997 and 2010. Both livestock and off-farm income shares registered marginal declines over the same period.

Table 1. Contribution of crop, livestock and off-farm activities to gross household revenue of rural smallholder farmers in Kenya, by agroecological zone

	Crop income		Livestock income		Off-Farm income	
Agro-ecological Zone	1997	2010	1997	2010	1997	2010
	---------- % of gross household revenue ----------					
Coastal Lowlands	14	25	7	8	80	67
Eastern Lowlands	25	36	17	11	58	52
Western Lowlands	37	49	19	14	45	37
Western Transitional	52	56	22	15	26	29
High Potential Maize Zone	50	38	25	29	25	33
Western Highlands	47	54	23	18	30	28
Central Highlands	43	52	24	18	33	29
Marginal Rain Shadow	23	26	29	21	48	52
Overall	41	45	22	19	37	36

Across agro-ecological regions, the results show that crop share of gross household revenue increased in all regions with the exception of the High Potential Maize Zone (HPMZ). For

instance, Coastal Lowlands recorded an 80% crop share growth, from 14% in 1997 to 25% in 2010. Eastern Lowlands and Western Lowlands zones also registered large crop share growth over the study period. On the other hand, crop shares in the HPMZ declined by nearly one-quarter, from 52% in 1997 to 38% in 2010. A closer scrutiny of the crop shares reveal that cereals accounted for nearly two-fifths (38%) of the gross household crop revenue (Table 7), and maize alone accounted for about one-third of total gross household revenue. Fresh produce and industrial crops contributed one-quarter (24%) and 16%, respectively. Overall, crop share increased from 41% in 1997 to 45% in 2010, and this might have been attributed to increases (Figure 16).

The share of livestock income shows a decline from the 1997 levels. In 1997, livestock income accounted for more than one-fifth of gross household revenue, but this declined to 19% in 2010. Only two regions (HPMZ, and Coastal Lowlands) had growth in livestock share of smallholder gross revenues while the rest registered declines (Table 1). In the HPMZ, livestock share of gross revenue grew by 15%, from 25% in 1997 to 29% in 2010. Coastal Lowlands, on the other hand, registered a marginal increase in livestock shares from 7% to 8%. In both these zones, the dominant livestock activity is dairy production. The Eastern Lowlands, Western Transitional, and Marginal Rain Shadow zones, respectively, experienced the largest decline in livestock share of gross household revenue over the study period

While crop agriculture remains the dominant household income source for most smallholder households in rural Kenya, off-farm income accounts for nearly two-fifth (36%) of total household revenue and this remained fairly stable over the survey period. With the exception of the Western Transitional, the HPMZ, and the Marginal Rain Shadow zones, off-farm income declined in all other agro-ecological zones between 1997 and 2010 (Table 1). Among the off-

farm activities, salaries and informal activity are the main sources of household income (Table 10). Notably, salary income has the same share as the informal business income, each accounting for 14% of the gross revenue. Remittances and labor away from own-farm are a small proportion of household revenue and together account for less than a tenth of the household income.

In the next section, we examine the smallholder diversification pattern among smallholder farmers in rural Kenya.

1.6.2 Smallholder diversification patterns in Kenya

An examination of the smallholder diversification trends in rural Kenya between 1997 and 2010 suggest that rural households in Kenya still are fairly diversified in their crop, agricultural and livelihood activities, with all diversification indices over the study period averaging more than 0.50 on a scale of 0 to 1 (Table 2). For all categories of smallholder diversification, there is a general slump in the diversification indices between 1997 and 2000, perhaps due to the 1998/99 drought which affected the broader agricultural production (World Food program, 2000), Between 2000 and 2004, there was a modest increase in smallholder diversification indices. Crop and broader agricultural diversification indices peaked at 0.59 and 0.65, respectively, in 2004 and remained fairly stable thereafter. Livelihood diversification also peaked at 0.65 in 2007 and stabilized thereafter. These aggregate trends suggest no firm movement, on average, by rural farm households towards specialization in cropping or broader agriculture. These results may be surprising, and are a departure from the similar trends recorded in parts of East and Southeast Asia, where increased diversification in the initial phases was followed by increased specialization (Delgado & Siamwalla, 1997; Pingali, 1997; Timmer, 1997). In the next few

sections, the study investigates if there could be evidence of any subgroups of household, either demographically or geographically, that have shown tendencies towards specialization

Table 2. Crop, agricultural and livelihood diversification indices in Kenya, 1997 – 2010

	Category of smallholder diversification		
Year	Crop	Agricultural	Livelihood
1997	0.59	0.63	0.64
2000	0.57	0.60	0.62
2004	0.60	0.65	0.64
2007	0.59	0.65	0.65
2010	0.59	0.64	0.65
Overall	0.59	0.63	0.64

1.6.3 Regional differences in smallholder diversification patterns

Although the overall trends suggest no evidence of the onset of specialization associated with agricultural transformation, regional patterns show variations in smallholder diversification trends. For example, the High Potential Maize Zone (HPMZ), Eastern Lowlands and Western Lowlands had an initial increase in crop diversification between 1997 and 2004, followed by a period of decline, suggesting that for these zones, farmers may have begun to specialize (Figure 2). Other zones such as the Western Highlands, Western Transitional, Western Lowlands and Central Highlands, on the other hand, showed an initial decline in crop diversification before an upward trend. These patterns are mirrored in the agricultural and livelihood diversification.

The HPMZ – the most productive area in the country – is the most specialized of any zone in crop and overall agriculture (crop and livestock) production, and became more so in 2010 (this is more clearly seen in Figure 3).

Results show that agricultural diversification sharply dropped in HPMZ between 2004 and 2007, and this coincides with the period of highest maize yields, suggesting that specialization in this

region is driven by greater emphasis on cereal crop production (Table 7). On the other hand, Western Highlands is the most diversified of any zone in all the three categories of diversification estimated. The Coastal Lowlands is the most livelihood-specialized of all zones and may have become more specialized between 2000 and 2007 (Figure 4). It has the lowest diversification index among all the regions in the study. It registered a sharp decline in the diversification index between 2000 and 2004, remained stable before increasing between 2007 and 2010. Notably, coastal region is the country's tourist hub and its economy is largely driven by the tourism industry. Evidence seems to suggest that when the tourism sector thrives, for instance, during the period between 200 and 2007, households tend to be livelihood-specialized, deriving nearly70% of the gross revenues from off-farm activities (informal business and salaries alone account for more than 60% of the gross household revenue). The period following the disputed 2007 general elections affected the tourist industry and may have led to increased livelihood diversification as households suffered income losses from off-farm activities. Though not the only reason, the diversification trends in the Coastal Lowlands tend to be driven by the tourism industry. Only two other zones, the High Potential Maize, and Eastern Lowlands show increased specialization between 2007 and 2010.

Figure 2. Trends in smallholder crop diversification in Kenya by regions, 1997 – 2010

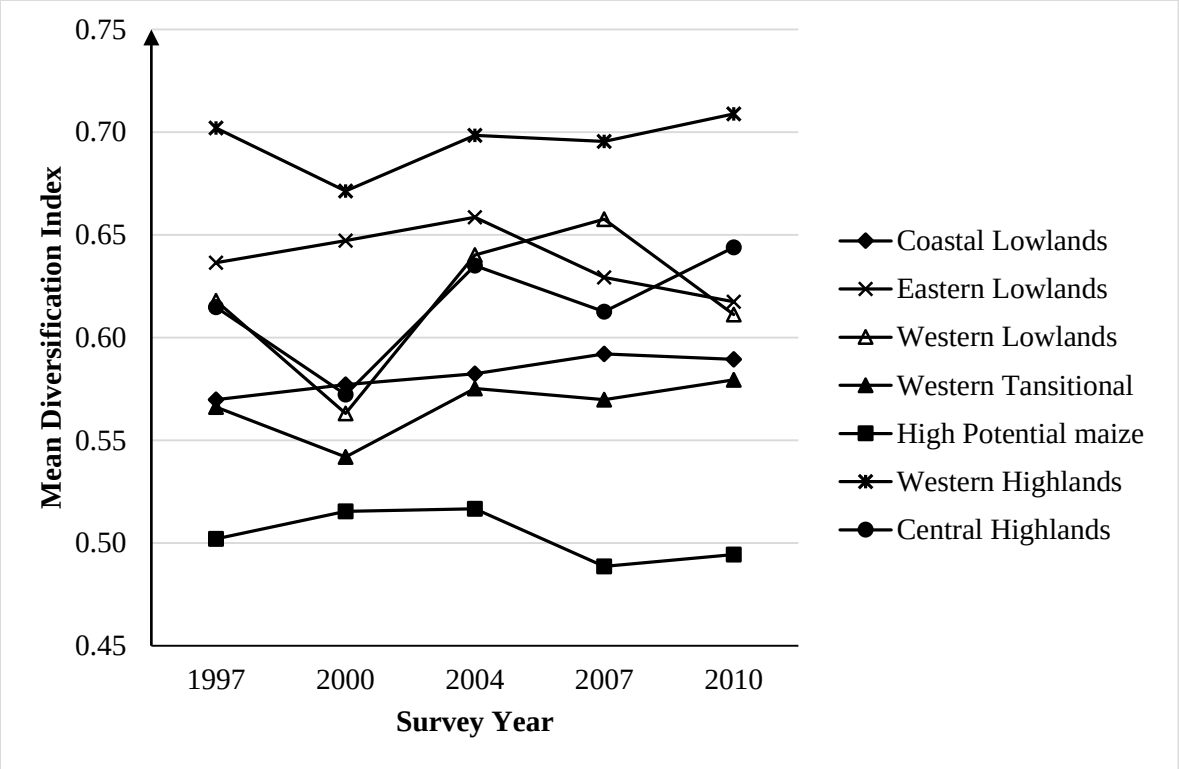


Figure 3. Trends in smallholder agricultural diversification in Kenya by region, 1997 - 2010

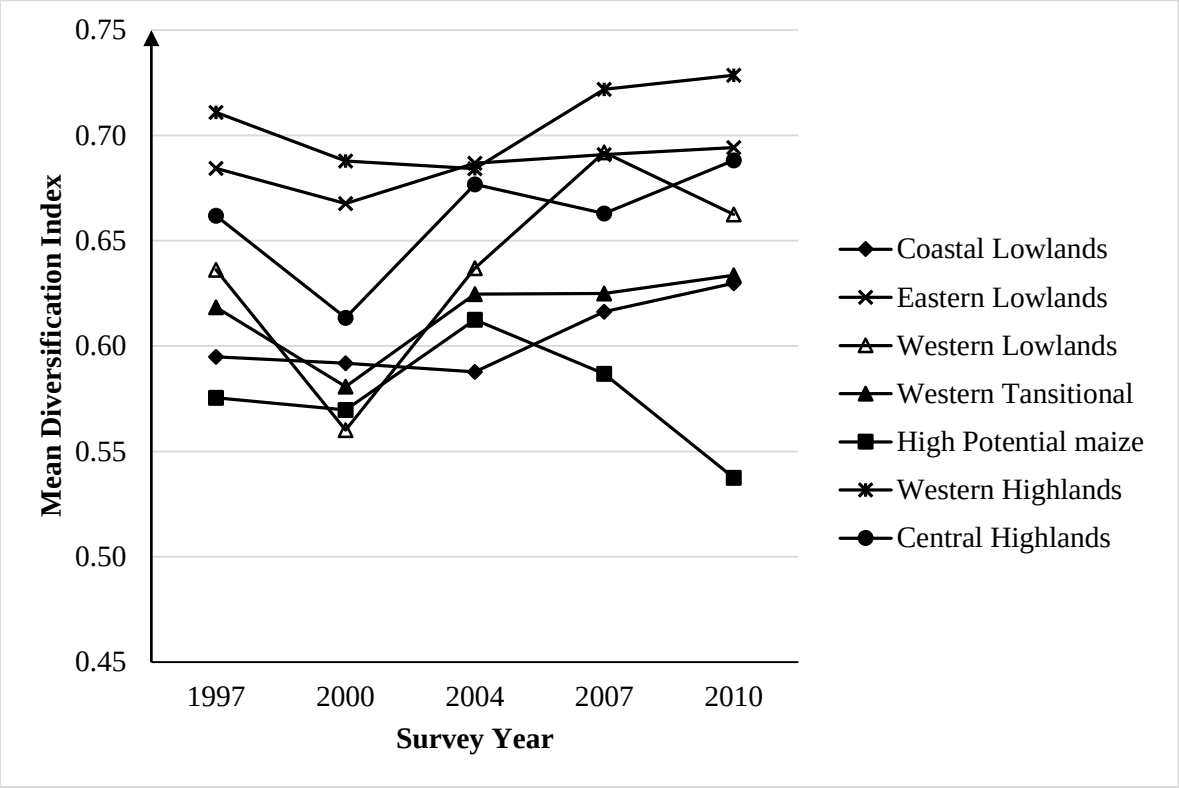
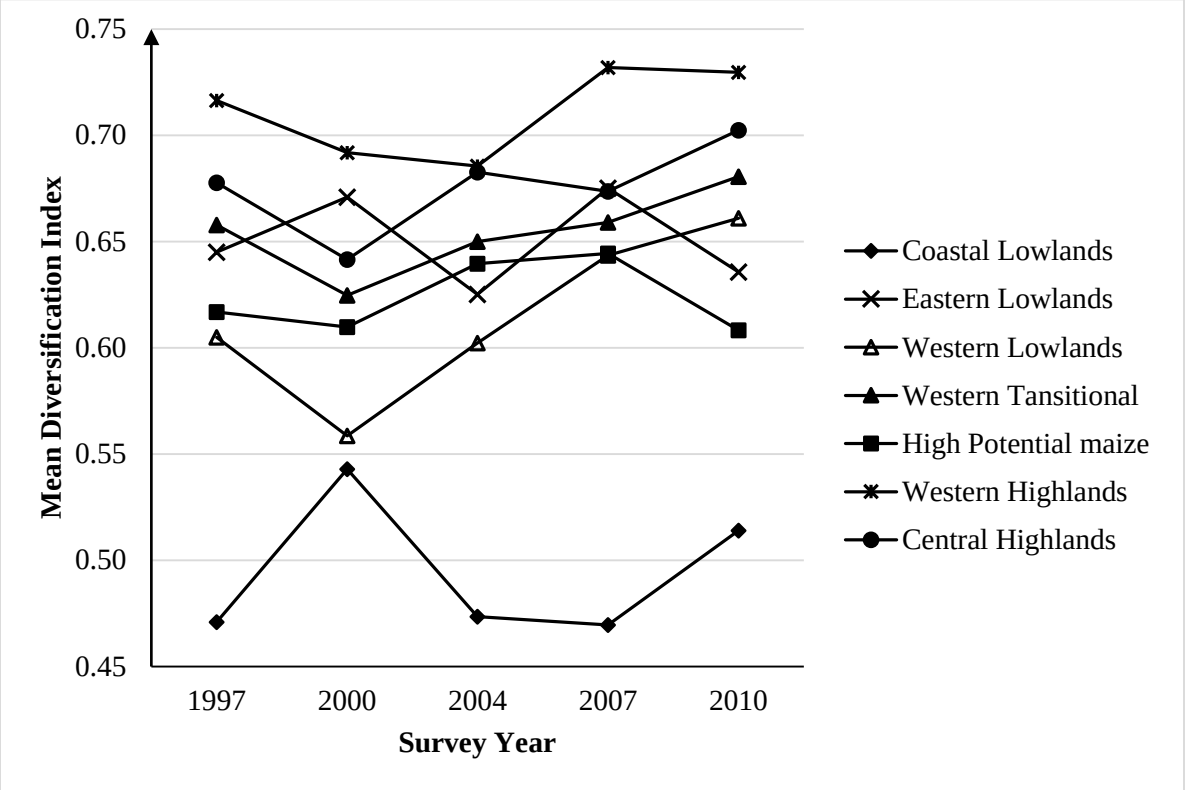


Figure 4. Trends in smallholder livelihood diversification in Kenya by region, 1997 – 2010



The CDF plots[2] for the various agro-ecological zones at given levels of diversification are presented in Figure 5. The figure shows the stochastic dominance of certain regions compared to others. First-order stochastic dominance is indicated by curves that lie below and to the right of other curves. On the other hand, second-order stochastic dominance is indicated by the curve that lies below and to the right over some range. From the plots, it can be observed that, for all the three diversification levels, the CDF curve for Western Highlands lies far to the right of and below all other curves, implying that it has first-order stochastic dominance in all the three diversification measures compared to other regions, This suggests that households in this zone are the most diversified of any other region.

[2] The cumulative density functions for each agro-ecological zone was computed from pooled data for all the survey years. In addition, yearly CDF were also compute and the graphs are presented in Figure 17 to Figure 19

Figure 5. Cumulative density function (CDF) plots of regional differences in smallholder diversification in Kenya, all years

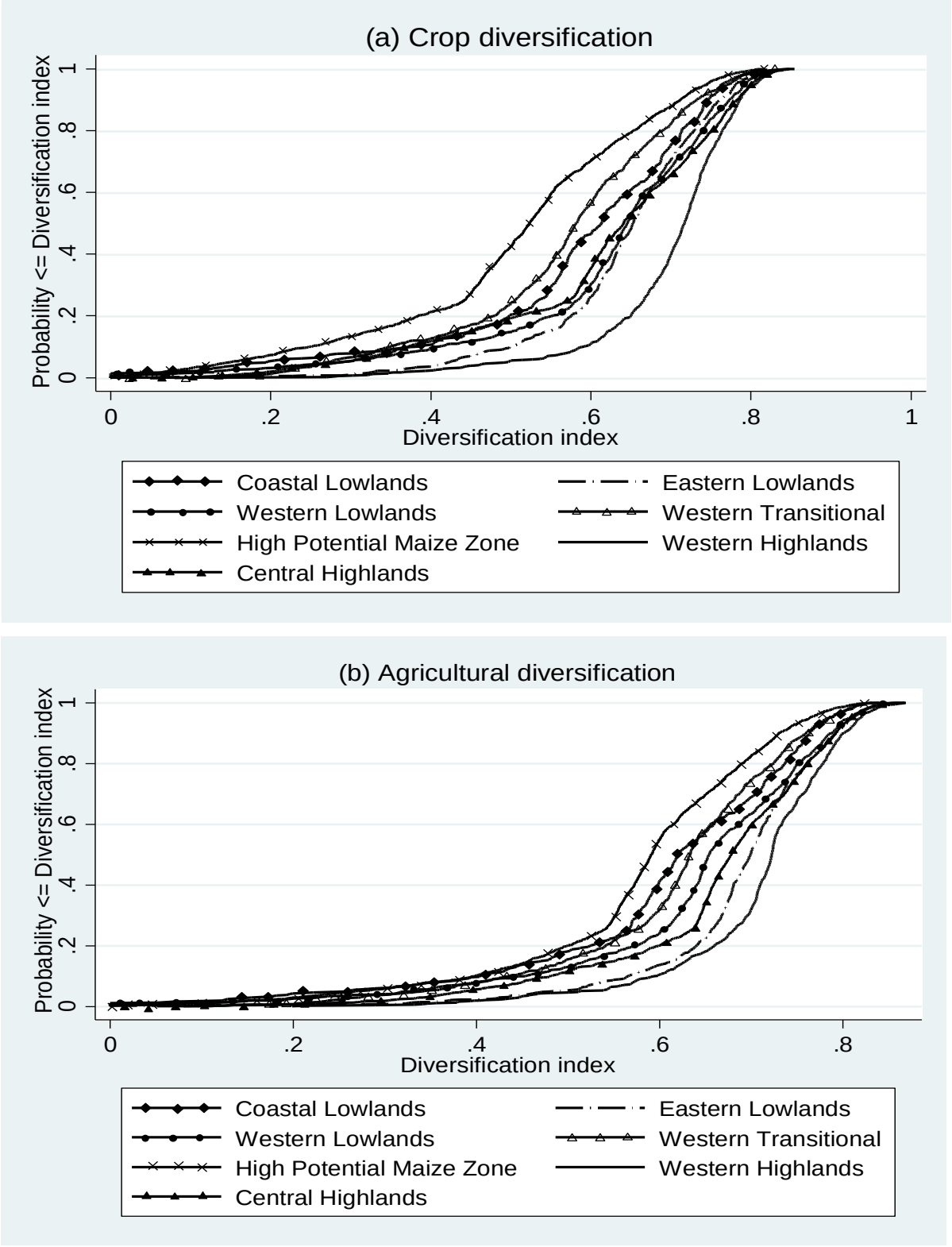
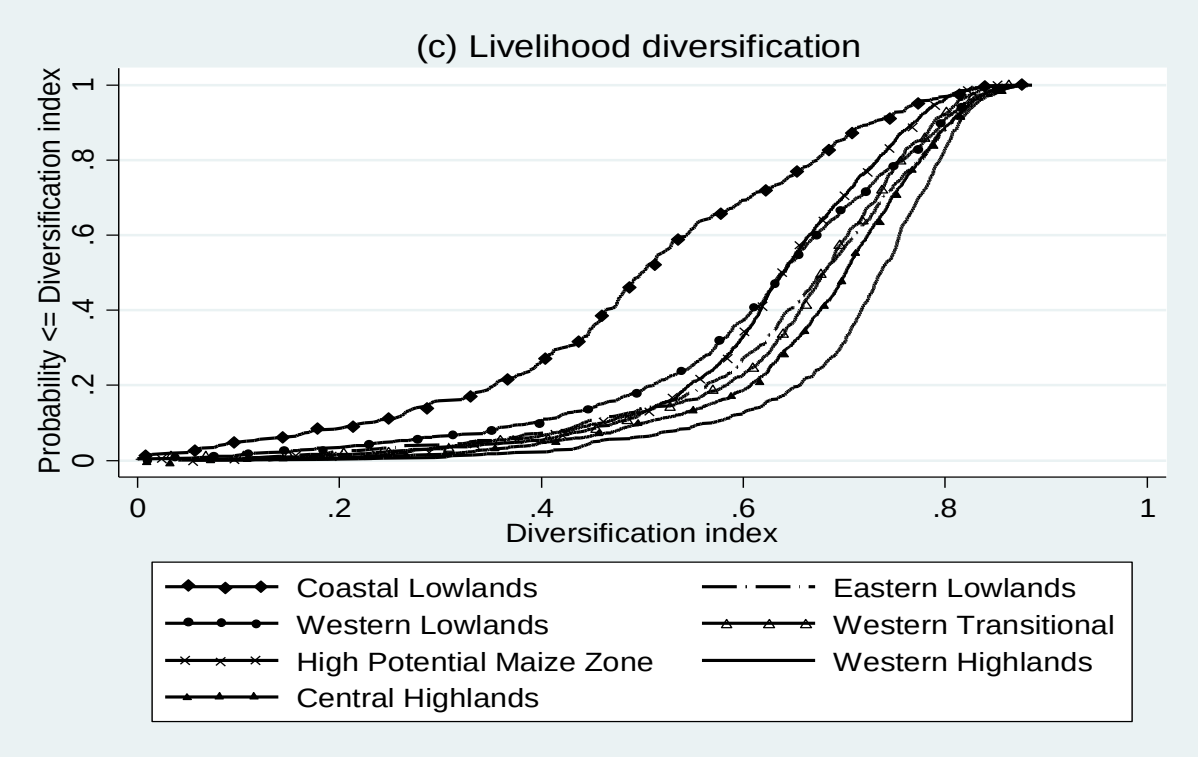


Figure 5 (cont'd)



On the other hand, the curve for the High Potential Maize zone lies to the far left and above all curves in at the crop diversification level is stochastically dominated by all zones in the first-order in crop diversification, but second-order stochastically dominated by other regions in agricultural diversification. Coastal Lowlands is stochastically dominated in the first-order by all other regions under livelihood diversification. Thus, using the findings from the CDF plots, it can be inferred that Western Highlands is the most diversified of any agro-ecological regions in all measures of smallholder High Potential Maize zone is the most specialized in crop and agricultural production.

What makes Western Highlands the most diversified of all regions and why is High Potential Maize zone the most specialized, at least in crop and broader agricultural production? These

patterns may be attributed to the socio-cultural and historical issues relevant in respective regions. A place like Vihiga County in Western Highlands zone (Table **5**) historically has been a significant source of outmigration by men to cities to seek employment in the service sector. This outmigration, accompanied by the small land sizes result in families treating the land as just a place for the family to live, and may encourage a more diversified cropping pattern than if the land were considered as the basis for a commercial farm enterprise. On the other hand, the high Potential Maize zone is has a higher comparative advantage in crop (mainly cereal) production and is well serviced by infrastructure that allow the farmers to access both output and input markets. In addition, historical policy initiatives have tended to favor maize production and opening up the markets to farmers. For example, Trans Nzoia and Uasin Gishu counties are well serviced by the input and output markets. Most of the seed companies are located within the zone. These factors may have encouraged reliance on markets and smallholder specialization in crop production. The fact that smallholder diversification rose for most regions between 2007 and 2010 could be attributed to a major drought that affected crop and livestock production in most parts of the country (Kioko, 2013).

1.6.4 Gender differences in smallholder diversification

Across gender, the results show that female-headed households are significantly more diversified in crop and livelihood portfolios but not in agricultural portfolios (Figure 6 to Figure 8). With the exception of 2004, when the indices of both genders are nearly similar, the indices for female-headed households appear to be consistently above their male counterparts. Notably, there is some evidence that male-headed households have slowed crop and broader agricultural diversification, especially in periods following 2004. These findings are supported by the statistical tests of gender differences: female-headed households are statistically significantly

more diversified in their crop and livelihood portfolios compared to their male counterparts. The findings for agricultural diversification are statistically non-significant (Table 3).

Further tests on key household variables shed more light of this observed gender differences in smallholder diversification (Table 3). Results show that male-headed households own and cultivate significantly more land compared to their female counterparts. Male-headed households tend to be younger and more educated, and have larger households. They (male-headed households) participate more in the market compared to the female-headed households as shown by the crop commercialization indices. Despite this, crops account for 44% of gross household revenue among male-headed households while, among the female-headed households, crops account for nearly half of gross revenue. The share of off-farm income is significantly higher among the male-headed households than it is among the female-headed households.

On the flip side, female-headed households have better food security prospects compared to the male-headed households, mainly because they retain nearly two-thirds of their crop for home consumption. Female-headed households also have significantly lower agricultural credit access compared to the male-headed households. This may limit access to agricultural inputs and hence may affect productivity. Indeed, male-headed households have significantly higher maize yields compared to female-headed households. These findings suggest that, while male-headed households may be pursuing income growth strategies, and, therefore, are more inclined towards specialization, the female-headed households may be pursuing a different objective, such as that of ensuring household food security through self-sufficiency.

Figure 6. Trends in smallholder crop diversification by the gender of household head, 1997 - 2010

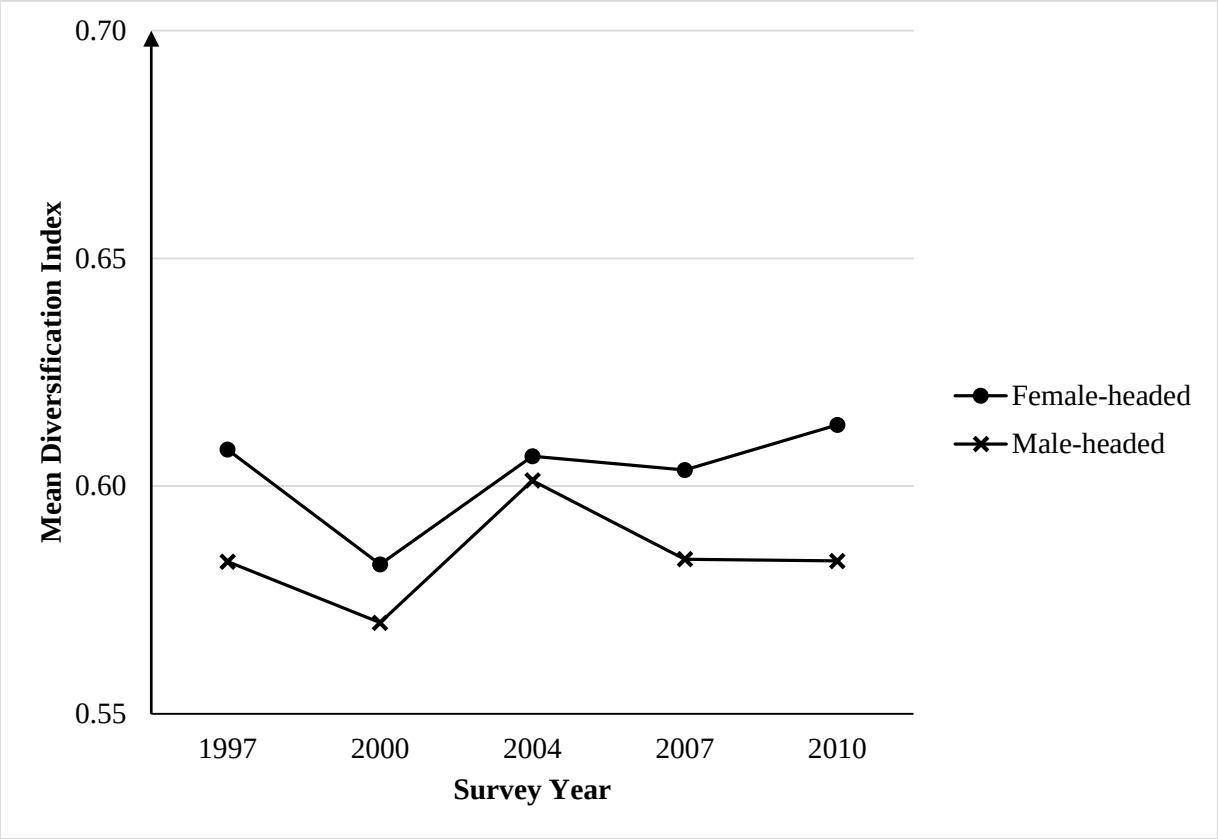


Figure 7. Trends in smallholder agricultural diversification by gender of household head, 1997 - 2010

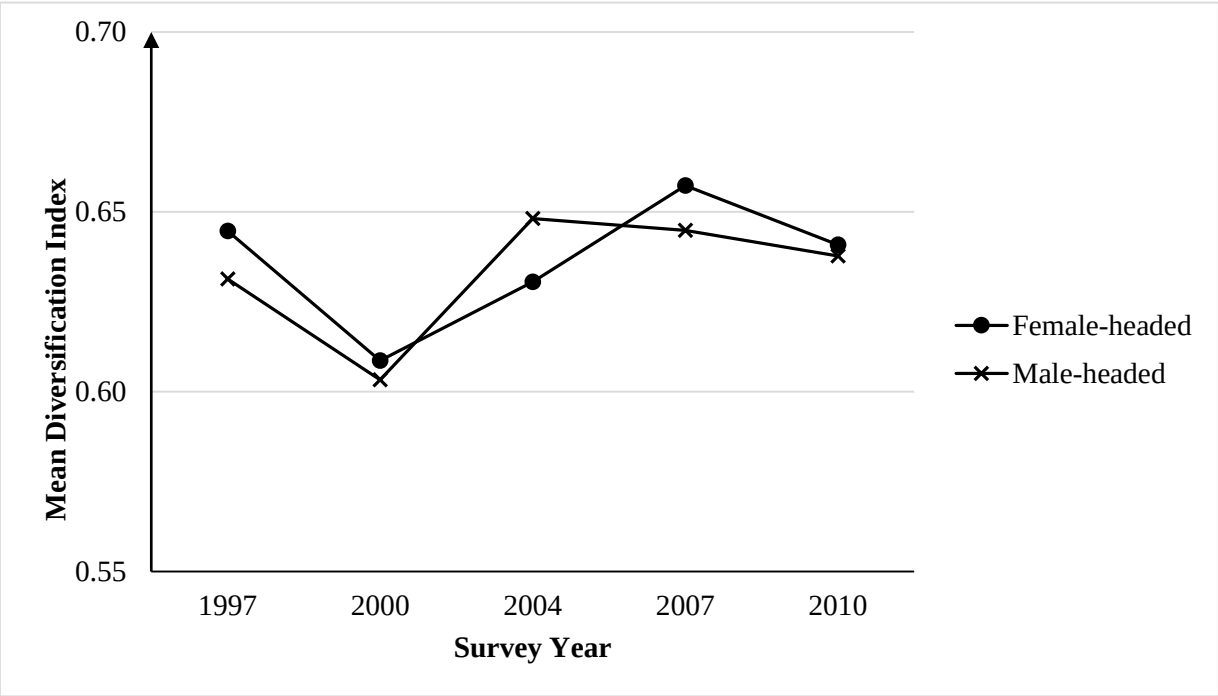


Figure 8. Trends in smallholder livelihood diversification by gender of household head, 1997 - 2010

