DISSERTATION

ROADS AND RURAL DEVELOPMENT: EVIDENCE FROM A LONGITUDINAL HOUSEHOLD SURVEY IN KENYA

by

Kiprono Philemon

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Abstract

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by: **Kiprono Philemon**

Dissertation Director: **Prof. Tomoya Matsumoto**

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Agricultural productivity continues to dwindle in Sub-Saharan Africa (SSA) countries, and, coupled with the high rate of population growth and the ever changing climatic conditions, these nations are exposed to extreme poverty. Unless drastic measures are undertaken to reverse the trend, food production will continue to decrease eventually setting the countries into poverty traps. Hardest hit will be the rural areas, where the majority of the vulnerable poor live. To avert this looming crisis, researchers have proposed a number of measures, including improving road infrastructure to aid market accessibility and integration, which is thought to have a larger and sustainable impact. Market accessibility and integration as a result of road infrastructure improvement is pertinent to the process of economic development, especially in rural areas, as commodity prices is linked to transport cost. High transportation costs are always reflected in high input prices and low output prices, thus forbidding smallholder farmers to engage in profitable agricultural investment. Documented evidence of the benefits of road infrastructure improvement have remained scarce, concentrating in Asia with a few studies in Africa.

In the recent past, there have been sizeable cash flows (in terms of concession loans

and grants) to the African continent to support the improvement of road infrastructure, yet a few studies have been carried out to asses the impacts of such a massive investment.

Using longitudinal data collected in Kenya between 2004 and 2012, and supplementary data for roads infrastructure, this study finds the positive impact of road improvement on a number of our outcome variables. Specifically, land allocated to hybrid maize, organic manure application, the yield of maize and market participation for milk increased in areas experiencing better road access. Although the use of inorganic fertilizer increased, it was not significantly associated with improved roads. Furthermore, this study finds that in areas experiencing road improvement, smallholder farmers' income, in particular farm income, livestock income and non-farm income have increased. It also finds increased household expenditures in areas receiving road improvement, especially expenditures on food.

Lastly, this study evaluates the determinants of the road improvement by combining longitudinal dataset collected in Kenya between 2004 and 2012 together with secondary election dataset and night-light dataset for the same period. The study finds that during the period between 2003 and 2012, there was no undue influence by politics on the allocation of Constituency Development Funds (CDF) as well as on road rehabilitation. We find that between 2004 and 2012, the areas represented by Members of Parliament (MPs) allied to the government did not receive more rural road improvement than areas represented by the opposition. In fact, there has been a significant reduction in the improvement of infrastructure in areas where cabinet members hail from. Similarly, the areas that voted for the winning presidential candidate did not receive more rural road improvement that other areas. For the road improvement to nearby big town, there is a positive association between road infrastructure improvement with our political variables, but may be a contemporaneous.

Using these findings, a number of policies geared towards the improvement of agricultural productivity and development have been suggested.

Dedication

To my parents
my wife Gladys
and
my daughters Ashley and Tamara.

Summary of the Dissertation

The global community is concerned about the escalating levels of poverty in developing nations. Many of these developing countries are facing acute starvation as a result of inadequate food production, exacerbated by climate change and inappropriate farming technologies. There are a number of studies demonstrating that agricultural productivity in SSA is declining and that this trend can be reversed if proper and modern farm techniques are employed, especially the utilization of organic fertilizers and the adoption of high yielding varieties. However, due to poor market accessibility as a result of dilapidated road infrastructure, farmers are unable to access the much-needed farm inputs like fertilizer and hybrid seeds, hence holding them back from increasing their farm productivity.

Good roads enable markets to integrate, enabling faster movement of commodities across markets. Besides physical movement of commodities, good roads reduces transportation costs both pecuniary and time cost, translating to reduced farm input prices and higher farm output prices making farming profitable. Furthermore, because of farmers' networks, good roads enables information infiltration, thus reducing information asymmetry on prices therefore reducing price spread across markets. This will enable farmers to make firm decisions wether to sell their farm produce at the farm-gate or take them to the markets where they can exercise their power to dictate output prices. Therefore, there is a need to have reliable roads to deliver these commodities.

Using new panel data from Kenya, this thesis evaluates the impact of road improvement on agricultural productivity and welfare improvement in addition to

investigating the determinants of road improvement.

First, in Chapter 1, we give a brief introduction of the thesis and significance of issues to be addressed, while in Chapter 2, we describe our data and procedure of some of the variable generation. Chapter 3 gives extensive review of studies on the impacts of infrastructure improvement.

In Chapter 4, we investigate the impact of road improvement on farming, especially fertilizer usage, maize yield and market participation for both maize and milk by smallholder farmers. Kenya has recently embarked on an ambitious road infrastructure improvement scheme, and the fact that 40 million people rely on 3.5 million smallholder farmers for food production calls for the urgent need to increase agricultural productivity in order to avert food shortages. Thus, the objective of this chapter is to ascertain whether the recent road improvement in Kenya road can nudge farmers to increase the adoption of yield enhancing farm inputs such as inorganic fertilizers and hybrids seeds, as well as participate in the marketing of their farm produce.

In Chapter 5, we investigate whether road improvement contributes to better household income and increased expenditures. The underlying idea is that when roads are improved, markets are integrated, and farmers are subsequently exposed to a number of opportunities of which they can take advantage and diversify their income sources. Therefore, the objective of this chapter is to ascertain if indeed road improvement can translate to increased incomes and expenditures, and if so, what are the pathways under which these benefits are channeled.

Having looked into whether road improvement leads to the adoption of farm technologies and increases market participation and whether road improvement leads

to increased household income and expenditures, Chapter 6 investigates the factors that might have influenced the rehabilitation of the road network in Kenya. Road rehabilitation in Kenya has always been marked by controversies, with politicians and government officials being accused of diverting resources meant for road rehabilitation. In this chapter, we seek to unearth the link between democracy, as measured by winninng presidential vote share, political party affilitaion, and as a cabinet member, and road construction. We control for the effects of other development activities as proxied by night-light data, and ethnic composition in the districst. The use of night-light data has gained importance of late in the field of econometric, especially in countries with little information on development records. Because it is difficult to document what the political leaders amass for their constituents, we believe by using night-light data, we can trace the progress of development in these constituencies.

This dissertation offers three main findings. First, the results show that land for hybrid maize, fertilizer intensification, maize yield and milk market participation increase more in areas with better road improvement. This suggests that the recent road rehabilitation in Kenya has improve agricultural productivity. However, there was a negative impact on sale of maize, and although we were not able to verify this, is attributed to two factors, namely the subsistence nature of the smallholder farmers, and over supply of maize in the markets, hence lowering prices prices to unprofitable levels. Therefore improving roads infrastructure increases agricultural productivity, especially in the areas experiencing road improvement.

Secondly, on whether there are benefits accruing from road improvement, this study finds that, overall, income and expenditures increased. In particular farm, livestock and non-farm income increased as a result of road improvement. On the other hand,

we did not find any evidence supporting the shifting of smallholder farmers' income and expenditure composition. This was expected in the sense that, even if road infrastructure improves, it will take time for farmers to switch to other channels of income generating activities. However, we found that there was an increase in expenditures on food items contrary to what Engel's theory predicts. A similar outcome has also been found in a study in Ethiopia.

Lastly, on the determinants of road improvement, we did not find any evidence linking roads improvement and our political variables. We investigated whether there was political influence in allocating Constituency Development Funds (CDF). The Constituency Development Funds (CDF) are funds allocated to each of the constituencies in Kenya by the central government through an independent agency, for the implementation of the various development projects, including the rehabilitation of rural roads. This fund was established in 2003 as part of the new government's agenda to improve status of living in the rural areas. We found no evidence of political interference. Specifically, on the road improvement to a nearby market, we found a strong association between roads condition in 2004 and the 2012 road improvement status. We also found that roads were more likely to be improved in areas with higher population density. We did not find any evidence linking our political variables with road improvement or ethnic favoritism. For the roads rehabilitation to the nearby big town, we found evidence that in areas areas with higher economic development, roads are more likely to be improved. Similarly, road improvement condition in 2012 dependent on the initial road condition in 2004. Although we found association between presidential vote share and road improvement, it is highly likely that it is spurious.

On the grounds of these results, this thesis proposes a number of policies. First, it

recognizes that road infrastructure is pertinent to development, especially in rural areas. Therefore, in order to sustain these positive impacts, more funds should be channeled to rural road infrastructure improvement. Alongside increasing funding for rural roads improvement, policy makers should initiate farming sensitization programs through its wide network of field extension officers to sensitize farmers on how to diversify and capitalize and identify their comparative advantage in crop production, in order to avoid flooding the markets with the same crop. Regarding income and household consumption, the increase in the source of income, especially non-farm and livestock income, shows that farmers are rational and responsive. Farmers keep livestock as savings to smoothen consumption during bad times by selling them as well as using them as a supplementary source of food. However, because they rely on the natural climate to raise their livestock, they are more prone to weather shocks. Therefore, the government should design affordable insurance coverage and sensitize farmers to insure their livestock so that in case of drought leading to loose of livestock, they can get compensated thus, maintaining their consumption patterns.

Lastly, on the determinants of road infrastructure improvement, there is evidence that political interference on public investments is diminishing in Africa. The insignificant coefficient of our political variables signals that there was no influence from the political leaders on the rehabilitation on rural road infrastructure. This is encouraging from the perspective that large infrastructure investment in Africa has been known to be marred by outward corruption in the form of political interference. This outcome is also encouraging in that the government can confidently expand the scheme to other projects like piped water supply and irrigation schemes, so as to widen the base for food production.

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Tokyo, Japan Kiprono Philemon

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Chapter 1

INTRODUCTION

This chapter discusses the importance of road access improvement in improving agricultural intensification and welfare improvement among smallholder households in developing nations, towards alleviating poverty. It is organized into three sections. The first section discusses the situation in Sub-Saharan Africa (SSA) as compared to her East-Asia and the Pacific counterparts. The second section discusses the issues to be addressed to improve agricultural productivity. The third section gives the outline of the thesis.

1.1 Introduction

Attaining self-sufficiency in terms of food security has proven to be a challenge to many developing nations and especially those SSA. Many of these developing nations depend on agriculture as the main driver of their economic growth (World Bank, 2013). However, the increasing population has put pressure on existing arable land, which has not expanded to meet the ever increasing food demands, hence leading to decline in agricultural productivity. This has been further worsened by the changing climate and dilapidated road infrastructure which has rendered extensive market fragmentation of farm inputs and outputs, thus denying smallholder farmers access to cheap yield-enhancing farm inputs (World Bank, 2007, 2009, 2014). The result is that these economies are faced with the real danger of acute starvation and high prevalence of poverty. Unless drastic measures are undertaken to address the issue of diminishing agricultural productivity, these economies will experience stagnant growth for the foreseeable future.

Unlike her counterparts in East Asia and the Pacific (EAP), who excelled in adopting the *Green Revolution* as a means of expanding food productivity, the agricultural sector in SSA is still dependent on rainfall and is small scale[1]. As explained in David & Otsuka (1994), much of the success of the Green Revolution in Asia is owed to well-managed irrigated fields which enabled the wider adoption of the high yielding varieties and fertilizer application. This has not happened in SSA Africa, because irrigation infrastructure is very poor. This has resulted in a huge divergence in cereal productivity and fertilizer consumption in SSA compared to EAP as shown in Figure 1. How the successful story of Green Revolution has not been adopted in SSA has puzzled many agronomists. There has been increased attempts to transfer the Asian model to Africa, but it has been very slow as a result of poor institutions, poor soils, lack of credit facilities and erotic rainfall (Dorward et al., 2004). Therefore, in order to increase the chances of successful adoption of Green Revolution in Africa, factors that enhances smallholder farmers' efforts to access farm inputs must be invested in. Thus, in order to jump start the process of increasing agricultural productivity and diversifying sources of income, this thesis studies the impact of road access improvement on smallholder farmers' agricultural productivity and welfare improvement as well as factors determining the road access improvement. We use a unique panel data from Kenya for the period 2004-2012, which is described in detail in Chapter 2.

The findings of the studies are useful to policy makers, not only in Kenya, in drafting policies to tame the runway poverty levels (Kedir, 2003).

[1]During the late 1960s in the quest for increased crop yield, scientists in Asia and Latin America bred improved variety seeds, and using fertilizers and other farm chemicals on irrigated farms, the yield dramatically increased. Thus, the term Green Revolution was coined to refer to this *miraculous* success.

1.2 Significance of issues

SSA nations continue to depend on agriculture as the main driver of their economy (World Bank, 2014). The share of contribution of agricultural sector in the labor market in Africa is over 60 percent, although agricultural share of GDP has gradually reduced from 21 percent in 1965 to just a little over 14 percent in 2011 (World Bank, 2014). Because it is the only occupation that has been adopted widely, agricultural development could prove very crucial in fighting poverty by directly providing employment opportunities, resuscitating markets (thus improving household income) as well supplying food directly to households.

However, agricultural development in SSA has continued to be unproductive, even 50 years after most of the countries in SSA attained their independence (Koffi-Tessio, 1998, Yu & Nin-Pratt, 2011). They have continued to import over 20 percent of their basic consumption needs even when their climate is favorable for food production (Anseeuw, 2010). This is less than ideal for the countries' economic growth, and sooner rather than later, they need to embrace successful projects like the *Green Revolution* in Asia in order to reverse import dependency (Otsuka & Kalirajan, 2006).

Two major factors have been identified as potential game changers in agricultural productivity in SSA if correctly addressed: irrigation and road access improvement. SSA depends entirely on natural precipitation for agricultural production. However, because of the unpredictability brought on by climate change and the increasing pressure on existing arable land due to the increasing population, agriculture development is never guaranteed to thrive in the region. The share of irrigated landed in SSA remains below 20 percent in 2012 compared to her East Asian counterparts (World Bank, 2014). Therefore, irrigation schemes as a means to impact food scarcity

needs to be initiated in SSA.

On road access improvement, there is a need for urgent upgrade of roads to motorable standards. The road density (km of road per 100 square km of land area) is very low in SSA compared to EAP and is in very poor condition. The poor infrastructure has numerous negative impact on smallholder farmers agricultural productivity. First, farmers are isolated from competitive markets because poor roads renders market integration untenable. This translates to large price volatilities and production shocks as farm inputs cannot reach the intended farmers at the right time when the main season starts, hence delaying the planting of crops (Badiane & Shively, 1998). On the other hand, farm produce cannot reach markets at the required time because there is no market connectivity. This leaves the smallholder farmers to produce small amounts that they can head-load to the markets and for home consumption because storing is not a viable option. Secondly, due to the poor market connectivity, the stimulation of rural entrepreneurship is difficult because rural areas are very isolated from outside markets, where other farmers engage in non-farm activates to supplement their farm household income (World Bank, 2014). Lastly, poor infrastructure leads to higher input-output relative price. For example, hybrid seeds and inorganic fertilizers are normally produced in big towns, therefore with poor infrastructure, the cost of transportation will increase the input prices. On the other hand, the poor road infrastructure will render smallholder farmers unable to dictate prices of their produce, hence remaining price takers. Therefore with improved infrastructure, all the shortcomings are bound to reduce to the benefit of smallholder farmers.