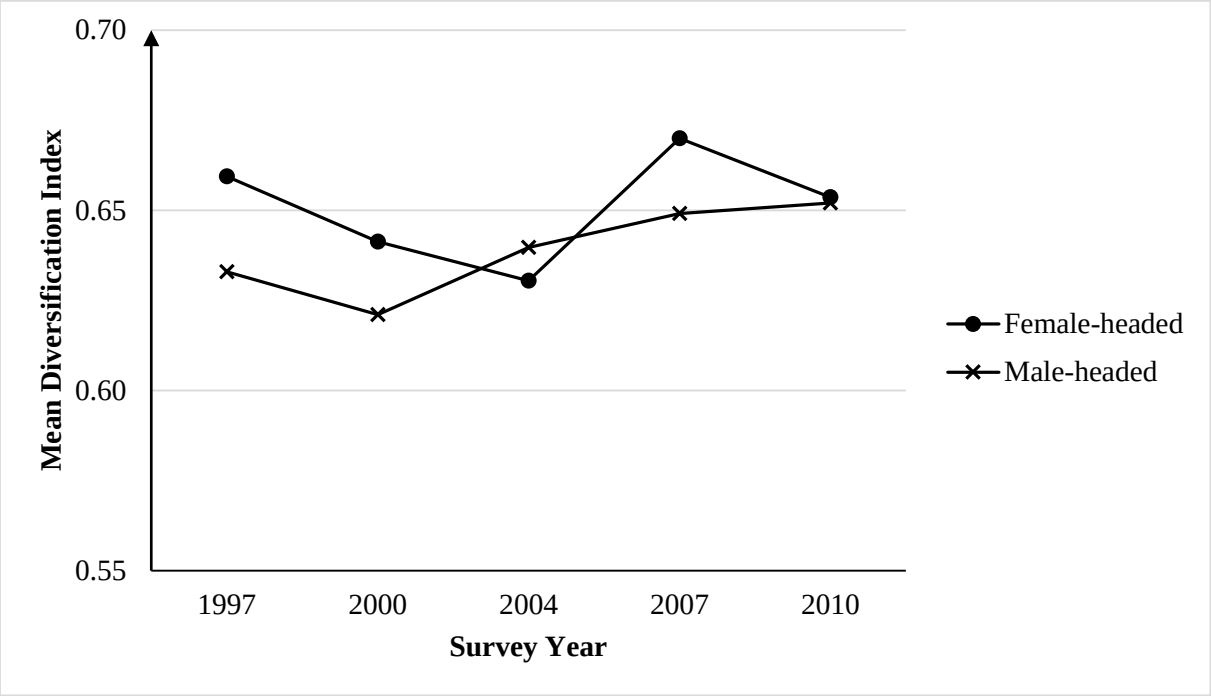


Table 3. Gender differences in smallholder diversification

	Head of household			
	Female	Male	p-value	sign
Diversification index				
Crop	0.61	0.58	0.000	***
Agricultural	0.64	0.63	0.108	
Livelihood	0.65	0.64	0.003	***
Household characteristics				
Age of head (years)	58	56	0.000	***
Education of head (years	4	7	0.000	***
Household size	5	7	0.000	***
Total Farm size (acres)	3.5	4.8	0.000	***
Acreage cultivated (acres)	3.6	4.9	0.000	***
Maize yield (kg/acre)	539	632	0.000	***
Real Income ('000 Ksh)	56	73	0.000	***
Real Assets ('000 Ksh)	90	90	0.916	
Commercialization index	0.35	0.44	0.000	***
Credit access	0.29	0.36	0.000	***
Maize security (calories/ae/day)	255	209	0.000	***
Share of gross income (%)				
Crops	0.49	0.45	0.000	***
Livestock	0.19	0.19	0.598	
Off-farm income	0.32	0.36	0.000	***

1.6.5 Household income and smallholder diversification

Comparison of household level diversification across income groups reveals that, in general, there is an inverse relationship between household income and smallholder diversification. With small exceptions, income is strongly negatively associated during every year with all the three types of diversification. Households with highest incomes are consistently (with the partial exception of 2000) much less diversified at crop and broader agriculture than other households (Figure 9 & Figure 10). The relationship across quartiles of income is monotonic during every year of survey for crop diversification. Livelihood diversification shows no difference between the lower two quartiles of income before 2004 (Figure 11). Thereafter, there is a slight increase in the livelihood diversification index for the all the quartiles in 2007, with the greatest increase observed in the lowest quartile of income. The highest quartile of income, on the other hand, registered slightly increasing but relatively stable livelihood diversification index between 1997 and 2004, followed by a decline in 2007 before slightly increasing in 2010).

Figure 9. Trends in smallholder crop diversification by household income, 1997 - 2010

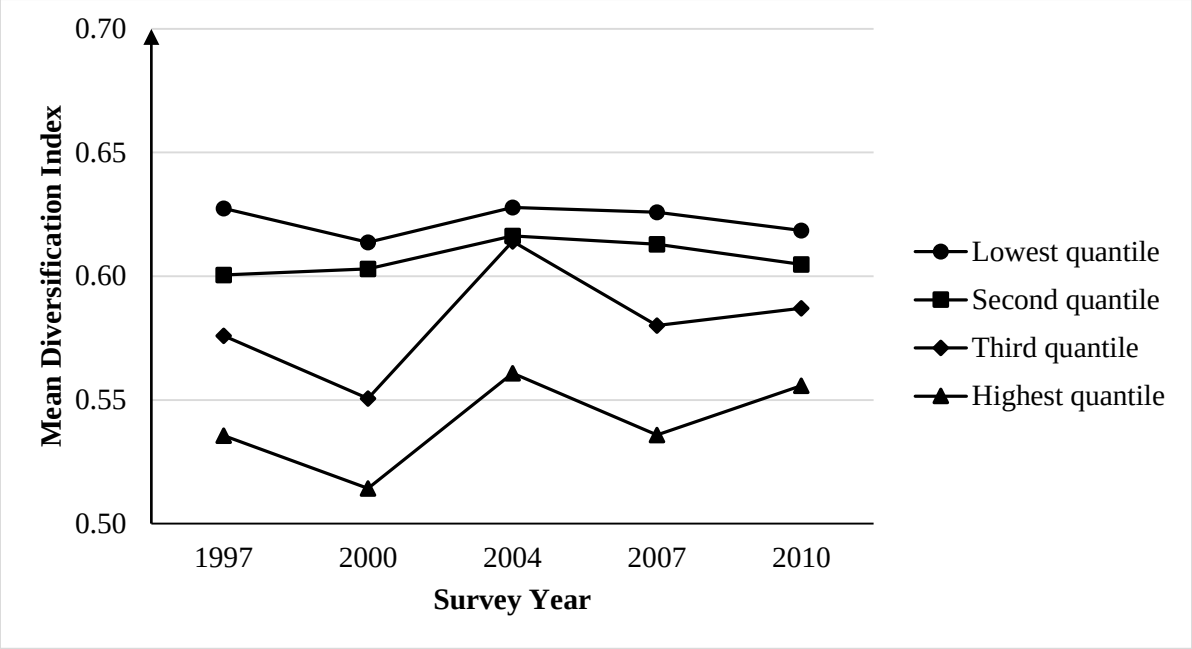


Figure 10. Trends in smallholder agricultural diversification by household income, 1997 - 2010

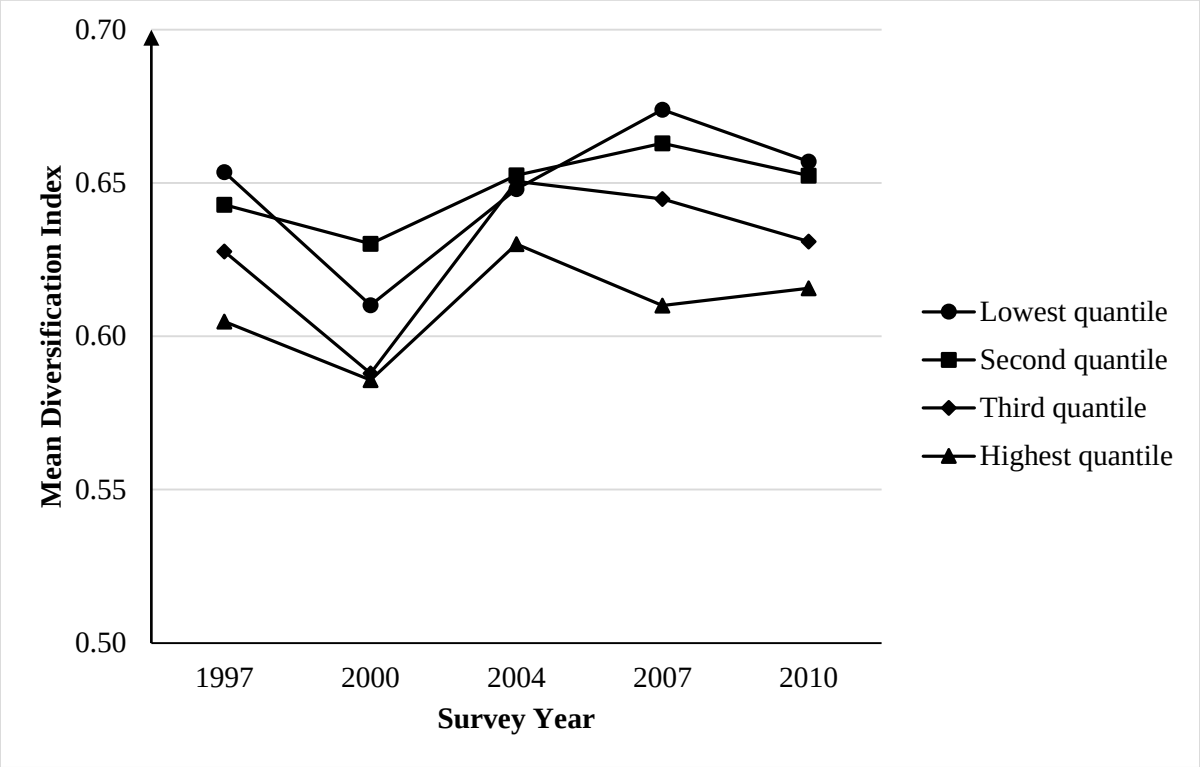
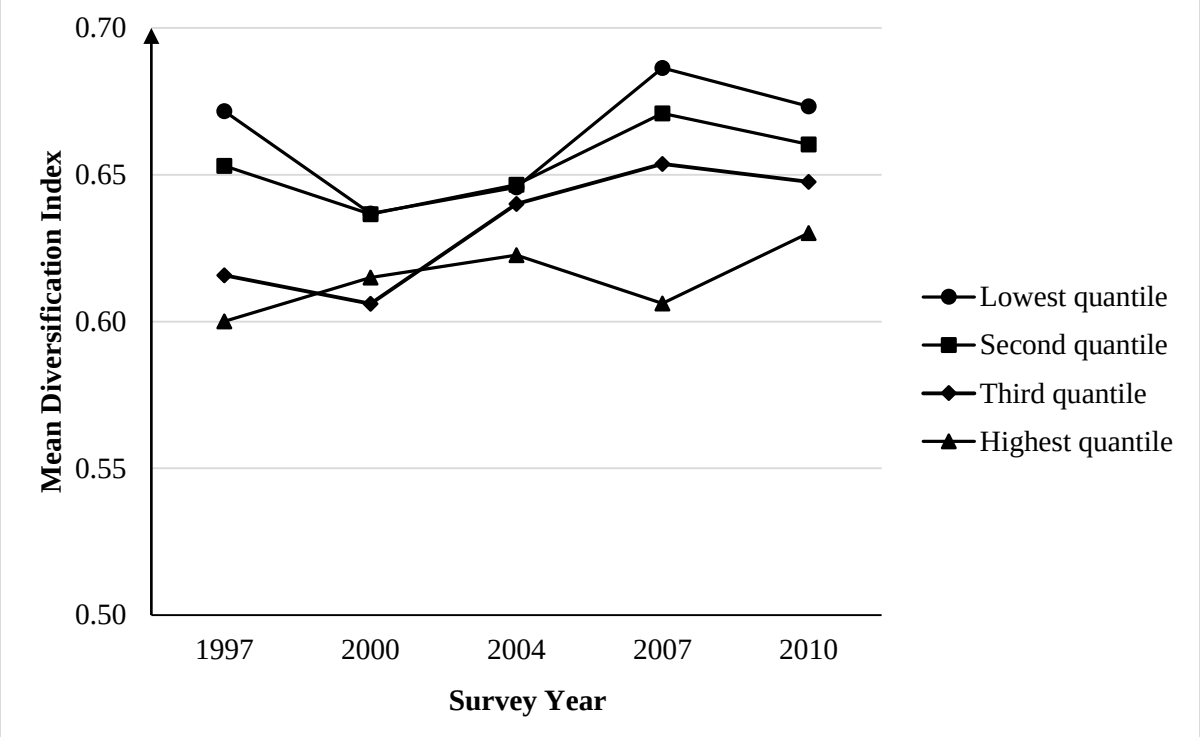


Figure 11. Trends in smallholder livelihood diversification by household income, 1997 - 2010



Over time, diversification indices of higher-income households may have slowed or shown trends towards less diversification. For example, rich households (third and fourth quartiles) exhibited a rapid increase in both crop and broader agricultural diversification between 2000 and 2004 followed by a sharp decline in 2007. These households recorded either a stable or slightly increased diversification in the period leading to 2010. In contrast, low-income households (first and second quartiles) registered fairly stable but higher crop diversification index. In addition, low-income households exhibited a slight increase in the agricultural and livelihood diversification indices 2004 and 2007 followed by a marginal decline thereafter. These findings may suggest that low-income households are more risk-averse compared to higher-income households. Overall there is a small trend towards increasing diversification of all three types.

1.6.6 Farm size and smallholder diversification

When households are categorized into quartiles of cultivated land size, the study finds that households in the highest cultivated acreage quartiles are consistently (2000 being the only partial exception) much less diversified at the crop and broader agricultural levels than other households (Figure 12 & Figure 13). Also, the relationship across quartiles of cultivated land size is monotonic during each of the last three survey periods. Moreover, the highest quartile has consistently specialized at the crop and agricultural levels since 2004, unlike all other quartiles. This relationship is inverted for livelihood diversification: the largest landholders are consistently the most diversified in livelihoods though they began to specialize after 2004 (Figure 14). The lowest two land quartiles experienced increased livelihood diversification since 2000.

Figure 12. Trends in smallholder crop diversification by quartiles of acreage cultivated, 1997 - 2010

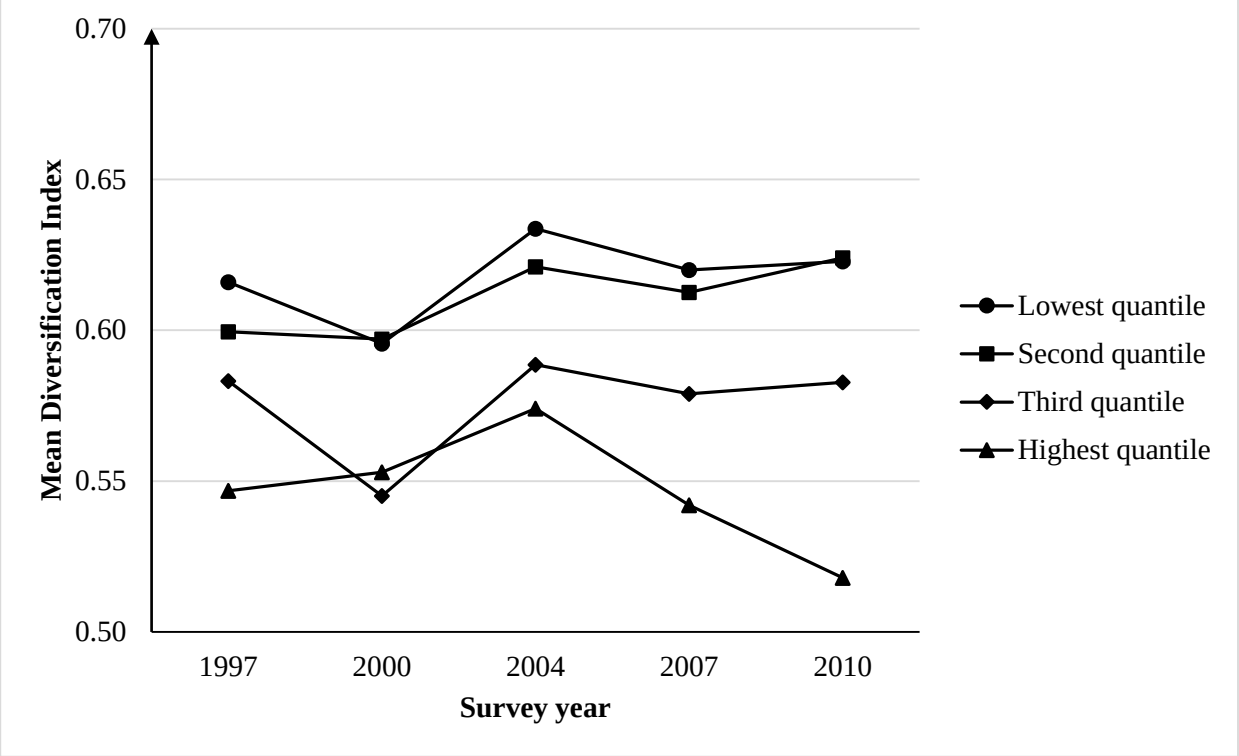


Figure 13. Trends in smallholder agricultural diversification by quartiles of acreage cultivated, 1997 - 2010

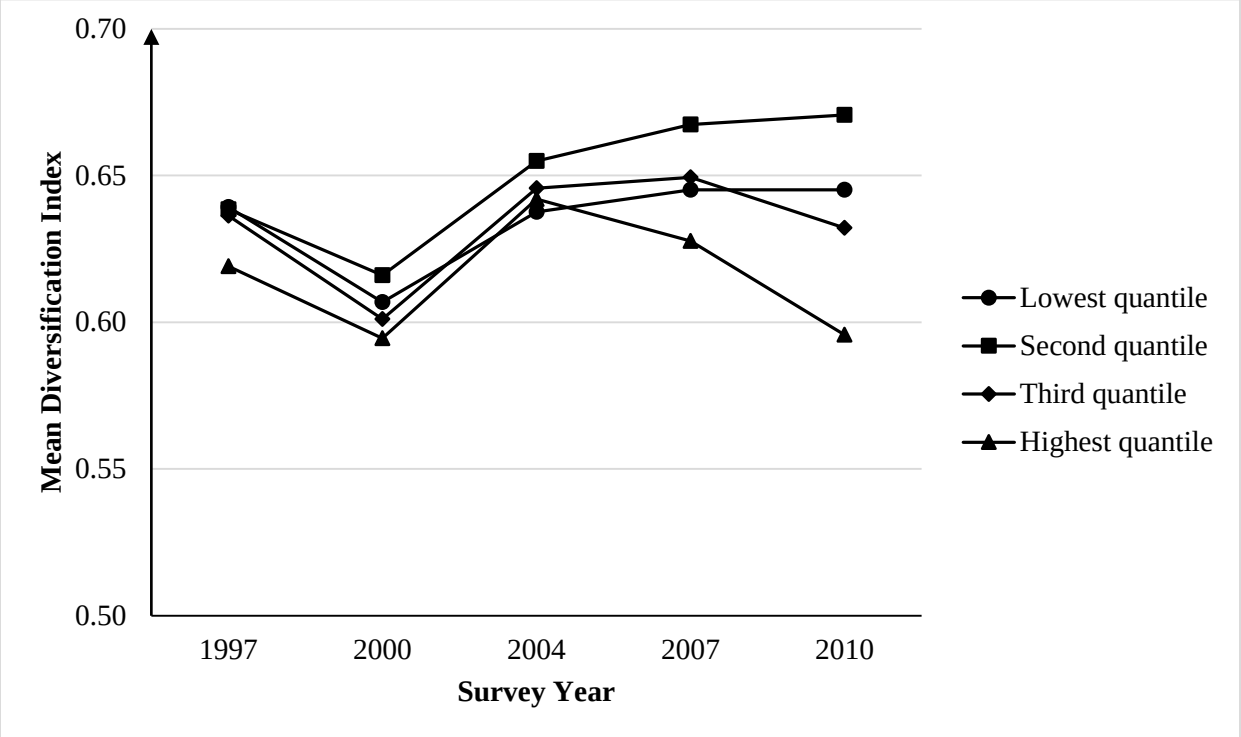
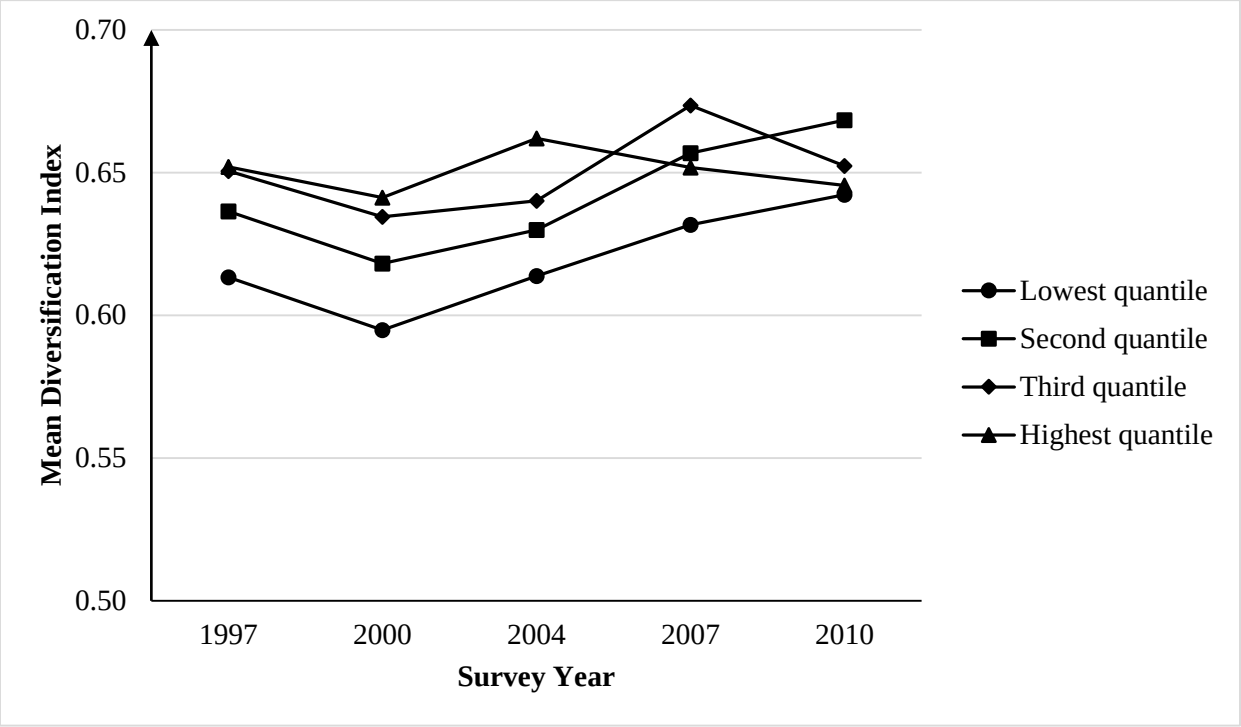


Figure 14. Trends in smallholder livelihood diversification by quartiles of acreage cultivated, 1997 - 2010

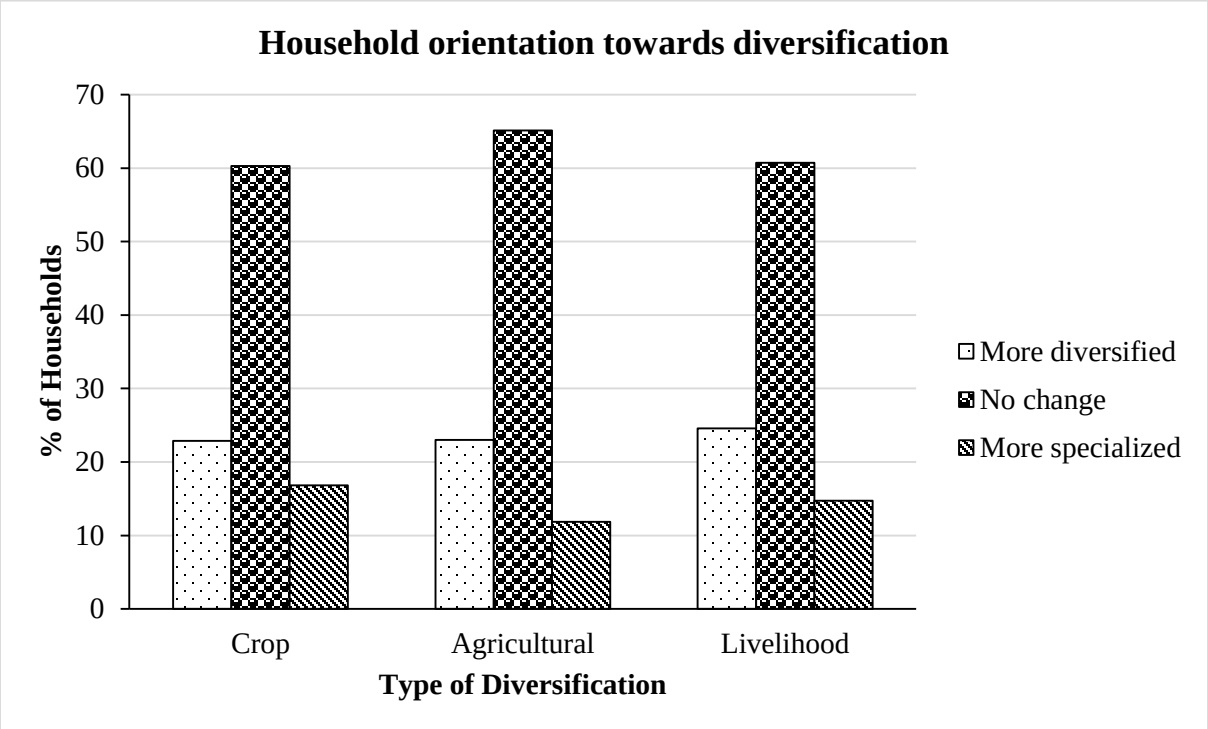


1.6.7 Characteristics of households by change in diversification

So far, the study has examined how diversification patterns differ across subgroups of smallholder households geographically or demographically. To further understand these differences, households were classified into three groups based on the change in their diversification index over the study period. For each type of household diversification (crop, agricultural or livelihood), households' mean index for the period 1997/2000 was compared to that of 2007/2010. Households were classified as having become "more-diversified" if the mean difference was more than 0.10, "more-specialized" if the mean difference was less -0.10 or less and "no-change" if the mean difference was less than or equal to the 10 percentage points in absolute terms. A t-test to ascertain if the two categories (the "more diversified" and "more specialized") were statistically non-distinct from the "no change" group was rejected at 1% level.

Results show that more households appeared to have diversified than specialized at all levels of household diversification over the study period (Figure 15). Across all measures of diversification, more than 60% of households, most households did not register meaningful statistical changes in their indices. In addition, the proportion of households that appeared to have diversified was higher at livelihood level than at either crop or broader agricultural levels. Even though there is evidence that households in some regions have become more diversified than others, it is important to note that both “more diversified” and “more specialized” households live side by side. Thus, smallholder specialization or diversification are not specific to regions but to individual households within those regions (Table 12).

Figure 15. Classification of household by orientation towards diversification



Across regions, and for all three types of household diversification, more households appear to have diversified than specialized their economic activities. The only exceptions are found in the Coastal and Eastern Lowlands, and High Potential Maize zones. In the High Potential Maize zone, more households became increasingly specialized in crop and the broader agricultural activities than those who diversified. An examination of activities that these "more specialized" households could be specializing into shows that cereal production is the leading economic activity among these households, with maize alone accounting for nearly half of gross crop revenue among the "more specialized" households. This finding is not surprising, given that the High Potential Maize zone is the country's bread basket. In the Eastern Lowlands, maize, pulses, and fruits account for nearly 70% of gross crop revenue among the "more specialized" households, while in the Coastal Lowlands, specialization is mainly towards maize and fruits (Figure 20 to Figure 22). Notably, maize contributes a substantial revenue share among both diversified and specialized households in nearly all regions. The results also show that specialization into industrial and high-value crops increases with income (Figure 20): the highest quartile of income derive higher income share from these two crop categories.

A summary of household characteristics by their diversification orientation is displayed in Table 4. Factors associated with becoming "more specialized" [3] at all three levels are age, gender, education, household size, incomes, and assets. The households that have become "more specialized" are younger, more likely to be male-headed, have more education and larger household sizes, and have higher per capita incomes and assets. Crop- and agricultural-specialized households have larger land under cultivation, higher maize yields, and a higher crop

[3] These factors show monotonic and significant change in % as one moves from "more diversified", to "no change" (not shown in the table), to "more specialized", in all three measures of smallholder diversification (crop, agricultural, and livelihood)

commercialization index. In addition, agriculturally-specialized (but not crop-specialized) households have significantly larger total landholdings (Table 4). Crop-specialized households have a highly significant cereal and industrial crop share of gross income, and lower shares of fresh produce and livestock production. On the other hand, agriculturally-specialized households have higher livestock share of gross income.

Households that have specialized at livelihood level have a higher salary and informal business share of gross income, but lower livestock and fresh produce shares. It is important to note that most of the infrastructure variables are non-significant, suggesting that both diversified and specialized households live side-by-side. Another unusual result is that access to credit appears not to affect a household's orientation towards diversification. Yet, because of significantly higher assets (at least at the agricultural diversification level), specialized household, are expected to be at a better position to access credit that is important in input acquisition.

The fact that larger households have become more specialized may be contrary to intuition since more labor might allow engagement in more activities. Yet these households have preferentially specialized, not diversified. Given that these specialized households also have larger cultivated farm size, more labor could be directed at fewer activities to benefit from the economies of scale

Table 4. Characteristics of smallholder households by their diversification orientation and level of analysis, 1997 - 2010

	Crop			Agricultural			Livelihood		
Variable	"More diversified"	"More specialized"	Sign.	"More diversified"	"More specialized"	Sign.	"More diversified"	"More specialized"	Sign.
Household demographics									
Age of head (yrs)	57	55	***	57	54	***	56	55	**
Gender of head (% m)	80	83	*	79	83	*	79	80	ns
Education of head(yrs)	6	7	***	6	6.8	***	6.3	6.5	ns
Household size	6.1	6.4	**	6.1	6.5	***	6.1	6.4	***
Acreage and productivity									
Total farm size (acres)	5.3	5.5	ns	4.1	5.4	***	4.6	4.4	ns
Cultivated land (acres)	4.8	5.5	**	4.4	5.1	**	4.5	4.9	ns
Maize yield (kg/acre)	609	696	***	575	688	***	572	558	ns
Real household income, assets, and services									
Income ('000 Ksh/ae)	73	77	ns	66	74	*	65	75	**
Assets ('000 Ksh/ae)	97	107	ns	82	103	**	87	101	*
Commercialization index (%)	42	49	***	40	47	***	41	39	**
Received credit (%)	35	33	ns	30	34	ns	34	32	ns
Distances (km) to									
fertilizer seller	4.8	4.8	ns	5.3	5.3	ns	5	6.1	***
tarmac road	6.7	7.8	***	7.5	7.2	ns	7.1	8.2	***
motorable road	0.8	0.8	ns	0.9	0.9	ns	0.9	9	ns
extension agent	5.4	5.2	ns	5.8	5.7	ns	5.7	5.6	ns
veterinary service	4.4	4.4	ns	4.6	4.8	ns	4.5	4.9	ns
Contribution of major economic activities towards gross income (%)									
Cereals	16	21	***	16	18	**	17	16	ns
Fresh produce	12	8	***	12	7	***	11	8	***
Industrial crops	9	14	***	9	14	***	9	8	ns
Dairy and beef	18	17	*	14	20	***	16	14	***
Salaries	11	12	ns	13	14	ns	12	19	***
Informal business	13	12	ns	14	13	ns	14	19	***

Note: Sign: *** difference significant at 1%; ** difference significant at 5%; * difference significant at 10%; ns: difference non-significant

1.7 Conclusions and policy implications

The objective of this essay was to examine the patterns and trends in rural livelihood portfolios and show how these patterns and trends vary across types of households as well as spatially. Patterns and trends of smallholder household diversification were examined at the crop, agricultural and livelihood diversification levels using data collected between 1997 and 2010, a period when many agricultural policy reforms took place. In addition, households were grouped by agro-ecological zones, gender, household income and amount of land cultivated and their behavior towards diversification examined.

The study findings reveal that Kenyan smallholders are still fairly diversified in all three types of diversification, and no absolute specialization is taking place at the national level. This is exemplified by the relatively high diversification indices in all the three diversification measures across the agro-regional zones. Mapped against the agricultural transformation framework, the findings suggest that agricultural transformation in Kenya may still be in initial stages, despite key policy reforms of the 1980s and early 2000s, and that smallholder farmers in Kenya may not have witnessed greater move towards specialization that was evident among the Eastern Asian states in the early 1990s that led to rapid agricultural transformation.

While there is no evidence of meaningful specialization of any kind taking place at the national level, there is evidence of some trend towards specialization at more disaggregated level. For example, across agro-ecological regions, the study shows that the High Potential Maize zone is the most specialized at the crop and agricultural level while Western highlands is the most diversified of all regions. The Coastal Lowlands, on the other hand, is the most livelihood-specialized of all regions. The High potential Maize zone, for example, became more specialized

in crop and broader agricultural production since 2004. The more-specialized households in this zone produced mainly cereals and industrial crops. The study shows that households that crop-specialized had significantly large farm sizes increased maize productivity, and higher crop commercialization index. On the other hand, agriculturally-specialized households had a higher livestock share of agricultural income, and this almost entirely came from dairy and beef production. Coastal Lowlands was the most specialized in livelihood activities of all zones, and this could be attributed to the high off-farm share of the household revenue, driven more by the tourism sector.

The study further shows an inverse relationship between land holding and crop and agricultural diversification, but a direct relationship with livelihood diversification. The study finds, for example that, Western Highlands, with the smallest landholdings and perhaps one of the highest population densities, has the highest diversification index. This is consistent with other findings (e.g., Bigsten & Tengstam, 2011) that households diversify into non-farm activities when faced with land shortage. The fact that larger households have become more specialized may be contrary to intuition since more labor allows households to engage in more activities. Yet these households have preferentially specialized, not diversified.

Overall, the study suggests that male-headed households were more specialized than female-headed counterparts. Also, the study shows that more-specialized households tended to be younger, more educated, wealthier and own and/or cultivate more land than their more diversified counterparts. In addition, “more specialized” household also have a higher commercialization index. Assuming, as evidence suggests, that crop specialization is more towards cereals and industrial crops while diversified households produce a variety of food crops, it can be inferred that female-headed households are more concerned about food

availability and ensuring household food security while male-headed households are more concerned with income-generating activities. Further, it can be inferred that diversification may be a strategy to address household food security, especially among the resource-poor households while specialization could be a strategy for household income and wealth growth.

In addition, the study finds an inverse relationship between household size and smallholder diversification: “more specialized” households tend to have larger households compared to more-specialized households, and this finding is replicated at all the levels of analysis. In fact, it can be argued that, since most of the specialized households also have larger land holdings, larger households are able to utilize economies of labor in their production. Larger households may put constraints in the case of diminishing land sizes and high population densities.

Based on these results, it may be important to carry out further research to understand how policy reforms may affect smallholder diversification. This is addressed in the next essay that investigates the key drivers of smallholder diversification.

APPENDIX

Table 5. Number of households interviewed in each survey period, by agroecological zone, 1997 - 2010

Agro-Ecological Zone	District Name(s)	Number of Households in the sample					% Attrition
		1997	2000	2004	2007	2010	
Coastal Lowlands	Kilifi, Kwale	80	79	78	75	74	6
Eastern Lowlands	Taita Taveta, Kitui, Machakos, Makueni, Mwingi	166	161	157	150	146	10
Western Lowlands	Kisumu, Siaya	188	177	170	161	157	14
Western Transitional	Bungoma, Kakamega	172	166	157	150	147	13
High Potential Maize zone	Bungoma, Kakamega, Bomet, Nakuru, Narok, Trans Nzoia, Uashin Gishu	411	399	385	365	350	11
Western Highlands	Kisii, Vihiga	156	151	147	145	144	7
Central Highlands	Meru, Muranga, Nyeri	268	259	253	248	246	7
Marginal Rain Shadow	Laikipia	59	54	50	48	45	20
Sample Totals		1500	1446	1397	1342	1309	11

Source: Tegemeo Rural Household surveys, 1997, 2000, 2004, 2007, 2010

Table 6. Comparison of crop, livestock, and off-farm activities across agroecological zones, 1997 - 2010

	Coastal Lowlands			Eastern Lowlands			Western Lowlands			Western Transitional			High Potential Maize		
Year	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm
	---------- % of gross household income ----------														
1997	14	7	80	25	17	58	37	19	45	52	22	26	50	25	25
2000	36	3	62	45	11	44	50	12	38	64	11	26	44	25	31
2004	25	5	69	35	13	52	42	14	44	56	17	27	50	25	25
2007	29	3	68	40	16	44	40	11	49	50	17	32	41	28	32
2010	25	8	67	36	11	52	49	14	37	56	15	29	38	29	33
All years	26	5	69	36	14	50	44	14	43	56	16	28	44	27	29

	Western Highlands			Central Highlands			Marginal Rain Shadow			Overall Sample		
Year	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm	Crop	Live-stock	Off-farm
	---------- % of gross household income ----------											
1997	47	23	30	43	24	33	23	29	48	41	22	37
2000	60	14	26	57	18	25	14	24	61	50	16	34
2004	48	21	31	52	21	27	30	27	43	46	19	35
2007	53	16	31	54	19	27	35	30	35	45	19	37
2010	54	18	28	52	18	29	26	21	52	45	19	36
Total	53	18	29	51	20	28	26	26	48	45	19	36

Table 7. Comparison of crop activities across agroecological zones, 1997 - 2010

Agro-regional zone	Year	Maize	All cereals	Tubers	Pulses	Fresh produce	Industrial crops	Other crops
		----------Proportion (%) of total crop value----------						
Coastal Lowlands	1997	34	44	10	9	38	0	0
	2000	31	35	11	7	47	0	0
	2004	28	33	11	10	46	0	0
	2007	37	39	7	13	41	0	0
	2010	42	44	5	16	35	0	0
Eastern Lowlands	1997	32	33	5	24	35	2	1
	2000	29	30	5	19	39	2	5
	2004	29	30	6	21	37	1	5
	2007	35	36	2	23	32	2	6
	2010	38	40	2	21	33	2	3
Western Lowlands	1997	36	54	11	21	3	10	0
	2000	31	48	8	13	22	9	0
	2004	26	36	8	14	33	9	0
	2007	36	49	4	14	27	5	1
	2010	38	52	4	22	15	7	0
Western Transitional	1997	30	32	13	12	17	25	0
	2000	21	22	6	7	18	45	2
	2004	35	37	7	8	20	26	2
	2007	33	34	4	10	20	29	3
	2010	32	33	5	12	16	32	2
High Potential Maize	1997	53	70	3	11	7	9	0
	2000	47	59	5	9	17	8	1
	2004	48	62	4	9	15	8	3
	2007	51	61	3	9	15	8	5
	2010	43	49	4	12	19	9	7
Western Highlands	1997	41	44	2	7	30	15	2
	2000	25	28	3	6	31	23	8
	2004	33	37	3	8	31	12	9
	2007	26	29	2	8	32	22	7
	2010	32	35	4	10	29	17	6
Central Highlands	1997	15	15	16	4	27	38	0
	2000	11	11	11	4	23	44	6
	2004	12	12	14	6	29	33	7
	2007	12	12	13	5	27	36	8
	2010	12	12	13	7	25	34	9
Marginal Rain Shadow	1997	19	21	31	19	28	0	1
	2000	6	7	27	13	48	0	5
	2004	23	29	16	23	23	0	8
	2007	26	29	13	20	33	0	6
	2010	45	47	14	19	11	2	7
Overall Sample	1997	35	26	9	12	19	16	0
	2000	29	13	7	9	25	20	3
	2004	31	30	7	11	27	14	4
	2007	34	24	6	11	25	16	5
	2010	34	31	6	13	23	15	5

Table 8. Average share of crop activities in gross household crop revenue among rural smallholders in Kenya, 1997-2010

Agro-regional zone	Crop activity							
	Maize	Other cereals	Tubers	Pulses	Vegetables	Fruits	Industrial crops	Other crops
	% of total crop value							
Coastal Lowlands	34	5	9	11	11	29	0	0
Eastern Lowlands	33	1	4	22	14	21	2	4
Western Lowlands	33	15	7	17	10	10	8	0
Western Transitional	30	2	7	10	7	11	31	2
High Potential Maize	48	12	4	10	8	6	8	3
Western Highlands	32	3	3	8	13	18	18	6
Central Highlands	12	0	13	5	11	15	37	6
Marginal Rain Shadow	24	3	20	19	25	3	0	6
Overall Sample	32	6	7	11	10	13	16	3

Figure 16. Average maize yield by agro-ecological regions, 1997 to 2010

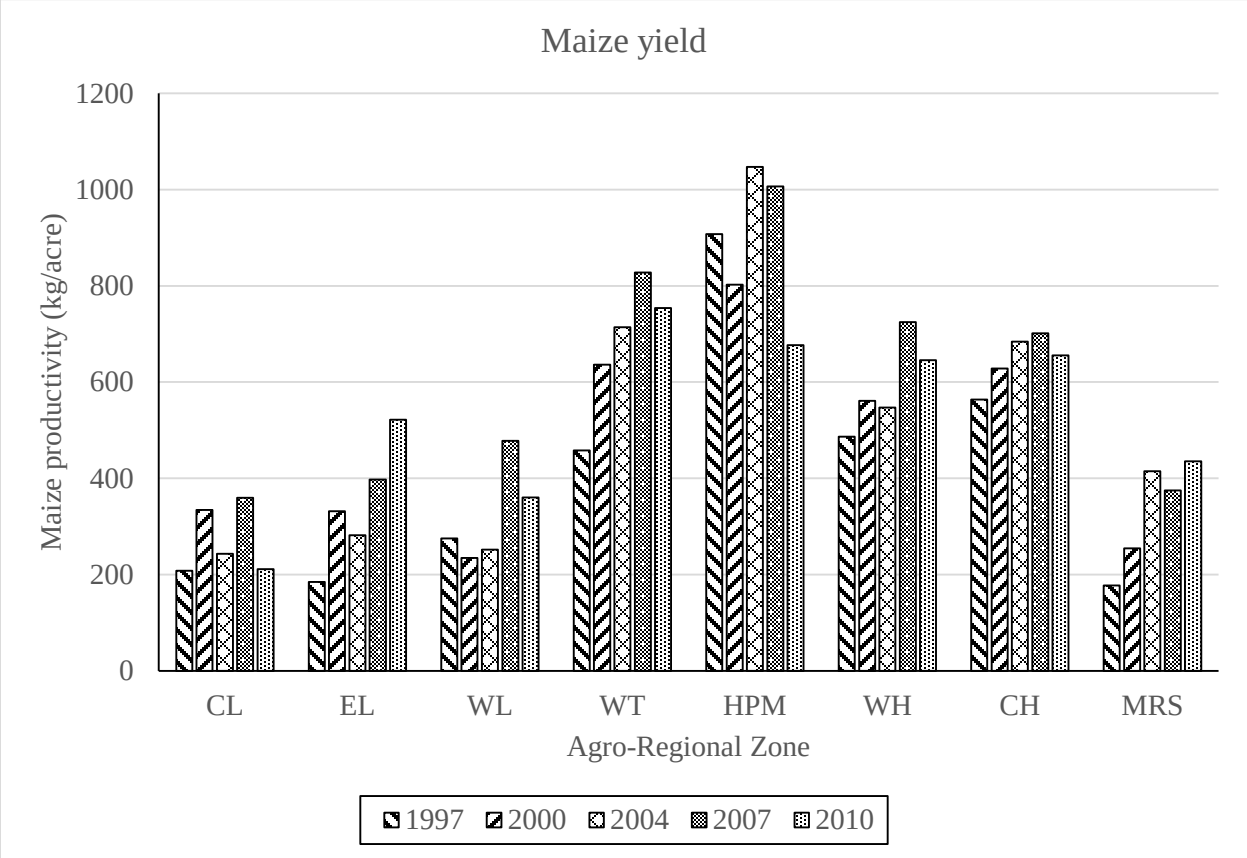


Table 9. Share of crop and livestock activities in household gross agricultural revenue, by agroecological zone, 1997 - 2010

Agro-regional zone	All crops	Livestock activity				All livestock
		Cattle	Goats, sheep & Pigs	Poultry	Other livestock	
		% of gross agricultural revenue				
Coastal Lowlands	84	6	3	7	0	16
Eastern Lowlands	73	20	2	4	0	27
Western Lowlands	77	19	2	2	0	23
Western Transitional	77	20	1	2	0	23
High Potential Maize	64	32	1	3	0	36
Western Highlands	73	24	0	2	0	27
Central Highlands	72	26	1	2	0	28
Marginal Rain Shadow	52	35	5	7	1	48
Overall Sample	71	24	1	3	0	29

Table 10. Distribution of crop, agricultural and off-farm income in gross household income, by agroecological zone, 1997 - 2010

Agro-regional zone	Crop	Livestock	Off-farm activity				Total off-farm
			Salaries	Remittance	Informal Business	Farm *Kibarua*	
		% of household revenue					
Coastal Lowlands	26	5	23	6	39	1	69
Eastern Lowlands	36	14	23	8	16	2	50
Western Lowlands	44	14	12	11	17	4	43
Western Transitional	56	16	8	3	14	3	28
High Potential Maize	44	27	11	3	12	3	29
Western Highlands	53	18	13	6	7	3	29
Central Highlands	51	20	13	5	9	2	28
Marginal Rain Shadow	26	26	24	6	11	8	48
Overall Sample	45	19	14	5	14	3	36

Figure 17. Cumulative density function (CDF) plot of regional differences in crop diversification, by agro-ecological zone, 2000 - 2010

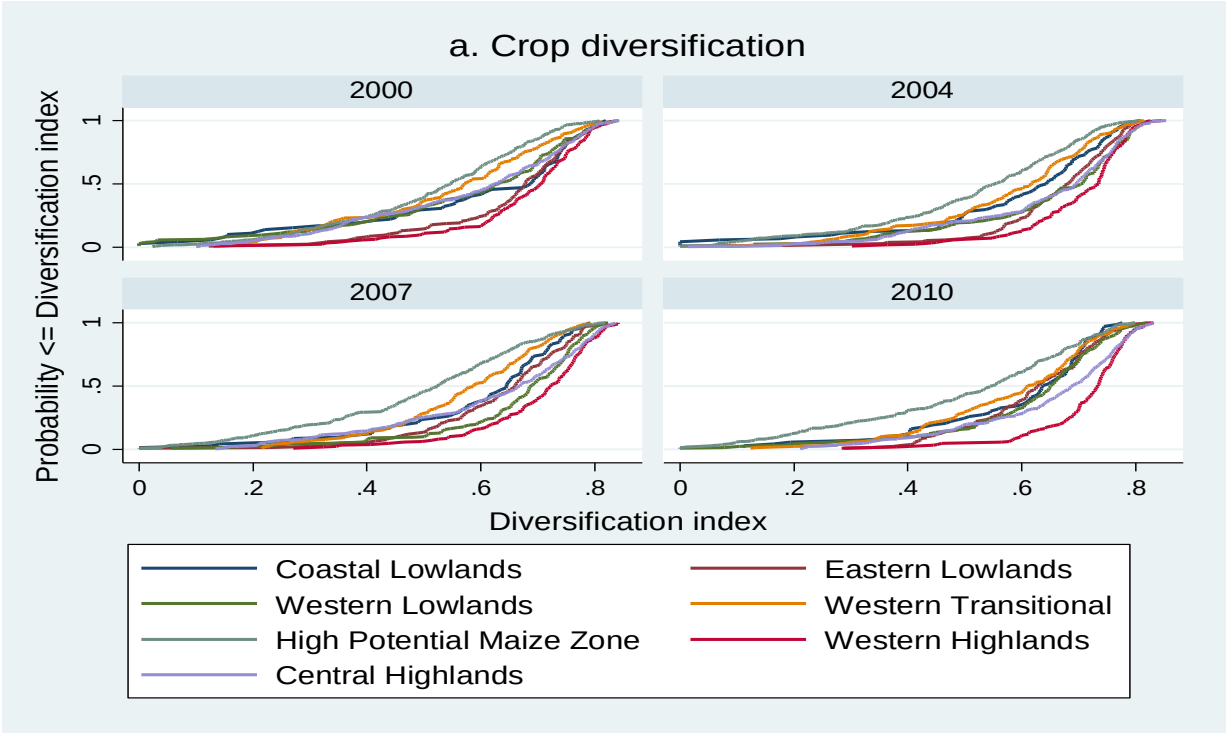


Figure 18. Cumulative density function (CDF) plot of regional differences in agricultural diversification, by agroecological zone, 2000 - 2010

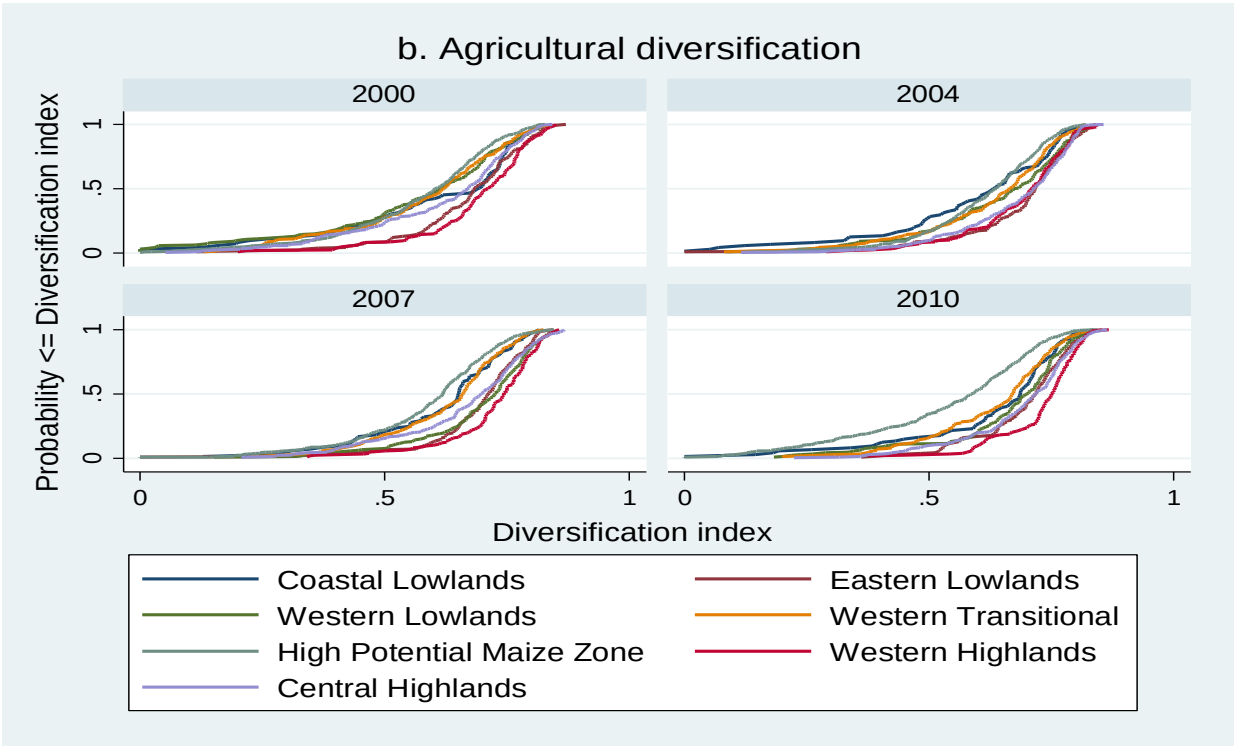


Figure 19. Cumulative density function (CDF) plot of regional differences in livelihood diversification, by agroecological zone, 2000 - 2010

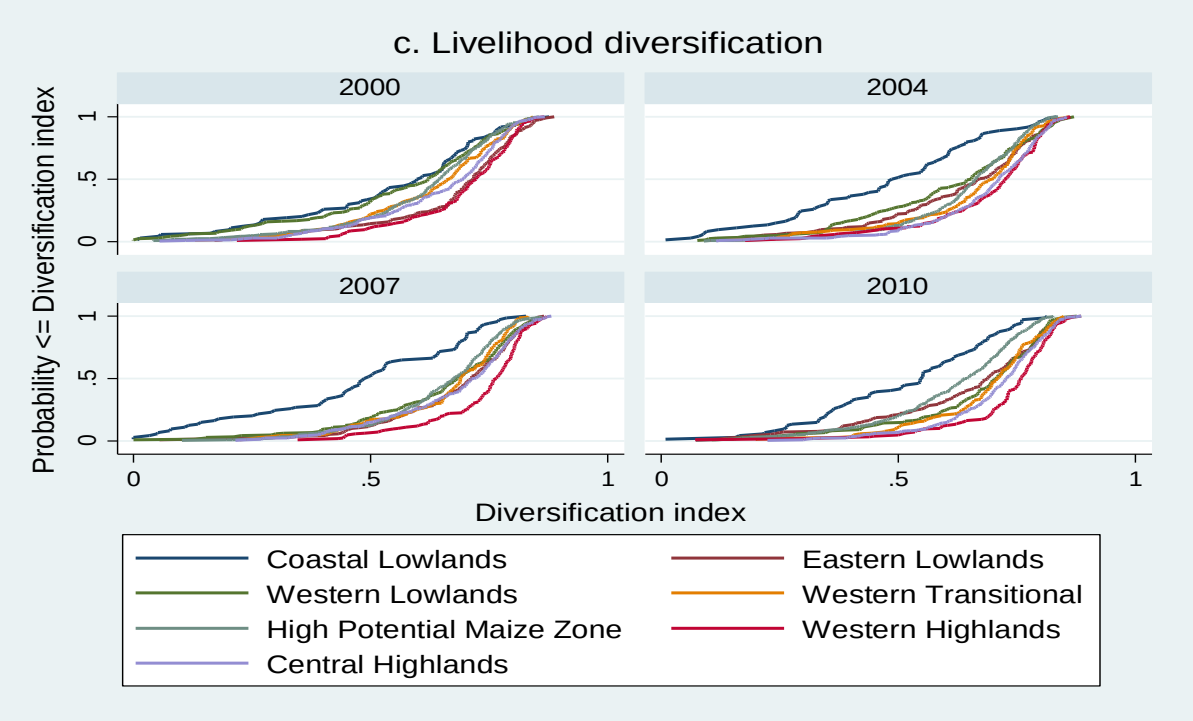


Table 11. Summary statistics of rural smallholder household in Kenya, by agroecological zone, 1997 - 2010

	Agro-ecological zone							
Variable	Coastal Lowlands	Eastern Lowlands	Western lowlands	Western Transitional	High Potential	Western Highlands	Central Highlands	MRS
Total acres owned	4.2	5.0	2.3	4.5	8.7	1.5	1.9	3.2
Total acres cultivated	5.0	6.2	3.4	5.0	6.1	3.0	3.0	3.1
Distance to fertilizer seller (km)	17.8	5.2	8.0	4.3	4.1	2.3	1.7	8.9
Distance to seed seller (km)	17.5	6.1	7.9	4.6	5.6	3.0	2.3	9.8
Distance to tarmac road (km)	9.5	12.5	5.9	8.0	7.0	7.1	5.3	13.8
Distance to motorable road (km)	1.5	1.2	1.1	0.5	0.9	1.0	0.4	1.7
Distance to tapped water (km)	6.8	7.0	5.8	5.0	7.5	6.6	0.6	13.9
Distance to extension agent (km)	9.6	5.8	6.5	4.7	5.7	4.7	2.9	2.7
Total rainfall (mm)	577.4	508.4	1130.9	1286.1	711.3	1361.7	745.0	585.2
Rainfall stress	0.6	0.5	0.2	0.1	0.3	0.1	0.5	0.6
Fertilizer quantity (kg)	10.6	7.4	6.6	40.9	49.0	31.2	37.7	3.5
Population density (persons/sq. km)	275.7	309.6	327.7	319.0	147.9	724.1	441.7	
Travel time to city of 25K (mins)	45.4	142.7	309.3	328.6	262.8	291.1	112.4	164.0

Table 12. Distribution of rural smallholder households in Kenya, by level of diversification, 1997 -2010

	Crop diversification			Agricultural diversification			Livelihood diversification		
Zone	More diversified	No change	More specialized	More diversified	No change	More specialized	More diversified	No change	More specialized
Coastal Lowlands	19	70	11	24	62	14	24	41	35
Eastern Lowlands	9	70	21	16	75	9	21	61	18
Western Lowlands	27	64	9	32	63	5	37	53	10
Western Transitional	27	54	19	30	56	14	25	63	12
High maize Potential	23	50	27	18	61	21	22	61	17
Western Highlands	15	72	13	16	77	7	23	65	12
Central Highlands	26	65	9	20	73	7	22	68	10
Marginal Rain Shadow	56	41	3	74	23	3	38	50	12
% in category	23	60	17	23	65	12	25	60	15

Figure 20. Share of various crop activities in household crop income, by agroecological zone and household diversification level, 1997 - 2010

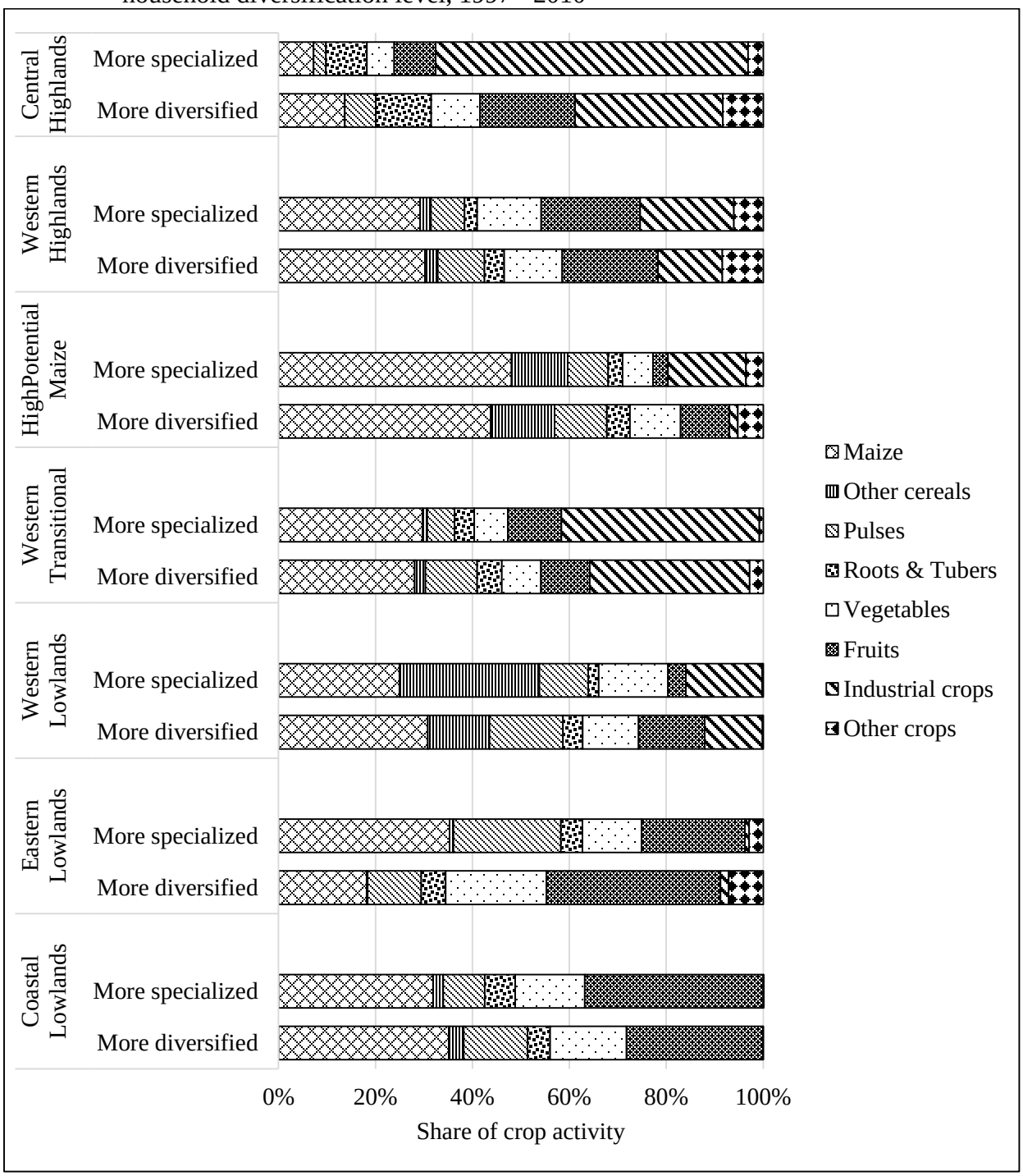


Figure 21. Share of various crop activities in household crop income, by quartile of income and household diversification level, 1997 – 2010

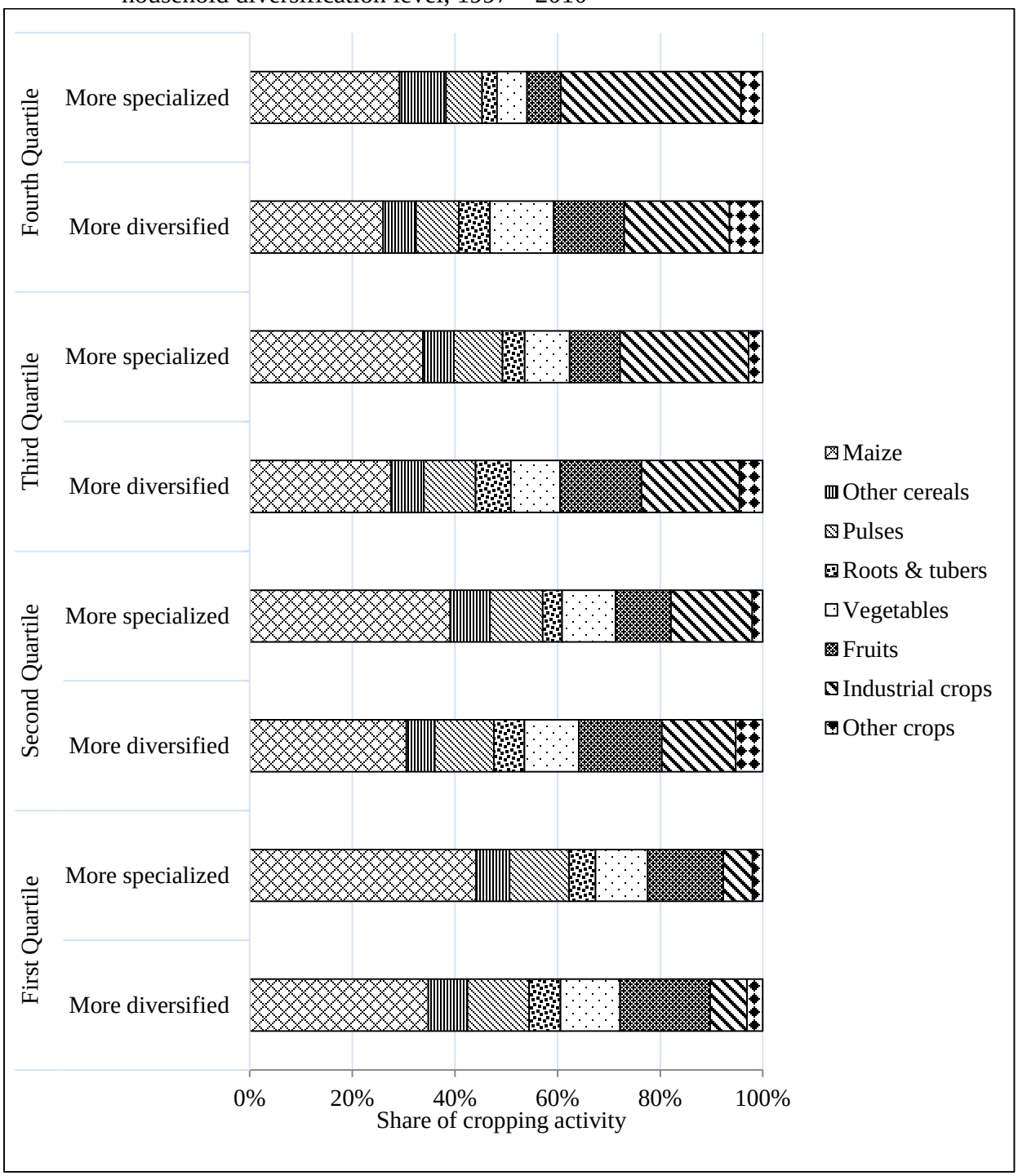


Figure 22. Share of various crop activities in household crop income, by quartile of landholding size and household diversification level, 1997 - 2010