But all is not lost. There has been renewed interest in infrastructure improvement in Africa, where the donor communities and concerned nations, in the spirit of Private

Public Partnership (PPP), have partnered to rehabilitate roads to motorable standards. African Development Bank (ADP) has pledged over USD 40 billion in bonds to finance infrastructure improvement in Africa while the World Bank in 2010 invested in excess of USD 9 billion in 2010 on infrastructure improvement Africa alone.

1.3 Objectives of the thesis

While the literature has recently continued to document the benefits of road infrastructure improvement of agricultural productivity and welfare improvement, many of these case studies are in Asia or Latin America, and it has been very difficult to shed light on the benefits of such investment in SSA. This is mainly due to the scarcity of data, or if they are available, the data are scattered and incomplete, making it difficult to make a conclusion about their benefits.

This dissertation, therefore, seeks to fill this gap by using new panel data obtained from a longitudinal survey and from government sources in Kenya for the period between 2004 and 2012 to offer new insights on the importance of improving road infrastructure in Kenya. This panel data set is superior to the cross-sectional data often used in the literature because in using it, we are able to minimize the effects of biases as a result of the non-random placement of roads as roads are often constructed in places with high population. By using a fixed effect (FE) model, we are able to difference out unobservable time invariant characteristics that might have influenced road placement, and assume that the residual are uncorrelated with the error term.

Based on the above discussions, we outline the objectives of this dissertation as follows: (a), to evaluate the impact of road access improvement on agricultural development; (b), to ascertain if the road improvement translates to increased household income and increased expenditures; and (c), to determine what factors

influenced the rehabilitation of the roads.

For the first objective, the study attempts to evaluate the impact of road access improvement on agricultural productivity, namely hybrid maize seed adoption, inorganic fertilizer intensification, farm productivity and market participation among smallholder farmers in Kenya. The literature has shown that in Asia and Latin America, the improvement of road infrastructure increases farm productivity and market development (Binswanger-Mkhize et al., 1993, Dorosh et al., 2012). Therefore, we seek to evaluate if the same impact can be achieved in SSA. On the second objective, we seek to uncover if indeed improved roads are beneficial in terms of increasing household income and expanding household expenditures. Road infrastructure improvement can alleviate poverty by providing an environment conducive for diverse income opportunities to thrive. The literature has shown that with improved roads, households are more likely to increase their income and expenditure (J. Gibson & Rozelle, 2003, Khandker & Koolwal, 2011).

Lastly, because road access improvement is a public investment, we seek to establish what factors could have influenced the road rehabilitation. We single out the political influence to study because in Africa, the political leadership has been known to interfere with public projects to benefit their own ambitions (Acemoglu & Robinson, 2012, Miguel, 2001). Even in other countries not in Africa, there has been evidence linking politics to nepotism and tribalism when public resources are being shared (Banerjee & Somanathan, 2007). Thus, in this study, we seek to find if the recent road rehabilitation in Kenya was politically influenced.

We find that indeed farmers respond to the improvement of roads. On average, farmers expanded their plots for growing hybrid maize seeds, increased fertilizer use,

and increased their participation in milk marketing, especially in areas experiencing road improvement. Furthermore, we find that maize productivity increased in areas with improved roads and particularly those smallholder farmers located far from the capital city. There was no evidence that roads access improvement impacted maize market participation, however. On welfare improvement, we find increases in farm, non-farm and livestock income as well as expenditures on food. The surge in food expenditure was not expected, as Engel's law predicts that when income increases, households tend to shift their consumption to non-food products, especially on leisure (Zimmerman, 1932). Our explanation is that the households have not reached self-sufficiency in terms of food security and until that threshold is achieved, any slight increase in income will translate to food expenditures on average (Girma & Kedir, 2003). Lastly, on the influence of road infrastructure rehabilitation, there was no evidence that politics interfered with the improvement of infrastructure. This is good news in that it shows that in a democratic environment, public goods investments can be implemented well without external influence from politicians. Other projects too can emulate road rehabilitation. In fact, we advocate that that such infrastructure should actually be devolved to the lowest level of administration for implementation and totally be detached from central governments.

This thesis, however, does not cover the distributive aspect of the benefits from roads improvement. The distributive aspect is important for policy makers to know who benefits most in order to design projects that target particular groups. This is left for future research.

1.4 Organization of the thesis

The rest of the thesis is organized as follows: Chapter 2 presents the data used in the dissertation and the algorithms for the generation of our variables of interests. while Chapter 3 gives the background and literature review. We present the two studies on impact of road access improvement in Chapters 4 and 5 and one study on the determinants of road access improvement in Chapter 6. We summarize the content of Chapters 4 to 6 in the following paragraphs.

Chapter 4 discusses the importance of infrastructure as means of improving agricultural productivity. It summarizes what literature have found on impacts of roads access improvement and what gaps and challenges exist in terms of data and methodologies used. It then discusses briefly about road infrastructure in Kenya, then in the data section, we describe the data used in the study as well as our estimation strategy. Results section presents extensive analysis of the results of the study as well as robustness checks. The chapter then concludes by outlining the main findings of the study and their policy implications.

Chapter 5 studies the impact of road infrastructure improvement on welfare of smallholder households. The introduction outlines the gaps that exist in literature, and how we overcome the challenges that exists and summarizes the findings of the study. The background section recounts the current situation on roads access improvement in Kenya. We describe the data used in this study in the data section and methodology and variables in empirical specification section. Extensive results of the study are narrated in Section 5.5 as well as robustness checks. Section 5.6 concludes and gives policy implication of the study.

Chapter 6 presents the determinants of road access improvement in Kenya. It

discusses the challenges often encountered in infrastructure improvement in Kenya. The background section of the chapter gives the chronology of road construction in Kenya, then discusses about political maturity in Kenya in political section. The data section presents the data used in the study, the summary statistics, hypothesis to be tested as well as the empirical specification. Results section presents our main results and robustness checks. The chapter concludes by summarizing the main findings of the study and their policy implication.

Chapter 7 wrapup this dissertation by summarizing the findings in the three studies. It then outlines the policies drafted basing on the findings of the studies, that will guide policy makers in drafting and implementing poverty reduction oriented action plans.

Chapter 2

DATA AND ALGORITHMS

2.1 Introduction

This chapter describe the data and the algorithms used in the thesis. It is important to include this chapter because the data we are using in different chapters are a conglomeration from a number of sources. The main sources are (a) the Research on Poverty, Environment, and Agricultural Technology (RePEAT) project (b) the Ministry of Roads (Kenya) (c) night lights data obtained from National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC) and (d) Independent Electoral and Boundaries Commission (IEBC). In the following sections, we present each of the data sets in detail together with algorithms used to generate the time distance variables as well as the night light variable.

2.1.1 Research on Poverty, Environment, and Agricultural Technology (RePEAT) data

The Research on Poverty, Environment, and Agricultural Technology (RePEAT) data is a detailed, geo-referenced longitudinal household and community survey conducted jointly by the National Graduate Institute for Policy Studies in Tokyo (GRIPS), Foundation of Advanced Studies on International Development (FASID, Japan) and its collaborators in three East African countries namely Kenya, Uganda, and Ethiopia. Four follow-up surveys have been conducted in Kenya since the initial one in 2004 namely in 2007, 2009, 2012 and 2013. Initially, 900 households (about 10 households in 99 villages) were randomly selected from 2,966 households that were previously interviewed by the International Livestock Research Institute (ILRI) in 1998 and 2000

drawn from the Rift Valley, Central, Nyanza, Western and Eastern provinces (Staal & ILRI, 2001, Waithaka et al., 2002)[1]. The 2012 RePEAT survey targeted 899 households that was surveyed in 2007, but 871 households were successfully traced. We made adjustments in the 2012 data to enable us make a balance panel. First, we dropped 82 households that were replaced and a further 24 households that could not be traced. 7 households refused to be interviewed, while 4 households had the head and spouse sick. In 3 households, we could not find eligible member to respond. We also dropped 22 households because of missing or erotic data. This cleaning of data resulted in an attrition rate of approximately 16% . The data is distributed as shown in Table 4.1. Thus, a panel of 729 observations remains to be used in the analysis. We investigate whether there is any systematic attrition in our data but the F-ratio test indicates no evidence of systematic attrition.

The survey contains detailed information on various household and community characteristics including demographics, education attainment, household income and expenditures, farm input use, land tenure system and land use. This data set is central to our analysis in this thesis. Figure 2 shows the area covered by the RePEAT survey in Kenya.

2.1.2 Road Network data

Since the beginning of 2003, the government of Kenya has been keen on turning around the condition of the roads which had been deteriorating since the early 90s in order to support the country's development agenda. Since her independence in 1963, the Kenya government has gradually increased the road network which stood at 45,000km to about 163,000 km as per the 2012 ministry's reports (Ministry of Roads, 2011). A number of programs have been implemented towards this improvement, and

[1]Full set of questionnaires can be obtained from http://www3.grips.ac.jp/~globalcoe/e/index.html

the most notable one started in 2001 when the then Ministry of Roads, with financing from World Bank, was mandated to conduct a comprehensive audit of the roads in the country under the Road inventory and Condition Survey for the Classified Roads (RICS) using Geographical Positioning Systems (GPS). The study resulted in the creation of a roads inventory database using the Geographical Information System (GIS). However, there were numerous shortcomings of the project in that it was not possible to clearly indicate condition of unclassified rural and urban roads thus forcing the government to initiate another study in 2006, this time funded by the Nordic Development Fund under the Northern Corridor Transport Improvement Project. The roads surveys were undertaken on a district by district basis between May 2007 and April 2009 amid numerous logistical problems. After the completion of the survey, the RICS data collected for the classified roads in 2003 was merged with the current data from the survey to create the complete roads network.

The complete road inventory has detailed physical road and bridge characteristics (e.g., paved or unpaved, road width, culverts) and visual condition classification (classified as excellent, good, fair, poor, and very poor) and is being updated regularly to capture the current developments at the grassroots level (Ministry of Roads, 2011).

2.1.3 Constituency Development Funds (CDF)

When the National Rainbow Coalition (NARC) took over the reigns of power after the 2002 general election in Kenya, the new government embarked on a process of resuscitating the economic growth which was then growing at a negative rate. A number of policy documents were drawn including the Constituencies Development Fund Act of 2003 to create the Constituencies Development Fund (CDF), an idea borrowed from the Indian model. The CDF was initiated with an aim of tackling the widely spread poverty

at the grassroots level. It is entirely funded by the government through apportioning a minimum of 2.5% of the national government ordinary revenue (Republic of Kenya, 2013). Each constituency, 210 of them as per year 2002 constituency boundaries, first received seed money of USD 68,634 in 2003 and in subsequent years, following the CDF Act of 2003, 75 percent of the allocated funds are shared equally among the 210 constituencies and the remaining 25 percent is allocated based on the national poverty index and constituency poverty index(Republic of Kenya, 2013)[2]. This fund has become been very popular with the electorate because it directly affects them and furthermore, it is controlled by their respective members of parliament. Over USD 1,574 million has been distributed since 2003.

2.1.4 Election data

Kenya has come along way in terms of democratising the process of political representation. Since her independence in 1963, Kenya has democratically changed governments four times, which has been characterised both by the single party and multi-party system of government as shown in Figure 7 adapted from Burgess et al. (2013). The mandate to conduct elections in Kenya is vested in an independent electoral body, but during the the single party system of government, was directly under the provincial administration. When the multiparty system of government, an independent electoral commission was created to see over and document elections in Kenya. Democratic elections have been held every five years since 1992.

The data used for this study was for the period 1997, 2002 and 2007 elections for the areas covered by the RePEAT survey. In total we have 35 constituencies covered by the RePEAT survey.

[2]Until 2012, Kenya was divided into 210 constituencies but has since been increased to 295. The exchange rate of 1 USD=87.64 Kshs was used to convert Kenya shillings to USD.

2.1.5 Population data

The population data were obtained from government-published materials namely the statistical abstract (Goverment of Kenya, 2014, KNBS, 2002, 2009). Kenya has moderate documented census data from her first census conducted in 1948 when it was still under British rule. Starting 1969, the census has been conducted every ten 10 years and is detailed to the lowest administrative structure, the village. It was last done in 2009, and the next one is on course for 2019. Kenya has been lauded by the international community for processing the census data in record time, the last one being released within a year of the survey. In this thesis, we use the 1999 and 2009 census data.

2.1.6 Night Lights data

The night light data was downloaded from National Oceanic and Atmospheric Administration's (NOAA) in the form of raster files containing complete world data (NOAA, 2014)[3]. The weather satellites manned by United States of America Air Force circles the earth 14 times each day, capturing the earth's imagery (Elvidge et al., 2012, NOAA, 2014). The timing is between about 8:30pm and 10pm when people are thought to be actively using lights. Once the data have been collected, the photos are converted into the raster files and are calibrated into light intensity pixels ranging from 0-63 digital numbers[4]. Complete raster files are available from 1992 to 2012 in three formats namely

(a) *F1?YYYY_v4c-cf-cvg.tif* which contain cloud-free raster files

(b) *F1?YYYY_v4c_avg_vis.tif* which contain raw average of the visible band digital number values and needs no further modification and

[3]Raster files are computer generated dot matrix representations of a photograph. The clarity of these images is dependent on the intensity of the dots in the file. The more the dots, the clearer the image.

[4]Digital numbering refers to assigning each dot (pixel) a number ranging from 0 to 63 depending on its illuminosity. In this thesis, 0 represents no light while 63 represents full light. NOAA uses very complex algorithms and procedures to produce the raster maps that can be used for analysis. The description of the procedures involved is beyond the scope of this thesis

(c) *F1?YYYY_v4c_stable_lights.avg_vis.tif* which contains stable, cleaned data and contain digital values from 1-63[5].

In this thesis, we use *F1?YYYY_v4c_stable_lights.avg_vis.tif* raster file because of its data stability.

The pixels in the raster files are approximately one square kilometer at the equator. We present a summary of information from night lights in Table 6.2 to shed some light on the data. Figure 8 clearly shows the progress of lighting in Kenya from 2003 to 2012. It can be seen that in areas circled in red, the intensity of lights was very low in 2003 while in blue circled areas, there were no lights at all.

2.2 Algorithm for variable generation

In this section, we detail the algorithm for constructing our time distance variables by motor vehicle and night lights data. We first look at the time distance variable in Subsection 2.2.1 then on the night lights in Subsection 2.2.2.

2.2.1 Algorithm for generating time distances

To generate the time distance variables, we digitized the maps of the road network of 2004 because the soft copy of the road network was not available and superimpose them on 2012 geo-referenced data using Desktop ESRI ArcGIS® 10 software[6]. Then we use historical Google® maps to verify the accuracy of the digitized maps[7]. Furthermore, we also used the self-reported road conditions to the nearby market by the households to further verify if the superimposed maps were correctly placed. We then assigned

[5]The question mark "?" represent a number use to identify the satellites from which the image was captured and the year for example F182012 is the file from satellite number F18 for the year 2012. Another file which we are not using in this thesis is the night flares file. This file contains lights from gas flares. Fortunately in Kenya, there are no gas flares hence there was no need to remove these regions.

[6]Fortunately, the road maps in 2004 were drawn using the same dataframe as the 2012 road network database, thus aligning the maps pose no problem

[7]See Figure 3 for a sample extract from Google® maps showing road access improvement in Karachuonyo district between year 2004 and 2014

each section of the road in the network a speed according to the classification shown in Table A.1. These speeds were largely drawn from official speed limits in Kenya, and where speed limits were unavailable, speeds were assigned to mimic the actual speeds on the roads. Using the ESRI ArcGIS® 10 software, we generated a road network dataset and run a route solver to pick the shortest time distance to the nearest market using households as the origin and markets as facilities. The solver uses an algorithm that takes into account the visual characteristics of the environment in which the road is passing, infrastructure accompanying roads, e.g culverts, condition, surface class and the type of road. Visual characteristics include surface type, surface condition, surface class e.g bituminous or unsealed, and the number of lanes. The same procedure was repeated for the time distance to a big town, changing the origin to the community center and big towns as the facilities. Then using the spatial geo-referencing tool, we linked the solved routes to the households and community centers and export the data as a complete panel data. Note that the time distance variable to a nearby local market is at the household level, while time distance to a nearby big town is at the community level. The two time distances play different roles; for example, the time distance to nearby market captures the local market conditions, while time distance to a nearby big town captures macro level social and economic factors.

2.2.2 Algorithm for generating night lights

The generation of time distance variables was less time consuming. Once the road network was complete, running the route solver on average took four minutes. However, for the night-lights the process was a bit complex. Processing a four-gigabit raster file in ArcGIS took about forty minutes. Once the files were loaded, we clipped them to Kenya's national boundary. From the clipped raster files for 2004 and 2012, we created fishnets

for extracting digital numbers from the raster files[8]. Once we finished organizing our files, then we followed the long procedure outlined in Lowe (2014) to obtain our tables of light intensity. Extracting information from one file on average took two hours.

Once the zonal tables were generated, then using the spatial tool as in Subsection 2.2.1, we merged the dataset to the RePEAT dataset.

[8]Fishnets are squares generated to cover the raster files under analysis to hold the digital number summary statistics

Chapter 3

Background and Literature Review

3.1 Introduction

Since the time of Aschauer (1989), the importance of evaluating the impact of investing in public infrastructure on poverty alleviation has been renewed and has gained great interest both in academic and political circles (Estache, 2010). A number of studies have documented the positive effects of infrastructure improvement on productivity and growth.

In this chapter, we review the studies evaluating the impact of road infrastructure improvement on productivity, poverty alleviation and factors that influence road access improvement. First, we summarize the history of farming in Kenya in Section 3.2 to set the stage for analysis. Then in Section 3.3 we review the relevant literature. In particular, Subsection 3.3.1 reviews the literature evaluating road infrastructure improvement on productivity and growth, while in Subsection 3.3.2, we review the literature relevant to road infrastructure improvement on poverty alleviation. Lastly, in Subsection 3.3.3, we summarize the literature analysing the factors influencing road infrastructure placement and construction.

3.2 Background of Farming in Kenya

Kenya's economy is dependent on agriculture for its growth. With a total land mass area of about 587,000 square km, only 16 percent is arable. The agricultural sector contributes over 24 percent of Kenya's GDP and employs over 70 percent of the population (KNBS, 2012). The population of Kenya is estimated to be 40 million and depends on 3.5 million smallholders farmers for its food supply (KNBS, 2012). The

ever rising population density as a result of high population growth, estimated to be 2.8 percent per annum, has put pressure on existing arable land (KNBS, 2012). Therefore, without investing in new farming methods, food security cannot be guaranteed. In the following subsections, we describe the steps that the government has undertaken in the agricultural sector since her independence in order to shield herself from food scarcity.

Kenya enjoys a good climate which is favourable for growing a variety of crops. From the slopes of Mt. Kenya to the shores of Lake Victoria, the weather in the regions is favourable for farming, both in short and long rains season. The main cash crops include tea and coffee, and of late, horticulture, which consist mainly of fruits, vegetables and flowers, has been doing very well. Most of these cash crops are exported to overseas markets.

The main staple food in the country is maize, which is cultivated by over 80 percent of the households. Maize is adaptable to a wide range of climatic conditions and is extensively grown in the western part of Kenya. Smallholder farmers in the region practise intercropping, planting maize and beans together. The beans are leguminous and thus help in fixing nitrogen in the soil, thus boosting maize productivity. However, maize productivity has been deteriorating over time owing to changing climatic conditions, declining soil fertility, the use of uncertified seeds and the lack of fertilizers and has been worsened by poor road infrastructure. Compared to East Asian and Pacific countries, maize production in Kenya is below average. Figure 1 gives a glimpse of the situation.

On farm input use, Kenya is rated highly in the use of organic fertilizers and hybrid seeds compared to her neighbours. Before the 1980s reforms on farm inputs

marketing, state agencies like the Kenya Farmers Association (KFA) were the only players in supplying the farmers with farm inputs. In the 1980s, the government scrapped the monopolistic control of fertilizer markets, opening the door for the private sector to invest in the commodity under government control. A number of challenges marred the process which included rent seeking from state officials (Ariga et al., 2006). Since then, the liberalization of fertilizer markets have continued to reinvent itself as the government has continued to ease restrictions of fertilizer and maize imports. This meant that farmers were to enjoy favourable fertilizer prices. However, due to high transportation cost as a result of poor roads, the fertilizer prices have become prohibitively high driving many farmers out of fertilizer use. The same applies to the use of hybrid seeds as well as other farm chemicals leading to reduced farm productivity.

Kenya's land tenure system has contributed immensely towards the agricultural productivity. Land titling, which has been effectively implemented since her independence in 1963, vests the right of the land ownership to the title owner. The tenure system traces its implementation directives from the Swynnerton Plan of 1954 (Ochieng' & Maxon, 1992). This property right have given the farmers the trust to invest in their farms without fear of being evicted as has been the case in Uganda (Mwesigye, 2014). The land titles have been historically used in Kenya as a collateral to secure bank loans especially in the early 1980s to purchase farm produce through the KFA. However, in most areas, the farmers defaulted on the loans; thus, the titles were retained by the banks.

Livestock forms part and parcel of household assets in many African countries. In this case, it provides regular income and acts as a safety net in times of food shortages or money liquidity problems. The most common livestock reared by the smallholders

farmers include cattle, goats, sheep and poultry. During the colonial period, the Europeans imported foreign breeds which were more productive and high yielding compared to the native breeds. In the areas that were occupied by the settlers, when independence came, Africans in their neighbourhoods had learnt about the high yielding livestock breeds. Most of the beneficiaries were from Central and Rift Valley regions. Today local and foreign cattle breeds have been adopted widely in the region to boost productivity.

To further improve the productivity of the animals especially cows, farmers have adopted modern ways of animal keeping in that they put the animals in stalls, a farming technique referred to as zero grazing. The zero grazing has led to an organic Green Revolution in Kenya, whereby farmers use manure from the stalls to fertilize the crops including animal feeds like napier grass and oats (Otsuka & Yamano, 2005). The nutrients from the manure makes the soil fertile by releasing small amounts of nutrients to the soil over a long period of time. The texture of the soil is improved because of the fiber content of the manure. In areas where land has become very scarce, zero grazing has been embraced widely. Many farmers plant vegetables, beans, potatoes, onions and many other cash crops in their small plots of land thus supplementing to a greater proportion the daily consumption of these items in the household which otherwise would have been purchased from the markets. This has let to improved incomes in the households.

3.2.1 Study site

The area covered by RePEAT survey stretches from the eastern to the western part of Kenya as shown in Figure 2. Except for the eastern part, these areas are agriculturally productive and have been referred to as the bread basket of the country. Beginning

in 1998, International Livestock Research Institute (ILRI) and its collaborators initiated interviews with 1,390 households in these regions covering eight districts, with a wide range of farm productivity potential and market access. Later in 2000, they expanded their research to include 1,576 households randomly selected from seven districts in western Kenya who were actively engaged in dairy farming (Waithaka et al., 2002). The first wave of the RePEAT survey was conducted in 2004 when a random sample of 1,000 households were selected from 2,966 households from 100 sub-locations the ILRI had mapped out in 1998 and 2001. 10 households were randomly selected from each of the 100 sub-locations ILRI had interviewed. Of the 1,000 household intended for interview, the first survey managed to locate 934 households and successfully interviewed 894 (Yamano et al., 2005). In 2012 survey, 871 households were interviewed of which 82 households were replaced for various reasons.

3.3 Literature review

The importance of infrastructure improvement in alleviating poverty is widely acknowledged and is well documented in the literature. However, it has concentrated in Asia and Latin America and very few studies have been conducted in Africa. In this section, we review some of the studies evaluating the impact of road infrastructure improvement.

3.3.1 Road access improvement and farm productivity

Agricultural productivity has been the key contributor to economic development in many developing nations, especially those countries in East Asia. Their success has mainly come from expanded use of farm inputs as well as adoption of new technologies. This has been facilitated by good road infrastructure that enables farmers to access farm inputs as well as market their farm produce in time. Critical

farm inputs like inorganic fertilizer and hybrid seeds use in Asia has almost reached optimal levels, but in SSA the usage is very low. This has led to diminishing agricultural productivity (Otsuka & Yamano, 2005, Pender et al., 2004). This is as a result of poor road infrastructure that has disrupted market networks leading to raised farm input prices making them unaffordable, low output prices making farming unprofitable as well as deterring other development infrastructure like the financial institutions that could provide credit to farmers (Christen & Pearce, 2005, Duflo et al., 2011, Matsumoto & Yamano, 2009, Morris et al., 2007). However, previous studies in Asis have found positive impact of road infrastructure improvement agricultural productivity and fertilizer adoption (Binswanger-Mkhize et al., 1993, Fan & Zhang, 2004, Gollin & Rogerson, 2014). These studies have found that improving road infrastructure and financial institutions leads to improved agricultural productivity with elasticity of over 0.2. Increased fertilizer consumption and agricultural output growth has also been associated with road improvement, with roads contributing 7 percent directly to the growth. Furthermore, non-farm productivity has also increased when roads infrastructure is improved, and the effect is larger in the rural areas (Fan & Zhang, 2004, Yamauchi et al., 2011).

However, most of these studies uses cross-sectional data in their analysis, combined with methodologies that are always critique as likely to produce biased results, because of endogeneity of road placement.

3.3.2 Road access improvement and income and expenditure

The ultimate goal of road infrastructure improvement is to alleviate poverty by either directly or indirectly, increasing household income and expenditures. Good infrastructure enables proper market integration, thus providing a number of

opportunities for people to engage in farm and non-income generating activities. Studies have found positive impact of the road infrastructure improvement on income through increased wages and rural non-farm income (Escobal & Ponce, 2003, Khandker & Koolwal, 2011). Trade has also been found to increase when roads are improved to motorable standards, and more so in rural SSA (Buys et al., 2010, Mu & van de Walle, 2011). Good roads infrastructure helps to reduce price divergence across markets hence making products available at competitive prices. This leads to higher levels of household consumption and per capita expenditure on food and non-food items, as a result of availability of variety of commodities in the market at fair prices (J. Gibson & Rozelle, 2003, Khandker & Koolwal, 2011).

On overall, roads have been documented to contribute largely towards poverty reduction (Warr, 2010)

3.3.3 Determinants of road access improvement

Road construction and rehabilitation requires many resource, and is often contracted out for implementation. If the process of resource allocation for road construction is not properly managed, it may be misused by politicians and influential government officials. The result will be skewed improvement of roads. Although not much literature is available on this topic, we start by reviewing other infrastructure of the same kind with varied outcomes.

Studies have summarized cases of corruption in public investments and find that it reduces growth by increasing public investments, and can further deteriorate the quality of existing infrastructure, lowering output and growth Tanzi & Davoodi (1998). In Uganda for example, between 1991-1995, 20 percent of GDP was allocated for primary education support, but only 13 percent of the funds reach the targeted

schools, and actually most of the schools did not receive the funds. The funds were captured by corrupt government officials and political elites (Reinikka & Svensson, 2004). In Kenya, the public have lost huge sum of money through dubious deals in the name of the Anglo-Leasing and the Goldenberg scandals (Bachelard, 2010, Bandiera et al., 2008, IMF, 2009, 2009).

Corruption in governments has been found to be deep rooted and the political elites are the main beneficiaries. This claim has been supported by a number of studies evaluating public funded projects. For example, Banerjee & Somanathan (2007) examine how rural public goods are funded by central government in India and finds that those who occupy higher positions in social hierarchy benefited more, although with diminishing returns over the disadvantaged groups. Studies have also found that in rural China, the allocation of fiscal resources between public goods and other expenditures rises when village leaders are elected directly by the people (Luo et al., 2010).

In a recent study in Kenya, of which this chapter relates to, the authors finds that during one party regime there was disproportionate investment in roads in Kenya. Using district-level expenditure data on roads from 1963-2011 together with historical ethnicity data on a fixed effect model, they show that in the district of president, roads expenditure was doubled resulting in very high per capita kilometers road density, relative to other areas (Burgess et al., 2013).

Corruption is not confined to politicians only. Nepotism by officials in non-democratic regimes have been found to favor their home communities when allocating public funds (Nguyen et al., 2011). In fact, studies have found no evidences of linking legislators to nepotism (Nguyen et al., 2011) or any political influence on allocating funds for the

targeting of the programs (Bardhan & Mookherjee, 2006).

Therefore, the importance of road access improvement in economic development of a country has been demonstrated, and more so if there is no skewed resource allocation by politicians or government officials. Thus, investment in road rehabilitation to initiate poverty reduction is studied in this thesis.