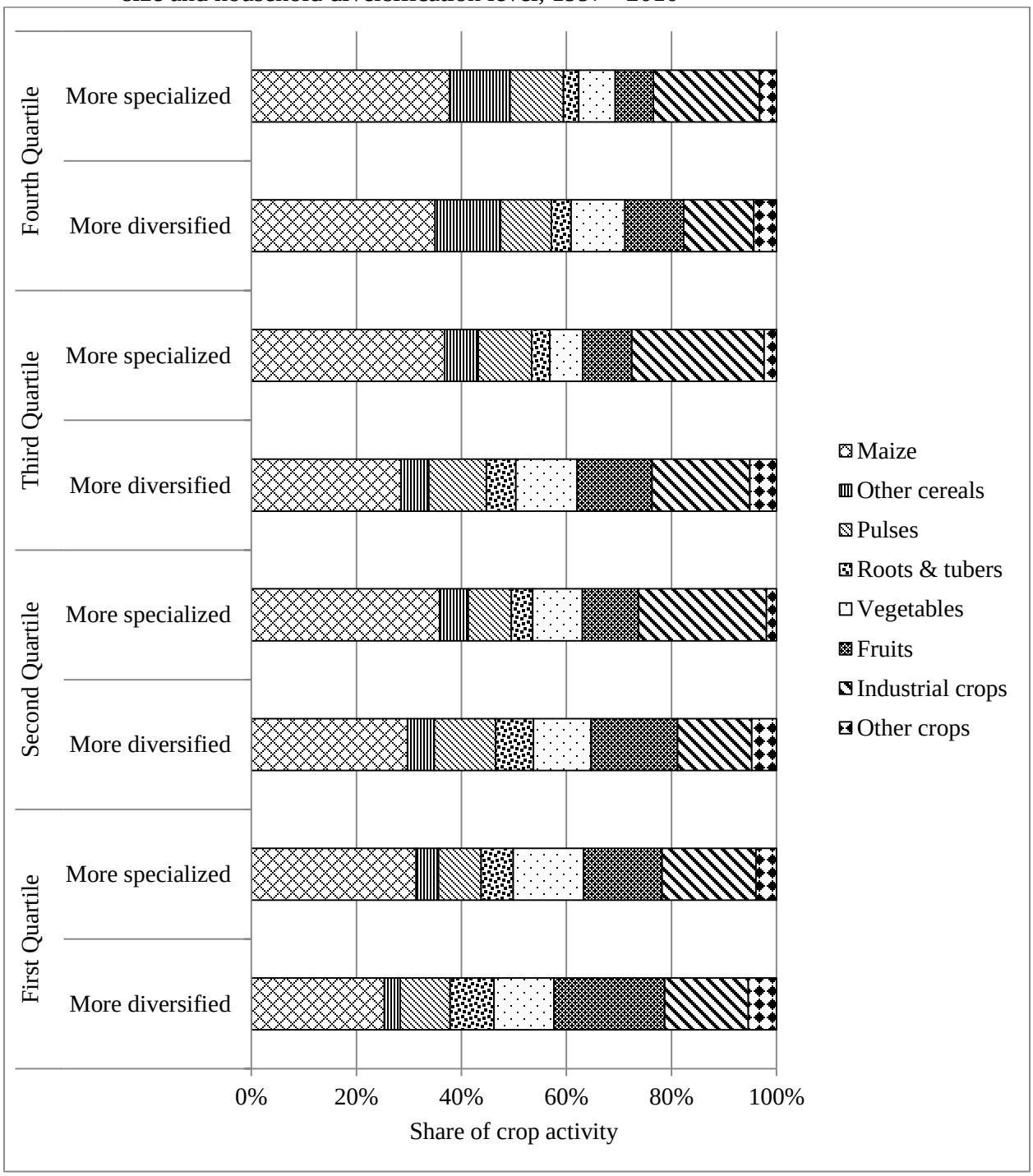


Table 13. Characteristics of households by diversification type and level of diversification, 1997 - 2010

	Crop diversification				Agricultural diversification				Livelihood diversification			
Variable	More diversified	No change	More specialized	Sig	More diversified	No change	More specialized	Sig	More diversified	No change	More specialized	Sig
Household demographics												
Age of head (yrs)	57	56	55	***	57	56	54	***	56	56	55	**
Gender of head (% m)	80	79	83	*	79	80	83	*	79	81	80	ns
Education of head(yrs)	6	6	7	***	6.0	6.3	6.8	***	6.3	6.3	6.5	ns
Household size	6.1	6.1	6.4	**	6.1	6.1	6.5	***	6.1	6.1	6.4	***
Acreage and productivity												
Total farm size (acres)	5.3	4.1	5.5	ns	4.1	4.6	5.4	***	4.6	4.6	4.4	ns
Cultivated land (acres)	4.8	4.4	5.5	**	4.4	4.6	5.1	**	4.5	4.6	4.9	ns
Maize yield (kg/acre)	609	592	696	***	575	613	688	***	572	642	558	ns
Income, Assets and services												
Real income ('000 Ksh/ae)	73	66	77	ns	66	70	74	*	65	70	75	**
Real assets ('000 Ksh/ae)	97	82	107	ns	82	89	103	**	87	87	101	*
Crop comm. index (%)	42	41	49	***	40	43	47	***	41	44	39	**
Received credit (%)	35	35	33	ns	30	36	34	ns	34	36	32	ns
Distances (km) to												
fertilizer seller	4.8	5.0	4.8	ns	5.3	4.6	5.3	ns	5.0	4.5	6.1	***
tarmac road	6.7	7.6	7.8	***	7.5	7.5	7.2	ns	7.1	7.4	8.2	***
motorable road	0.8	0.9	0.8	ns	0.9	0.8	0.9	ns	0.9	0.9	09	ns
extension agent	5.4	5.2	5.2	ns	5.8	5.1	5.7	ns	5.7	5.0	5.6	ns
veterinary service	4.4	4.3	4.4	ns	4.6	4.7	4.8	ns	4.5	4.1	4.9	ns
Share of (%) gross household income												
Maize	13	13	16	***	14	14	14	ns	14	14	13	ns
Cereals	16	16	21	***	16	16	18	**	17	17	16	ns
Fresh produce	12	11	8	***	12	11	7	***	11	11	8	***
Industrial crops	9	9	14	***	9	10	14	***	9	11	8	ns
Dairy and beef	18	16	17	*	14	17	20	***	16	17	14	***
Salaries	11	15	12	ns	13	14	14	ns	12	13	19	***
Informal business	13	14	12	ns	14	14	13	ns	14	12	19	***

Table 14. Dispersion of change in household diversification index, 1997 - 2010

Percentiles	Crop diversification			Agricultural diversification			Livelihood diversification		
	More diversified	No change	More specialized	More diversified	No change	More specialized	More diversified	No change	More specialized
	……Change in diversification index……..								
1%	0.10	-0.10	-0.56	0.10	-0.10	-0.67	0.10	-0.10	-0.61
5%	0.11	-0.08	-0.47	0.11	-0.09	-0.46	0.11	-0.08	-0.41
10%	0.12	-0.07	-0.37	0.12	-0.08	-0.36	0.12	-0.07	-0.37
25%	0.16	-0.03	-0.29	0.15	-0.04	-0.28	0.15	-0.03	-0.28
50%	0.24	0.02	-0.19	0.21	0.01	-0.19	0.21	0.01	-0.21
75%	0.34	0.06	-0.14	0.30	0.06	-0.14	0.31	0.06	-0.15
90%	0.48	0.08	-0.11	0.43	0.08	-0.12	0.44	0.08	-0.11
95%	0.60	0.09	-0.11	0.53	0.09	-0.11	0.51	0.09	-0.11
99%	0.70	0.10	-0.10	0.66	0.10	-0.10	0.65	0.10	-0.10
Dispersion									
% in category	38.2	50.0	11.8	31.4	56.2	12.4	31.2	53.9	14.9
Smallest	0.10	-0.10	-0.58	0.10	-0.10	-0.76	0.10	-0.10	-0.64
Largest	0.80	0.10	-0.10	0.83	0.10	-0.10	0.71	0.10	-0.10
Mean	0.27	0.01	-0.23	0.24	0.01	-0.23	0.25	0.01	-0.23
Std. Dev.	0.14	0.05	0.11	0.13	0.06	0.11	0.13	0.06	0.10
Variance	0.02	0.00	0.01	0.02	0.00	0.01	0.02	0.00	0.01
Skewness	1.17	-0.25	-1.22	1.40	-0.24	-1.68	1.19	-0.15	-1.20
Kurtosis	3.89	2.05	4.04	4.82	1.90	6.66	3.97	1.94	4.87

CHAPTER 2

ANALYSIS OF THE DETERMINANTS OF CROP, AGRICULTURAL AND LIVELIHOOD DIVERSIFICATION AMONG HOUSEHOLDS IN RURAL KENYA

2.1 Introduction and study rationale

Diversification is a strategy often practiced by smallholder households in many developing countries. The motive for diversification among households may vary depending on the objective pursued by the household. For example, households may diversify in order to expand their income opportunities, reallocate resources among competing enterprises or in response to or anticipation of some shock. These motives may be driven by the "push" and "pull" factors. According to this line of reasoning, households are "pushed" to diversify their portfolio of activities in response to some factor constraint such as population pressures, that may lead to land fragmentation, or to mitigate some risk or uncertainty, or in reaction to constraints to financial access or high transaction costs (Barrett et al., 2001). Thus, households may diversify when they have weak systems to deal with a given risk, such as posed by climatic uncertainty. On the other hand, households may be "pulled" into diversification, for example, when prevailing market conditions present opportunities that offer them a comparative advantage.

A key question that development researchers continue to ask is, what drives patterns and trends in smallholder diversification in Sub-Saharan Africa? The answer to this question may vary depending on a country's stage in the agricultural transformation process. For example, household income may lead to increased diversification in the pre-transformation period, but may encourage specialization in later phases The determinants may also differ depending on the level at which the study is undertaken. Studies have shown that there is a relationship between agricultural transformation and economic diversification (e.g., Timmer, 1997). In Phase I of the

agricultural transformation (Figure 1) when markets are weaker or lacking and households produce mainly for subsistence, there is a direct relationship between smallholder diversification and agricultural transformation: factors that facilitate agricultural transformation will also tend to promote smallholder diversification. But, as incomes rise and households develop confidence in food markets, they are likely to abandon self-sufficiency in favor of the market and engage in agricultural production to cater both for themselves, and for the market.

Among the key determinants of smallholder diversification, previous findings in Sub-Saharan Africa (SSA) show that the effect of land very mixed. For example, some studies, especially those carried at a more aggregated level (for example, district or country) have shown that, large farms tend to be more specialized in their cropping activities (producing one or just a few crops), but more diversified in their livelihoods (Asmah, 2011;Delgado & Siamwalla, 1997). For example, in a study examining rural livelihood diversification and household welfare in Ghana, Asmah, (2011) used two-period cross-section data to show that livelihood diversification into non-farm activities and household welfare are driven mainly by a household's net worth, and household characteristics (e.g., age structure, education level, and gender), market access (for both output and inputs) as well as infrastructure. The study also finds that diversification and land size are negatively correlated. On the other hand, studies that have been carried out at the household level, or those that use cross-section data show a positive relationship between land size wand smallholder diversification (Idowu, et al, 2011; Wanyama et al., 2010). In Nigeria, Idowu, et al, (2011) used the inverse Herfindahl index of income diversity (Ersado, 2006) and Tobit regressions to show that household size, per capita land holding size and per capita animal wealth increase rural household income diversification in Southwest Nigeria. Other key

determinants of livelihood[4] diversification have been identified as diminishing returns to productive resources (e.g., land and labor), market failures (e.g., for credit) or frictions (e.g., for mobility or entry into high-return niches), and production and market risks (Barrett, Reardon, & Webb, 2001).

In Kenya, studies have examined key determinants of smallholder diversification (Barrett et al., 2001; Reardon & Delgado, 1992; Reardon, 1997; Wanyama et al., 2010). Wanyama et al, (2010), for example, investigated the determinants of livelihood diversification strategies amongst rural households in maize based farming systems of Kenya. Using multinomial Logit and Tobit models, they showed that a majority of farmers in maize farming systems diversified into cash crops and off-farm income activities, but were constrained by production inefficiency, pricing, and marketing and lack of capital. In addition, they showed that land size positively impacted livelihood diversification, while low education levels negatively influenced it. Their study findings, however, were limited to only maize farmers in coffee production areas of the Central province.

Even fewer studies have incorporated the effect of weather shock in the analysis of determinants of smallholder diversification (Bradshaw, Dolan, & Smit, 2004; Huang, Jiang, Wang, & Hou, 2014), and rarely have these studies been carried out in Africa. For example, Bradshaw et al., (2004) show that farms have tended to specialize, rather than diversify cropping patterns in the face of anticipated climate variability. Other studies suggest that farmers tend to diversify as a

[4] Barrett et al, 2001 and Delgado & Siamwalla use off-farm income diversification as a measure of livelihood diversification. Asmah, (2011) also defines diversification as a household's participation in non-farm activities

strategy to mitigate the adverse weather conditions (Huang et al., 2014). In addition, is lacking regarding how the drivers of smallholder diversification differ among groups of households.

This study investigates the determinants of crop, agricultural and livelihood diversification in the presence of weather uncertainty using household panel data techniques. In addition, the study examines how the key drivers of smallholder diversification differ among groups of households.

The overall objective of this essay is to provide an understanding of the key determinants of rural agricultural and livelihood diversification and how these differ among types of rural households and to use these findings to make inference about the process of agricultural transformation in Kenya. Specifically, the study aims to:

a) Investigate the key determinants of rural crop, agricultural and livelihood diversification among rural farm households in Kenya
b) examine heterogeneity in rural smallholder diversification based on differences in landholding size, education, and wealth
c) Use the study findings to infer about effects of policy reforms on agricultural transformation in Kenya

The results of these findings are used to infer about the process of agricultural transformation in Kenya. The rest of the chapter is organized as follows. The study objectives are discussed in the next section, followed by study methodology and data sources. Method and data sources are presented in section 2.3, followed by a presentation of the study results in section 2.4. Discussion and study implications are presented in section 2.5.

2.2 Methods and data

2.2.1 Conceptual model for estimating determinants of smallholder diversification

Diversification can take different forms, ranging from production of a variety of crops, producing both crop and animals, or any combination of such crop, livestock, and off-farm activities (Gulati, Minot, Delgado, & Bora, 2007; Ryan & Spenser, 2001; Pingali & Rosegrant, 1995). Any particular strategy adopted by the household depends on the farmer's motive for diversification. For example, if a farmer's motive is to mitigate a perceived risk, such as poor weather, households may respond by shifting productive resources to crops and crop varieties that can withstand the adverse weather conditions. If, on the other hand, the farmer's motive is to address food insecurity, they may produce a variety of staple foods and also engage in other non-farm income activities. Still, if the motive is income or wealth growth, then they would tend to engage in high-value crops and industrial crop production.

Various methods have been used to analyze smallholder diversification among smallholders. Some studies have used multi-period data in the analysis of determinants of smallholder diversification (e.g., Kurosaki, 2003) while others are based on cross-section data (e.g., Minot, 2006; Asmah, 2011). These studies also tend to be highly aggregated. As a result, farm-level implications cannot be easily inferred from these studies. In addition, the indicators used to estimate diversification differ across studies. While some have used the number of crops, share of acreage allocated to a given crop or even an index of some sort (e.g., Minot, Epprecht, Anh, & Trung, 2006), other studies have used longitudinal data methods that account for unobserved heterogeneity, but use more aggregated data (e.g., Asmah, 2011; Kurosaki, 2003) . These methods can produce very varied results and inferences.

The purpose of this study is to investigate the key determinants of smallholder diversification among rural households in Kenya. The study uses longitudinal data disaggregated to the household level. This disaggregation is necessary especially in the attempt to explain how national agricultural policy reforms have shaped decision-making at the farm level. Also, the study undertakes analysis at three levels of diversification, namely, the crop, agricultural, and livelihood diversification. This analysis is important since it is possible that the key drivers may have varying effects depending on the level at which analysis is carried out.

The generalized form of Panel data model specification for a household can be stated as follows:

$$Y_{it} = \alpha + X'_{it}\beta + \varepsilon_{it} \quad (5)$$

where,

$$\alpha = c_i + \eta_t$$

In this specification, Y_{it} is the dependent variable, X_{it} is a vector of regressors, c_i is the individual-specific effects, η_t is the time-invariant effects, and ε_{it} is the idiosyncratic error term. Two panel data models are often used: the Fixed-Effects (FE) and Random-Effects (RE). The choice of which model to adopt depends on the assumptions regarding the individual-specific and time-invariant effects, α, and the error term. Under the FE model, α is assumed to be correlated with the regressors, X_{it}, thereby allowing for limited form of (Cameron & Trivedi, 2010; Greene, 2008; Wooldridge, 2010). Using the first-difference method eliminates the time-invariant unobservable effects. The RE model, on the other hand, assumes that both α and the error term ε_{it} are purely random processes uncorrelated with the regressors, i.e., it assumes zero correlation between observed explanatory variables and the unobserved effects. As a result, the

model yields estimates for both time-varying and time-invariant variables. Estimation can be carried out by feasible generalized least-squares (FGLS) estimator (Wooldridge, 2010).

Another method that is increasingly gaining use in longitudinal studies is the Correlated Random effects (CRE) model. First proposed by Mundlak, (1978) and relaxed by Chamberlain, (1982), the CRE model allows for correlation between observed explanatory variables and the individual unobserved effects. The major difference between the FE and CRE approaches is in the way the relationship between the observed explanatory variables and the unobserved individual effects are treated. In the FE model, this relationship is left entirely unspecified, while, in the CRE model, the unobserved individual effects are treated as random. This allows for the estimation of the coefficients of the time-invariant variables (Chamberlain, 1982).

2.2.2 Empirical model

This study adopted the Fixed Effects method of panel data analysis. The reduced-form Fixed Effects model for the determinants of smallholder diversification can be stated as:

$$DI_{it,k} = \alpha_i + DEM'_{it}\delta + SOC'_{it}\beta + PROD'_{vt}\gamma + INF'_{it}\theta + WTH'_{vt}\omega + YR'_t\tau + \eta_t + \varepsilon_{it} \qquad (6)$$

Where,

$DI_{it,k}$, the dependent variable, is household *i's* diversification index at time *t*, measured at the appropriate level (cropping activity, agricultural, or livelihood). The diversification index was estimated using the Herfindahl diversification index. For an individual household *i*, the Herfindahl Index $DI_{it,k}$ at period *t* at an appropriate diversification level *k* (crop, agricultural or livelihood) was estimated as:

$$DI_{it,k} = 1 - \sum_{a=1}^{N} \left(S_{at,k}\right)^2 \quad (7)$$

$S_{at,k}$ = the share of the total income, at the appropriate level of analysis *k* and time *t*, from economic activity *a*

$$\sum_{a=1}^{N} \left(S_{at,k}\right) = 1 \; and,$$

N = the total number of economic activities that a household engages in at the appropriate level of analysis *k* and time *t*

k = the level at which the smallholder diversification is being estimated, i.e., crop, agricultural, or livelihood

DEM'_{it} is a vector of the household' demographic variables, including, gender (dummy=1 if male, 0 if female), age and education level of the household head, household size and village population density.

SOC'_{it} is a vector of household's socioeconomic variables which include real income per adult equivalent, real household assets per adult equivalent, and acreage under cultivation. Also included I the set of socioeconomic variables is the access to credit

$PROD'_{vt}$ is the village-level crop productivity, measured by the village average maize yield per acre.

INF_{it}' is a set of variables used to assess how accessible households are to key infrastructure such as roads, markets, extension and inputs.

YR_t' is a vector of year dummies

WTH_{vt}' is a vector of weather variables deemed to influence household decision to diversify. These include rainfall and rainfall stress. The variables are measured at village level

α_i, η_t and ε_{it} are, respectively, individual and time-invariant fixed effects (e.g., locational dummies), and the idiosyncratic error term

$\delta, \beta, \gamma, \theta, \omega,$ and τ are vectors of parameters to be estimated.

2.2.3 Explanatory variables

Smallholder household diversification is conjectured to be influenced by a number of factors, which could be demographic (gender, age, education and household size), socioeconomic (income, assets, acreage and crop productivity) access to key infrastructure and services (inputs, on, credit, markets) among other factors. The direction of and degree of influence of these determinants depend on the motives for diversification, the access to and allocation of the productive resources, household choices and preferences as well as the phase of agricultural transformation. In general, three motives for diversification can be identified: income growth, resource redistribution, and risk mitigation. This motives cut across the transformation phases, and may be pursued individually or in combination. The interpretation of results may, therefore, be different for the different circumstances facing the smallholder farmer. . A summary of the hypothesized relationships between key variables and smallholder diversification at various levels of analysis is presented in Table 15.

Household demographic variables predicted to influence a household's diversification decision include gender, age and education level of the household head as well as household size. Gender (dummy 1=male, 0=female) of the household head can affect the ownership and allocation of productive resources such as land and assets which affect household production and productivity. Studies also show disparities in farm-household objectives depending on the gender of household head, with males mainly concerned with income generation activities while female heads are concerned with household food security (Bugri, 2008; Jayne et al, 1997). In many African countries, gender participation in agricultural production is constrained by access to productive resources which is often male-dominated (Sichoongwe, Mapemba, Ng'ong'ola, & Tembo, 2014). The direction of influence of gender on smallholder diversification is hypothesized to be ambiguous at all the three levels of analysis.

Age of the household head may be used to as a measure of farmer's experience. Older farmers are likely to be more experienced with production techniques and are likely to be more specialized compared to younger farmers because they view farming as a business and a way of life (Minot et al., 2006; Sichoongwe et al., 2014). Age of household head is thus hypothesized to have a negative influence on a farmer's decision to diversify.

Previous studies show a positive relationship between education level and household diversification (e.g., Ibrahim et al, 2009). More-educated household heads are likely to find employment outside of farming. In addition, heads with higher education are able to acquire better production skills allowing them to engage in the production of a variety of crops. On the other hand, education may also lead to more specialization since more educated households may withdraw labor from on-farm activities to off-farm activities. This is likely to occur when the agricultural sector is transformed. The education level of the head is thus hypothesized to have

an ambiguous influence on a household's decision to diversify. Household size, measured by the number of people residing in the household during the production year, has been used in various studies as a measure of labor availability. For example, Benin et al, (2004) showed that household has a direct influence on smallholder diversification. Yet, it is also expected that when household size increases, it may lead to a decline in labor productivity per worker, prompting households to seek gainful employment out of the crop agriculture. Therefore, household size may have an ambiguous effect on smallholder diversification.

Apart from the demographic variables, household socioeconomic variables are also likely to affect their diversification decisions. Studies have shown contrasting results with regard to household income and wealth. While some studies show a positive relationship between household diversification and income and wealth (e.g., Ibrahim et al., 2009), others show that higher income may lead to diversification in the earlier stages, but specialization in the later stages (Kimenju & Tschirley, 2008; Timmer, 1997). Also, acreage under cultivation by a household is also hypothesized to result either in diversification or specialization, depending on the phase of the agricultural transformation process (Asmah, 2011; Benin et al., 2004; Ibrahim et al., 2009; Sichoongwe et al., 2014).

Table 15. Expectations about direction of effect of key determinants of smallholder diversification among rural farm households

Variable	Variable description	Expected sign under diversification type		
		Crop	Agricultural	Livelihood
Demographic variables				
Gender	Dummy variable for gender of household head (1=male, 0=female)	+, -	+, -	+,-
Age	Age of household head (years)	-	-	-
Education	Years of school completed by household head	+, -	-	-
Household size	Number of members residing in the household during the production period	+	+	+
Socioeconomic variables				
Income	Lagged log of real household income per adult equivalent (KSh)	-	-	-
Assets	Log of real value of household assets per adult equivalent (Ksh)	+, -	+,-	+,-
Acreage under cultivation	Lagged log of acreage under cultivation by household in a production period	+,-	+/-	+,-
Infrastructure and services variables				
Distance to fertilizer seller	Distance (km) to nearest fertilizer seller	+	+	+
Distance to tarmac road	Distance (km) to nearest tarmac road	+	+	+
Distance to motorable road	Distance (km) to nearest motorable road	+,-	+,-	+,-
Distance to extension agent	Distance (km) to nearest extension agent	-	-	-
Access to credit	Dummy variable =1 if any member of household received agricultural credit	-	-	-
Technology variable				
Potential agricultural productivity	Crop productivity proxied by village average maize yield (kg/acre)	-	+	+
Weather variables				
Expected total rainfall	Two-year mean of village levels of total rainfall (mm) received within a village during a production period	+,-	+,-	+,-
Expected rainfall stress	Expected rainfall stress, computed as the village-level mean of two-year rainfall stress (the proportion of days in a 20-day cycle in a production period that total rainfall received is less than 40 mm) prior to the production period	+	+	+
Interaction terms				
Income*Stress	Interaction between lagged real household income and expected rainfall stress	+	+	+
Assets*Stress	Interaction between real household assets and the expected rainfall stress	+	+	+
Acreage*Stress	Interaction between acreage under cultivation and the expected rainfall stress	+	+	+
Agricultural transformation				
Transformation year	Dummy equal to 1 if survey year=2004, 0 otherwise	-	-	-,+

Among the key infrastructure and service variables, distance to input and output markets is expected to have a positive influence on a farmer's decision to diversify. In addition, distances to tarmac and motorable roads, which are indicators of the relative condition of physical infrastructure, and therefore the relative access to output markets, are hypothesized to have an ambiguous influence on the decision to diversify depending on whether a household is a net-producer or net consumer (Minot et al., 2006). Distance to extension agent, a measure of ease of access to production technology, is hypothesized to have an inverse influence on smallholder diversification: farm households in close proximity to extension agents are likely to be at a vantage position to receive better extension information about what and when to produce, application of scientific research and better agricultural practices, making them more likely to specialize. Also, access to credit can help solve the resource constraints that often hinder farmers from specializing.

Potential agricultural productivity[5] is used to examine the influence of production technology on smallholder diversification. Studies have shown a negative influence of crop productivity on crop diversification, but a positive influence on agricultural and livelihood diversification (Kimenju & Tschirley, 2008), implying that higher productivity drives households to specialize in cropping activities, but may also lead to more diversified agricultural and livelihood portfolios. Potential agricultural productivity is thus hypothesized to have a negative effect on crop diversification, but positive effect on agricultural and livelihood diversification. Two weather variables have been included in the analysis: the expected total rainfall and expected

[5] Potential agricultural productivity is measured by the village average maize yield (kg/acre)

rainfall stress.[6]. Studies in other parts of the world show contrasting results about how farm-households respond to climate variability (Bradshaw et al., 2004; Huang et al., 2014).

2.2.4 Estimation

This study adopted both the Fixed Effects (FE) model to analyze the determinants of smallholder diversification[7]. In order to capture heterogeneity among households, households were grouped into dichotomous groups by landholding size ("land-poor" and "land-rich")[8], wealth (asset-poor and asset rich)[9] and education level (primary and post-primary education level)[10]. The analysis was then conducted to examine how the key drivers of smallholder diversification differ among groups of farm households. The analysis was conducted at three levels of smallholder diversification (crop, agricultural, and livelihood) for the whole sample, and for specific household groups using STATA command *xtreg* (Cameron & Trivedi, 2010).

[6] Expected total rainfall was estimated as the two-yea mean of village-level rainfall received prior to the relevant production period. Expected rainfall stress, on the other hand, was estimated as the two-year mean rainfall stress (proportion of days in a 20-day cycle that total rainfall received is less than 40 mm)..

[7] The results of the FE models were compared to those of the Correlated Random Effects (CRE) models at respective levels and found to be comparable. The main advantage of the CRE model over the FE model in a panel analysis is that CRE model keeps all the time invariant observables in the model but the FE model does not. This is particularly important when it is necessary to display the outcome of the time-invariant unobservables such as regions. When the results are comparable, Fe models is a more acceptable as a panel data method of analysis because of its desirable assumptions and properties(Cameron & Trivedi, 2010; Wooldridge, 2010). Therefore, only FE model results are reported here.

[8] Two approaches were considered in grouping household by landholding size. The first used total landholding size owned by a household, in which case, a household was considered to be "land-rich" if it owned more than 5 acres, and "land-poor" if it owned 5 acres or less,. This classification was based on preliminary findings showing that more than 70% of households sampled owned 5 acres or less. The second approach used the zonal mean landholding size. Under this classification method, a household was considered to be "land-rich" if its landholding size was more than the zonal mean landholding size, and land-poor otherwise. After trying both methods of classification, the study adopted the second approach, because it accounted for regional differences even though the regression results based on these two approaches were fairly comparable,.

[9] For the purposes of this study, poor households are those whose net worth is less than or equal to the zonal mean net worth, while wealthy households are those with net worth greater than the zonal mean net worth.

[10] Households whose head had eight years or less formal schooling were categorized as having primary education while those with more than eight years were categorized as having post-primary education

2.2.5 Data sources

Data used for this study is from the Kenya rural household rural surveys collected by Egerton University's Tegemeo Institute of Agricultural Policy and Development, collected in four-panel waves (2000, 2004, 2007 and 2010)[11]. The survey covered 24 administrative districts grouped into eight (8) distinct agro-ecological zones (AEZs). The initial sample comprised 1500 households (Argwings-Kodhek, 1998), but by 2010 only 1309 households were interviewed, representing an attrition rate of 11%. Of the 1309 households that were surveyed in 2010, 1301 participated in all five panel waves. Questionnaire remained fairly stable over the last four surveys, enabling accurate capture of the household and demographic changes over time. The data was then organized to reflect the key variables of importance to this study. Because the dependent variable was a proportion ranging between 0 and 1, data transformations were done on larger explanatory variables including household income, real assets, cultivated acres, village-average maize yield, village-level population density and proximity and access to a major city[12]. Other variables entered the regression models as levels.

[11] Even though the data consisted of five waves (1997, 2000, 2004, 2007 and 2010), this study used only four latter waves since some weather variables were missing for the 1997 survey period

[12] Access to major markets was measured by the travel time to a city of 250,000 people. This variable provides information on both the distance to the market and road quality. A positive coefficient implies that the household is located farther from the major markets or that there are poorer access roads linking the farmer to the major markets.

2. 3 Study findings

This section discusses the findings of regression analysis on the key determinants of smallholder diversification. Section 2.3.1 discusses the determinants of smallholder diversification for the whole sample, landholding, and wealth, and education level of the household head.

2.3.1 Determinants of smallholder diversification

The results of the Fixed Effects regression of key determinants of smallholder diversification at crop, agricultural and livelihood levels of analysis are displayed on Table 16. A dummy variable indicating the year agricultural transformation is hypothesized to have taken place in Kenya (2004) was included in the regression models. In addition, interaction terms between the expected rainfall stress and household income, and cultivated acreage were also included. The findings reveal that the key determinants of smallholder diversification (those that are significant in at least one equation) include acreage under crop cultivation, potential agricultural productivity (measured by the village average maize yield, distance to extension agent and expected total rainfall within a production period. Other determinants are gender and education of the household head, access to credit, crop commercialization index, credit access, expected rainfall stress and the dummy for agricultural transformation (Table 16).

Table 16. Fixed Effects regressions of determinants of crop, agricultural and livelihood diversification among smallholders in rural Kenya, 2000 - 2010

	Type of smallholder diversification		
VARIABLES	Crop	Agricultural	Livelihood
Gender of household head (1=m, 0=f)	-0.0288***	-0.0166	-0.0177
	(0.0111)	(0.0108)	(0.0112)
Age of household head (years)	-0.0001	0.0000	0.0004
	(0.0004)	(0.0004)	(0.0004)
Education of household head (years)	0.0017*	0.0019**	0.0001
	(0.0010)	(0.0009)	(0.0010)
Household size	0.0015	-0.0002	-0.0022
	(0.0015)	(0.0014)	(0.0015)
Lagged log of real household income (Kshs)	-0.0029	-0.0035	-0.0011
	(0.0055)	(0.0053)	(0.0050)
Lagged crop commercialization index	0.0777***	0.0352***	-0.0058
	(0.0122)	(0.0120)	(0.0118)
Log of real household net assets (Ksh/ae)	0.0036	0.0036	0.0025
	(0.0056)	(0.0054)	(0.0055)
Log of cultivated acres (acres)	0.0110	0.0160**	0.0370***
	(0.0081)	(0.0077)	(0.0078)
Household received agricultural credit (1=yes)	-0.0139**	-0.0060	0.0067
	(0.0054)	(0.0051)	(0.0055)
Log of potential agricultural productivity (kg/acre)	-0.0027	0.0484***	0.0371***
	(0.0077)	(0.0067)	(0.0056)
Distance to fertilizer seller (km)	0.0008	0.0001	0.0003
	(0.0006)	(0.0006)	(0.0006)
Distance to tarmac road (km)	0.0000	0.0005	0.0016**
	(0.0008)	(0.0009)	(0.0008)
Distance to motorable road (km)	-0.0021	0.0003	-0.0024
	(0.0020)	(0.0017)	(0.0015)
Distance to extension agent (km)	-0.0022***	-0.0015**	-0.0012**
	(0.0006)	(0.0006)	(0.0006)
Expected rainfall stress†	0.1273**	0.0792	0.0185
	(0.0638)	(0.0624)	(0.0682)
Expected total rainfall (mm)‡	0.0308***	0.0229**	0.0499***
	(0.0104)	(0.0097)	(0.0106)
Lagged log of household income * expected rainfall stress	0.0066	0.0099	0.0277**
	(0.0127)	(0.0121)	(0.0131)
Log of real household assets * expected rainfall stress	0.0048	0.0041	0.0045
	(0.0117)	(0.0115)	(0.0119)
Log of cultivated acreage * expected rainfall stress	-0.0116	0.0017	-0.0131
	(0.0192)	(0.0186)	(0.0182)
Agricultural transformation year (>2004=1)	-0.0061	0.0077	0.0251***
	(0.0057)	(0.0051)	(0.0055)
Constant	0.3430***	0.1144	0.0019
	(0.0937)	(0.0862)	(0.0887)
Observations	4,579	4,579	4,579
Number of households	1,161	1,161	1,161
R-squared	0.034	0.060	0.059

Robust standard errors in parentheses

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

† Expected rainfall stress = 2-year previous rainfall stress mean

‡ Expected total rainfall = 2-year previous total rainfall during main growing season

Two variables, the distance to the extension agent and the expected total rainfall during a production period, have significant but opposing influence on smallholder household diversification in all the three equations. Distance to extension agents has a highly significant negative influence on a household's crop diversification index (at 1% significance level) and a significant (at 5% level) influence at the agricultural and livelihood diversification levels: the nearer a household is situated relative to the extension agent, the more likely they will become specialized in their crop, agricultural and livelihood activities. Expected total rainfall, on the other hand, has a positive highly significant influence at the crop and livelihood levels and a significant effect at the agricultural diversification level, suggesting that when households expect better total rainfall in the production season, they are more likely to diversify their crop, agricultural and livelihood income activities.

Besides the distance to extension agent and the lagged total rainfall, acreage under crop cultivation, potential crop productivity, education of the household head and lagged crop commercialization index show statistical significance in two of the three equations. The amount of farmland cultivated by a household has a statistically significant positive influence on agricultural diversification, and a highly positive effect at the livelihood diversification level. Also, a household's potential crop productivity[13] has a positive and highly statistically significant effect on household agricultural and livelihood diversification, but a negative and non-significant influence on crop diversification. These findings suggest that farm households cultivating large tracts of land, and those with higher crop productivity are more likely to be diversified in their agricultural and livelihood activities. Contrary to the hypotheses that area

[13] A household's potential agricultural productivity is measured by the village average maize yield, computed for every survey period. This variable measures the potential yield a household could realize

under crop cultivation would lead to more household crop diversification, and that productivity would lead to more crop specialization, the findings show that these two variables do not affect smallholder crop diversification.

In addition, lagged crop commercialization index, the proportion of gross crop value that is marketed by a household during its immediate past production period, has a highly positive influence on a household's current crop and agricultural diversification, but no effect on livelihood diversification. Past crop sales as a proportion of the gross value of crop production provide households with income that they can use to secure resource to engage in the production of other crops and livestock activities.

A number of variables in the results show significance in only one equation but not in others. These include a household's access to credit, expected rainfall stress and its interaction with a household's past income, and the dummy variable for agricultural transformation. Access to credit has a negative and significant effect on crop diversification, but no effect on agricultural or livelihood diversification. Households that accessed agricultural credit were more likely to be specialized at the cropping activity level than those that did not access agricultural credit and this finding is significant at 5% level. This finding suggests that lack of credit may be a constraint to crop specialization. Also, the findings reveal that in the presence of agricultural transformation, households diversify in their livelihood activities, but no effect is observed at the crop or agricultural diversification levels.

The findings on gender show a very strong and negative influence on crop diversification. Compared to male-headed households, female-headed households are likely to be more diversified in their cropping activities. The effect of gender on agricultural and livelihood

diversification is, however, nonsignificant. In addition, education of the household head has a positive influence and significant influence (at 5% level) on the household's decision to diversify agriculturally, but only a marginal influence at the cropping activity level. On the other hand, household size and age of household head do not seem to affect smallholder diversification.

The effect of expected rainfall stress[14] on household diversification, measured by the two-year mean village rainfall stress prior to production, may occur directly, or indirectly through its interaction with household income, assets or acreage under cultivation. The findings show that expected rainfall stress has a significant direct effect (at 5%) on household crop diversification, but no indirect effect. When households anticipate a 10% increase in rainfall stress on the basis of information obtained from prior rainfall stress patterns, they increase crop diversification by 12.7%. The results show that expected rainfall stress affects smallholder livelihood diversification only indirectly through its interaction with household income. The coefficient of the interaction term between household income and expected rainfall stress in the livelihood diversification equation is positive and statistically significant at 5% level, suggesting that households adopt crop diversification as a strategy to mitigate the effect of anticipated drought or bad weather. The findings further suggest that smallholder crop and livelihood diversification are sensitive to weather shocks.

Also, household's access to agricultural credit has a negative but marginal (at 10% significant level) effect on crop diversification. Households receiving agricultural credit during a production year are more likely to be specialized in their crop activities compared to households not

[14] The expected rainfall stress was measured as the mean of two production periods' rainfall stress prior to the actal production period. For example, the expected rainfall stress for the 2000 survey period (1999 main period harvest) was computed as the mean of the rainfall stress for the 1998 and 1999.

receiving credit. Even though household income has the negative sign, its influence is non-significant. Also, household net assets exhibit a positive but non-significant effect on smallholder diversification at all diversification levels.

Besides examining the key drivers of smallholder diversification over the whole sample, analysis of what drives diversification among groups of households may shed more information about the behavior of rural farm households. For example, household behavior towards diversification or specialization may be conditioned by the amount of land they own, the level of education of the head of the household or even the household wealth status. This heterogeneity among households with respect to drivers of diversification is explored in this section. A dichotomous categorization of households was done based on their landholding size, education level of the household head and household wealth. Analysis on each of the dichotomous groups was conducted using the Fixed Effects regressions techniques, after which the regression results were compared.

2.3.2 Smallholder diversification and landholding size

The results key determinants of smallholder rural households when households are grouped by the size of landholding are displayed in Table 7. Previous findings on this variable suggest highly diverse results. On the one hand, some studies show that the size of landholding is an important driver of smallholder diversification (Idowu et al., 2011; Wanyama et al., 2010) while others have shown an inverse relationship between the landholding size and smallholder diversification. (e.g., Asmah, 2011; Delgado & Siamwalla, 1997). Fewer studies have examined how households with different landholding sizes respond to these drivers. In this subsection, we explore the heterogeneity among households with regard to the landholding size. Households were divided

into two groups based on the mean zonal landholding size: “land-poor” households (those owning total land less than or equal to zonal mean landholding size) and the “land-rich” households (households with more than the mean zonal landholding size). The results of the Fixed Effects regressions for the three levels of household diversification are displayed on Table 17.

The results show that there is a gender difference in the determinants of smallholder diversification when households are grouped according to landholding size. The coefficient of gender variable is negative and significant for the “land-poor” households at the cropping activity and livelihood levels, but gender is not a major determinant of smallholder diversification among the land-rich households. Thus, female-headed land-poor households are likely to be more diversified at the crop and livelihood levels compared to their male counterparts, perhaps suggesting the important role of women in food security. In addition, even though the household size is not significant in the full model or among the less land-endowed households at any diversification level, it positively influences crop diversification among the “land-rich” households. Larger households are able to meet the labor needs that allow may them to diversify into other crops.

Table 17. Fixed effects regressions of determinants of smallholder diversification by zonal mean household landholding size, 2000 to 2010

	crop diversification		Agricultural diversification		Livelihood diversification	
VARIABLES	"Land-poor"	"Land-rich"	"Land-poor"	"Land-rich"	"Land-poor"	"Land-rich"
Gender of household head (1=m, 0=f)	-0.0290**	-0.0027	-0.0182	0.0190	-0.0265**	0.0171
	(0.0127)	(0.0314)	(0.0123)	(0.0265)	(0.0129)	(0.0295)
Age of household head (years)	-0.0002	0.0001	-0.0002	0.0007	0.0005	-0.0009
	(0.0005)	(0.0012)	(0.0005)	(0.0009)	(0.0006)	(0.0010)
Education of household head (years)	0.0016	0.0032	0.0013	0.0032	-0.0004	0.0020
	(0.0011)	(0.0027)	(0.0011)	(0.0023)	(0.0013)	(0.0024)
Household size	0.0001	0.0064**	-0.0012	0.0039	-0.0025	0.0005
	(0.0021)	(0.0028)	(0.0019)	(0.0025)	(0.0018)	(0.0038)
Lagged log of real household income (Kshs)	-0.0022	-0.0136	-0.0009	-0.0103	-0.0058	0.0028
	(0.0065)	(0.0125)	(0.0063)	(0.0117)	(0.0061)	(0.0127)
Lag of crop commercialization index	0.0781***	0.0631**	0.0372***	0.0262	-0.0011	-0.0024
	(0.0145)	(0.0277)	(0.0142)	(0.0276)	(0.0136)	(0.0294)
Log of real household net assets (Ksh/ae)	0.0000	0.0338**	-0.0004	0.0217	0.0014	0.0145
	(0.0068)	(0.0145)	(0.0066)	(0.0134)	(0.0068)	(0.0151)
Log of cultivated acres (acres)	0.0084	0.0237	0.0188*	0.0112	0.0430***	0.0167
	(0.0112)	(0.0226)	(0.0108)	(0.0196)	(0.0109)	(0.0223)
Household received agricultural credit (1=yes)	-0.0121*	-0.0037	-0.0028	0.0006	0.0079	-0.0022
	(0.0065)	(0.0125)	(0.0060)	(0.0116)	(0.0067)	(0.0140)
Potential agricultural productivity (kg/acre)	0.0049	0.0126	0.0456***	0.0615***	0.0451***	0.0305***
	(0.0093)	(0.0146)	(0.0091)	(0.0120)	(0.0082)	(0.0095)
Distance to fertilizer seller (km)	0.0020***	-0.0010	0.0017**	-0.0011	0.0013	0.0007
	(0.0008)	(0.0011)	(0.0008)	(0.0010)	(0.0009)	(0.0011)
Distance to tarmac road (km)	0.0012	0.0019	0.0007	0.0016	0.0015	0.0022
	(0.0009)	(0.0017)	(0.0009)	(0.0022)	(0.0010)	(0.0016)
Distance to motorable road (km)	0.0026	-0.0029	0.0013	-0.0016	-0.0009	-0.0043
	(0.0022)	(0.0040)	(0.0022)	(0.0034)	(0.0022)	(0.0037)
Distance to extension agent (km)	-0.0027***	-0.0004	-0.0018**	-0.0020	-0.0013	-0.0031**
	(0.0008)	(0.0013)	(0.0007)	(0.0014)	(0.0008)	(0.0015)
Expected rainfall stress†	0.1399*	0.2035	0.1487*	0.0155	0.0347	0.0968
	(0.0779)	(0.1671)	(0.0759)	(0.1708)	(0.0841)	(0.1982)
Expected total rainfall (mm)‡	0.0394***	0.0297	0.0288**	0.0130	0.0520***	0.0455*
	(0.0122)	(0.0264)	(0.0117)	(0.0245)	(0.0131)	(0.0273)
Lagged log of household Income * expected rainfall stress	0.0031	0.0251	-0.0068	0.0259	0.0266	0.0242
	(0.0148)	(0.0274)	(0.0149)	(0.0252)	(0.0171)	(0.0284)

Table 17 (cont'd)

VARIABLES	crop diversification		Agricultural diversification		Livelihood diversification	
	"Land-poor"	"Land-rich"	"Land-poor"	"Land-rich"	"Land-poor"	"Land-rich"
Log of real assets * expected rainfall stress	0.0084	-0.0349	0.0055	-0.0155	0.0051	-0.0226
	(0.0143)	(0.0276)	(0.0141)	(0.0275)	(0.0150)	(0.0311)
Log of cultivated acreage * expected rainfall stress	0.0090	-0.0365	0.0162	0.0101	-0.0006	-0.0006
	(0.0309)	(0.0395)	(0.0291)	(0.0376)	(0.0278)	(0.0462)
Agricultural transformation year(>2004=1)	0.0042	-0.0145	0.0129**	0.0010	0.0239***	0.0247*
	(0.0068)	(0.0133)	(0.0063)	(0.0120)	(0.0068)	(0.0131)
Constant	0.2716**	0.1328	0.1200	0.0128	-0.0037	0.0322
	(0.1272)	(0.2628)	(0.1196)	(0.2419)	(0.1220)	(0.2543)
Observations	3,372	1,207	3,372	1,207	3,372	1,207
Number of households	1,088	598	1,088	598	1,088	598
R-squared	0.047	0.043	0.065	0.109	0.073	0.050

Robust standard errors in parentheses

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

† Expected rainfall stress = 2-year previous rainfall stress mean

‡ Expected total rainfall = 2-year previous total rainfall during main growing season

Land categorization: "Land-poor" household own total land less than the zonal average landholding size; "Land-rich" own more than the zonal mean landholding size

Despite the expectation that increased income should lead to less diversification (especially beyond Phase I of agricultural transformation) the study finds a statistically no significant effect of household income at all the three levels and for both land groups. Also, household wealth positively influences crop diversification among the more land-endowed households but has no effect g the least-land-endowed. However, crop commercialization index is positive and highly significant for the "land-poor" at the crop and agricultural diversification levels, and for the "land-rich" at the cropping activity level. This suggests that, irrespective of their landholding size, households tend to be more diversified when they participate more in output markets. Also, the coefficient of household assets is for the "land-rich household only at the cropping activity level, but non-significant elsewhere Thus, an increase in household wealth among the "land-rich" increases their ability to diversify their income portfolio at crop, agricultural and livelihood levels

The findings further show that agricultural and livelihood diversification increases with potential agricultural productivity for both land endowment groups, but has no significant effect at the cropping activity level. Thus, agricultural productivity is important in spurring growth in the agricultural and non-farm sub-sectors. Also, even though the full model shows that smallholder agricultural and livelihood diversification increases with an area under cultivation, the effect is nearly entirely observed among the more land-endowed households. This finding is supported by previous some studies that show a positive relationship between landholding size and smallholder diversification (e.g., Idowu et al., 2011; Wanyama et al., 2010).

Despite the fact that results of the full model show a negative and significant influence of the distance to extension agent, there are differences between the two landholding groups with regard to how access to infrastructure and services influence the household decision to diversify.

For example, access to extension services has an inverse effect on a household's decision to diversify cropping, agricultural and livelihood activities among the "land-poor", but no effect on the "land-rich" households, implying that better access to extension agents (shorter distance) is associated with smallholder diversification among the least land-endowed. Better access to agricultural credit, on the other hand, leads to crop specialization among the less land-endowed, though the finding is only significant at 10% level. Access to credit has no effect among the more land-endowed households. This finding suggests that credit constraint may be a constraint to crop specialization among the least land-endowed. In addition, distance to agricultural input market has a direct relationship with crop and agricultural diversification among the least land-endowed, but no effect among the well-endowed households. Poor input market infrastructure increases transaction costs of acquiring inputs. When poor households have good access to input (and output) markets, they may increase their total production through the use of high-quality inputs and this may lead to specialization among the least-endowed households. This finding is supported by previous studies (e.g., Minot et al., 2006).

Weather variables also influence the land-poor households towards diversification but has nearly no influence among the land-rich. Results show that expected total rainfall during a growing season had a strong positive influence on diversification among the least land-endowed at all the three diversification levels, but had a marginal influence among the well-endowed households only at the livelihood level. Also, expected rainfall stress marginally led to crop and agricultural diversification among "land-poor" but had no effect among the more land-endowed households. When less-endowed households anticipate drought, their response is to spread their risk across a number of cropping and agricultural activities. This might explain one of the motives for smallholder diversification.

2.3.3 Smallholder diversification and household head education

In addition to examining heterogeneity in drivers of smallholder diversification by the size of landholding, households were grouped by the level of education of the household head into a) those with zero and eight years of formal schooling (primary education), and, b) those with more than eight years of education (post-primary education) and then the Fixed effects analysis was applied to each group. The findings show that acreage under cultivation increases agricultural and livelihood diversification for the least-educated households, and livelihood diversification for the more-educated households (Table 18). As with previous findings, potential agricultural productivity leads to agricultural and livelihood diversification for all education groups. Also, crop commercialization encourages agricultural and livelihood diversification among the least-educated households, and crop diversification for the more educated.

Distance to extension service, on the other hand, has a negative and significant effect on crop diversification for the less-educated households, suggesting that better access to extension service leads to crop diversification among the less educated. On the other hand, distance to tarmac and motorable roads have opposing effects on livelihood diversification for the less-educated households. Distance to tarmac road is positive and significant at 5% level for the less-educated households, implying that that better access to major markets would lead households to produce marketable surplus and this, in turn, leads to specialization among the least-educated. Poor access, on the other hand, leads to more diversification (Minot et al., 2006). The distance to motorable road is, however, negative but less significant.

Table 18. Fixed effects regressions of determinants of smallholder diversification by household head education level, 2000 to 2010

	crop diversification		Agricultural diversification		Livelihood diversification	
Variables	Primary	Post-primary	Primary	Post-primary	Primary	Post-primary
Gender of household head (1=m, 0=f)	-0.0336***	-0.0056	-0.0236*	0.0497	-0.0227*	0.0249
	(0.0130)	(0.0430)	(0.0125)	(0.0381)	(0.0126)	(0.0311)
Age of household head (years)	0.0002	0.0009	0.0002	0.0022	0.0005	0.0042**
	(0.0005)	(0.0015)	(0.0005)	(0.0014)	(0.0005)	(0.0018)
Education of household head (years)	0.0012	0.0000	0.0024	0.0008	0.0018	-0.0030*
	(0.0018)	(0.0019)	(0.0017)	(0.0015)	(0.0017)	(0.0018)
Household size	0.0022	0.0045	0.0010	-0.0030	-0.0016	-0.0039
	(0.0017)	(0.0034)	(0.0016)	(0.0032)	(0.0017)	(0.0039)
Lagged log of real household income (Ksh)	-0.0054	0.0003	-0.0036	-0.0015	0.0013	-0.0089
	(0.0058)	(0.0176)	(0.0056)	(0.0175)	(0.0056)	(0.0114)
Lagged crop commercialization index	0.0902***	0.0510**	0.0480***	0.0053	-0.0057	0.0062
	(0.0141)	(0.0254)	(0.0140)	(0.0262)	(0.0139)	(0.0236)
Log of real household net assets (Ksh/ae)	-0.0004	0.0176	-0.0000	0.0171	0.0037	0.0092
	(0.0063)	(0.0128)	(0.0060)	(0.0124)	(0.0063)	(0.0122)
Log of cultivated acres (acres)	0.0140	0.0043	0.0205**	-0.0060	0.0338***	0.0397**
	(0.0090)	(0.0198)	(0.0087)	(0.0187)	(0.0087)	(0.0187)
Household received agricultural credit (1=yes)	-0.0216***	0.0083	-0.0101	0.0092	0.0065	0.0141
	(0.0068)	(0.0103)	(0.0064)	(0.0089)	(0.0069)	(0.0100)
Log of village average maize yield (kg/acre)	-0.0034	0.0072	0.0522***	0.0380***	0.0363***	0.0479***
	(0.0086)	(0.0201)	(0.0079)	(0.0136)	(0.0063)	(0.0128)
Distance to fertilizer seller (km)	0.0009	0.0005	0.0002	0.0003	0.0003	-0.0005
	(0.0006)	(0.0018)	(0.0006)	(0.0016)	(0.0007)	(0.0016)
Distance to tarmac road (km)	-0.0006	0.0015	0.0003	0.0018	0.0018**	0.0025
	(0.0009)	(0.0018)	(0.0011)	(0.0015)	(0.0009)	(0.0018)
Distance to motorable road (km)	-0.0029	0.0008	-0.0011	0.0024	-0.0029*	-0.0035
	(0.0021)	(0.0040)	(0.0020)	(0.0033)	(0.0017)	(0.0033)
Distance to extension agent (km)	-0.0020***	-0.0013	-0.0008	-0.0036*	-0.0011	-0.0023
	(0.0006)	(0.0018)	(0.0006)	(0.0018)	(0.0007)	(0.0019)
Expected rainfall stress†	0.0781	0.2536	0.0598	0.1588	0.0412	-0.0790
	(0.0699)	(0.1836)	(0.0705)	(0.1737)	(0.0766)	(0.1717)
Expected total rainfall (mm)‡	0.0265**	0.0480**	0.0219*	0.0220	0.0511***	0.0456*
	(0.0123)	(0.0218)	(0.0113)	(0.0210)	(0.0124)	(0.0236)
Income * expected rainfall stress	0.0067	0.0079	0.0071	0.0087	0.0231	0.0390
	(0.0134)	(0.0397)	(0.0133)	(0.0374)	(0.0150)	(0.0312)

Table 18 (cont'd)

Variables	crop diversification		Agricultural diversification		Livelihood diversification	
	Primary	Post-primary	Primary	Post-primary	Primary	Post-primary
Assets * expected rainfall stress	0.0150	-0.0238	0.0125	-0.0315	0.0020	0.0051
	(0.0130)	(0.0283)	(0.0127)	(0.0277)	(0.0139)	(0.0252)
Cultivated acreage * expected rainfall stress	-0.0160	0.0036	-0.0131	0.0705	-0.0128	0.0120
	(0.0208)	(0.0514)	(0.0199)	(0.0526)	(0.0206)	(0.0445)
Agricultural transformation year(>2004=1)	-0.0032	-0.0182	0.0103*	-0.0123	0.0273***	-0.0069
	(0.0070)	(0.0125)	(0.0062)	(0.0110)	(0.0066)	(0.0145)
Constant	0.4315***	0.0047	0.1203	0.0160	-0.0245	-0.1630
	(0.1137)	(0.3053)	(0.1069)	(0.2901)	(0.1096)	(0.2280)
Observations	3,318	1,261	3,318	1,261	3,318	1,261
Number of households	939	424	939	424	939	424
R-squared	0.043	0.029	0.070	0.055	0.062	0.078

Robust standard errors in parentheses

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

† Expected rainfall stress = 2-year previous rainfall stress mean

‡ Expected total rainfall = 2-year previous total rainfall during main growing season

Note: Education categorization: 0 to 8 years of schooling = Primary level; More than 8 years of schooling = Post-primary level

In addition, expected total rainfall has a positive and highly significant effect on smallholder crop and livelihood diversification for the least-educated households. Among the most-educated, expected total rainfall is significant at the livelihood diversification level. This suggests that most smallholders rely on rain-fed agriculture. Therefore, better prospects of rainfall in the coming production period provides an opportunity to diversify especially their cropping activities. Despite the coefficient of expected rainfall stress being significant at the cropping activity level in the full model, findings across education groups are not significant at any of the diversification levels. This may suggest that lack of inadequacy of rainfall stress data upon which households could base their diversification decisions.

The study further shows that gender of the household head has a highly significant negative influence among the least-educated households at the cropping activity level, but only a marginal influence under the agricultural and livelihood models. Thus, less educated female-headed households are more diversified in their crop activities compared to the more-educated households. In contrast, gender has no observable effect on smallholder diversification among the more-educated households.

2.3.4 Smallholder diversification and household wealth

Another way of understanding differences among households is to group them by their wealth status. Households were grouped into poor and wealthy households. The Fixed Effects regression results based on wealth heterogeneity is presented in Table 19. The findings mirror previous results. For example, an increase in area under cultivation by the least wealth-endowed households encouraged more agricultural and livelihood diversification, with more robust results observed at the livelihood level. Among the more wealth-endowed households, however, the area under cultivation only influenced livelihood diversification. In addition, potential agricultural productivity had a positive influence on agricultural and livelihood diversification for both wealth groups, but there is no observable no influence at the cropping activity level. Notably, the coefficient of potential agricultural productivity at the livelihood level is markedly higher for the wealthy households than it is for the poor households.

Also, poor input market infrastructure (e.g., longer distance to fertilizer seller) led to crop diversification among the poor households but has no observable influence on diversification decisions for the wealthy households. In addition, distance to motorable road is inversely associated with crop diversification for the wealthy households but has no observable effect among the least wealth-endowed households. Furthermore, better access to extension service (shorter distance to the extension agent) encourages crop and agricultural diversification among poor households, but only marginally affects livelihood diversification among the wealthy households. In addition, least wealth-endowed households with less access to agricultural credit are more diversified in their cropping activities than those with more credit access, suggesting that access to agricultural credit promotes crop specialization, especially among the resource-poor.

Table 19. Fixed effects regressions of determinants of smallholder diversification by mean household wealth, 2000 - 2010

	crop diversification		Agricultural diversification		Livelihood diversification	
VARIABLES	"Poor"	"Wealthy"	"Poor"	"Wealthy"	"Poor"	"Wealthy"
Gender of household head (1=m, 0=f)	-0.0324**	-0.0053	-0.0108	-0.0019	-0.0121	-0.0108
	(0.0129)	(0.0255)	(0.0128)	(0.0244)	(0.0134)	(0.0238)
Age of household head (yrs)	-0.0002	0.0017*	-0.0004	0.0017*	-0.0001	0.0025**
	(0.0005)	(0.0010)	(0.0004)	(0.0009)	(0.0005)	(0.0010)
Education of household head (years)	0.0015	-0.0002	0.0013	0.0013	-0.0008	0.0000
	(0.0013)	(0.0017)	(0.0012)	(0.0016)	(0.0015)	(0.0016)
Household size	0.0026	0.0026	0.0022	-0.0022	-0.0016	-0.0035
	(0.0020)	(0.0030)	(0.0018)	(0.0030)	(0.0019)	(0.0033)
Lagged log of real household income (Ksh)	-0.0094	0.0007	-0.0090	0.0065	-0.0004	0.0041
	(0.0059)	(0.0116)	(0.0059)	(0.0103)	(0.0061)	(0.0124)
Lagged crop commercialization index	0.0973***	0.0450*	0.0506***	0.0148	-0.0158	0.0243
	(0.0146)	(0.0268)	(0.0145)	(0.0254)	(0.0148)	(0.0256)
Log of real household net assets (Ksh/ae)	0.0019	0.0160	0.0048	0.0048	0.0024	-0.0135
	(0.0073)	(0.0147)	(0.0071)	(0.0142)	(0.0075)	(0.0141)
Log of cultivated acres (acres)	0.0079	0.0248	0.0144*	0.0228	0.0357***	0.0411**
	(0.0084)	(0.0240)	(0.0075)	(0.0242)	(0.0094)	(0.0194)
Household received agricultural credit (1=yes)	-0.0145**	-0.0053	-0.0051	0.0022	0.0107	0.0016
	(0.0071)	(0.0111)	(0.0064)	(0.0105)	(0.0067)	(0.0122)
Log of village average maize yield (kg/acre)	-0.0095	0.0248	0.0396***	0.0613***	0.0397***	0.0362***
	(0.0087)	(0.0171)	(0.0089)	(0.0134)	(0.0077)	(0.0111)
Distance to fertilizer seller (km)	0.0013*	-0.0012	0.0007	0.0000	0.0006	0.0004
	(0.0007)	(0.0015)	(0.0007)	(0.0013)	(0.0008)	(0.0013)
Distance to tarmac road (km)	0.0002	0.0005	0.0010	-0.0001	0.0018*	0.0032
	(0.0010)	(0.0018)	(0.0010)	(0.0022)	(0.0009)	(0.0020)
Distance to motorable road (km)	0.0005	-0.0098***	0.0004	0.0001	-0.0020	-0.0033
	(0.0023)	(0.0028)	(0.0024)	(0.0025)	(0.0022)	(0.0024)
Distance to extension agent (km)	-0.0022***	-0.0007	-0.0013**	-0.0013	-0.0009	-0.0029*
	(0.0007)	(0.0013)	(0.0007)	(0.0016)	(0.0008)	(0.0015)
Expected rainfall stress†	0.0668	0.1568	0.0823	-0.0593	0.0481	-0.1424
	(0.0776)	(0.1933)	(0.0781)	(0.1846)	(0.0793)	(0.2401)
Expected total rainfall (mm)‡	0.0307**	0.0219	0.0180	0.0170	0.0474***	0.0468**
	(0.0132)	(0.0208)	(0.0128)	(0.0177)	(0.0142)	(0.0202)
Income * expected rainfall stress	0.0185	0.0035	0.0106	0.0018	0.0176	0.0225
	(0.0141)	(0.0288)	(0.0145)	(0.0233)	(0.0159)	(0.0311)

Table 19 (cont'd)

	crop diversification		Agricultural diversification		Livelihood diversification	
VARIABLES	"Poor"	"Wealthy"	"Poor"	"Wealthy"	"Poor"	"Wealthy"
Assets * expected rainfall stress	0.0080	0.0035	0.0010	0.0303	0.0028	0.0311
	(0.0153)	(0.0298)	(0.0153)	(0.0305)	(0.0156)	(0.0349)
Cultivated acreage * expected rainfall stress	-0.0115	-0.0534	-0.0112	0.0231	-0.0123	-0.0211
	(0.0229)	(0.0524)	(0.0210)	(0.0528)	(0.0217)	(0.0464)
Agricultural transformation year(>2004=1)	-0.0001	-0.0284**	0.0134**	-0.0121	0.0288***	0.0167
	(0.0068)	(0.0119)	(0.0063)	(0.0108)	(0.0067)	(0.0120)
Constant	0.4881***	0.0140	0.2902**	-0.1410	0.0417	-0.0891
	(0.1241)	(0.2230)	(0.1173)	(0.2021)	(0.1258)	(0.2081)
Observations	3,193	1,386	3,193	1,386	3,193	1,386
Number of households	1,016	591	1,016	591	1,016	591
R-squared	0.044	0.049	0.048	0.101	0.057	0.072

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1
† Expected rainfall stress = 2-year previous rainfall stress mean
‡ Expected total rainfall = 2-year previous total rainfall during main growing season

The results further show differences among wealth groups with respect to the effect of crop commercialization index. While the full model shows the significance of the crop commercialization index at the crop and agricultural levels (Table 6), this effect is almost entirely attributable to the least wealth-endowed households. When they anticipate better value for their crop sales, the least wealth-endowed households are likely to be more diversified. In addition, weather variables show that expected total rainfall may lead to livelihood diversification for both wealth groups, but only affects crop diversification for the poor households. Expected rainfall stress, however, has no observable influence on smallholder diversification, contrary to the expectation.