3.4 Conclusion

From the literature review above, it is evident that the importance of road infrastructure improvement, especially in the rural areas, cannot be denied. Most of the reviewed studies find positive impacts on productivity and poverty alleviation. Also, the implementation of such infrastructure are prone to political manipulation. These studies have largely concentrated in Asia or Latin America because of data availability, although they use cross-sectional data for analysis which are prone to biases as a result of the endogenous placement of roads.

In conclusion this dissertation seeks to add to the thin literature of road infrastructure improvement in Africa by expanding the already rich literature in Asia and Latin America on the benefits of road infrastructure improvement on farm productivity, market participation and poverty alleviation among the smallholder farmers in SSA. As has been outlined in Section 3.3, the evaluation of road infrastructure, and other public investments of this nature, is complex as these projects are expansive and often implemented where there is high population, and almost always have some political influences.

In this thesis, we seek to determine the importance of road access improvement in Kenya using panel data to mitigate the problem of endogeneity. The panel data are useful in that when the fixed effect (FE) model is used, the fixed characteristics that

might have influenced road placements will be differenced out, and the factors that remain are assumed to be random and have no correlation with the error term. We first seek to establish if smallholder farmers are responsive to road access improvement by expanding the use of hybrid seeds, intensification of fertilizer usage and market participation because many authors have asserted that the low productivity of farms in SSA is the result of expensive farm inputs or the unavailability of the same due to poor road conditions (Matsumoto & Yamano, 2009).

Secondly, we investigate if the road access improvement translates to better income and increased expenditures of smallholder farmers. Opening up rural areas results in better market integration, resulting in more opportunities to increase and diversify income sources. Moreover, the market integration makes goods available, hence driving the prices down and enabling consumers to have variety of choices.

Lastly, we analyse the factors that influence road access improvement. Many studies have concluded that such public projects are prone to political influence, and as a result, not always implemented in the right places (Addison & Anand, 2012, Bardhan & Mookherjee, 2006, Nguyen et al., 2011). In Kenya, the issue of corruption has been in the public domain especially in the public sector (Thuo, 2011, Transparency International, 2013, World Bank, 2009). Therefore we seek to establish if during periods of democracy, corruption could still play part in the allocation of public resources.

Chapter 4

ROADS AND FARMING: THE EFFECT OF INFRASTRUCTURE IMPROVEMENT ON AGRICULTURAL INTENSIFICATION.

4.1 Introduction

Alleviating poverty through road access improvement has been one of the goals in many developing nations' agendas. Road are thought to be the catalyzer in the process of economic development (Rostow, 1962) and are a particular important factor in the growth of rural areas (de Vera Garcia, 1984). In the recent past, there have been huge investments into the improvement of road in developing nations by major donors, yet very few studies have been carried out to ascertain the impact[1].

The improvement of road in developing nations, especially rural road, has received growing funding and evaluation interest (Estache, 2010). The World Bank (World Bank, 2007) and other donor communities have labeled the improvement of road as an instrument of poverty alleviation in developing nations. As Sub-Saharan African (SSA) nations depend on agriculture as the backbone of their economy, the improvement of road will have far reaching effects on agricultural productivity (Gollin & Rogerson, 2014). The African Development Bank (ADB) estimates that only 34% of rural Africa (where 80% of the citizens dwell) can access road compared to 90% in the rest of the world (African Development Bank, 2010). In SSA, the total road network is estimated at 204 km per 1,000 km^2 of land area, of which only about 25% is paved, compared to the world average of 944 km per 1000 km^2 of land (African Development Bank,

[1]In Africa, the African Development Bank (ADB) invested more than USD 1 billion in 2007 alone. The World Bank approved more than USD 9 billion in 2010 towards infrastructure development. In Kenya, about 20 percent of GDP ($4 billion) is dedicated for infrastructure development (Briceño-Garmendia & Shkaratan, 2011)

2010)[2]. The majority of road networks is poorly developed or in a dilapidated state. Studies have also shown stagnated investment in agricultural sector (Morris et al., 2007, Otsuka & Yamano, 2005, Pender et al., 2004) and coupled with poor access to markets, these nations are prone to extreme poverty.

As outlined in Chapter 3, the most of the literature on the impacts of road access improvement have concentrated in Asia and Latin America and have shown positive impacts on a number of outcomes: a reduction in poverty levels (J. Gibson & Rozelle, 2003, Jalan & Ravallion, 1998, van de Walle & Mu, 2011), alteration of land use (Jacoby, 2000), increased household income and consumption (Escobal & Ponce, 2003, Jalan & Ravallion, 2002, Khandker et al., 2006), investments in health and education (Lokshin & Yemtsov, 2003, Stifel & Minten, 2008); crop intensification and other production decisions (Khandker et al., 2006, van de Walle, 2009), migration (Fafchamps & Shilpi, 2009), a reduction in transport costs (Jacoby & Minten, 2009) and promotion of market activity (Mu & van de Walle, 2011). Other related literature reporting benefits from transport infrastructure improvement include firm expansion and gross domestic product (GDP) growth in China (Banerjee et al., 2012) and growth in interregional and international trade in India (Donaldson, 2010) and an increase in trucking and retail sales in USA (Michaels, 2008). In Africa, this line of literature is thin. However, there are a few studies that have attempted to evaluate the impacts of road access improvement. Dercon et al. (2007) assess improved road accessibility on access to agricultural extension in Ethiopia and find that poverty reduced by seven percentage points with the improvement of road. Dorosh et al. (2012) using a cross-country regression in SSA found a substantial increase in agricultural production. Kingombe & di Falco (2012) on the impacts of change in road access on farm

[2]United Nations (United Nations, 2008) categorises SSA countries as least developed

productivity and crop choices in rural Zambia found inconclusive results. Shiferaw et al. (2013) found a positive impact on the manufacturing sector in Ethiopia. Gachassin (2013) found migration to have decreased in Tanzania as a result of improved road.

Estimating the impact of infrastructure improvement in SSA, especially road, is a challenging task due to data limitations (often incomplete or unreliable sources) and methodological constraints. Furthermore, road are constructed in densely populated areas and the fact that people do not randomly select where to settle may bias evaluation results due to endogenous road placement (construction)[3]. Using methodologies such as the instrumental variables (IV) approach or propensity score matching (PSM) to assess the impacts of road improvement may yield unreliable results because observable characteristics may be influenced by the effects of the road placement (van de Walle, 2009). Furthermore, techniques approximating random trials are unsuitable and almost impossible to implement[4]. The use of panel data can mitigate these problems, but collecting large panel data is an expensive undertaking and the timeframe for such evaluations may be too short to capture the long-term benefits of intervention (Mu & van de Walle, 2011). Thus, correct modeling is required for precise outcomes[5].

In this chapter, we estimate the impact of improving road accessibility from 2004 to 2012 on the change in technology adoption, fertilizer intensification, maize productivity and market participation by smallholder farmers in Kenya[6]. In particular,

[3] Jalan & Ravallion (1998) have cited endogeneity bias where the targeted poor areas typically lack infrastructure and other initial endowments, which could bias the results.

[4] And if resource allocation is politically motivated (Burgess et al., 2013), then if it becomes known that the government is randomizing on road projects, then incumbent politicians may face a backlash from their electorate, who expect their elected leaders to amass resources for them. Hence, randomizing interventions like road access improvements is almost impossible.

[5] Ravallion (1999) noted that returns to infrastructure may seem enormous but when *simultaneity bias* and *spurious correlation* have been econometrically controlled for, the returns are much reduced.

[6] By smallholder, we refer to an individual who manages a family farm holding with one or several small dispersed parcels of land or farms (approximately 20 acres in total) Collier & Dercon (2009) notes that poverty is concentrated in rural areas among smallholders, hence any policies targeting lower poverty levels must start with smallholders.

we focus on the impact of rural-road infrastructure improvement in 15 districts in Kenya[7]. We use geo-referenced panel data from Research on Poverty, Environment and Agricultural Technology (RePEAT), merged with road network data. This dataset is unique for the following reasons: First, because of the geo-referenced data, we are able to merge two very independent datasets collected almost at the same time to provide a balanced panel. Second, our new panel data enable us to use modern techniques such as fixed effect (FE), which makes it possible to control both the biases due to omitted variables as a result of the non-random placement of road as well as reverse causality. To the best of our knowledge, this is the first study to empirically document the impacts of road rehabilitation on technology adoption, agricultural input use, farm productivity, and market participation in Kenya.

Our results show increased land allocation to hybrid maize seeds, fertilizer intensification, increased manure application, increased yield of maize as well as enhanced market participation for both milk and maize in areas experiencing better road access.

The rest of the chapter is organized as follows: Section 4.2 presents our data description as well as our estimation strategy. Section 4.3 discusses our econometric estimates, result discussion and robustness check, while section 4.4 concludes.

4.2 Data and estimation framework

In this section, we briefly discuss our data as well as the estimation strategy.

4.2.1 Data

The data used in this study are obtained from two main sources: (a), the Research on Poverty, Environment, and Agricultural Technology (RePEAT) project and (b), the

[7]Rural-road : Small local road and tracks in rural areas that have low or no motorized traffic volumes linking villages (van de Walle, 2009)

Ministry of Roads (Kenya). We use the data from the 2004 and 2012 surveys to match with the road data. The 2012 RePEAT survey targeted 899 households to be surveyed, but 871 households were successfully traced. In this study, we made adjustments to the data as follows: first we dropped households that were replaced (82 households), no-contact (24 households), refused to be interviewed (7 households), head and spouse sick (4 households), no eligible member to respond (3 households) and missing and erotic data (22 households) in 2004 and 2012, resulting in an attrition rate of approximately 16% and is distributed as shown in Table 4.1[8]. Thus, a panel of 729 households remains to be used in the analysis. In addition to household data, community level data were also collected by means of focus groups. These groups comprised of village leaders headed by the chief or the sub-chief. [9].

4.2.2 Descriptive statistics

Table 4.1 shows the distribution of the sampled units used in this study. Summary statistics are presented in Table 4.2. Households are aging with the household size declining by 14% over the span of the survey. This is expected as children grow up and migrate to urban centres to look for jobs or participate in other income-generating activities while others get married and start new households. In Kenya, household members are the key source of farm labor, and the declining household size may negatively affect farm production, especially where farm labour supply is scarce and farm mechanization is unaffordable. A second notable point is the seven percent increase in households headed by females. Female-headed households living in the rural areas are vulnerable to many vagaries (Chapoto et al., 2011, Dercon & Krishnan, 2000, Duflo & Udry, 2003), and hence this variable may affect negatively our

[8]We investigate whether there is any systematic attrition in our data. The F-ratio test indicates no evidence of systematic attrition.

[9]Sub-chiefs are the representative of the central government, responsible for the lowest form of the central government, the sub-location. The chief represent the government at location level (herein referred to as community).

explained variables.

[INSERT TABLE 4.1 ABOUT HERE]

The survey results reported numerous brands of inorganic fertilizer in the market in 2012 compared to 2004 partly due to fertilizer market liberalization (Freeman & Kaguongo, 2003) and partly due to a modified survey questionnaire. Therefore, in order to compare smallholder farmers using different types of fertilizer, we converted the fertilizers into primary nutrients measured in terms of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O_5) contained per kilogram of fertilizer (hereafter, NPK). In Table 4.2, although the percentage of households planting maize and using inorganic fertilizer did increase overall, the increase was much more pronounced in areas nearer to capital city as shown in Figure 5. The amount of organic fertilizer usage has also increased, but with a higher degree of usage variation. This increase has been experienced in areas further from the capital city, although the intensification of organic fertilizer is still highest nearer to the capital city, where adoption of dairy farming (zero grazing) is higher as noted by Otsuka & Yamano (2005). Framers nearer to the capital city did not increased organic intensification as shown in Figure 5, plausibly because they had already reached application threshold, although in the same areas, improvement of roads to a nearby market was small.

[INSERT TABLE 4.2 ABOUT HERE]

Land set aside for planting hybrid maize increased by 17% on average over the study period and the increase was larger in areas nearer to the capital city as shown in Figure 5. This increase can be attributed to scarcity of land as a result of higher population density therefore farmers are using high yielding maize seeds to increase maize production. As for the maize yield, there is a 14% increase and the increase is largely felt nearer to the

capital city. There seems to be a positive correlation between the use of land for planting hybrid maize seeds and organic fertilizer and the maize yield, but the relationship may not be causal (Figure 5).

Travel time by vehicle to a nearby active market improved by 30%, with large improvement experienced further away from the capital city. For the improvement of roads to nearby big town, travel time to a nearby big town improved by 18%. This is as a result of road infrastructure improvement initiated by the government after the implementation of the Roads Act of 2007.

As for market participation, the proportion of milk marketed increased by three percent while the ratio of maize sold to harvest did not change significantly. The increase in sales was largely experienced nearer to the capital city

Regarding mobile phone network coverage, all communities in our study were covered by a mobile phone network in the year 2012, which was an improvement from 62% in 2004. This has led to an 81% jump in household mobile phone ownership.

Table 4.3 shows the pairwise correlations between the time distance variables and the farming variables. Column 1 shows the correlation between the log of centered time to a nearby market and various outcome variables, while column 2 shows the correlation between the log of centered time to the nearby big town and the same outcome variables. There is a negative correlation between log of centered time to nearby market and land for planting hybrid maize and this correlation is even stronger for time to nearby big town. Furthermore, a strong correlation between log of centered time and inorganic fertilizer application, but this relation is reversed for the travel time to the nearby big town. Similarly, there is a strong negative correlation between the log of centered time to a nearby big town and inorganic manure application, maize yield and milk marketing.

On the other hand, there is no evidence of a correlation between the log of centered time to a nearby active market and organic fertilizer application.

4.2.3 Conceptual framework and empirical strategy

Smallholder farmers' willingness to adopt productivity-enhancing technology is based on the state of infrastructure and market conditions with which they are faced. Thus, by improving rural connectivity through the rehabilitation of roads, it is expected that the propensity of smallholder farmers to adopt productivity-enhancing technology and the intensification of fertilizer are bound to increase. This effect is assumed to be realized through lower transportation costs of goods and services that raise smallholder farmers' net output prices as well as lower production cost due to cheaper and more accessible farm inputs such as fertilizers, seeds and pesticides. Therefore, we hypothesize that:

Hypothesis 1. *Improving road access increases the propensity to increase land share for hybrid maize, intensification of fertilizer use and farm productivity in smallholder households living in remote areas before road access improvement because it is profitable now.*

The second hypothesis that we wish to test is that by improving roads, smallholder farmers naturally take advantage of market accessibility to market their farm produce. They will either sell their produce in the market or at the farm gate. For perishable farm produce like vegetables, fruits and milk, market accessibility is the key to fetching high prices because the commodities are in demand while still fresh. In this hypothesis, the underlying idea is that, with improved road networks, many smallholder farmers would engage in the production of fresh farm produce like milk. Although we expect road improvement not to influence market participation for non-perishable produce, we argue that the improvement of roads to a nearby big town may stimulate market activity,

especially for dry cereals, because markets not reached hitherto may now be accessible. Therefore, we hypothesize that:

Hypothesis 2. *Smallholder farmers living in remote areas before road improvement are more likely to engage in the selling of perishable farm produce when market accessibility is improved because they can now access a broad market base faster, hence fetching higher income from fresh produce sales in the intergraded markets.*

The descriptive statistics suggests a positive impact of change in road access on the number of household outcomes, identifying factors that affect each of the outcome and assessing their importance requires econometric analysis. The goal is to examine the impact of change in road access on various farm outcomes. We utilize the new panel data and take advantage of the improvement of roads to obtain unbiased estimates of our model.