2.3.5 Effects of policy reforms on smallholder diversification in Kenya

A key question this study sought to answer was whether the policy reforms of the 1980s and early 2000s had an effect on smallholder diversification. In order to examine the effect of policy reforms (and hence agricultural transformation) on smallholder diversification in rural Kenya, a year dummy variable (=1 if year 2004 or later, and zero otherwise) was included in the regression models. A significantly negative coefficient of the year dummy at an appropriate level would signal increased specialization in the post-policy reform period compared to the reform period. On the other hand, a positive and significant coefficient of the year dummy would suggest that relative to the pre-reform period, households became more diversified.

The full model (Table 16) results indicate that the coefficient of the year dummy is positive and highly significant only in the livelihood model, but not at other diversification levels. However, at a more disaggregated level, results show some heterogeneity. For example, wealthier households became more specialized at the cropping activity levels in the post-reform period. At

the agricultural and livelihood levels, there was an observed increase in diversification among the least wealth-endowed households. On the other hand, livelihood diversification increased during the post-reform period for both wealth groups. This suggests that the policy reforms may have triggered crop specialization among the wealthy households, but may have led to increased diversification at the livelihood level. With regard to the landholding size and education level of household head, the findings show that, there is no effect of the year dummy at the cropping activity level for any landholding group, but that land-poor households may have experienced increased agricultural and livelihood diversification in the post-policy reform period compared to the pre- reform period.

2.4 Conclusions and implications

The overall objective of this essay was to investigate what drives rural agricultural and livelihood diversification and how these drivers differ among types of rural households following the agricultural policy reforms that took place in the 1980s and early 2000s. Specifically, the study investigated the key determinants of the rural crop, agricultural and livelihood diversification among rural farm households in Kenya, and examined heterogeneity among rural households using landholding size, education and household wealth as grouping variables. Below is a summary of key findings and their implication for policy.

2.4.1 Summary of findings and discussion

A number of key drivers of smallholder diversification were identified in this study. The study showed that area under cultivation is a key driver of household diversification, especially at the agricultural and livelihood diversification in the overall sample. At a more disaggregated level, the area under cultivation had a positive effect on smallholder agricultural diversification among

least wealth-endowed and least-educated households but has less or no effect among the wealthy and well-educated households. The implication of this finding is that households with large landholding sizes are likely to be agriculturally diversified. Moreover, more land provides a household the flexibility for resource-poor households to spread its risk across more income-generating activities at the agricultural and livelihood diversification levels. For example, with more land under cultivation, households may diversify into livestock production (for example, produce fodder). The findings of this study support some earlier household level findings that large acreage encourages smallholder diversification (Idowu et al., 2011; Wanyama et al., 2010), especially at the agricultural and livelihood levels, but. contradict results from more aggregated levels that suggest an inverse relationship between farm size and smallholder diversification (e.g., Asmah, 2011; Benin et al., 2004; Delgado & Siamwalla, 1997; Gulati et al., 2007; Sichoongwe et al., 2014; Weiss & Briglauer, 2000). It can, therefore, be inferred that at the household level, more land under cultivation is necessary for increased smallholder diversification.

The study also found that increased crop commercialization leads to smallholder crop and agricultural diversification, but the results were more robust for the least-endowed household. This suggests that market participation holds a lot of promise for the resource-poor household in their pursuit for income growth. In addition, while potential agricultural productivity had no observable effect on crop diversification, it had a positive and significant influence on a household's decision to diversify into agricultural and livelihood activities, This finding supports previous studies that showed that increased agricultural productivity is a necessary tool for diversification into non-crop and off-farm activities ion (Kimenju & Tschirley, 2008; Timmer,

1988) that higher agricultural productivity led to higher farm incomes that households could invest into nonagricultural portfolios such as informal business.

The findings on weather variables are mixed. While there was no observed effect of expected rainfall stress on smallholder diversification at any level in the full model, it had a positive effect on crop, agricultural and livelihood diversification among "land-poor households. Thus, when "land-poor" household anticipate severe rainfall stress (such as drought) based on previous weather patterns, their reaction is to spread the weather risk through diversification. On the other hand, expected total rainfall had a positive effect on smallholder diversification at all the three diversification levels. Also, the interaction term between expected rainfall stress and lagged household income increases livelihood diversification, suggesting that households may be using diversification as a strategy to mitigate the effect of anticipated drought. At a more disaggregated level, total rainfall had a positive and significant effect on crop and livelihood diversification among the least land-endowed households, but no effect among the most land-endowed, suggesting that households constrained by land diversify their crop and livelihood activities in the presence of higher expected total rainfall. Expected total rainfall also led to increased crop diversification for both education groups, but also led to more livelihood diversification for the least-educated households. Thus, better rainfall also encourages livelihood diversification among the wealthy households.

Access to agricultural services was also shown to influence smallholder diversification. For example, the study found that access to agricultural credit has a negative effect on smallholder crop diversification in the full model. At a more disaggregated level, however, the study shows that these effects are typically found only for the least well-endowed households, whether in the land, education, or wealth. Thus, access to agricultural credit improves a household's ability to

acquire the necessary inputs such as fertilizer and certified seed and specialized agricultural equipment for crop specialization. Households that accessed to agricultural credit were more t likely to be specialized in crop production than those that did not receive credit.

Furthermore, distance to extension agent was found to be inversely related smallholder diversification. Better access to extension service (shorter distance to the extension agent) stimulated smallholder crop and agricultural diversification among the land-poor and less wealth-endowed households, and livelihood diversification among the more land-endowed households. Access to timely and relevant extension services significantly drives their decision to diversify. The findings on the effects of policy reforms were captured using a year dummy.

With regard to the effect of policy reforms on smallholder diversification, the results, in general, show that agricultural policy reforms led to a more diversified livelihood in the post-reform period (2004 and later) compared to the pre-reform period. The results further suggest that effect of the policy reforms are not uniform across households, but differ depending on the type of household and their resource endowment. For example, crop specialization may have occurred among the wealthier households as a result of these policy reforms but no effect was observed among the less wealthier households. Instead, the least well-endowed households (whether in land, wealth or education) experienced increased agricultural and livelihood diversification as a result of the policy reforms. So, while crop specialization may have begun, evidence suggests that Kenya's agricultural sector remains fairly diversified in their agricultural and livelihood activities. These results suggest that Kenya could still be in the earlier stages of agricultural transformation, but that it may have started the process towards specialization, at least in cropping activities

In summary, the study shows that smallholder diversification increases with acreage under cultivation, expected total rainfall, poor access to input markets, inadequate access to agricultural credit, better access to extension services, prospects for market participation (such as crop commercialization) and male-headedness. Agricultural diversification is driven primarily by the same factors, in addition to education of the household head and potential agricultural productivity. At the livelihood level, key drivers of smallholder diversification include acreage under cultivation, potential agricultural productivity, expected total rainfall and the interaction between expected rainfall stress and lagged household income, as well as the agricultural policy reforms.

2.4.2 Policy implications

What do these findings mean for Kenya's agricultural sector? In order to realize the full potential of agricultural transformation, policy reforms should be focused on providing an enabling environment for continued transformation of the sector. First, better land policies can improve farm households' access to agricultural land. Also, policies on agricultural research and extension could spur growth in smallholder incomes. The study finds that agricultural productivity is an important determinant of smallholder agricultural and livelihood diversification. Access to better timely and relevant extension service has been shown to stimulate increased agricultural and livelihood diversification. In addition, availability of affordable high-quality seed and agricultural inputs is necessary to spur productivity growth among smallholder farm households through improved yields. There is need to strengthen the research-extension-farmer linkages to ensure farmer access to appropriate technologies in a timely manner. In addition, farmer education can greatly enhance assimilation of research

findings and uptake of appropriate technologies. Therefore, policies that target agricultural research and extension can be important in spurring growth in smallholder incomes

The study also showed that anticipated total rainfall greatly leads to smallholder diversification, suggesting that most households rely on rain-fed agriculture. On the other hand, the study found that expected rainfall stress led to diversification especially among the least-endowed households. From a policy perspective, there is need for accurate and reliable weather forecasting, and timely dissemination to enable farm households to make informed production and economic decisions. Also, investment in irrigation equipment could ensure the continuous flow of water during the critical production period and hence minimize the adverse effects of poor rainfall distribution. This will ensure that farmer's decision to produce is not based on rainfall availability. This is likely to increase production and revenues among households. In addition, access to credit has been shown to stimulate crop specialization among the least-endowed households, whether in land, education or wealth. Thus, making credit more accessible and affordable to smallholders can help transform the agricultural sector. Also, policies that encourage market participation can help grow smallholder incomes.

CHAPTER 3

EFFECTS OF AGRICULTURAL AND LIVELIHOOD DIVERSIFICATION ON RURAL HOUSEHOLD WELFARE IN KENYA

3.1 Introduction and study rationale

A major task for many developing country governments is to enact policies that can promote agricultural growth, and reduce chronic poverty and household food insecurity. In Kenya, majority of households depend, directly or indirectly, on agriculture for their livelihoods. In an attempt to address the major challenges facing Kenyans, the Government in 2003 developed an economic blueprint, the Economic Recovery Strategy for Wealth and Employment Creation (ERS), which aimed among other things at employment creation and poverty reduction ((Republic of Kenya, 2003).In addition, the government developed the Strategy for Revitalizing Agriculture (SRA) to help raise household incomes, create employment and ensure food and nutrition security, which had been identified as a key challenge to majority of Kenyans. , whose overall objective is to raise household incomes, create employment and ensure food and nutrition security (Republic of Kenya, 2004). And recently, the government rolled out the Vision 2030, which aims to transform Kenya into a newly-industrializing middle-income economy offering high quality to her citizens (Republic of Kenya, 2007) through, among other things, increasing crop and livestock productivity and improving market access for smallholders. All these blueprints have had one goal: improving the welfare of the citizenry.

Despite its importance, the agricultural sector continues to face a number of constraints that have slowed its growth including inadequate input and output markets, poor market infrastructure, inadequate access to agricultural credit, weak or ineffective extension-research and uncoordinated policy reforms. In order to reverse these trends and make agriculture commercially viable, governments often formulate policies that address the inadequacies in the

sector. These policy reforms often influence decisions regarding smallholder diversification and household welfare.

Diversification at the household level is often accompanied by reallocation of resources (land, labor and other productive assets) from some economic activity the household deems to be less profitable to those deemed viable and profitable (Pingali, 1997). For some households, this may mean, for instance, withdrawing resources from maize production to the production of high-value products and livestock, while, for others, it could be the reverse: specialization into maize production. This reallocation is likely to influence the household welfare. In addition, households may be able to build their wealth from increased income arising from diversification. In the absence of well-functioning markets, this resource reallocation may lead to household food insecurity.

Food security in developing countries has received considerable attention from development agencies (Babatunde & Qaim, 2010; Babatunde & Qaim, 2009; Clover, 2003; Devereux & Maxwell, 2001; Dose, 2007; Pinstrup-Andersen, 2009). According to Food and Agriculture Organization (FAO) of the United Nations, food security is a situation in which households at all times have access to adequate quantities of safe and nutritious food to lead a healthy and active life (World Food Summit, 1996). This definition emphasizes three critical aspects of food security namely, availability, access, and risk. Access refers to the ability to obtain the necessary food, either through own production or from the market. Inherent in this statement is the aspect of affordability. Risk arises when a household's food security situation is affected by fluctuations in production or purchasing power, thereby creating production and market risks.

Food insecurity has remained a major challenge and a focus of policy reform in many developing countries. In Sub-Saharan Africa (SSA), it is estimated that nearly one-quarter of the population

faced with chronic food insecurity (FAO, 2014) and that most of the affected population reside in the rural areas. The report further shows that food insecurity in Africa lags behind global trends. Key challenges to achieving food security in the rural areas are population growth, urbanization and income growth, underdeveloped agricultural sector, dwindling land sizes, barriers to market access, and natural disasters such as drought, among other factors. Agricultural transformation through appropriate policy reforms has been hypothesized as one of the possible solutions to the SSA food insecurity situation. According to (Swift & Hamilton, 2001), rural households in Africa follow highly diversified livelihood portfolios in response to the risks posed by uncertain weather patterns. These portfolios affect household food security incomes and net worth.

Besides household food security, crop, agricultural and livelihood diversification are likely to affect other aspects of household welfare. Two important measures of household welfare likely to be affected by diversification/specialization are the household net worth and household income. Fewer studies have been carried out to highlight these impacts in Africa to investigate the long-term effects of smallholder diversification on household welfare. Babatunde & Qaim, (2010), for example, investigated the relationship between household calorie intake and off-farm income. Using a structural model, they showed that off-farm income contributes to higher food production and farm income thereby easing capital constraints. They further showed that both farm and off-farm income led to improved household food security through increased calorie intake. Ersado, (2006) examined the changes and welfare implications of livelihood diversification among rural and urban populations of Zimbabwe following a series of macroeconomic changes and weather shocks of the 1990s. He found that wealthy households were more diversified than poor households, and were able to withstand unfavorable impacts of policy and weather shocks than poor households. He also showed that the poor were more

vulnerable without proper safety nets. Other studies also found that livelihood diversification increases smallholder incomes and may be used as a poverty reduction strategy (e.g., (Babatunde & Qaim, 2009; Olale & Henson, 2013). However, lack of data poses constraints in the extent to which diversification affects household food security estimation over time.

The welfare effect of smallholder diversification in rural areas is hypothesized to be correlated to the agricultural transformation process. In the absence of markets, households are likely to rely solely on own production and they tend to produce mainly for subsistence. As markets begin to function, diversification is likely to increase household income and wealth, but reduce the household's ability to be food-secure, especially if diversification implies transferring resources from food crops to commercial crops in response to market opportunities. But as markets improve (or as land sizes rise), incomes are likely to be increased by specialization, not by diversification, and households no longer have to rely on self-sufficiency to be food-secure. More-specialized households at this stage in the transformation process are likely to be more food secure (Kimenju & Tschirley, 2008; Niehof, 2004; Timmer, 1988). Moreover, studies also show that climate change may affect a farm household choice of income activities that ultimately determine the household welfare (e.g., Mubanga, Umar, Muchabi, & Mubanga, 2015)

While there is expected to be a relationship between smallholder diversification and household welfare, evidence is often lacking to show this relationship. Moreover, very few studies have investigated the welfare effects of smallholder diversification in the presence of weather uncertainty. The purpose of the study is to determine the welfare effects of crop, agricultural and livelihood diversification on farm households. Three measures of household welfare were examined: household food security (measured by the amount of maize calories available for consumption at the household per adult equivalent), household net-worth (measured by the value

of real net assets) and household income[15]. The guiding hypothesis for the welfare analysis is that households diversify in order to mitigate the risks to their income, food security and net worth.

Based on these expectations, the overall objective of this essay is to investigate the welfare effects of agricultural and livelihood diversification at the household level. Specific objectives for the study are to:

a) Determine the effects of crop, agricultural and livelihood diversification on three measures of rural household welfare, namely, income, food security, and net-worth in the presence of rainfall stress and policy reforms of the 1990s
b) Examine heterogeneity in household welfare effects of livelihood diversification between groups of households

The rest of the chapter is organized as follows. Study methodology, including the data used for the study, are presented in the next section. Findings of the study are presented in section 3.3followed by a discussion of the findings and policy implications in section 3.4

3.2 Methods and data

As is the case with any panel data, the dependent variable is observed over time, and observation in the current period may be influenced by observations in the previous periods. When dependent lagged variable is present in the model, Ordinary Least Square regression (OLS) leads to inconsistent estimates because the dependent lagged variable introduces endogeneity. Thus, a dynamic model that accounts for the endogeneity is appropriate. Consistent estimators can be

[15] Household food security was measured by the amount of maize calories available for consumption at the household per adult equivalent. Household net worth and income was estimated, respectively, by the value of real net assets and real gross income per adult equivalent

obtained by instrumental variable (IV) estimation of the parameters in the first-differenced (FD) model using appropriate lags of regressors as instruments (Arellano & Bond, 1991; Cameron & Trivedi, 2010). The study adopted the dynamic panel data estimation to investigate the welfare effects of smallholder diversification.

3.2.1 The dynamic panel data model

Dynamic panel data method allows for separation of three key effects: (i) the direct correlation through lagged dependence in preceding periods (the true state dependence), (ii) the direct correlation through observed regressors (the observed heterogeneity), and (iii) the indirect correlation caused by the time-invariant individual effects (the unobserved heterogeneity). The general model for an autoregressive model of order ρ (i.e. having ρ lags of dependent variable, hence referred to as AR(ρ) model) is stated as:

$$y_{it} = \alpha_1 y_{i,t-1} + \alpha_1 y_{i,t-2} + \cdots + \alpha_1 y_{i,t-\rho} + \beta' x_{it}^{*} + \eta_i + \upsilon_{it}, \quad t = \rho + 1, \dots, T \qquad (8)$$

For an AR(1) model, the equation (8) can be re-written as:

$$y_{it} = \alpha y_{i,t-1} + \beta' x_{it}^{*} + \eta_i + \upsilon_{it}$$

$$= \theta x_{it} + \eta_i + \upsilon_{it} \qquad (9)$$

where $\mathrm{x_{it}} = \left(\mathrm{y_{i,t-1}}\ \mathrm{x_{it}^{*}}\right)$ is a $k\ x\ 1$ vector of endogenous and exogenous regressors, η_i is a vector of time-invariant variables and υ_{it} is the disturbance term. The model assumes that random sample of *N* individual time series $(y_{i1}, \dots, y_{iT})$ is available, where *T* is small and *N* is large. The υ_{it} are assumed to have finite moments (Arellano & Bond, 1991). Specifically, the model assumes that the error terms are not serially correlated normality of the error term, i.e., $E(\upsilon_{it}) = E(\upsilon_{it}\upsilon_{is}) = 0,\ s \neq t$. However, the model does not assume independence over time. These

assumptions allow the use of second and subsequent lagged dependent variables to be used as valid instruments in the FD model.

The FD model for an AR(1) specification can be stated as:

$$\Delta y_{it} = \alpha_1 \Delta y_{i,t-1} + + \beta' \Delta x_{it}^* + \Delta v_{it}, \quad t = 2, \dots, T \tag{10}$$

Where

$$\Delta y_{it} = y_{it} - y_{i,t-1}$$

$$\Delta x_{it}^* = x_{it}^* - x_{i,t-1}^*$$

$$\Delta v_{it} = v_{it} - v_{i,t-1}$$

In contrast to the static model, the ordinary least squares (OLS) estimate of the first-differenced data produces inconsistent parameter estimates because the regressor $\Delta y_{i,t-1}$ is correlated with the Δv_{it}, even if v_{it} are serially uncorrelated. For serially uncorrelated error term v_{it}, the FD model error $\Delta v_{it} = v_{it} - v_{i,t-1}$ is correlated with $\Delta y_{i,t-1} = y_{i,t-1} - y_{i,t-2}$ because $y_{i,t-1}$ depends on $v_{i,t-1}$. Moreover, Δv_{it} is uncorrelated with $\Delta y_{i,t-k}$ for $k \geq 2$, meaning we could use these lagged variables as instruments for the endogenous variables.

The form of the optimal matrix of instruments depends on the nature of the right-hand side variables in the vector x_{it}^*. Three types of variables can be identified: strictly exogenous, predetermined or weakly exogenous, or endogenous. A regressor is strictly exogenous if it is uncorrelated with past, present or future error terms, i.e., x_{it}^* is strictly exogenous, if $E(x_{it}^* v_{is}) = 0$, for all s, t. Strictly exogenous variables present no estimation problems and need not be instrumented since they serve as their own instruments.

Predetermined and contemporaneously endogenous regressors need to be instrumented in order to obtain consistent estimates. A predetermined or weakly exogenous repressor is one that is correlated with past errors, but uncorrelated with the present or future errors (Cameron & Trivedi, 2010), i.e.,

$E(x_{it}^{*}\upsilon_{is}) \neq 0,\ s < t$ and,

$$\mathrm{E}(x_{it}^{*}\upsilon_{is}) = 0,\ \ s \geq t \qquad (11)$$

A regressor is classified as contemporaneously endogenous if it is correlated with the past and present but not future error terms, that is,

$E(\mathrm{x}_{\mathrm{it}}^{*}\upsilon_{\mathrm{is}}) \neq 0,\ \mathrm{s} \leq \mathrm{t}$ and,

$$E(x_{it}^{*}\upsilon_{is}) = 0,\ \ s > t \qquad (12)$$

In this case, $E(x_{it}^{*}\upsilon_{it}) \neq 0$, and the first lag is no longer a valid instrument in the first-differenced model. Predetermined regressors are instrumented using subsequent lags of x_{it}^{*}, (i.e., $x_{i1}^{*}, x_{i2}^{*}, \ldots, x_{i,s-1}^{*}$) which are valid instruments in the differenced equation for period s. Valid instruments for contemporaneously endogenous regressors are therefore the second and further lags.

Estimation of the dynamic panel data models often uses one of two different IV estimators can be obtained: the Two-Stage Least Squares (2SLS) and the General Method of Moments (GMM). However, because the introduction of instruments leads to over-identification of the model, a situation in which the number of instruments is greater than the estimated parameters, the GMM, also known as the two-step estimator, gives more efficient estimation over the 2SLS.

3.2.2 Empirical welfare models

Three measures of household welfare were estimated: household income (measured by the real gross household income per adult equivalent), household food security (measured by maize kilocalories per adult equivalent per day[16]), and the household to investigate the effect of agricultural and livelihood diversification on household food security and net worth. Based on the framework above, two separate models were estimated. For estimation purposes, the study assumed first-order autoregressive (AR (1)) representation, i.e., only one-period lag of dependent variable was included. This assumption seemed plausible given that there was a three to four year period between successive surveys.

The household income model uses income per adult equivalent as the dependent variable. The reduced form equations for this analysis take the form:

$$HINC_{it} = HINC'_{i,t-1}\alpha + X'_{it}\beta + D'_{it}\varphi + \omega'_{jt}\gamma + \pi'_{it}\sigma + \eta_i + v_{it} \quad (13)$$

where

$HINC_{it}$ = natural logarithm of real household income per adult equivalent for household *i* at time *t*, in Kenya shillings

X'_{it} = a vector of exogenous, predetermined and endogenous regressors for household *i* at time *t*

[16] Maize kilocalories per adult equivalent is computed from maize retained for home consumption (including stocks from previous years, if it was used in the current period consumption), purchased or received in kind

D_{it}' = an appropriate diversification index (crop, agricultural or livelihood) for household *i* at time *t*

ω_{jt}' = village level rainfall stress, measured as the realized rainfall stress (the proportion of days in a 20-day cycle that rainfall received was below 40 mm) during the main growing season

π_{it}' = interaction between village level rainfall stress, $\omega_{jt,}'$ and individual household diversification index, D_{it}'.

η_i = individual and region specific time-invariant heterogeneity

v_{it} = the error term

$\alpha,\ \beta,\ \varphi,\ \sigma$ and δ are parameters to be estimated.

The second welfare indicator investigated in this study is the household maize security. Household food security can be measured in two conventional ways: the expenditure approach, which estimates the monetary amount actually spent on household food purchases, or the calorie approach, which estimates the amount of calorie available for every member of the household and compares this to the widely established calorie intake requirements. Since the dataset used in this study did not capture all expenditures on all food items by the household, the calorie measure might be a better indicator of the household food security situation.

Studies have shown that cereals (specifically maize) provide most of the household calorie requirement (Devereux & Maxwell, 2001). In Kenya, as in many countries of East and Southern Africa, maize is the main staple food for a majority of households, and reference to food security is often a reference to a household's ability to access adequate maize to meet its consumption

needs. The study used log of household maize security (HMS_{it}) as a proxy for household food security. Household maize security was defined as the maize calories available for consumption per adult equivalent, including maize meal and/or maize grain purchased, received as gift, or retained from own production.

The reduced-form equations for the effect of diversification on food security are given as:

$$HMS_{it} = HMS'_{i,t-1}\alpha + X'_{it}\beta + D'_{it}\varphi + \omega'_{it}\delta + \pi'_{it}\sigma + \eta_i + \upsilon_{it} \quad (14)$$

where,

HMS_{it} = natural logarithm of maize available for consumption per adult equivalent in household *i* at time *t*, in kilocalories

X'_{it} = a vector of exogenous, predetermined and endogenous regressors for household *i* at time *t*

$D_{it}{}'$ = an appropriate diversification index (crop, agricultural or livelihood) for household *i* at time *t*

ω'_{jt} = village level rainfall stress, measured as the realized rainfall stress (the proportion of days in a 20-day cycle that rainfall received was below 40 mm) during the main growing season

π'_{it} = interaction between village level rainfall stress, $\omega'_{jt,}$ and individual household diversification index, $D_{it}{}'$.

η_i = individual and region specific time-invariant heterogeneity

v_{it} = the error term

$\alpha,\ \beta,\ \varphi,\ \sigma$ and δ are parameters to be estimated.

Interaction terms between the dummy variables and the relevant explanatory variables will also be included in the model.

The third welfare indicator, the household net worth, is defined as the total assets less any liabilities (e.g. any loans owed by the household). Consistent with the agricultural transformation framework (Figure 1), it is hypothesized that in the early phases of agricultural transformation, there is a positive correlation between household net-worth and diversification: households increase net worth by diversifying their economic activities. However, in later phases, when markets are functioning and especially when households are confident of being able to cost-effectively purchase food staples in rural areas, they will increase their net worth by specializing, not by diversifying.

A dynamic panel data model of household net worth was estimated. Therefore, the estimation model for the effect of agricultural and livelihood diversification on household net-worth was stated as:

$$HNW_{it} = HNW'_{i,t-1}\alpha + X'_{it}\beta + D'\varphi + \omega'_{jt}\delta + \pi'_{it}\sigma + \eta_i + v_{it} \qquad (15)$$

where,

$HNW_{it}{}'$ = a 1x1 vector of natural logarithm of real household net worth per adult equivalent for household *i* at time *t*, in Kenya shillings

$X_{it}{}'$ = a vector of exogenous, predetermined and endogenous regressors for household *i* at time *t*

D_{it}' = an appropriate diversification index (crop, agricultural or livelihood) for household *i* at time *t*

ω_{jt}' = village level rainfall stress, measured as the realized rainfall stress (the proportion of days in a 20-day cycle that rainfall received was below 40 mm) during the main growing season

π_{it}' = interaction between village level rainfall stress, $\omega_{jt,}'$ and individual household diversification index, D_{it}'.

η_i = individual and region specific time-invariant heterogeneity

v_{it} = the error term

$\alpha,\ \beta,\ \varphi,\ \sigma$ and δ are parameters to be estimated.

The coefficient of the interaction term between diversification index and rainfall stress provides explains whether households use diversification as a strategy to mitigate or reduce the weather risk. A positive and significant interaction term would imply that households indeed use diversification as a strategy to mitigate the adverse effects of the weather risk while a negative one suggests that the motive by the household might just be that of resource allocation from some income portfolios to others. The marginal effect of smallholder diversification on household welfare was computed. Algebraically, suppose equations (13), (14) and (15) are restated in a more generic form, ignoring the subscripts as:

$$W = A'\emptyset + D'\varphi + \pi'\sigma$$

$$= A'\emptyset + D'\varphi + (\omega D)'\sigma \qquad (16)$$

where, W is the measure of household welfare (natural logarithm of household income, net worth or maize security), A' is a vector of all other variables controlled in the equation, and $\emptyset$ is a vector of parameters, and D', φ, ω, π' and σ, are as defined above

Taking the partial derivative of equation (16) yields

$$\frac{\partial W}{\partial D} = \varphi + +\omega'\sigma \quad (17)$$

Thus, the marginal effect of smallholder diversification varies both with the coefficient of the diversification index and the level of rainfall stress. A post-estimation analysis of the marginal effect of diversification on the respective welfare variables was conducted to simulate how respective household welfare indicators are affected by smallholder diversification at various rainfall stress levels. The marginal effects were presented in a graphical form.

Finally, in order to examine heterogeneity among the households, households were grouped by land size into two categories: “land-poor” (cultivating 5 acres or less) and “land-rich” (cultivating more than 5 acres) households. Dynamic panel data analysis applied to these groups. For simplicity, the analysis was conducted using only livelihood diversification index.

3.2.3 Specification tests

In order to ensure that the models are correctly specified, two essential assumptions needed to be tested. First was a test of over-identifying restrictions, and the second was to test the critical assumption of no serial correlation in the error terms in subsequent years. For each regression model at the appropriate level, two specification tests were carried out.

First, the models were tested for consistent estimation using the Arellano-Bond test for serial autocorrelation (Cameron & Trivedi, 2010). In order to obtain consistent estimators, the Arellano-Bond estimators require that the error term υ_{it} be serially uncorrelated. Specifically, υ_{it} are serially uncorrelated when $\Delta\upsilon_{it}$ is not correlated with $\Delta\upsilon_{i,t-k}$ for $k \geq 2$, that is, $\Delta\upsilon_{it}$ are uncorrelated with $\Delta\upsilon_{i,t-1}$[17]. Test for no serial correlation in the first-differenced model is a test of whether the second and subsequent lags of the error term are serially correlated. The null hypothesis is that there is no serial correlation in the first-differenced errors, that is, $Cov(\Delta\upsilon_{it}, \Delta\upsilon_{i,t-1}) = 0$ for $k = 1,\ 2, 3$. Under this test, the null hypothesis of zero autocorrelation in the first-differenced errors would be rejected for the first lag, but not in the subsequent lags. In the models presented below, this condition was met.

Because of potential endogeneity problem caused by, a) the inclusion of the lagged dependent variable and, b) the potential endogeneity of some right-hand side variables, a test for validity of the instrumental variables was carried out using the *Sargan* test of overidentifying restrictions (Cameron & Trivedi, 2010). The null hypothesis was that overidentifying restrictions are valid. This is a Chi-square test, with the degrees of freedom being the number of identifying

[17] To see how, $Cov(\Delta\upsilon_{it}, \Delta\upsilon_{i,t-1}) = Cov(\upsilon_{it} - \upsilon_{i,t-1}, \upsilon_{i,t-1} - \upsilon_{i,t-2}) = -Cov(\upsilon_{i,t-1}, \upsilon_{i,t-1}) \neq 0$. For $k \geq 2$, however, $\Delta\upsilon_{it}$ will not be correlated with $\Delta\upsilon_{i,t-k}$

restrictions, i.e., the number of excess instruments used to estimate the parameters. The null hypothesis was rejected if *p-value* < 0.05, implying that the population moment conditions were correct.

3.2.4 Data sources

This study uses a five-wave rural household panel data collected by Egerton University's Tegemeo Institute between 2000 and 2010 with an interval of 3 – 4 year between survey periods. The initial sample size was 1500 households spread across eight (8) agro-ecological zones. As of 2010, 1309 households of participated in the survey and only 1,243 households participated in all the five survey periods. Key household and demographic variables were tracked over the survey period, ensuring that the questionnaire remained fairly stable over time. A detailed description of the survey design and implementation is found in Argwings-Kodhek (1998).

3.3 Effect of smallholder diversification on household welfare

In this section, the results of the welfare effect of smallholder diversification are presented. Dynamic panel data regressions were carried out on three measures of household welfare, namely, the natural logarithms of real household income, household maize security, and real household net worth. The analysis was carried at three diversification levels. Marginal effect analysis was conducted to establish the effect of smallholder diversification in the presence of rainfall stress. These findings are presented in sections 3.3.1 through 3.3.3.