We employ a simple Fixed Effect (FE) model to identify the impact of improving roads infrastructure on a number of household outcomes. Our base model is:

$$Y_{ijt} = \beta_0 + \beta_{RM}.RM_{ijt} + \beta_{RT}RT_{jt} + \beta_{interact}.(RM_{ijt} \times RT_{jt}) + \beta_H.H_{ijt} + \beta_C.C_{jt} + (\beta_{agrozone} \times t) + \zeta_i + \varepsilon_{ijt}, \quad (4.1)$$

where i indexes households, j indexes communities and t indexes year of survey. Y_{ijt} denotes the variable of interest; the proportion of land allocated for hybrid maize, fertilizer intensity, farm productivity or market participation of the ith household living in the jth community at time t. H_{ijt} is a vector of household specific regressors namely: age of the household head and its squared term, log of household size, a gender dummy equal to 1 if the household head is female, the number of years of education of the household head and its squared term, household land size and its squared term and the log of per capita asset value, number of men, women and girls in

the household and whether the household subscribes to a community self-help group[10]. C_{jt} controls for observable community level characteristics which include the log of population density. RM_{ijt} is the log of centered time distance in minutes to the nearby market from a household, while RT_{jt} is the log of the centered time distance in minutes from community reference point to the nearby big town[11]. $RM_{ijt} \times RT_{jt}$ is the interaction term between the time to the nearest market and the time to the nearest big town. This term will capture the additive (synergistic) effect of improving both types of roads. The synergy is important to analyze as it shows (if any) the extra benefit from improving roads to nearby big towns, for an averaged improved road to nearby big market. ζ_i is the unobserved household fixed effects. ε_{ijt} is the household idiosyncratic errors. $(\delta_{agrozone} \times t)$ dummies were also included to control for agrozone specific time effects such as temperatures which affect agricultural productivity as most farms are under natural environment[12]. We also included a dummy variable to control for season when they are in regression analysis. We use the heteroskedastic robust standard errors clustered at the community level. β_{RM}, β_{RT} and $\beta_{interact}$ are our coefficients of interest.

To analyze the factors influencing smallholder farmers to participate in the marketing of farm produce, we use a modified version of Equation (4.1). First, we use as the dependent variable, y_{ijt}, a dummy variable for market participation if a household sold part of the product (in this chapter either milk or dry maize). We use the linear probability model (LPM) with the household FE model and the controls as in Equation (4.1).

[10]We define assets as the value of all physical assets reported by the household namely tools, equipment, and machines excluding financial assets such as savings and livestock. We treat livestock investment in this paper as a form of savings.

[11]Measurement of time distances is discussed in Section 4.2. A big town here refers to market centers with a population over 100,000.

[12]The agro-zones are (1). High Potential Maize (2). Western Highlands (3). Central Highlands (4). Eastern Lowlands

Although our explained variable is a binary, we prefer the LPM technique in the analysis because we do not need to make any arbitrary assumptions like in logit, which entails the interpretation of marginal effects which are often difficult to infer.

4.3 Econometric Results

In this section we present the estimates of our FE regression with controls. First, we estimate Equation (4.1) and present the results in Tables 4.4 to 4.7. Then we estimate for market participation and present the results in Tables 4.8 to 4.11.

4.3.1 Effect on hybrid maize land expansion

Equation (4.1) is used to estimate the determinants inducing smallholder farmers to allocate more land to hybrid maize. Our variables of interest are the log of centered time distance to a nearby market and the log of centered time distance to the nearest big city; these variables captures the influence of the market through prices as well as inputs accessibility. Both of these variables are expected to influence adoption propensity positively. Therefore, we expect a negative coefficient because of the reduction in travel times. In order to analyze impact of roads improvement in terms of the remoteness of the location of smallholder farmers, we classify our data into 4 quartiles using the 2004 physical distance to Nairobi (the capital city of Kenya) namely from 0-84 km, 85-165 km, 166-305 km and over 306 km.

Table 4.4 presents the results of the impact of the change in road access on the propensity to allocate more land to hybrid maize. All the specifications control for observable household and village characteristics, as well as unobservable (fixed) household effects.

[INSERT TABLE 4.4 ABOUT HERE]

Column 1 of Table 4.4 presents the results excluding the time distance to a nearby

big town. The sign of the coefficient is as expected and significant. Similarly, column 2 presents the results excluding the time distance to a nearby market. The coefficient is of the expected sign although not significant. When we interact both time distances in column 3, the coefficient of the time distance to a nearby big market reduces, and becomes insignificant but the coefficients for the time distances to a nearby big market and the interaction term becomes significant. The significant results of the interaction term signifies a synergistic effect of the two roads types improvement. This effect is stronger for the improvement of roads to big town, perhaps signifying the availability of improved seeds, which are normally produced in big towns.

Columns 4-7 present the results of our sub-samples. Within 84 km from Nairobi, the coefficient of time to a nearby market remain significant but increased in magnitude. None of our time distance variables in significant in column 5

A clear pattern emerges in Table 4.4. The coefficient of the time to a big town remains significant within 166-305 km from Nairobi. Similarly, the interaction term is positive and significant in column 6. This suggests a synergistic effect between the improvement of roads to nearby markets and to big towns: in remote areas where roads to nearby markets were improved, the allocation of land for planting hybrid maize was higher in areas experiencing improvement in the roads to nearby big towns. There seems to be no effect of particular change in road access in the regions over 166 km from Nairobi.

A significant elasticity of -0.24 in column 3 implies that a 1% improvement in roads to the nearby big town will induce smallholder farmers to allocate more land to hybrid maize by almost 0.3% , for an averaged improved road to a nearby market. Although the magnitude appears small, this is quite substantial in the sense that in Kenya, the planting of hybrid maize is not a new technology (Matsumoto & Yamano, 2009).

On average, female headed households are more likely to increase land for hybrid maize. On further analysis, these female households are found to be less endowed with land, lower education but are more likely to participate in Rotating Savings and Credit Associations (ROSCAS). Because of the scarcity land means they need to plant hybrid maize for higher production. Being a member of a ROSCAS also helps them in securing credit to purchase the hybrid maize seeds, besides being avenues of information sharing especially on farm technologies.

4.3.2 Effect on intensification of inorganic fertilizer (NPK equivalent)

In this section, we estimate the impacts of changes in road access on the intensity of fertilizer application using the same set of controls as in Equation (4.1)[13]. The dependent variable is the logarithm of NPK equivalent (kg/ha) of fertilizer used in planting maize. We expect fertilizer intensification on maize fields to increase because access to input markets is improved. We measure the intensification rates by the amount of NPK equivalent fertilizer applied to one hectare of maize field (kg/ha). The results are presented in Table 4.5.

[INSERT TABLE 4.5 ABOUT HERE]

Columns 1 to 3 of Table 4.5 show insignificant coefficients of the log of centered travel time to a nearby market and the log centered travel time to big towns respectively. At first, it may depict that there was no impact of road access improvement on fertilizer intensification. But when we restrict our analysis to sub-samples, two results emerges. In column 4, coefficient of time distance to nearby market is positive and significant suggesting a negative impact of road improvement on fertilizer usage. First, we note that within 84 km from the city, there was minimal improvement of roads, and in the areas

[13]The household decision to expand land on hybrid maize is independent of fertilizer usage, but fertilizer usage is conditional on the use of hybrid seeds because of their high responsiveness to fertilizer application Otsuka & Yamano (2005).

that received less improvement, there was an increase in fertilizers usage. Secondly, in these areas, farmers practice zero grazing to capitalize on milk marketing as well as other cash crop because of the ready markets in the city. Thus we suspect that the farmers may be substituting inorganic fertilizers for organic produced in their farmers. Although column 6 and column 7 shows negative coefficients of road infrastructure improvement to a nearby active market implying that the road improvement had positive impact of fertilizer intensification far way from the capital city, they are not significant.

Matsumoto & Yamano (2009), in their study on factors behind the low application rates of external fertilizers in Kenya and Uganda, found that Kenyan smallholder farmers have achieved the optimal nitrogen application level. To further increase the application rates, they suggested a market-based approach that influences fertilizer prices (price reduction) as well as the maize output price (price increase).

4.3.3 Effects on the intensification of organic fertilizer

The summary statistics of RePEAT survey revealed that many smallholder farmers living near big towns practise mixed farming, both keeping livestock and planting crops. Some have adopted zero grazing and as a result, they are able to collect large amounts of manure which they use to fertilize their farms. Because it releases nutrients to the soil slowly, the use of manure improves the organic matter in the soil, which has long-term benefits when used in farms.

To investigate the factors leading to the intensification of manure and to check if there was any substitution between inorganic fertilizer and organic manure use, we regressed the log of manure intensification (kg/ha) on the same set of regressors as in the previous section. The results are presented in Table 4.6.

[INSERT TABLE 4.6 ABOUT HERE]

Columns 1 and 2 of Table 4.6 show negative and significant coefficients of the log of centered travel time to a nearby market and the log centered travel time to big towns respectively. When we interact the two time distances, both the coefficients of the travel time to the nearby market and town reduce in magnitude and the coefficient for travel time to big town looses significance. The interaction term is not significant suggesting the non-synergistic effect of road access improvement. When we restrict our analysis to the sub-sample, column 4 and 5 shows a significant effect of road access improvement to a nearby market for those farmers living within 165 km from the capital city. This result is consistent with our earlier assertion that those farmers living within short a distance to the capital are practising zero grazing. Most of the impact of road access improvement on organic fertilizer intensification is felt between 85-165 km from the capital city. With distance greater than 165 km from the capital city, road improvement to nearby big town does not influence the use of organic fertilizer. This is due to the fact that per-capita land ownership in these areas is still sufficient; hence, farmers practice the free range system of animal husbandry where collection of animal excreta is cumbersome.

4.3.4 Effects on farm maize productivity

In this section, we estimate the determinants of maize productivity[14]. In Kenya, maize is the staple food crop and is cultivated by almost all homesteads. The majority of these households grow maize for subsistence.

To investigate the impact of the change in road access on maize yield, we again regress the log of yield of maize (kg/ha) on the same set of regressors as in Table 4.4. Table 4.7 presents the results of the regression.

[INSERT TABLE 4.7 ABOUT HERE]

[14]Maize is produced in favorable environments where production is expected to be profitable (specifically revenue must be greater than production costs). Mathematically crop production is given as $y^*_{ijt} = \beta' X_{ijt} + \varepsilon_{ijt}$. We observe maize yield in household $i(y_{ijt} = y^*_{ijt}\ if\ y^*_{ijt} > 0)$ only when it is profitable, otherwise zero production is observed $(y_{ijt} = 0\ if\ y^*_{ijt} < 0)$.

The coefficients of the full model in column 3 is significant at 10% percent for the time distance to the big town. This implies that the improvement of roads to the nearby big town is important for maize yield, though indirectly. The effect may be through price reduction of farm inputs like fertilizer as well as their availability. When we restrict our analysis to the sub-samples, there is no evidence that road improvement impacts positively on maize productivity up to 84 km from Nairobi. In Subsection 4.3.2, we found that farmers within 84 Km from the capital city did not increase inorganic fertilizer application but instead used compost manure for maize production. As is known, hybrid maize responds well to inorganic fertilizer application, and although farmers within 84 km from the capital city on average increased land for planting hybrid maize, the use of organic fertilizer could be contributing to the reduced maize productivity. Between 166 and 305 km from the capital city, there is evidence that improving roads to a nearby big town improves maize productivity in remote areas (columns 6). This shows that the far flanked areas can now supply their maize to markets away from their traditional markets within their locality.

4.3.5 Effect on market participation

In this section, we analyze the impact of road improvement on market participation for milk (which is perishable) and maize (non-perishable). We choose to analyze these two farm outputs because over 90% of the surveyed households are engaged in producing milk and maize. Our conjecture was that the estimated coefficients of travel time would be larger for milk than for dry maize. Furthermore, we expected that the impacts of the change in road access would be more pronounced in remote areas. First, we estimated the factors affecting participation in the milk market and the ratio of sales to production for milk, after which we used the same estimation strategy for dry maize.

Table 4.2 shows about a 43% increment in the amount of milk sold per month by milk producing households while the proportion of milk sold increased by about 8% during the same period. We also examined the effect of improving roads on the share of milk produced that was actually marketed[15]. Equation (4.1) is used to analyze the impact of change in road access on market participation for both milk and maize.

Table 4.8 present the determinants of selling fresh milk in the milk market. Although the coefficient of the time to the nearby market is of the right sign in column 1, it is not significant. However, the coefficient of the time to a the big town is significant even when interacted with the time to a nearby market. Although we argued in Subsection 4.3.3 that smallholder farmers living near Nairobi practice zero grazing, column 4 of Table 4.8 shows no evidence of improved milk market participation [16]. This is as a results of better roads conditions near Nairobi in 2004, thus the small change in road condition did not excite farmers to expand their milk sales. Its worth pointing out that most of the milk processing plants are in the region near Nairobi and farmers may have exhausted their milk production capabilities. As for the roads improvement to nearby big town, impact is experienced in the regions between 166 to 305 km from Nairobi. The significant coefficients in column 6 implies that improvement of roads to nearby big towns enables milk produced from remote areas be transported to external markets not accessed before. Furthermore, households that are wealthier and have higher number of members are more likely to participate in milk marketing. This is true in the sense that milk processing is labour and capital intensive.

[INSERT TABLE 4.8 ABOUT HERE]

[15] Average proportion of liters of milk sold over the milk produced per month.

[16] The channels of milk marketing included the private ventures (hawkers who increased by 9%, private coolers increased by 8%, and other private other co-operatives increased by 5%) and Kenya Co-operative Creameries (KCC) which increased by 5%. Hawkers traverse vast areas, moving from household to household looking for potential milk sellers. The improvement of infrastructure is of great benefit to them.