3.3.1 Effects of smallholder diversification on household income

The results of the welfare effect of smallholder diversification on household income are displayed on Table 20. The findings show a significantly negative persistence in the model, especially at the crop and livelihood level. Lagged household income has a negative residual effect on the current household income. Household assets, on the other hand, has a positive and significant effect in models containing crop or agricultural diversification, but a less significant effect in the model with livelihood diversification. Net worth has a positive and highly significant effect on a household's income level[18]. Wealthy households have more productive resources which can be invested to generate higher income compared to poor households, and, therefore, are more likely to invest in activities that lead to household income growth.

Household access to credit has a negative and highly significant effect on household income at the crop and agricultural diversification levels, but no significance at the livelihood level all the three models. Among the demographic variables, only household size has an inverse but highly significant effect on household income. The larger the household size, the lower the household income per adult equivalent, unless this can be accompanied by greater labor productivity. Also, education of the household head is significant in all the models, but the significance is stronger in the livelihood diversification model. More educated household heads may increase household labor productivity and hence incomes. Compared to the years before the major agricultural reforms (before 2004) real household income has increased in the subsequent years, suggesting a positive welfare response by households to the policy reforms of the 1990s and early 2000s.

[18] A household net worth position, is an endogenous variable in the sense that past and present net worth may be correlated to future income. The dynamic panel data controls for this fact in the model

Table 20. Dynamic panel data regressions of the effect of smallholder diversification on household income, 2000-2010

VARIABLES	Regression model containing Crop diversification	Agricultural diversification	Livelihood diversification
Lagged log of household income (Ksh/ae)	-0.0501**	-0.0420*	-0.0816***
	(0.0248)	(0.0237)	(0.0228)
Log of real household net assets (Ksh/ae)	0.1114**	0.1282***	0.0785*
	(0.0454)	(0.0429)	(0.0407)
Log of acreage cultivated (acres)	0.3464***	0.3530***	0.4011***
	(0.0443)	(0.0446)	(0.0436)
Crop commercialization index	0.6592***	0.6624***	0.7150***
	(0.1206)	(0.1040)	(0.0905)
Access to credit (1=y, 0=n)	0.3044***	-2.4477***	0.0529
	(0.1092)	(0.6915)	(0.0363)
Rainfall stress	-1.6683***	-1.3043***	-2.3432***
	(0.5781)	(0.3882)	(0.8960)
Diversification index	-1.0086***	0.3842***	-3.1081***
	(0.3420)	(0.1071)	(0.7328)
Rainfall stress * diversification index interaction	3.2705***	4.3485***	4.4420***
	(0.8737)	(1.0083)	(1.4222)
Log of main season total rainfall (mm)	0.0507	0.0405	0.1467**
	(0.0588)	(0.0615)	(0.0611)
Gender of household head (1=m, 0=f)	0.0556	0.0546	0.0251
	(0.0699)	(0.0709)	(0.0716)
Age of household head (years)	-0.0008	-0.0007	0.0002
	(0.0026)	(0.0027)	(0.0026)
Education level of household head (years)	0.0105*	0.0105*	0.0110**
	(0.0059)	(0.0061)	(0.0052)
Household size	-0.0903***	-0.0938***	-0.0978***
	(0.0100)	(0.0104)	(0.0107)
Agricultural transformation (=1 if year>=2004)	0.0960**	0.1014***	0.1074***
	(0.0378)	(0.0391)	(0.0361)
Constant	3.3653***	3.5386***	4.3526***
	(0.6242)	(0.6320)	(0.5978)
Number of observations	3,579	3,579	3,579
Number of households	1,210	1,210	1,210
Model Specification Tests			
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors			
AR(1)	-11.962***	-12.618***	-10.687***
AR(2)	1.003	1.950	-0.210
2. Sargan Test of overidentifying restrictions			
Degrees of freedom	25	25	23
χ^2(df)	36.515	36.172	30.852
Prob > χ^2(df)	0.064	0.069	0.127

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

In addition, the amount of land cultivated by the household has a positive and highly significant effect on the household income in all the three models, suggesting that an increase in the amount of land a household puts under cultivation, other factors constant, leads to an increase in household income. Specifically, a 10% increase in acreage under cultivation results in a 3.4% increase in household income at the crop and agricultural models and a 3.9% increase in the livelihood diversification level[19]. Also, crop commercialization index[20] has a highly significant and positive effect on the household income in all the models, suggesting that household income increases with participation in output markets.

Results show that adverse weather such as drought has a negative and highly significant effect on household income in all the three models. Thus, adverse weather affects production and productivity of crops and livestock, thereby lowering a household's income. Total rainfall, on the other hand, affects household income only at the livelihood level, where it has a positive and statistically significant effect on household income at 5% level. Better rainfall may increase labor productivity and result in household income growth. These findings suggest that weather changes have an effect on household income.

In order to better understand the effect of smallholder diversification on household income, two variables require particular attention, namely, the diversification index the interaction term between the diversification index and the rainfall stress. Diversification can have a direct and

[19] When both the dependent and predictor variables are log-transformed, the expected effect on the outcome variable from a given change, say, x% in the predictor variable can be computed as, $100\% * \left(1 + \frac{x}{100}\right)^{\beta}$, where β is the coefficient of the predictor variable (Wooldridge, 2010). For example, the effect of a 10% increase in acreage under cultivation on a household's income per adult equivalent at the cropping activity level is estimated as $100\% * (1.10)^{.3464} = 3.4\%$. In cases where the dependent variable is log-transformed, but the predictor variable is not, the expected effect of the predictor variable on the outcome variable is computed as $100\% * (e^{\beta} - 1)$.

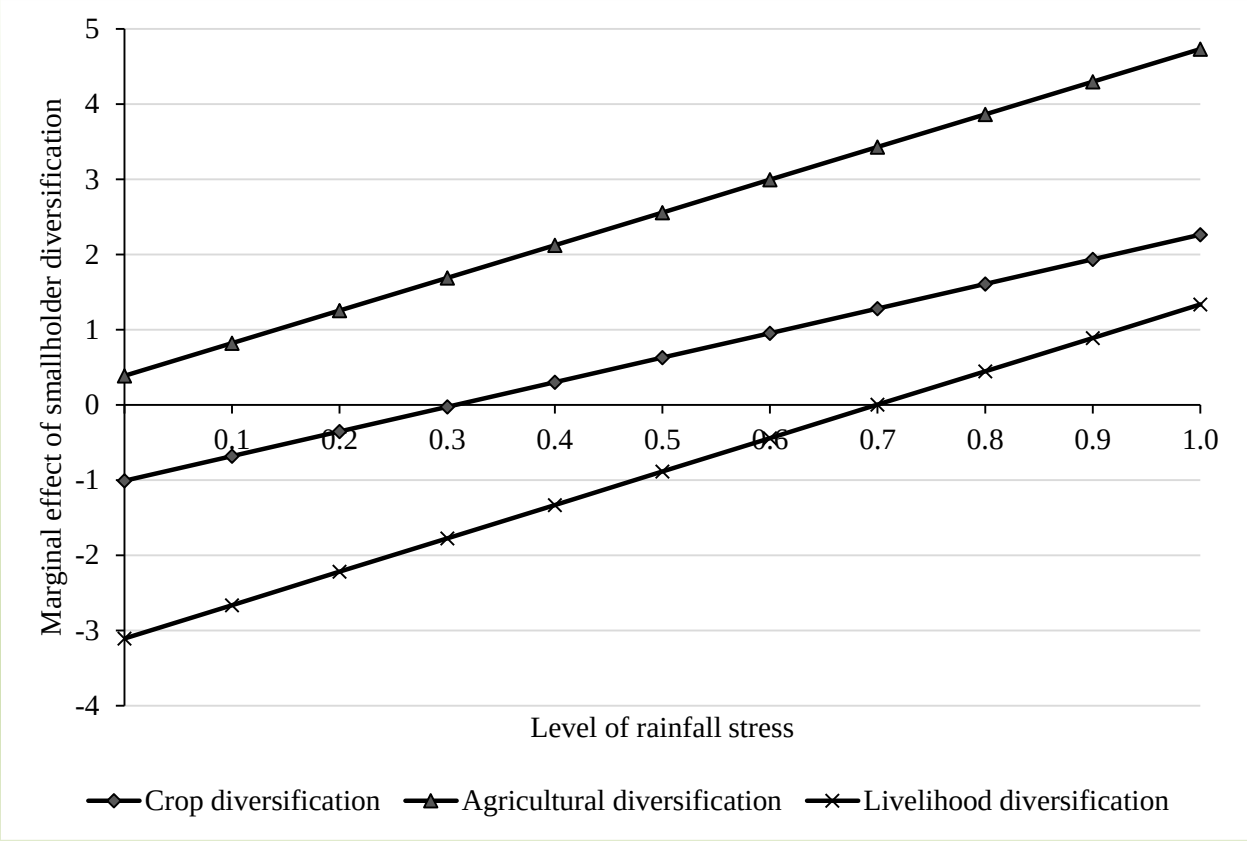
[20] Crop commercialization index is defined as the proportion of crop value that is actually sold by the household

indirect effect on household welfare. Directly, diversification can affect household income through the income generated from a diversified income portfolio. This is captured by the coefficient of the diversification index variable. The results show that the coefficients of crop and livelihood diversification are negative and highly significant at 1% level, but the coefficient of agricultural diversification index is positive (Table 20). Indirectly, it can act through its ability to mitigate the effects of adverse weather or drought. The indirect effect is in the models s captured by the interaction term. Controlling for other variables, the interaction term is positive and highly significant term in all the three models at 1% level.

To understand the magnitude and direction of the effect of smallholder diversification on household welfare indicators, marginal effect analysis was undertaken. A graph showing the marginal effect of smallholder diversification on household income for various levels of diversification and rainfall stress is displayed in Figure 23. A number of observations can be made. First, the marginal effect[21] of smallholder diversification increases monotonically with an increase in rainfall stress: the more severe the rainfall stress, the higher the marginal effect of smallholder diversification. This suggests that households adopt diversification as a strategy to mitigate the adverse effect of drought.

[21] The marginal effect of smallholder diversification on household welfare is estimated as the change in the welfare variable with respect to a small change in the smallholder diversification, holding other factors constant. For example, the marginal effect of smallholder diversification, at the appropriate level of analysis, on household income is computed as $\frac{\partial \ln(income)}{\partial divindex}$.

Figure 23. Marginal effect of smallholder diversification on the log of household income among rural households, 2000 – 2010



Second, the findings show that, of the three indices, agricultural diversification has a positive and higher marginal effect on household income while crop and livelihood diversification exhibit negative effect at lower rainfall stress levels and positive effect at higher levels of rainfall stress. The coefficient of rainfall stress is negative and highly significant while the coefficient of the interaction term between stress and smallholder diversification is positive and highly significant in all the three models (Table 20). This higher marginal effect is due in part to the high positive and highly significant coefficients of both agricultural diversification index and the interaction between agricultural diversification and rainfall stress, which more than offset the negative effect of the rainfall stress.

The marginal effect of crop diversification on household income is monotonically higher than that of livelihood diversification but lower than that of agricultural diversification for all rainfall stress levels: the marginal returns of smallholder diversification are highest with agricultural diversification and lowest with livelihood diversification. At stress levels below 30%, the marginal effect of crop diversification on household income is negative. However, at higher levels, the marginal effect of crop diversification is positive. In comparison, the marginal effect of livelihood diversification on household income is negative at rainfall stress levels below 70% but positive at higher levels

These findings suggest that households that diversify agriculturally are able to mitigate the effects of drought on household income at all rainfall stress levels. At low rainfall stress levels, crop diversification is not as effective a strategy as the agricultural diversification to mitigate the effect of drought on household income. However, at higher levels, crop diversification would mitigate against weather risk better than livelihood diversification

3.3.2 Effect of smallholder diversification on household maize consumption

Besides household income, smallholder diversification was also hypothesized to have an effect on household food security. Table 21 displays the dynamic panel data regressions of the effects of smallholder diversification on household maize consumption. The findings show that there is no persistence at any of the three diversification levels. Thus, past household maize security does not seem to influence its current maize security situation. Results further indicate that both total acreage under cultivation and the acreage under maize cultivation[22] are important determinants

[22] Different models were estimated, one using the village average maize yield and the other using the maize acreage. Only the model with maize acreage converged and yielded significant results. Therefore in the estimation of effects of smallholder diversification on household maize security, the study adopted the model with maize acreage instead of maize yield.

of household maize security. Total acreage under cultivation by a household is significantly positive at 5% level in all the three models. Acreage under maize cultivation is also positive and highly significant at 1% level. Thus the more land a household places under maize cultivation, the more likely it is to be maize secure. A 10% increase in acreage cultivated, other factors constant, increases household maize consumption by about 2%. On the other hand, a 10% increase in acreage of maize cultivated by a household results in about 1.5% increase in the amount of calories available for consumption. These findings perhaps suggest the importance of household reliance on their production to meet most of their maize needs.

However, a household's participation in the market, measured by the crop commercialization index, has a positive and highly significant effect on a household maize security, and the magnitude of the effect is higher than those obtained by the increase in acreage. The results suggest that households are increasingly relying on the market for their maize consumption. The findings further show that household income is negatively related to household maize calories and the significance increases from as one moves across from model with crop diversification to the model containing livelihood diversification. This is consistent with the Engel's law, that poorer households tend to devote a larger share of household income on food compared to richer households (Houthakker, 1957).

Table 21. Dynamic panel data regressions of effect of smallholder diversification on household maize security, 2000 – 2010

VARIABLES	Regression model containing Crop diversification	Agricultural diversification	Livelihood diversification
Lagged log of maize calories (cal/day/ae)	0.0063	0.0033	0.0071
	(0.0057)	(0.0063)	(0.0064)
Log of acreage cultivated (acres)	0.1821**	0.2209**	0.2214**
	(0.0778)	(0.0872)	(0.0905)
Log of Maize acreage (acres)	0.1424***	0.1682***	0.1369***
	(0.0354)	(0.0408)	(0.0411)
Log of real household net assets (Ksh/ae)	0.1113**	0.0969*	0.1341**
	(0.0446)	(0.0513)	(0.0527)
Log of real household income (Ksh/ae)	-0.2391*	-0.3889**	-0.3041**
	(0.1277)	(0.1524)	(0.1452)
Crop commercialization index	1.2112***	1.2762***	1.0274***
	(0.3385)	(0.3262)	(0.3366)
Rainfall stress	-1.4382**	-2.7352**	-3.6054***
	(0.7302)	(1.0916)	(1.2268)
Diversification index	-0.2938	-1.0968*	-1.6009**
	(0.3913)	(0.6008)	(0.6816)
Rainfall stress * diversification index	2.5146**	4.4332***	5.7321***
	(1.1061)	(1.5947)	(1.8539)
Log of main season total rainfall (mm)	0.0184	0.0510	0.0359
	(0.0628)	(0.0695)	(0.0715)
Gender of household head (1=m, 0=f)	-0.1152	-0.1619	-0.1671
	(0.0893)	(0.0999)	(0.1045)
Age of household head (years)	0.0042	0.0045	0.0067
	(0.0039)	(0.0041)	(0.0045)
Education level of household head (years)	-0.0062	-0.0028	-0.0032
	(0.0063)	(0.0068)	(0.0068)
Household size	-0.1620***	-0.1777***	-0.1681***
	(0.0188)	(0.0213)	(0.0211)
Agricultural transformation (=1 if year>=2004)	0.0462	0.0315	0.0090
	(0.0440)	(0.0475)	(0.0490)
Constant	5.7188***	6.7048***	6.6281***
	(0.7555)	(1.0068)	(0.9689)
Number of observations	2,826	2,826	2,826
Number of households	1,032	1,032	1,032
Model Specification Tests			
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors			
AR(1)	-2.444**	-2.679***	-2.573**
AR(2)	0.717	1.074	1.212
2. Sargan Test of overidentifying restrictions			
Degrees of freedom	40	38	34
χ^2(df)	53.381	39.420	35.092
Prob > χ^2(df)	0.078	0.406	0.416

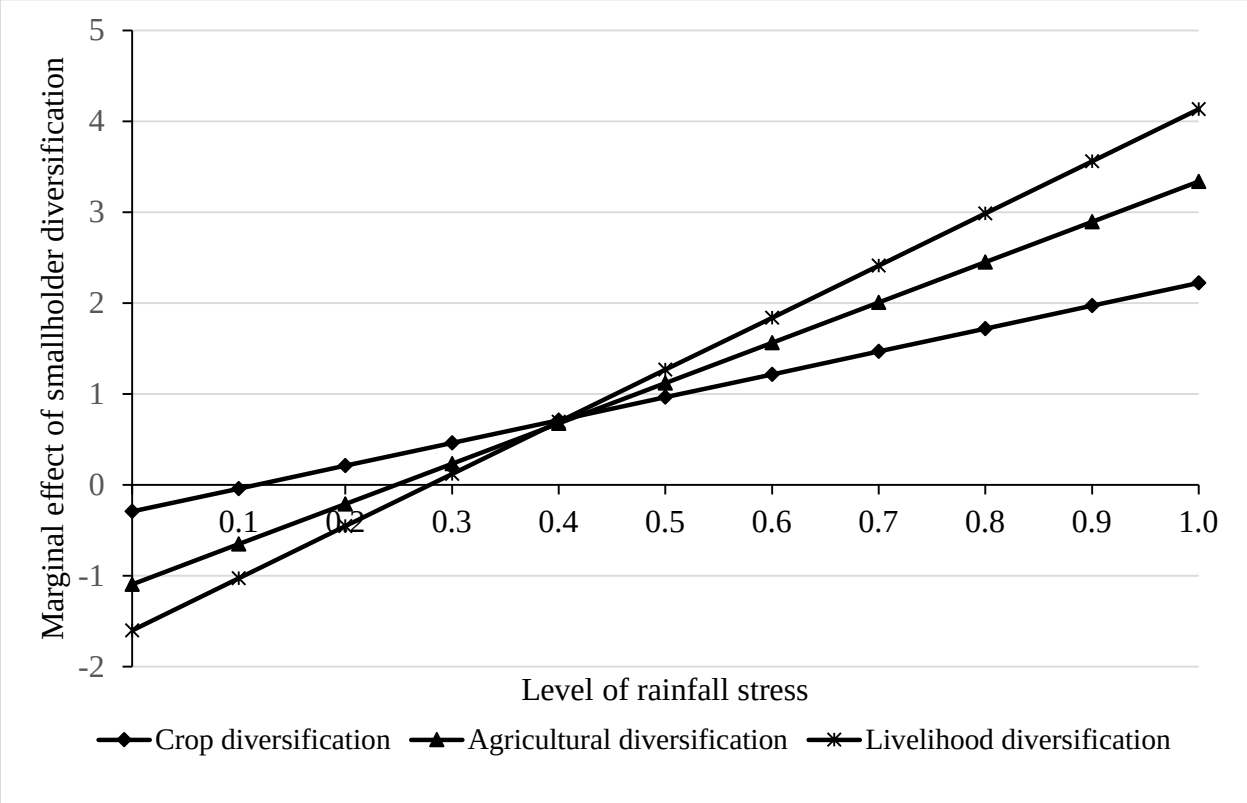
Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Also, household net worth has a positive effect on household maize security, implying that wealthier households are likely to have a better maize security situation compared to less wealthy households. In addition, household size is negative and highly significant in all the models, suggesting that larger households, other factors held the same, are likely to be maize-insecure than smaller households. An increase in the household size by one adult equivalent increases household maize insecurity by between 15% and 17%, *ceteris paribus*. The findings show no significance on the dummy for agricultural transformation. Thus, household maize security may not have improved with agricultural transformation. This suggests that agricultural transformation may not directly affect household food security, but may have an indirect effect through influence on incomes and market access. Other demographic variables (gender, age, education of household head) are non-significant

The effect of smallholder diversification can be inferred from the coefficients of diversification indices and the interaction between diversification and rainfall stress level. The effect of rainfall stress is negative and significant in all the three models: drought reduces a household's ability to be food secure. In addition direct effect of diversification is non-significant in the crop model, but negative and significant in the agricultural and livelihood models. However, the coefficient of the interaction term is positive and significant. The balance between the direct and indirect effects determines the overall effect of smallholder diversification on household maize security. For example, a larger negative direct effect and a smaller interaction effect will result in a negative effect on household maize security, and vice versa. The marginal effect of smallholder diversification on diversification on household maize security is displayed on Figure 24. Two points observed. First, at rainfall stress levels below 40%, the marginal effect of crop diversification on household maize security is higher than that of either agricultural or livelihood

diversification for the same stress level. At rainfall stress levels higher than 40%, the patterns are reversed, and the marginal effect of livelihood diversification is higher than that of either crop or agricultural diversification. At a rainfall stress level of 40%, the effect of crop, agricultural and livelihood diversification strategies are equal.

Figure 24. Marginal effect of smallholder diversification on the log of household maize security among Kenyan rural farmers, 2000 – 2010



These findings suggest that different diversification strategies may be used by household to mitigate the adverse effects of drought depending on the level of rainfall stress. At lower levels, crop diversification may be an effective mitigation strategy against drought than either agricultural or livelihood diversification strategies. At higher drought levels, livelihood diversification is an effective strategy compared to the other two, since it yields the highest

positive effect on household maize security. However, at rainfall stress level of 40%, any of the diversification strategies can be adopted by households to mitigate the adverse effects of drought.

The second observation from the marginal effect analysis is the point at which each of the marginal effects changes from being negative to being positive. For example, the marginal effect of crop diversification is negative for rainfall stress levels below 10%. The marginal effect of agricultural diversification is negative below stress levels of 25% while, in the case of livelihood diversification, it is negative at levels below 28%. These findings suggest that at rainfall stress levels below 10%, neither of the diversification strategies yield positive marginal effect on household maize security and, therefore, no diversification strategy is suitable in mitigating the effect of drought. At rainfall stress levels above 10% but below 25%, smallholder crop diversification will be a suitable strategy to mitigate the effect of drought but neither agricultural nor livelihood diversification is. And at rainfall stress levels between 25% and 28%, both crop and agricultural diversification strategies can be used to lessen the effect of drought, but livelihood diversification is not suitable. At stress levels above 28%, any of the diversification strategies can be used to minimize the negative effect of drought on household maize security. Thus, a better understanding of the level of rainfall stress can lead to an appropriate diversification strategy that yields the greatest marginal effect on household maize security.

3.3.3 Effects of smallholder diversification on household net worth

The third measure of household welfare examined in this study is the household net worth. The dynamic panel data regression results of the effect of smallholder diversification on household net worth are displayed on Table 22. The findings reveal that the net worth models have only a marginal persistence, especially at the crop and agricultural levels, but no persistence at the

livelihood level. Thus, past household net worth levels have a weak influence on the current net worth levels. Household income has a positive and highly significant effect on smallholder net worth. Richer households tend to have higher wealth accumulation and vice versa. On the other hand, crop commercialization index negatively affects household net worth at the crop and agricultural levels but has no significant effect at the livelihood level. Also, access to agricultural credit negatively affects household wealth accumulation, perhaps because credit is a liability to the household[23]. Both acreages under cultivation and crop productivity have significantly positive effects on a household's wealth accumulation in all the models. A 10% increase in acreage under cultivation results in household wealth growth of between 5.5% (in the livelihood model) and 7.8% (in the agricultural model). Similarly, a 10% increase in crop productivity leads to a 2.5%, 2.6% and 1.4% increase in household net worth at the crop, agricultural and livelihood levels, respectively.

Among the demographic variables, only household size has an effect on household wealth accumulation. The coefficient of household size is negative and highly significant in all the three models. An additional household member lowers the household net worth by nearly 12%, other factors held constant[24]. The findings further show evidence of increased net worth in the years 2004 and 2007, compared to the base year. The coefficient of the year dummy for agricultural transformation is positive and significant in all the three models, suggesting that compared to the period before 2004, households have accumulated more wealth. This may be an indication that the agricultural policy reforms of the 1990s and 2000s may have resulted into growth in smallholder household wealth.

[23] By definition net worth is the total assets net of any household liability

[24] The change in net worth as a result of an additional household member at the cropping activity level is $100\% * (e^{0.1216} - 1) = -11.4\%$, while it is 11.5% at the agricultural level and 11.2% at the livelihood level

Table 22. Dynamic panel data regressions of effect of smallholder diversification on household net worth, 2000 – 2010

VARIABLES	Regression model containing Crop diversification	Agricultural diversification	Livelihood diversification
Lagged log of real net household assets (Ksh/ae)	0.0402*	0.0390*	0.0349
	(0.0215)	(0.0215)	(0.0218)
Log of acreage cultivated (acres)	0.7197***	0.7856***	0.5540***
	(0.1477)	(0.1546)	(0.1424)
Log of village average maize yield (kg/acre)	0.2576***	0.2706***	0.1419*
	(0.0692)	(0.0716)	(0.0741)
Log of real household income (Ksh/ae)	0.1249***	0.1327***	0.1105**
	(0.0461)	(0.0485)	(0.0479)
Crop commercialization index	-0.9231**	-0.7755**	0.0941
	(0.3973)	(0.3793)	(0.3705)
Access to credit (1=y, 0=n)	-0.2544**	-0.3196***	-0.2618**
	(0.1080)	(0.1155)	(0.1052)
Rainfall stress	-1.4665**	-0.1352	0.7723*
	(0.6556)	(0.8368)	(0.4174)
Diversification index	-1.5856**	-0.0807	0.3041
	(0.6193)	(0.7039)	(0.2248)
Rainfall stress * diversification index	2.2291**	-0.1747	-1.3038**
	(1.0657)	(1.2960)	(0.5505)
Log of main season total rainfall (mm)	0.1477*	0.1076	0.1970***
	(0.0771)	(0.0814)	(0.0761)
Gender of household head (1=m, 0=f)	-0.0363	-0.0049	0.0349
	(0.0861)	(0.0831)	(0.0777)
Age of household head (years)	-0.0026	-0.0032	-0.0035
	(0.0030)	(0.0030)	(0.0029)
Education level of household head (years)	0.0015	0.0009	-0.0004
	(0.0067)	(0.0070)	(0.0063)
Household size	-0.1216***	-0.1220***	-0.1185***
	(0.0118)	(0.0121)	(0.0113)
Agricultural transformation (=1 if year>=2004)	0.1638***	0.1578***	0.1900***
	(0.0457)	(0.0474)	(0.0437)
Constant	2.0107***	1.1972	1.0730*
	(0.6888)	(0.7410)	(0.5620)
Number of observations	3,592	3,592	3,592
Number of households	1,220	1,220	1,220
Model Specification Tests			
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors			
AR(1)	-10.636***	-10.341***	-11.889***
AR(2)	1.403	1.872	0.970
2. Sargan Test of overidentifying restrictions			
Degrees of freedom	38	36	36
χ^2(df)	53.206	50.679	50.487
Prob > χ^2(df)	0.052	0.053	0.055

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

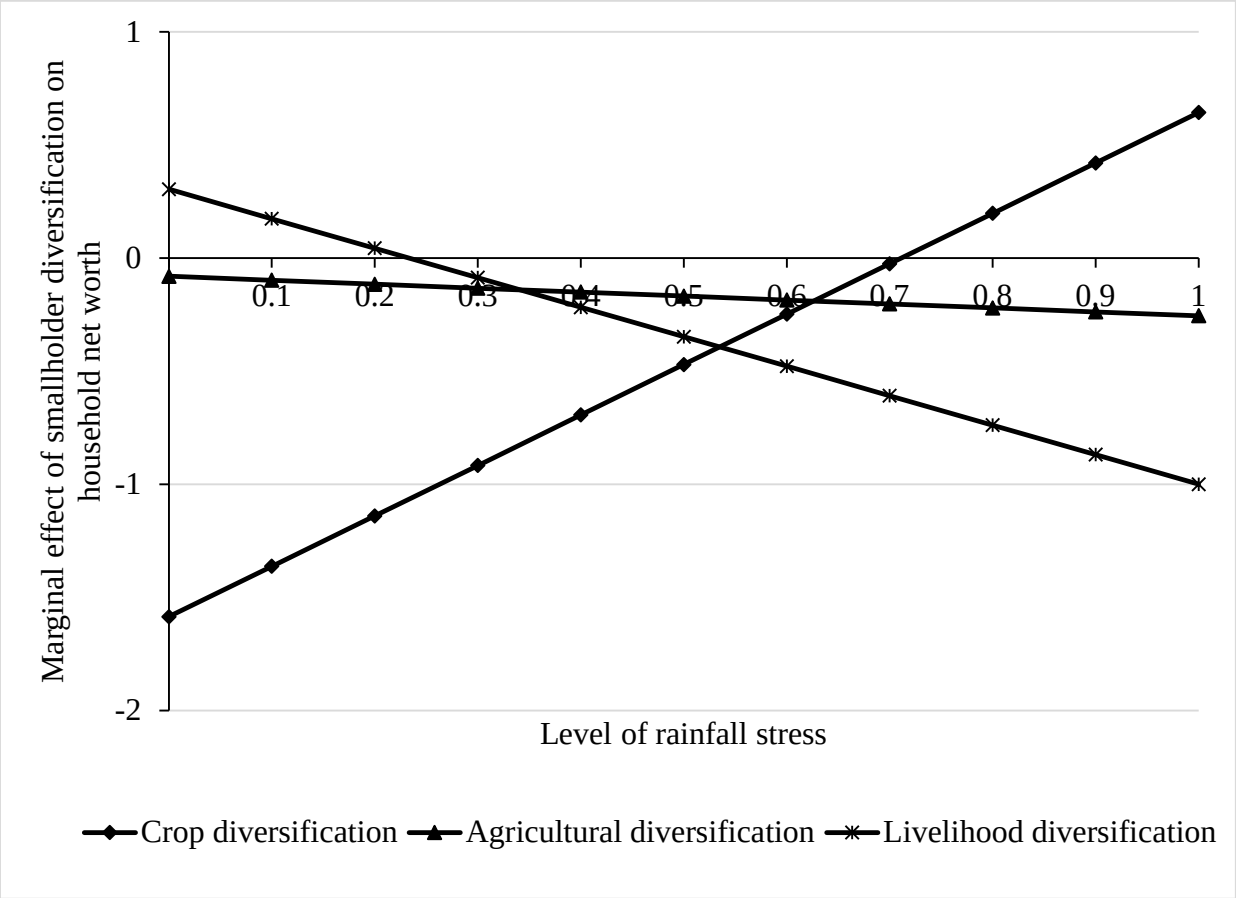
Weather variables, also seem to affect household wealth. The findings indicate that total rainfall positively increases household wealth at the livelihood level, but has marginal or no effect at the crop or agricultural levels. Rainfall stress, on the other hand, has mixed results, being negative and significant in the crop model, positive and weakly significant in the livelihood model and non-significant in the agricultural model. Thus, drought has an impact on crop growth and productivity, which influences the returns from crop production and hence wealth accumulation. Drought may also lead to the reallocation of labor away from crop and agricultural activities to off-farm and non-farm activities that are not affected by drought. This may lead to accumulation of wealth.

The findings further show that the direct effect of smallholder diversification on household wealth is not significant in the crop model, but negative in the agricultural and livelihood models. Furthermore, the direct effect of drought is negative and significant in all the three models, suggesting that drought reduces the ability of a household to accumulate wealth. However, the coefficient of the interaction term is positive and significant, suggesting that households may be using diversification as a strategy to mitigate effects of drought on wealth accumulation.

The marginal effect of effect of smallholder diversification on household net worth is displayed on Figure 25. It can be observed that the marginal effect of crop diversification is increasing while that of livelihood and agricultural diversification are decreasing. In fact, the marginal effect of agricultural diversification is below zero at all levels of rainfall stress. At rainfall stress levels of 70% and below, the marginal effect of crop production is negative, implying that at these levels, crop diversification is not able to mitigate the negative effects of rainfall stress on household net worth, since its marginal effect is negative over this range. At rainfall stress levels

above 70%, the effect of crop diversification is positive, meaning that households are able to positively mitigate the negative effect of rainfall stress on household net worth.

Figure 25. Marginal effect of smallholder diversification on household net worth (log) among Kenyan rural farmers, 2000 – 2010



The marginal effect of agricultural diversification on household net worth is below zero and declines further with higher rainfall stress. This suggests that agricultural diversification as a coping strategy may not be able to mitigate against adverse weather patterns such as drought. This is evident in the model (Table 22) which shows nonsignificance in both the agricultural diversification index and the interaction term.

The marginal effect of the livelihood diversification is positive for rainfall stress levels below 25% and negative thereafter. Livelihood diversification is used as a coping mechanism by households at low levels of rainfall stress when diversification leads to a marginal increase in household net worth. At higher rainfall stress levels, livelihood diversification leads to a marginal decline in household wealth. It is evident that at rainfall stress level between 25% and 70%, no diversification strategy yields positive marginal returns.

3.4 Household welfare effect of livelihood diversification, by cultivated land size

In addition to understanding the welfare effects of smallholder diversification over the whole sample, the analysis could be done on groups of households. It is unlikely that welfare effects will be uniform across all farms household. Differences are likely to emerge, depending on household resource endowments. For example, effects of smallholder diversification on household welfare may differ depending on the amount of land a household has at its disposal. This kind of analysis helps inform policy debates. While diversification may be a strategy risk-reducing for some household group, it may be a strategy to shift to higher-value crops or off-farm income for the other group. This heterogeneity is explored in this section using land under cultivation as the grouping variable. Households were grouped into two categories: those that cultivated 5 acres or less (“land-poor”) and those cultivating more than acres (“land-rich”). Dynamic panel data analysis was then carried out on each household group to examine if there were differences in welfare effect of diversification across households at the livelihood level. The findings are presented in sections 3.4.1 through 3.4.3

3.4.1 Effect on household income growth

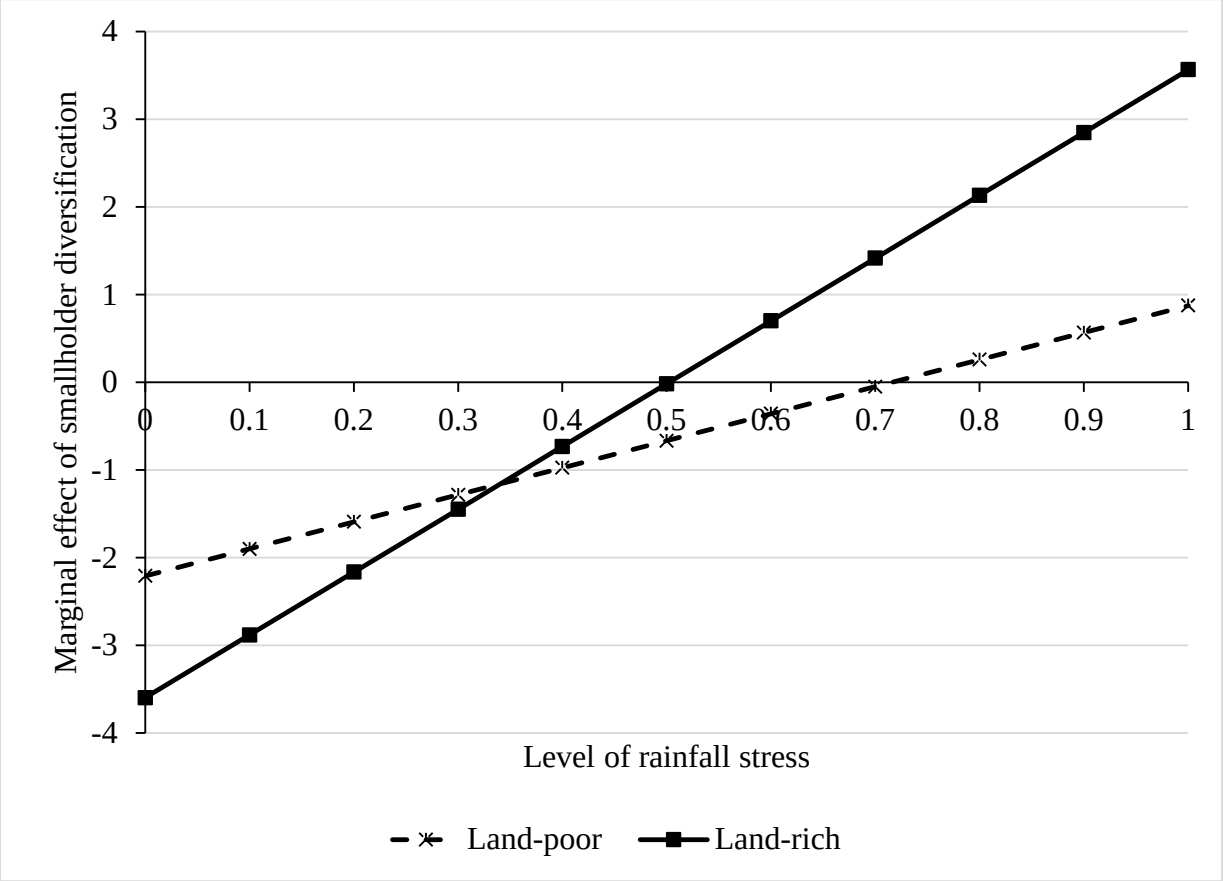
When households are grouped by the amount of land that they cultivated, and dynamic panel data analysis conducted at the livelihood level, a number of observations were made (Table 23). First, there is persistence in the income growth model for “land-rich” households, but no persistence for the “land-poor”. On the other hand, household assets have a positive effect on household income among the “land-poor” households, but no effect on the “land-rich”. Both acreage and crop commercialization index have a positive and significant effect on household income for both groups of households. Also, education of the household head has a significant effect on household income for the “land-poor” and no significant effect among the land-rich. These findings suggest that income growth for the “land-poor” households is derived from participating more in the market, increasing acreage and engaging in off-farm activities.

The coefficient of the rainfall stress is negative for both groups, but highly significant for the “land rich” households, suggesting that, the more land a household cultivates, the higher the losses in income it is likely to incur from severe drought. In fact, the coefficient of rainfall stress is four times higher for the “land-rich” compared to the “land- poor” (Table 23). For both groups, the direct effect of smallholder livelihood diversification is negative and highly significant. The coefficient of the interaction term is positive and significant for both groups of households, but highly significant for the “land-rich” households

The graph showing the marginal effect of smallholder livelihood diversification on household income for the two land groups is displayed on Figure 26. The results show that marginal effect of livelihood diversification is upward sloping for both groups. However, the slope of the slope

of the marginal effect for the “land-rich” households is steeper than that of the “land-poor” households.

Figure 26. Marginal effect of smallholder diversification on household income among Kenyan rural farmers, grouped by acreage under cultivation, 2000 – 2010



At rainfall stress levels below 35%, the marginal effect of livelihood diversification on household income is higher among the land-poor households than it is among the land-rich households. Also, at rainfall stress levels below 50%, none of the marginal effects are positive, implying that additional diversification results in loss of household income in both land groups. i.e., livelihood diversification cushions the land-poor more than it does the land-rich against the adverse effects of drought. For rainfall stress levels above 35%, it is the land-rich that are cushioned more than the “land-poor”. For the “land-rich” households, the marginal effect of

livelihood diversification is negative for rainfall stress levels below 50%. Beyond this stress level, the marginal effect is positive

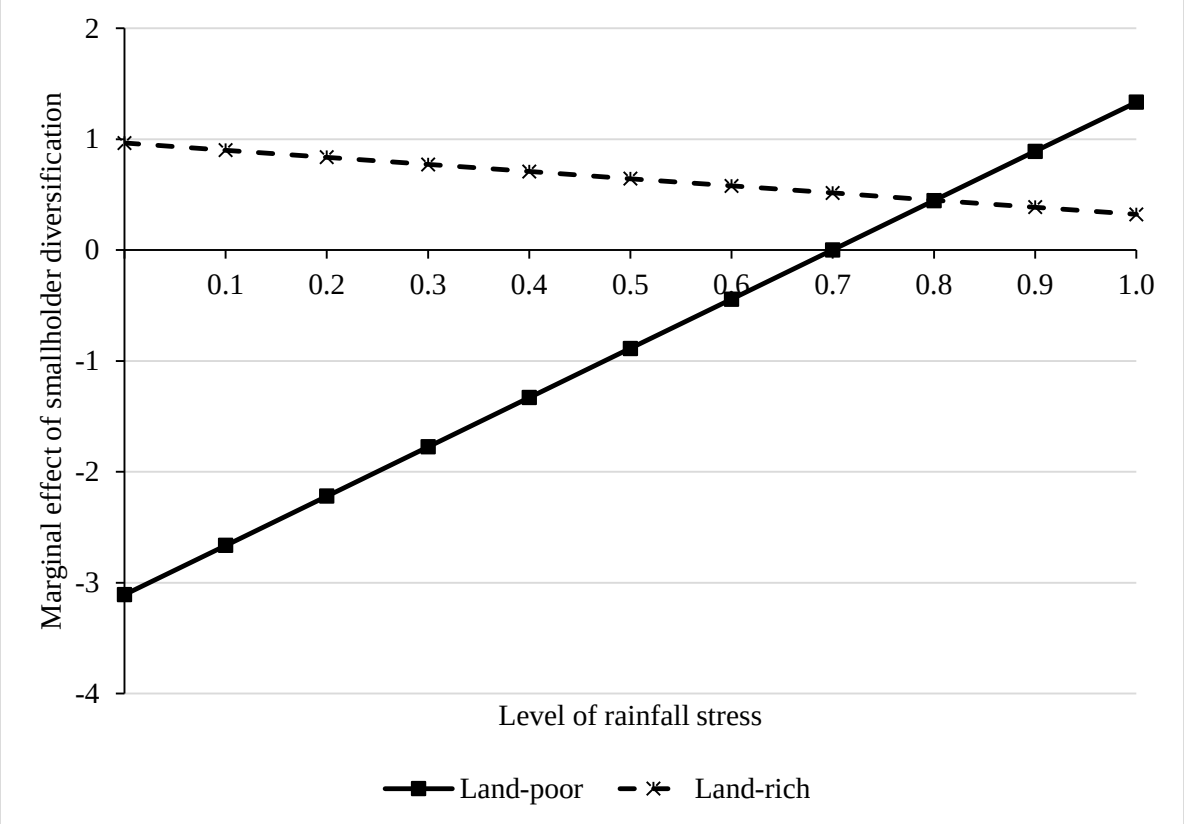
These findings suggest heterogeneity among households with respect to household income growth. “Land-rich” households appear to be most hit by rainfall stress and are likely to suffer greater losses from drought, judging by the size of the coefficient of rainfall stress variable (Table 23). As a result, they also tend to benefit more from livelihood diversification by spreading their risk across crop, agricultural and off-farm activities. Compared to the “land-rich” households, the “land-poor” households are less sensitive to severe weather since their scale of production is lower compared to the “land-rich” households. They tend to grow their income through engagement in income activities that benefit more from the use of available resources. The findings show that both household groups may benefit from livelihood diversification, and use livelihood diversification as a strategy to mitigate the adverse effects of poor rainfall distribution, even though the level of rainfall stress at which each household group may benefit from livelihood diversification differs.

3.4.2 Effect on household maize security

The results of dynamic panel data regressions on the effect of livelihood diversification on household maize security when households are grouped by the land size are displayed on Table 24. It should be noted that while the model for the land-poor households pass both the test for serial correlation (*Arellano-Bond* Test) and the test of overidentifying restrictions (the *Sargan* Test), the model for the “land-rich” households fails the serial correlation test. Therefore, the findings related to the “land-rich” households should be interpreted with caution. Nonetheless, the findings show that among the “land-poor” households, the marginal effect of smallholder

livelihood diversification on household maize security is an increasing function of the rainfall stress level (Figure 27). The marginal effect is significant at 5% level (Table 26). At rainfall stress levels below 70%, the marginal effect of livelihood diversification on household maize security among the "land-poor" is negative. However, above rainfall levels of 70%, the marginal effect is positive. This suggests that livelihood diversification may increase household maize security is a strategy among "land-poor" households to mitigate the effects of drought on household maize security at higher levels of rainfall stress

Figure 27. Marginal effect of smallholder diversification on household maize security among Kenyan rural farmers, grouped by acreage under cultivation, 2000 – 2010



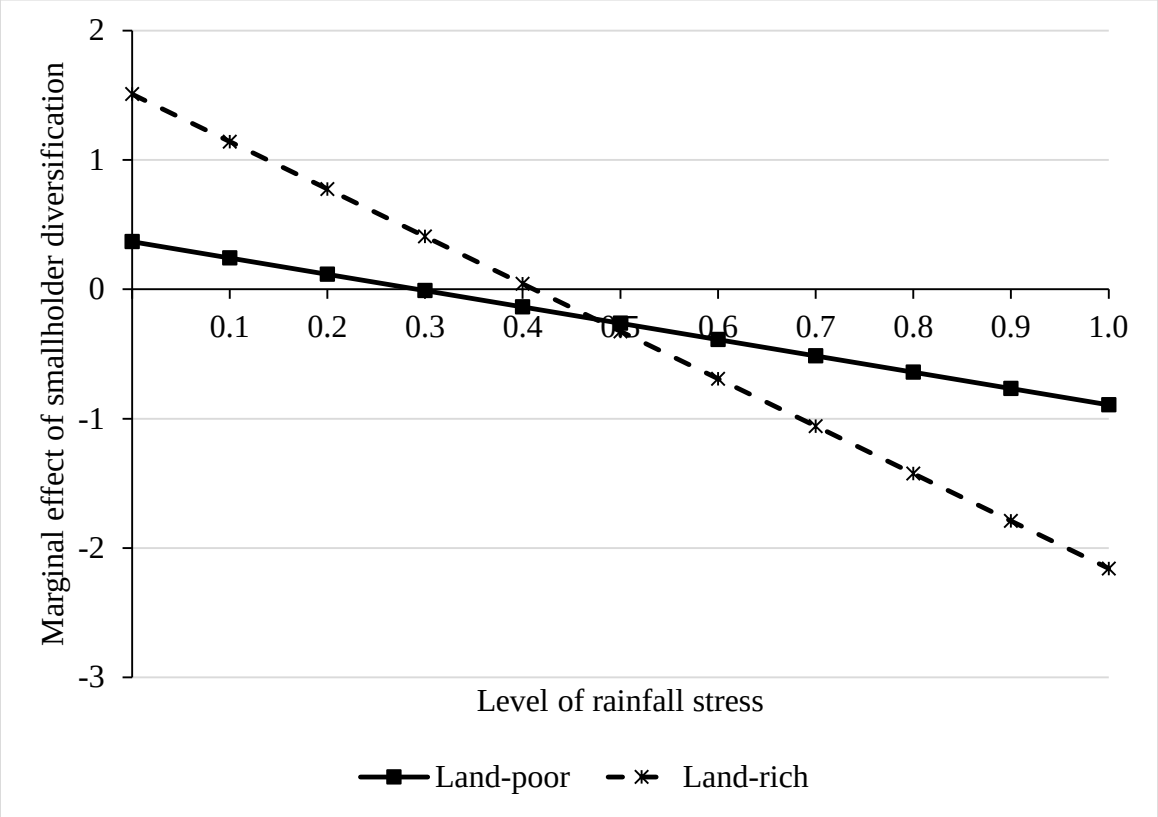
Other than livelihood diversification, the results show that increased household maize security is associated with an increase in area under maize cultivation by the household (Table 24). Also, crop commercialization index has a positive and highly significant effect on household maize

security. The higher the proportion of crop value of sales, the more likely will be able to increase their maize security situation.

3.4.3 Effect on household net worth growth

When households are categorized by acreage under cultivation, the marginal effect of livelihood diversification on household net worth for households when grouped by the area under cultivation reveals that household net worth is a declining but not statistically significant function of the rainfall stress level (Figure 28). The marginal effect for both groups begin at positive levels, but declines with the level of rainfall stress, eventually becoming negative. A test of the significance of the marginal effect, however, shows this effect is not significant at 5% level for both groups of households as well as in the full model (Table 22), suggesting that livelihood diversification is not a significant determinant of the household wealth. The findings show that livelihood diversification, other factors held constant, has no direct effect on household wealth among the land poor, but a significant effect among the land rich (Table 25). On the other hand, diversification has a negative indirect effect through the interaction among the “land-poor”, but only a weakly negative effect among the “land-rich” households.

Figure 28. Marginal effect of smallholder diversification on household net worth among Kenyan rural farmers, grouped by acreage under cultivation, 2000 – 2010



Other findings mirror those in the full model (Table 25 and Table 22 last column). For example, household income has a positive and significant effect on household wealth for both land groups at 5% level. Acreage cultivated also has a significant effect on household wealth for both land groups, with the results for the land-poor households showing more robustness. Also, household size has a negative and highly significant effect on household wealth.

These findings show that there is no significant difference between the land-poor and land-rich households in the effects of household livelihood diversification on household wealth growth. Overall, the findings reveal that livelihood diversification may not be a strategy for building household wealth, especially in the presence of drought. Households often adopt other ways to build household wealth. For example, “land-poor” households build household wealth through

increasing acreage under cultivation, income growth, and yield increases. The “land-rich” households mainly income growth and acreage expansion to grow their wealth.

3.5 Conclusions and policy implications

The aim of this study was to investigate the effects of smallholder diversification on three measures of rural household welfare, namely, household income, household maize security, and household net worth in the presence of rainfall stress. An additional objective of the study was to examine heterogeneity among households with respect to diversification effects using land cultivated as a grouping variable. Dynamic panel data methods were used to analyze the data. A summary of study findings is presented below, followed by a discussion of policy implications

3.5.1 Summary of findings and discussion

One of the key findings of this study is the resilience of dependent variables in some of the models and non-persistence in others. Results show that household income has a negative resilience in all the three. In addition, the household net worth shows weak persistence, especially at the crop and agricultural level, but not at the livelihood level. These findings how that past incomes and wealth do indeed influence future household welfare. For example, because of its cumulative nature, a household’s past wealth is likely to positively influence current and future wealth. Household maize security, on the other hand, has no persistence over time: a household maize security situation in the past does not seem to affect its current or future maize security situation.

The findings also reveal that acreage under cultivation has a positive effect on all the three measures of household welfare and at all the three levels of smallholder diversification. The study finds that even among different household groups, land under cultivation is an important

factor that positively affects household welfare. First, more land under crop cultivation implies increased production and a greater marketable surplus. Second, more land allows the farmer the flexibility to expand existing income portfolios as well as introduce new ones, such as, engage in livestock production (by, for example cultivating fodder), or engage in other high-value products such as fruits and vegetables. These are likely to increase farmer's income portfolio, and hence welfare. Third, larger farms are more likely to be more technology-efficient because of economies of size. In the presence of working markets, this may result in higher household incomes, maize security, and net worth. In the case of household maize security, the area under maize cultivation by a household has also been shown to have a very significant positive effect on smallholder maize security, suggesting that despite market development, households still rely heavily on their own maize production to meet their maize calorie needs.

Access to credit has been touted by a number of studies as welfare-enhancing because of.

This study finds a significantly negative effect of credit access on household income and net worth. This suggests that, while agricultural credit provides the farm household with the opportunities to expand production and overcome resource constraints, and, therefore, lead to income and wealth growth, credit is a liability to the farmer.

Among the demographic variables, household size shows a significantly negative effect on all the three household welfare indicator, either in the full models or at the household group level. Thus, even though household size may be important in providing the family labor, it may also put a strain on household resources and result in reduction in welfare. In addition, education of the household head improves household income. Education provides the opportunity to engage in activities that may be income-increasing. First, higher education allows the households to assimilate and adopt new technologies that may boost their yields and hence incomes. Second,

education affects one's employability: higher education level is associated with higher wages. Therefore, education enhances the ability of the farmer to engage in other off-farm and non-farm activities such as salaried employment. This is likely to raise a household income. Among the household groups, education has a highly positive significant effect on household income among the "land-poor", but no effect among the land-rich.

The findings show that rainfall stress has a negative effect on all the three measures of household welfare at all levels of analysis, especially at the crop and agricultural levels, suggesting that drought lowers household welfare. Poor rainfall distribution and drought may lead to crop failure and yield reduction. When households anticipate poor rainfall distribution, they may cut down on the production of crops that are susceptible to poor rainfall, choosing to transfer productive resources to other less susceptible income-generating activities. If the resource transfer involves a shift away from cereal (maize) production, this may lead to less maize production and hence availability for consumption at the household level. At the same time, if most households withdraw resources from maize production in response to anticipated poor rainfall distribution, there will, on aggregate, be less marketable maize surplus, which may lead to higher the maize market prices, further lowering the quantity that households can purchase. The result may be a lower household maize security. Drought also affects household income growth through influence on a household's allocation of land to the production of various crop and livestock activities during a production period. In an agrarian system like Kenya, drought reduces total production and yields and hence results in lower household income. Since most small-scale farmers rely on crop production for the bulk of their revenues, drought also increases a household's liability, and may result in wealth reduction.

Effects of smallholder diversification on household welfare in the presence of rainfall stress, the subject of this study, shows some interesting results. The results from the analysis of the effect of diversification on household income indicate that smallholder diversification has a positive marginal effect on household income at all the three diversification levels. The effects emanate from a negative direct effect and a larger positive indirect effect through its interaction with the rainfall stress variable that more than offsets the direct effect. The study shows that the marginal effect of smallholder diversification is higher under agricultural diversification than it is under either crop or diversification, at all levels of rainfall stress. These findings suggest that agricultural diversification can be used at any level of rainfall stress to mitigate the effect of drought on household income at any level of rainfall stress. Also, at rainfall stress levels above 30% and 70%, respectively, households may use crop and livelihood diversification as strategies to minimize the effect of adverse weather. Furthermore, the study finds a positive and significant effect of smallholder diversification on household maize security in the presence of increasing rainfall stress, suggesting that households adopt smallholder diversification as a strategy to mitigate the effect of drought. Diversification into other income activities.

Diversification, however, has a negative and significant effect on household maize security at the cropping activity level, and a positive effect at the livelihood level. At the cropping activity level, diversification into other cropping activities implies reallocation of resources away from staple production. If this is not accompanied by increased incomes, the effect will be lower household maize security. On the other hand, livelihood diversification, because it involves off-farm and non-farm activities which do not compete for the land resource, is income-increasing and likely to result in higher maize availability.

3.5.2 Policy implications

The major conclusion from this study is that diversification may be an important strategy by households to cushion them against the adverse effects of drought or to reallocate productive resources away from low-value to high-value enterprise and other off-farm and non-farm activities. Based on the study findings, a number of policy initiatives can help grow smallholder household incomes and net worth, and ensure rural household maize insecurity.

The study finds that rainfall stress lowers household welfare. There are a number of policy initiatives to address this. There is a need to strengthen the weather surveillance system to provide accurate, relevant and timely weather reports. Proper, precise and timely weather forecasting and information sharing, can greatly aid households in planning their production decisions. Also, there is need for sound irrigation policies that provide households with continuous water supply during peak production period. This might involve providing an environment for the development of low-cost irrigation equipment and installation. Finally, strengthening and streamlining the agricultural insurance can greatly cushion households against unpredictable crop failures.

In order to grow household incomes and wealth and to ensure household maize security, there is need to address market imperfections. Policies that encourage market development can greatly enhance rural household welfare. Investment in rural infrastructure, including the physical infrastructure (markets for inputs and output, and roads) and soft infrastructure (market information, credit) are needed for farmers to access the urban and regional markets. Besides the traditional markets, rural smallholder farmers can greatly benefit from information that links

them to regional and export markets. This requires, for example, providing production and marketing support to the smallholders to access regional and export markets.

The fact that there is a highly significant and negative effect of credit on rural household welfare suggests that access to agricultural credit is wealth-reducing. Therefore, efforts that make the cost of accessing credit cheaper can enhance more credit access and lead to welfare improvement. Policy initiatives that lessen credit market rigidities could greatly enhance household welfare. Reducing interest rates on agricultural credit, or lowering the collateral requirement could be incentives for farmers to access more loans. In addition, strengthening the farmer cooperatives could promote access to cheap agricultural credits by farmers.

Potential agricultural productivity has been shown in this study to greatly increase household net worth. Therefore, policies targeting agricultural research and information sharing could greatly enhance smallholder welfare. Availability of affordable high-quality seed and agricultural inputs can augment household productivity and increase the marketable surplus. There is need to strengthen the research-extension-farmer linkages to ensure farmer access to appropriate technologies in a timely manner. In addition, farmer education can greatly enhance assimilation of research findings.

Because of the important role that land plays in household welfare, and, because of the continued diminishing land sizes, sound land policies can greatly lead to rural household welfare growth. Policies that provide secure land rights regarding rental and ownership and development of markets for these rights can ensure that available land is put to its most productive use, and can also influence a household's investment decisions towards welfare growth.

Finally, even though this study only focused on the household maize security, sound food and nutrition security policy can help reduce chronic hunger. Such a policy should provide linkages between rural farm production and market demand, and the skillset needed to adapt and adopt new technologies and livelihoods to respond to the ever-increasing food demand.

APPENDIX

Table 23. Dynamic panel data regressions of the effect of smallholder livelihood diversification on household income, by acreage cultivated, 2000-2010

VARIABLES	Effect on household income among "Land-poor"	"Land-rich"
Lagged log of household income (Ksh/ae)	-0.0282	-0.1677***
	(0.0227)	(0.0392)
Log of real household net assets (Ksh/ae)	0.1459***	0.0162
	(0.0389)	(0.0754)
Log of acreage cultivated (acres)	0.3268***	0.3056***
	(0.0417)	(0.0657)
Crop commercialization index	0.8535***	0.8377***
	(0.0985)	(0.1892)
Access to credit (1=y, 0=n)	0.0418	0.0827
	(0.0387)	(0.0782)
Rainfall stress	-1.5082*	-4.2997***
	(0.7737)	(1.5673)
Livelihood Diversification index	-2.2094***	-3.5892***
	(0.6537)	(1.1488)
Rainfall stress * livelihood diversification index interaction	3.0847**	7.1635***
	(1.2344)	(2.4334)
Log of main season total rainfall (mm)	0.0914	0.1508
	(0.0574)	(0.1651)
Gender of household head (1=m, 0=f)	0.0322	0.0451
	(0.0832)	(0.1331)
Age of household head (years)	-0.0007	0.0033
	(0.0030)	(0.0049)
Education level of household head (years)	0.0134**	0.0110
	(0.0062)	(0.0106)
Household size	-0.1150***	-0.0480***
	(0.0114)	(0.0185)
Agricultural transformation (=1 if year>=2004)	0.0626	0.2165***
	(0.0425)	(0.0693)
Constant	3.8291***	4.9207***
	(0.5940)	(1.2334)
Number of observations	2,619	960
Number of households	1,076	540
Model Specification Tests		
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors		
AR(1)	-9.7832***	-4.725***
AR(2)	0.018	0.380
2. Sargan Test of overidentifying restrictions		
Degrees of freedom	40	40
χ^2(df)	54.010	55.644
Prob > χ^2(df)	0.069	0.051

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 24. Dynamic panel data regressions of effects of smallholder livelihood diversification on household maize security, by acreage cultivated, 2000 -2010

VARIABLES	Effect on household maize security among "Land-poor"	"Land-rich"
Lagged log of maize calories (cal/day/ae)	0.0027	-0.0028
	(0.0075)	(0.0075)
Log of acreage cultivated (acres)	0.0520	0.1924**
	(0.0821)	(0.0913)
Log of Maize acreage (acres)	0.1571***	0.1875***
	(0.0453)	(0.0703)
Log of real household net assets (Ksh/ae)	0.0878*	-0.0709
	(0.0531)	(0.0689)
Log of real household income (Ksh/ae)	-0.0236	-0.0111
	(0.1436)	(0.1123)
Crop commercialization index	1.0367***	0.4252
	(0.3833)	(0.3502)
Rainfall stress	-2.8154**	0.8144
	(1.2870)	(0.8617)
Diversification index	-1.1100	0.9651**
	(0.6997)	(0.4467)
Weather stress * diversification index	4.3346**	-0.6431
	(1.9125)	(1.2098)
Log of main season total rainfall (mm)	-0.0317	0.2690**
	(0.0764)	(0.1332)
Gender of household head (1=m, 0=f)	-0.1683	0.0429
	(0.1094)	(0.1184)
Age of household head (years)	0.0063	-0.0105**
	(0.0046)	(0.0047)
Education level of household head (years)	-0.0046	-0.0143
	(0.0078)	(0.0095)
Household size	-0.1440***	-0.1281***
	(0.0192)	(0.0206)
Agricultural transformation (=1 if year>=2004)	0.0245	0.1025
	(0.0582)	(0.0669)
Constant	5.8955***	3.9662***
	(0.9278)	(1.1134)
Observations	2,060	766
Number of households	896	440
Model Specification Tests		
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors		
AR(1)	-5.268***	-1.2194
AR(2)	-1.077	1.529
2. Sargan Test of overidentifying restrictions		
Degrees of freedom	34	42
χ^2(df)	35.524	35.316
Prob > χ^2(df)	0.396	0.758

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 25. Dynamic panel data regressions of the effect of smallholder livelihood diversification on household net worth, by acreage cultivated, 2000-2010

VARIABLES	Effect on household net worth among "Land-poor"	"Land-rich"
Lagged log of household net assets (Ksh/ae)	0.0400	0.0143
	(0.0253)	(0.0466)
Log of real household income (Ksh/ae)	0.1144**	0.1895**
	(0.0513)	(0.0861)
Log of acreage cultivated (acres)	0.4700***	0.2421**
	(0.0932)	(0.1095)
Log of village average maize yield (kg/acre)	0.1570*	0.1385
	(0.0853)	(0.1139)
Crop commercialization index	-0.1550	0.0872
	(0.3997)	(0.4486)
Access to credit (1=y, 0=n)	-0.1413	-0.2851*
	(0.1176)	(0.1644)
Rainfall stress	0.7253	1.3736
	(0.4432)	(1.4024)
Livelihood Diversification index	0.3970	1.5090**
	(0.2481)	(0.7205)
Rainfall stress * livelihood diversification index interaction	-1.2619**	-3.6672*
	(0.6113)	(2.1978)
Log of main season total rainfall (mm)	0.1645*	-0.1314
	(0.0853)	(0.1339)
Gender of household head (1=m, 0=f)	0.0284	-0.0317
	(0.0860)	(0.1303)
Age of household head (years)	-0.0030	0.0031
	(0.0033)	(0.0048)
Education level of household head (years)	0.0008	0.0057
	(0.0074)	(0.0091)
Household size	-0.1184***	-0.1192***
	(0.0141)	(0.0148)
Agricultural transformation (=1 if year>=2004)	0.2352***	0.0965
	(0.0567)	(0.0713)
Constant	1.1438*	2.7573***
	(0.6543)	(1.0354)
Observations	2,628	964
Number of households	1,086	543
Model Specification Tests		
1. Arellano-Bond Test for Zero Autocorrelation in first-differenced errors		
AR(1)	-10.333***	-4.546***
AR(2)	0.898	-0.290
2. Sargan Test of overidentifying restrictions		
Degrees of freedom	36	29
χ^2(df)	49.712	22.069
Prob > χ^2(df)	0.064	0.817

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 26. Tests of significance of the marginal effect of smallholder livelihood diversification on household welfare, 2000 - 2010

	Model containing			Household group	
Dependent Variable	Crop diversification	Agricultural diversification	Livelihood diversification	Land-poor	Land-rich
Log of Household income					
$\chi^2(2)$	14.05	19.29	18.08	11.42	10.07
$Prob > \chi^2$	0.0001	0.000	0.000	0.003	0.007
Log of Household maize security					
$\chi^2(2)$	6.72	11.75	12.25	7.07	6.83
$Prob > \chi^2$	0.035	0.003	0.002	0.029	0.033
Log of Household net worth					
$\chi^2(2)$	6.69	0.55	5.62	4.38	5.45
$Prob > \chi^2$	0.035	0.758	0.060	0.112	0.065

Table 27. Household welfare indicators by quartile of land cultivated, 2000 to 2010

	Measure of household welfare indicator		
Quartile of land cultivated	Real income ('000 Ksh/ae)	Maize security (Kcal/ae/day)	Real net worth ('000 Ksh/ae)
1st (Lowest)	44.17	161.20	54.59
2nd	56.61	188.02	73.44
3rd	69.05	211.81	81.55
4th (Highest)	109.56	307.74	150.19

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