Table 4.9 presents the determinants of the proportion of milk actually sold. Column 1 show a significant coefficient of time distance to a nearby market indicating road improvement impact. Columns 2 and 3 of Table 4.9 show significant coefficient for road improvement to a nearby big town, but the coefficient of time distance to nearby big market lost significance. The improvement of road to the nearby big town increases the proportion of milk marketed. When we restrict our analysis to the sub-samples, column 6 show a significant coefficient for the roads to the nearby big town implying that a one percentage improvement of roads to the nearby big town increases the proportion of milk sold by 0.7% given an averaged improved road to the nearby market. The full model in column 3 shows that households endowed with large wealth and higher number of family members are more likely to increase the proportion of milk being marketed. However, the sales decreases with increase in male adults in the households.

[INSERT TABLE 4.9 ABOUT HERE]

Next, we present the results of participating in selling maize in Table 4.10. Except for column 4 and 5, the coefficient of road to the nearby big market is consistently positive and significant. This implies that the improvement of roads to the big town led to fewer people participating in the maize market. This is contrary to our expectation that the improvement of roads would nudge farmers to participate in the maize market. One explanation for this result is that either surplus maize in the markets caused selling prices to plunge to very low levels, making it unprofitable to sell maize and instead farmers decided to hoard maize. The other plausible explanation is that the smallholder farmers are autarkic; they grow maize for subsistence. The other aspect, although we could not verify, is that farmers could be substituting selling maize by selling cash crops

that fetch higher prices in the market. The sales of maize increases with education of the household head as well as land endowment.

[INSERT TABLE 4.10 ABOUT HERE]

Table 4.11 presents the impact of road improvement on the proportion of actual maize marketed. Columns 2-4 show positive and significant coefficients. This shows that the improvement of roads did not improve the amount of maize marketed. The results of Table 4.11 shows that households that produces more also sales more, as depicted by the results in Table 4.10

[INSERT TABLE 4.11 ABOUT HERE]

4.3.6 Robustness check

In this section, we investigate the robustness of our results. Because we have many zeros in our data, running a fixed effect model may bias our results. Thus, we run the tobit fixed effect model as suggested by Honoré (1992). The results are presented in Table 4.12

[INSERT TABLE 4.12 ABOUT HERE]

From Table 4.12, the results are similar to the ones we presented in Subsections 4.3.3 to 4.3.5, with some coefficients slightly becoming significant. This is because the tobit model takes into account both true zeros and generated zeros while estimating the coefficients of the regression

Next, we interacted the mobile phone network coverage together with our variables of interest. Our conjecture is that both the improvement of roads and the mobile phone network expansion are synergistic, thus providing a better platform for

technology adoption, fertilizer intensification as well as market participation to thrive. We use a modified version of Equation (4.1) as shown in Equation (4.2) below

$$S_{ijt} = \alpha_0 + \alpha_{RM}.RM_{ijt} + \alpha_{RT}.RT_{jt} + \alpha_{interact}.(RM_{ijt} \times RT_{jt}) + \alpha_{mobavai} + \alpha_{RMM}.RM_{ijt}.Mobavai + \alpha_{RTM}.RT_{jt}.Mobavai + \alpha_{interactM}.(RM_{ijt} \times RT_{jt}).Mobavai + \alpha_H.H_{ijt} + \alpha_C.C_{jt} + (\alpha_{agrozone} \times t) + \theta_i + \mu_{ijt} \tag{4.2}$$

where S_{ijt} is the outcome, $Mobavai$ is a dummy=1 if a community is covered by mobile phone network, and the rest of the regressors are as described in Equation (4.1). Table 4.13 presents the results of the regression.

[INSERT TABLE 4.13 ABOUT HERE]

The coefficient of the interacted term for the time distance to the nearby big town becomes remains significant for the proportion of land under hybrid maize. The increase in the significance by the interaction on the significant coefficients of Table 4.13 may be attributed to interdependence between road improvement and rolling out mobile network expansion. In Kenya, mobile network expansion first occurred in areas with good infrastructure. The coefficient of inorganic fertilizer intensification is insignificant for both road time distances but mobile phone dummy is significant. Coefficient of organic fertilizer intensification and maize productivity are also insignificant. The sign and significance of coefficient of time distance to nearby big town for proportion of maize sales and milk remain unchanged, thus, our results are robust to a different specification.

4.4 Conclusion and policy implications

Dilapidated road infrastructure has resulted in slow agricultural development in Africa because farm inputs become scarce are hence expensive and markets for farm produce become inaccessible. Coupled with poor climatic conditions, the agricultural yields are becoming poorer, further exacerbating the already widespread poverty conditions on the continent. Therefore, enhancing smallholder farmers' capability to expand farm productivity as well as market participation in rural Africa through road rehabilitation is considered an important undertaking towards alleviating poverty. Kenya has recently experienced an expansive road rehabilitation programme that has seen many dilapidated rural roads brought to maintainable standards. As far as farm inputs are concerned, the prices are expected to fall while those of farm outputs are expected to rise, thus giving smallholder farmers more income, especially in the remote areas.

Using longitudinal survey data on smallholder households in Kenya and corresponding GIS road maps, we have estimated the impact of the change in road access from 2004 to 2012 on the change of technology adoption, fertilizer intensification, maize productivity and market participation. Our results have provided empirical evidence on the impact of road improvement in Kenya. These results show that the use of maize hybrid seeds, manure use, yield of maize and milk market participation increase more in areas with better road access improvement. However, there was no evidence to support the hypothesis that the improvement of road infrastructure could lead to an increase in maize market participation or use of chemical fertilizers,. Overall, the results show that even though there was a widespread improvement of roads, the impact was experienced more in areas with poorer road access in the initial period. Therefore, the recent infrastructure investment

has contributed to productivity enhancement, especially in remote areas.

Overall, our study sheds light on the importance of improving infrastructure, especially in the remote areas, where the impact can have far reaching benefits. Because our study was based in rural areas, we postulate that the results presented here are lower bound. More exploration is needed to ascertain the importance of our results to enable us to generalize to other settings such as urban areas. These findings imply that road improvement is a key factor towards alleviating poverty in the country. It, therefore, will guide policy drafters in Kenya to channel more funds to this type of infrastructure to realize the full potential of exploiting resources in the rural areas, and especially in this period when Kenya's government system has change to a devolved type. more funds should be channeled to rural road infrastructure improvement. Alongside to increasing funding to rural roads improvement, policy makers should initiate farming sensitization programs through its wide network of field extension officers to sensitize farmers on how to diversify and capitalize on comparative crop advantage in order to avoid flooding the markets with the same crop. However, we are cautious in interpreting our results because in most of our regressions, the elasticities are very large.

Finally, there could me more benefits to the improvement of road infrastructure in rural areas, for example, in land use alteration and human capital investment. We, therefore, propose further research on the importance of improving road infrastructure other than agricultural intensification and market participation in Kenya.

Chapter 5

The Effect of Road Access Improvement on Smallholder Farmers' Income and Consumption in Rural Kenya.

5.1 Introduction

Having demonstrated in Chapter 4 that road access improvement has led to an increase in the adoption of farm technologies, maize yields and market participation, we investigate in this chapter if the results have translated to improvement in the livelihoods of smallholder farmers. We seek to evaluate if road access improvement has led to increased household income as well as consumption.

Improvement of rural roads is an essential process of economic development as it is an important foundation to the growth of rural areas (de Vera Garcia, 1984, Lipton & Ravallion, 1995, Qin & Zhang, 2012, Rostow, 1962). In Sub-Saharan Africa (SSA) where the majority of the people live in rural areas and are poor, the main occupation is subsistence farming which is poorly practiced. Thus, in order to alleviate the poverty levels in these areas, they need to be integrated to farm input and output markets so that the smallholder farmers can access inputs cheaply and in a timely manner as well as market their farm produce. Collier & Dercon (2009) note that poverty is concentrated in rural areas among smallholders, hence any policies targeting lower poverty levels must start with smallholders farmers. As discussed in Chapter 4, extensive resources have been channeled towards road access improvement in Africa, yet there are very few studies that have quantitatively evaluated the impact of roads access improvement on the welfare of smallholder farmers.

As has been outlined earlier in Chapter 4, road accessibility in SSA still remains a

mirage for many Sub-saharan Africaans (African Development Bank, 2010). Although there has been spirited funding towards roads access improvement in SSA, the majority of the road networks is poorly maintained or in a dilapidated state. Some authors have championed industrialization as the most probable solution to help Africa free herself from the yoke of poverty (Kairiza, 2012); however, the agricultural sector still commands a bigger share of developing nations' GDP (World Bank, 2014). This dominance demonstrates the need to invest in the expansion of the agricultural sector to widen the platform to foster economic growth in these regions. However, without proper market access and integration to enable farmers to access farm inputs and market their farm produce, achieving increased agricultural productivity may be a tall order. Therefore, good roads are essential for successful agricultural development.

A number of authors have documented some positive impacts of road infrastructure improvement on household welfare improvement. J. Gibson & Rozelle (2003), Jalan & Ravallion (1998) and van de Walle & Mu (2011) all the linked improvement of roads to a reduction in poverty levels, while Escobal & Ponce (2003), Jalan & Ravallion (2002) and Khandker et al. (2006) found increased household income and consumption. Banerjee et al. (2012) find growth in GDP in China due to railway construction, and Donaldson (2010) has associated expansion of rail-roads in India to the growth in interregional and international trade. From the trade perspective, Michaels (2008) and Donaldson (2010) found price convergence.

Most of the studies have concentrated on Asia and Latin America, but in Africa, although there has been huge investment on road infrastructure improvement, only a few studies have attempted to assess effects of road improvement including Dercon et al. (2007) and Dercon (2009) which study the impact of improved road accessibility on access to agricultural extension in Ethiopia. They find poverty reduced by seven

percentage points with the improvement of roads. Dorosh et al. (2012) using cross-country regression in SSA found a substantial increase in agricultural production.

Due to methodological constraints and data limitations, and despite renewed attention to infrastructure investment in the past decade World Bank (2007), it has been difficult to shed light on the extent of the benefits accruing from road improvement. As the roads are normally constructed in populated areas, the problem of endogeneity may bias the results. Moreover, the methodological constraints discussed in Chapter 4 make it difficult to make authentic evaluation. Because of our new panel data, we are able to mitigate these problems and obtain unbiased results of our estimation regressions.

In this chapter, we estimate the impact of improving rural-road accessibility from 2004 to 2012 on smallholder farmers' welfare; per capita income and per capita expenditure in 15 districts in Kenya. We use geo-referenced panel data as described in Chapter 2 and is unique in the following ways: First, the roads data enable us to construct time distance variables to the nearby market and to the nearest big town using algorithm described in Chapter 2 which minimizes biases due to endogeneity of placement of roads. Secondly, the geo-referenced data enable us to merge two very independent datasets collected almost at the same time to provide a balanced panel. Thirdly, our new and large panel data enable us to use modern techniques such as fixed effect (FE), which makes it possible to control the regression biases as a result of non-random placement of roads. To the best of our knowledge, this is the first study to directly evaluate the impacts of road rehabilitation on smallholder farmers' welfare in Kenya.

Our results show that overall per capita household income and per capita expenditure

has increased over the study period [1]. This suggest that improvement of roads to nearby market by one percent increases household income and expenditure by two percent, while improving roads to the big towns by one percent increases household income and expenditure by one percent. These estimates are significant at one the percent level of significance and are robust to different specifications and are consistent with the findings from literature. This study, therefore adds to the existing literature on the benefits of rural road access improvement by shedding light on the effects of rural roads investments on agriculture and poverty alleviation in Kenya.

The rest of the chapter is organized as follows: Section 5.2 gives an overview of Kenya's road infrastructure. Section 5.3 present our data description and statistics, while 5.4 presents our estimation strategy. Section 5.5 combines our econometric estimates, result discussion and robustness check, while section 5.6 concludes.

5.2 Background

Kenya's economic growth relies on agriculture as its main driver. The agricultural sector contributes 25 percent to national gross domestic product (GDP) and employs over 40 percent of the population. However, this sector has not performed very well compared to industry and services sectors, averaging just 0.7 percent growth in the past five years, while the industry and services have grown by 4.7 and 5.1 percent respectively (KNBS, 2012). This has been attributed to the high prices of farm inputs compared to farm output as a result of poor market integration, as well as erratic climatic conditions as most farms are rain fed. Kenya's population is approximately 40 million of which 3.5 million are smallholder farmers (KNBS, 2012). Majority of them live in the rural areas and are mostly disadvantaged (Kirimi et al., 2011). The majority of the smallholder

[1] We define the household expenditure as the sum of expenditures on major items in a household including food and non-food items

farmers practice subsistence farming and are net consumers of farm produce, especially maize.

Kenya's primary and secondary road network is approximately 160,886 km and is made up of paved and unpaved sections. Paved roads accounts for seven percent while unpaved roads accounts for 93 percent (Ministry of Roads, 2011). Most of these roads trace their origins from the colonial period where they were constructed to serve the white highland settlement as well as serve the colonial administrative headquarters. Once the Kenya government was granted independence, the government initiated the Rural Access Roads Programme (RARP) in 1974 with the objective of providing more effective rural transport services and improving standard of living of the rural population. In order to ease the flow of goods and services, the government has embarked on an ambitious program to bring all the roads to reparable standards. In line with public-private partnership (PPP) ideology, some organizations like One Acre Fund have provided over 70,000 smallholder farmers with farm inputs on credit to ensure that they plant their crops at the right time because farmers rely on natural precipitation[2]. They are able to deliver farm inputs to within walking distances from the farm houses, thanks to improved road access, as well as to train farmers on correct agronomy techniques and to provide agricultural extension services thereby improving crop yields.

5.3 Data and Descriptive Analysis

5.3.1 Data

This study uses data from two main sources: a geo-referenced household level data obtained from the Research on Poverty, Environment and Agricultural Technology (RePEAT) project and geo-referenced road infrastructure data obtained from the

[2]One Acre Fund is an Non Governmental Organization (NGO) in Kenya, Rwanda, Burundi and Tanzania which was initiated in 2006 to help farmers invest and generate a permanent gain in farm income to reduce poverty and hunger(Wikipedia, 2014).

Ministry of Roads (Kenya). The complete description of the data and algorithm for generating time distances can be found in Chapter 2.

5.3.2 Descriptive analyses

In this section, we present the summary statistics of our study. The distribution of our samples is as described in Table 4.1 in Chapter 4. We use household level data and after cleaning, we remain with 729 observations per year for analysis.

Table 5.1 gives the summary statistics of the household and community level variables. Table 5.1 shows an increase in migration leading to a reduction in household size by 14 percent over the span of the survey. Households headed by females have increased by five percent between 2004 and 2012. Households headed by females especially in Africa are very prone to economic shocks because they own very few assets that could be used to smoothen the adversity of the shocks. Furthermore, these households may suffer reduced incomes resulting from the breakdown of networking channels initiated by their deceased spouses (Angelucci et al., 2010, Fafchamps & Lund, 2003).

Per capita land holdings have not change significantly over the study period. Except for non-fresh food and non-food items, there is a notable increase in nominal income and expenditures for the items studied. In particular, per capita farm income has increased by over 200 percent while per capita non-farm income increased by 100 percent. Income generated from livestock sales has also increased significantly, but with a high degree of variation. On the expenditures, per capita expenditure on staple food has increased tremendously as well as expenditures on fresh food items[3]. The huge increase is as a

[3]Staples: Maize grain, Maize meal/flour, Millet/Sorghum, Wheat flour, Rice Cassava (Fresh form), Cassava (Dry), Sweet potatoes, Irish potatoes, Matoke; Fresh Food: Beans, Ground nuts, Green Peas , Vegetable/Fruits, Chicken, Fish, Meats, Eggs, Dairy products; Non-Fresh Food Items: Sugar, Salt, Cooking oil/Ghee, Coffee/Tea, Drinks, Tobacco/Cigarettes; Non-food Items: School fee, textbooks, Medical fee, Transportation, Clothing/Shoes, Cooking/Lighting fuel, Soap/washing products Contributions: Remittances to relatives, Churches/Mosques, Mutual Support Groups, Cooperatives/committees, Other local organizations; Savings: ROSCAs.

result of slight modification of the questionnaire used in 2012, although we made efforts to make sure that the items listed in 2012 questionnaire were as comparable as possible to those in 2004.

Regarding time distances, travel time by vehicles to a nearby active market has improved by 30 percent, while travel time to a nearby big town improved by 18 percent. This is as a result of road infrastructure improvement initiated by the government. On mobile phone network coverage, all communities in our study were covered by a mobile phone network in the year 2012, which was an improvement from 61 percent in 2004. This has led to an 81 percent jump in household mobile phone ownership.

Table 5.2 shows the correlations between the log of centered time distance to a nearby market and to a nearby big town versus income and expenditure. The negative (positive) coefficients means improvement of roads (reduction in travel time) increased (reduced) income or expenditure. Column 1 shows the negative and significant correlation between the log of centered time distance to a nearby market and the log per capita overall expenditure, log per capita expenditure on stable food, share of expenditure on staple food and log per capita expenditure on fresh food items. Column 2 shows the negative and significant correlation between log of centered time distance to big town and the log per capita overall income and the log per capita overall expenditure. Also showing negative and significant correlation in column 2 are the log per capita livestock income, the log per capita non-farm income and the log per capita non-labor income. Similarly, on expenditure, there is negative and significant correlation with log per capita expenditure on stable food, log per capita expenditure on fresh food items, log per capita expenditure on non-food items and log per capita expenditure on savings.

[INSERT TABLE 5.1 ABOUT HERE]

5.4 Estimation models and variables

The objective of this study is to evaluate the impact of change in road access on smallholder farmers' welfare in rural Kenya. We utilize the new panel data and take advantage of the improvement of roads to obtain unbiased estimates of our model. As shown in Table 5.1, income and expenditures on average have increased over the study period, but a simple comparison of the road improvement and welfare indicators may result in biased results because sources of biases such as omitted variables have not been accounted for. Thus, there is need for econometric analysis that take into account a number of factors, including the omitted variable problem, to identify the true effect

of road access improvement. In this study, we use a simple fixed effect (FE) model to estimate the effect of road access improvement, controlling for various factors that could have influenced road placement.

5.4.1 Estimation model

Our base model is simple Fixed Effect (FE) model, and is presented in Equation (5.1) below.

$$\begin{aligned} Y_{ijt} = \beta_0 + \beta_{RM}.RM_{ijt} + \beta_{RT}.RT_{jt} + \beta_{interact}.(RM_{ijt} \times RT_{jt}) + \beta_H.\mathbf{H} + \beta_C.\mathbf{C} \\ + (\delta_{agrozone} \times t) + \zeta_i + \varepsilon_{ijt}, \end{aligned} \tag{5.1}$$

where i indexes households, j indexes communities and t indexes year of survey. Y_{ijt} denotes the variable of interest; household per capita income and expenditures and their components, of the ith household living in jth community at time t. **H** is a vector of household specific regressors: gender of the household head (*fhh*), average size of the household (*hhsize*), number of men in the household (*men*), number of boys (*boys*), average head of the household head (*headage*) and its square (*headagex2*), average education of men (*meanedumen*), average education of women (*meaneduwomen*), whether the household belongs to a self help group in 2012 (*memberrosca*), per capita assets (*pcvassets*) and per capita land size (*pclandhold*). **C** is a vector of observable community level characteristics which include the log of population (*lnpopdensity*).[4] RM_{ijt} is the centered log of time distance in minutes to the nearby market from a household while RT_{jt} is the centered log of time distance in minutes from community reference point to the nearby big town.[5] $RM_{ijt} \times RT_{jt}$ is the

[4]All our log transformed variables used the formula $lnvar = ln(var + min(var)|_{var>0} - very\ small\ value)$ where var is the variable to be transformed. Negative values in livestock and farm income (approximately six percent) where replaced with 1 and a dummy variable showing which entry was replaced was included in the regression

[5]Measurement of time distances is discussed in Chapter 2. A big town here refers to market centers with a population over

interaction term between time to the nearest market and time to the nearest big town. ζ_i is unobserved household fixed effects. ε_{ijt} is the household idiosyncratic errors. $(\delta_{agrozone} \times t)$ dummies were also included because we were concerned about the dependent variables being correlated with any region-specific fixed effect. We use the heteroskedastic robust standard errors clustered at the community level. β_{RM}, β_{RT} and $\beta_{interact}$ are our coefficients of interest.

5.4.2 Testable hypotheses

Having widely discussed in Chapter 3 the importance of road access improvement of household welfare, we state our hypotheses in this section.

Because of good infrastructure, traders engaged in farm products are able to travel from one market to another and even to the farmers' households to make product purchases. This makes the market for farm produce very competitive to the benefit of smallholder farmers. The farmers can sell the farm products at their farm gates, where they can exercise their power to control the prices if they have information about the prevailing market prices.

Good infrastructure also enables farmers to engage in other non-farm activities like operating *kiosks* and bicycle repairs shops in order to supplement their farm income. There we hypothesize that

Hypothesis 3. *Smallholder farmers living in remote areas before road access improvement are more likely to increase their per capita household income after the improvement of roads because agricultural markets are integrated, hence prices of farm inputs and outputs as well as other commodities are competitive, making farm and non-farm activities profitable.*

Our second hypothesis endeavors to test the impact of road access improvement on household expenditures. The decision of the household to spend the extra income,

100,000.

the marginal propensity to consume (MPC), depends on many factors included in the household's decision model of which income plays a big role. Thus, we hypothesize that

Hypothesis 4. *Smallholder farmers living in remote areas before road access improvement are more likely to increase their per capita expenditures after improvement of infrastructure because commodities not accessed hitherto can now be accessed at very competitive prices and in variety.*

5.4.3 Variables

Time distances variables were generated after we digitized the maps of the road network of 2004 and superimposed them on the 2012 geo-referenced data using Desktop ESRI ARCGIS® 10 software. The complete algorithm used is outlined in Chapter 2. The household level variables used include the gender of the household head(*fhh*), average size of the household (*hhsize*), number of men in the household (*men*), number of boys (*boys*), average head of the household head (*headage*) and its square (*headagex2*), mean men's education (*meanedumen*), mean women's education (*meaneduwomen*), whether the household belongs to a self-help group in 2012 (*memberrosca*), per capita assets (*pcvassets*) and per capita land size (*pclandhold*). Community level characteristics include the log of population (*lnpopdensity*) and the coefficient of variation of rainfall (*cv*). Lastly, we include year-agrozone dummies to capture year-agrozone specific effects.

5.5 Results

In this section, we present the results of estimating Equation (5.1) that establishes the relationship between roads access improvement and smallholder farmers' income and expenditures. For each of the outcome variables, we run five different models: pooled ordinary least squares (OLS) regression, FE model without time distance to big town, FE model without time distance to nearby markets, FE model without controlling for year-agrozone effects, full RE model and full FE model. Our preferred model is the full

FE model and because of numerous tables, we will be presenting the preferred model estimates only.

5.5.1 The impact of road access improvement on income

We first discuss the results of the impact of road access improvement on overall per capita household income in column 1 of Table 5.3. The coefficients of both travel times to nearby market and to a nearby big towns are of the right sign. The elasticity of travel time to a nearby big town is significant at one percent, implying that the improvement of roads to nearby big town has impact on the overall household income. The increase in percapita household income is negative correlated with female headed households and household size. But average education attaintment and wealth endowment have positive impact on overall household income. The interaction term of the two time distances is positive and significant, indicating a synergistic impact.

Regarding the composition of household income, column 2 presents the results of the effect of road improvement on per capita farm income. The coefficients of both the travel times to a nearby market and to nearby big towns are of the right sign. The elasticity of travel time to nearby big town is significant at one percent implying that improvement of road infrastructure affects per capita farm income positively. The coefficient of travel time to a nearby market remain insignificant. Farm income increases with increased in land holdings. The coefficient of household size is negative and significant, an indication that farm income reduces with increase in household membership. Although farm activity is labour intensive, the proliferation of use of machines in farms have rendered household membership not a factor to determine farm productivity. Thus this result might be capturing the intensification of farm mechanization.

Similarly, column 3 estimates the impact of road improvement on per capita livestock income. The elasticity of travel time to a nearby big town is significant at the one percent, while the coefficient of a travel time to nearby market becomes significant at the one percent significance level. The coefficient of the interaction term is insignificant, indicating non-synergy in the two roads improvement in terms of generating livestock income.

Column 4 presents the estimates for the impact of road access improvement on per capita non-farm income. The FE estimates of travel time to a nearby big town is significant at the one percent significance level suggesting that smallholder households are engaging more in non-farm activities as a result of road improvement to nearby big towns. The interaction term is significant indicating synergistic effect. Non-farm income has continued to play a vital road in generation of household income. With improvement of roads, there are more opportunities to generated income by engaging in non-farm activities like operating a kiosk, a cycle repair shop or selling bricks, which are on demand as the area is opened up. Non-farm income is skill intensive as shown by positive of education, but decreased with aging household head.

Column 5 presents the estimates of the impact of road access improvement on non-labor income. Our preferred variables are statistically significant, suggesting that road improvement to a nearby market and to a nearby big town is enabling smallholder farmers to increase their non-labor income.

[INSERT TABLE 5.3 ABOUT HERE]

5.5.2 The impact of road access improvement on the share of composition of income

Regarding the share of the composition of smallholders farmers' income in Table 5.4, none of our variables of interest is significant although a number of them are of the right

sign. Share of farm income decreases with household size and education of female in the households. Share of non-farm income decreases with land endowment. The share of non-labor income increases with education of women.

The insignificant results of our time distance variables indicates that even if road access improvement leads to an increase in individual components of income, the share of the source of the income does not vary significantly in these households. This is true for the reason that in remote rural areas where subsistence farming is the major activity, farmers occupations rarely shift. Therefore even if there is improvement in rural road infrastructure, rural non-farm activities are limited hence farmers will take time to learn and switch occupations.

[INSERT TABLE 5.4 ABOUT HERE]

5.5.3 The impact of road access improvement on expenditures

The determinants of household expenditure have been of great interest to many economists since the time of Engel (1895). Increased household expenditures and increased incomes are positively correlated. However, the nature and patterns of food purchases and consumption of different items are different in poor and non-poor households. Of great interest to many economist are the poor households, who are always vulnerable to economic shocks. In this section, we also examine the impact of roads improvement on smallholder farmers' household expenditures. We present the results of Equation (5.1) for expenditures in Table 5.5.

Column 1 presents the estimates of the overall per capita household expenditure. The elasticities of time distance to a nearby big market as well as for the time distance to a big town are both the right sign and significant. For an averaged improved road to a nearby big market, improving travel time to the nearby big town by one percent

increases overall household expenditures by one percent. This is consistent with consumption theory, whereby an increase in income will necessitate households to expand their expenditures. In the following paragraphs, we discuss the impact of road improvement on the composition of household expenditures. Expenditures increases with number of men in the household as well as education of women. Being a member of a ROSCAS in 2012 also increases household expenditures, but ROSCAS are a form of savings in the household.

Column 2 to column 7 present the results of the composition of expenditures. In column 2, the results show that improving road accessibility to a nearby big market as well as to a nearby big town has a big impact on per capita expenditures on staple food. Both variables are highly significant at the one percent significance level. Expenditures on staple food increases with education of women, percapita land holding as well as being a member of ROSCAS in 2012.

Column 3 presents the results of per capita expenditure on fresh food. The coefficients are highly significant, implying the improvement of roads accessibility to a nearby market and to a big town increases expenditures on fresh food items.

The estimation results in column 4 and 6 suggest that market accessibility improvement reduces per capita expenditure on non-fresh food items and contributions in areas experiencing road access improvement. As for the non-fresh food items (column 4), there has been an increase in their prices as they are manufactured goods. The increase in their prices has been driven by external factors such as the increase in oil prices, which the manufacturers always pass to the consumers (Shively & Arega, 2014). Thus, although the markets accessibility has been improved, the prices of these commodities remained out of the reach of poor

households. There is evidence that improved road access to nearby big towns increases expenditures on non-food items (column 5). Regarding savings, we do find significant association between road improvement to nearby big town and savings at the 10 percent significance level. Savings also increases with being a member of ROSCAS in 2012.

[INSERT TABLE 5.5 ABOUT HERE]

5.5.4 The impact of road access improvement on the share of the composition of smallholders farmers' expenditures

On the share of the composition of smallholders farmers' expenditures, we present the share results of our estimation in Table 5.6. Unlike the share of the composition of income, we find evidence that market access has an impact on the share of composition of household expenditure. Column 1 and 2 shows that the share of expenditures on staples and fresh food items has increased as a result of road improvement to a big town. In particular, for an average improved road to a nearby market, improving roads to a big towns increases the expenditures on staple food and fresh food items. This is contrary to Engel's law, which predicts that as income rises, consumers increase their spending on food at a rate lower than the increase in income. However, our results mirror those found by Girma & Kedir (2003) in Ethiopian where consumers increased their expenditures on food in total expenditures, and only starts to decline after some threshold level of expenditure. The expenditure shares of non-fresh food items and contributions has decreased over the study period. We do not find any evidence that farmers are motivated to participate in social savings when infrastructure improves. However, the share of expenditures on non-fresh food items, non-food items as well as on contributions have been significantly negatively affected by roads access improvement. As described above, the effect on non-fresh food items

and non-food items is as a result of higher prices that could not be absorbed by the improvement of roads.

[INSERT TABLE 5.6 ABOUT HERE]

5.5.5 Robustness check

To ascertain the robustness of our results, for all our outcome variables, we run pooled OLS regressions, the FE model without adding time distance to a big town, FE model without adding time distance to a nearby market, RE model without controlling for year-agrozone effects, full RE model and full FE model using Equation (5.1) as mentioned earlier. Furthermore, we interact the time distance variables with mobile availability and run Equation (5.2).

$$S_{ijt} = \alpha_0 + \alpha_{RM}.RM_{ijt} + \alpha_{RT}.RT_{jt} + \alpha_{interact}.(RM_{ijt} \times RT_{jt}) + \alpha_{mobavai}.Mobavai + \alpha_{RMM}.RM_{ijt}.Mobavai + \alpha_{RTM}.RT_{jt}.Mobavai + \alpha_{interactM}.(RM_{ijt} \times RT_{jt}).Mobavai + \alpha_H.H_{ijt} + \alpha_C.C_{jt} + (\alpha_{agrozone} \times t) + \theta_i + \mu_{ijt}, \tag{5.2}$$

where S_{ijt} is the outcome variables as in Equation (5.1), $Mobavai$ is a dummy=1 if a community is covered by a mobile phone network and the rests of the regressors are as described in Equation (5.2). We present the results in Table A.2-Table A.5.

[INSERT TABLE A.2-TABLE A.5 ABOUT HERE]

Then we run the FE Tobit model of Equation (5.1) as suggested by Honoré (1992) and present the results in Table A.6-Table A.9.

When we compare the results across all the specifications in Table A.6-Table A.9 for our preferred model, the coefficients slightly changed but remained significant and of the right sign, except for some gain in significance. Thus our earlier estimates for FE full model are robust.

[INSERT TABLE A.6-TABLE A.9ABOUT HERE]

5.6 Conclusion and Policy Implication

By using new geo-referenced primary household survey data and road the improvement data, we have evaluated the impact of improvement of market accessibility on smallholder farmers' welfare in rural Kenya. We find evidence of increased household income and expenditures as a result of road improvements. Specifically, there is a significant increase in farm profit, livestock profit and non-farm income. Similarly, expenditures on staple food items and fresh food items increased over the study period. However, compared to components of expenditures, the impact or rural road improvements on the shares of income is rather minimal. The insignificant impact on the components of income is attributed to the rigidity in the change of occupation by farmers in the rural areas because even if there is improvement in roads infrastructure, rural non-farm activities are rather limited hence farmers will take time to learn and switch occupations. Although we expected an impact of rural road access improvement on non-labor income, farmers' migration decisions may have little to do with local infrastructure conditions, hence the share of income due to remittance may not change.

In Chapter 4, we found that road access improvement facilitates the adoption of new farming technologies as well as facilitates market participation by farmers. The results in this study corroborates these findings. Although our results show a positive impact of road improvement on smallholder farmers income and expenditures, we are cautious in interpreting the results because our elasticities are huge. They do not necessarily suggest that in order to grow rural economies, roads infrastructure should be accelerated in all rural areas, as the marginal cost of investing in such projects may far outweigh the benefits derived. Thus, if any investment is to be made on this type of development

infrastructure, it is prudent to do a thorough cost-benefit analysis (CBA) so as to shade light on the real benefits that might accrue there after.

In conclusion, in order to meet the growth and poverty reduction targets, SSA countries must invest in infrastructure, especially road infrastructure in the rural areas to facilitate the movement of goods and services as well as labor mobility. This will attract investors who can exploit resources in remote areas to capitalize on emerging opportunities in domestic, regional and international markets for processed and higher-value agro-industrial products. This will not only diversify income sources hence enhancing food security but also help in meeting targets set under the Comprehensive African Agriculture Development Programme (CAADP) and the Millennium Development Goals (MDGs). More research is needed to ascertain these impacts especially to do with spillover effect from numerous projects that the government has initiated since 2004.

Chapter 6

Determinants of Road Access Improvement: Panel Evidence from Kenya (2004-2012)

6.1 Introduction

Now that we have shown in Chapter 4 and Chapter 5 that road access improvement has impacted positively on hybrid maize adoption, milk market participation, maize yield and household welfare, in this chapter, we examine the factors determining the road access improvement in Kenya between 2004 and 2012. Our aim is to examine if there was political influence in the road construction. Often, elites in government have been accused of interfering with project funds allocations, to suit their political ambitions (Acemoglu & Robinson, 2012, Burgess et al., 2013).

Good road network is important as it facilitates quick access to goods and services, besides the integration of markets, reducing price dispersion of commodities across markets. However, in SSA, the road infrastructure network is very poor and dilapidated, stagnating development growth in the region (African Development Bank, 2010, Buys et al., 2010, Jerome, 2011). Recently, there has been revived interest by the developing nations and donors to invest in road infrastructure improvement (African Development Bank, 2010, World Bank, 2007). However, road access improvement is an expensive investment and requires huge resources; both human and capital. In SSA, such kind of huge investments is always undertaken by central government. This leaves the central government as the only player both in tendering for construction as well as monitoring the actual process of construction. This state of affairs creates a favourable environment for misuse by politicians influence

government officials to award tenders to suit their political ambitions (Burgess et al., 2013, Tanzi & Davoodi, 1998). The result is the skewed distribution of investments in infrastructure across the country.

As described in Chapter 1, there are a number of studies documenting external influence by politicians and government elites on public resource sharing. Officials occupying high government positions, their families and friends are more likely to benefit much from project manipulations (Banerjee & Somanathan, 2007, Nguyen et al., 2011). Tanzi & Davoodi (1998) summarized cases of corruption in public investments and linked them to political influences or corrupt public officials. Adserý (2003) has linked the under performance in governments' service delivery to political corruption and resource mismanagement. Most of these studies have been undertaken in Asia and other developed nations. However, there has been a shortfall in literature on infrastructure investment in SSA. This is because of poor documentation of investment processes or unwillingness by governments to share investment data.

In this chapter, we examine the factors that influenced the rehabilitation of roads in Kenya between 2004 and 2012. Like many other developing nations, Kenya has invested heavily in road infrastructure improvement. Before the change in regime in 2002, public officials had been accused of diverting public resources in favor of projects from their ethnic regions or in favor or regions perceived to be politically supportive (Burgess et al., 2013). This caused prolonged public outcry from the opposition parties and the civil society, strengthening their quest to win the 2002 general elections.

We use data from the RePEAT survey, as well as other sources described in Chapter 1, to construct time distance variables, political variables and development proxy variables to test factors determining road improvement.

Our results show that in the period 2003-2012, normally referred to as the second democratic regime in Kenya, road access improvement was not influenced by political inclination, as shown by the insignificant political variables. The factors influencing the road improvement are funds allocated to CDF and population densities. This is attributed to sufficient democratic space available that has enabled the tightening of reporting and monitoring and evaluation mechanisms in Kenya for public projects (International Monetary Fund. African Dept., 2013). This is encouraging results as other public investments can emulate the road construction projects.

This chapter is organized as follows: Section 6.2 gives a brief history of Kenyan politics from the election perspective. Section 6.3 gives an overview of Kenya's road infrastructure. Section 6.5 presents our data description, summary statistics and our estimation strategy. Section 6.6 combines our econometric estimates, results discussion and robustness check while Section 6.7 concludes.

6.2 Kenyan politics from the election perspective

The road to democracy in Kenya has been long since her independence in 1963 (Throup & Hornsby, 1998). It has been marked by several struggles, some of which nearly left the country torn apart.

In order to ease the transition from the colonial rule to self-governance in the 1963, the government of President Kenyatta and the ruling party Kenya African National Union (KANU) adopted the British style of governance, where the country was divided into provinces, districts, divisions, locations, and sub-locations. These administrative divisions were meant to implement central government policies at the grassroots. The country was divided further into constituencies, which followed the ethnic boundaries demarcated by the British colony. Unlike the administrative divisions where the heads

are appointed by the president, the constituencies segmentations are political, and are headed by an elected Members of Parliament. Citizens above the age of 18, within each of the constituencies, are required to register and elect their Member of Parliament to air their grievances in the August house. However, during the period from 1963 until the early 1990s, the government was governed under a one-party system and the president had the sole prerogative of hiring and dismissing government administrators as well as cabinet ministers. The government officials then were accused of nepotism, tribalism and corruption in terms of sharing of government resources. This created widespread discontentment among other political parties, leading to the push for multiparty system. The government, whom the opposition had coined an oppressive regime, yielded to the demands of the opposition and the first democratic elections were held in 1992. President Moi won the elections, and the subsequent one in 1997. Thereafter, the constitution was changed to allow a president to govern for a maximum of two terms in office if elected twice (each term constitutes five years, see Figure 7). This meant that President Moi was not eligible to vie for presidency in the general 2002 elections, that President Mwai Kibaki, under the National Rainbow Coalition (NARC) umbrella, won.

President Kibaki's administration moved fast to bring the economy back to growth, which was then underperforming. The government, from the pledges they made during their campaigns, drafted the first national road map document known as the Kenya Economic Recovery Strategy for Wealth and Employment Creation (ERS-WC,2003-2007) to guide her implement the her pre-election pledges (Government of Kenya, 2003).

During President Kibaki's regime, a number of positive strides were made, including sealing loopholes that were used to syphon government resources. However,

in the aftermath of the 2007 post-election violence which brought the economy to a standstill, the gains that had earlier been made were eroded (Ksoll et al., 2009, Yamano et al., 2010). A quick fix by the international mediation team set the coalition government rolling and a new constitution was passed in the year 2010, setting the stage for a devolved government system (Burgess et al., 2013, C. C. Gibson & Long, 2009, Throup & Hornsby, 1998).

6.3 Road infrastructure in Kenya

The construction and rehabilitation of roads in Kenya can traced back to colonial periods where roads were constructed to connect areas occupied by European settlers, known as the White Highlands, to the colonial administrative headquarters (Ochieng' & Maxon, 1992). When the Imperial British East African Company (IBEAC) was inaugurated to control the region between Uganda and the Kenyan coast, a number of trading centers sprang up on the transport corridors namely Machakos, Dagoretti, Fort Smith, Eldama Ravine and Mumias. This compelled the IBEAC to modernize her transport infrastructure in order to me the demands of the growing centers. Her priority then shifted to constructing the first modern road for wheeled motor vehicles, then known as the Mackinnon Road, between Mombasa and Kibwezi (see Figure 10). Construction began in the summer of 1890 and extended from Mombasa to the Rift Valley, and to the Uganda border (see Figure 10). When the construction of then Uganda Railway began in 1896 from the port of Mombasa and arrived at Kisumu in 1901, a number of sections of the Mackinnon-Sclater Road were abandoned because the railway provided a faster and more reliable means of transport. By 1910, most of the European-occupied farms were linked by service roads and tracks for transportation of farm produce to markets and to link up to administrative headquarters. The period between 1920 and 1940 saw an expansive construction of

roads to serve the newly settled European farmers in the frontier districts of Trans-Nzoia, Nanyuki and Laikipia. These new settlement areas were very productive, and more Africans were forced into African Reserves forcing the company to extend feeder roads to the reserves (Berman, 1990, Ochieng' & Maxon, 1992)[1]. The construction of roads continued, and by 1946, a total of 27,162 km had been constructed.

When Kenya attained her independence in 1963, her priority was to settle the people who had been in the camps or fighting in the bushes. Food production took center stage, and because of the settlement schemes that were left behind by the settlers, the government decided to continue to use the Swynnerton Plan of 1954 as a benchmark to expand her road networks[2]. Because the feeder roads to settlement schemes were narrow, the government embarked on an expansive program to put asphalt to major roads and to construct new feeder and minor roads.

6.3.1 Rural access roads

The Rural Access Roads Programme (RARP) was initiated in 1974 with the objective of providing more effective rural transport services and improving the standard of living of the rural population. The hallmarks of the programme were the use of labour-intensive techniques and grassroots participation in the selection of roads from the then unclassified roads network, comprising mainly short links between farms and the classified road network. Provisions were made for 4 m wide gravel surfaces, following existing tracks, usually of not more than 5-10 km length, with traffic volumes unlikely to exceed 10 vehicles per day following improvement (Ministry of Roads,

[1] African Reserves were camps were displaced Africans by European settlers were concentrated for easier control

[2] The Swynnerton Plan was used during the colonial periods in Kenya to intensify agricultural practise. The plan was aimed at expanding local cash-crop production by intergrading markets trough road construction, distribution of farm inputs, and consolidation of land holdings (Thurston & of Cambridge. African Studies Centre, 1987)

2011). By 1985, when the Minor Roads Programme (MRP) began as a successor to RARP, about 8,000 km of farm to market roads had been constructed using labour-based methods, concentrated in 15 districts in 6 provinces. Roads were usually numbered separately in each district, starting from R1[3]. The average R link length is about 7.3 km; though there are a few of substantially greater length. Today, it is managed by Kenya Rural Roads Authority (KuRRA). These classification are still used to date (Ministry of Roads, 2011).

6.3.2 The Kenya Roads Act, 2007

Before the reforms that took place in the Kenyan government after the 2002 general elections, the roads sub-sector was marred by outright corruption and a lack of accountability in terms of roads construction and rehabilitation. Uncertainties, duplication of roles and inconsistency in the road asset management system had become routine, and it adversely affected road construction and rehabilitation resulting in dilapidated roads in the country. Because of the lack of a coordinating mechanism, Ministries concurrently exercised road management responsibilities through some of their departments and agencies (Ministry of Roads, 2011). Furthermore, most road management agencies employed inefficient operational procedures under bureaucratic civil service regulations and lacked clarity in the legal, operational and structural relationships amongst themselves. The results was poor maintained roads, leading to the deterioration of roads standards.

When the NARC government took over the reigns of power in 2002, there was the need to urgently turn around this shortcoming. As a result of deep consultations, the Sessional Paper No. 5 of 2006 was birthed and was approved by Parliament on 19th October 2006. It spelt out policies to be pursued by the Government in the medium

[3] R for Roads

term for sustained growth and provided the legal and institutional framework for the management of roads (Ministry of Roads, 2011). The reforms under the Sessional Paper No 5 of 2006 realized the four basic building blocks necessary for effective roads management : ownership, clarified responsibility, stable financing and commercialized management. Further amendments of the Sessional Paper No 5 of 2006 culminated the drafting of The Kenya Roads Bill, 2007. The bill provides for the establishment of various roads governing agencies namely the Kenya National Highways Authority, the Kenya Urban Roads Authority and the Kenya Rural Roads Authority, to foresee various categories of roads (Republic of Kenya, 2007).

In 2007, the Kenya Roads Act came into force and the three Roads Authorities with the responsibility of clearly defined mandates on the management of respective road networks were created ushering in a new dawn in roads management.

6.4 Conceptual Framework

As has been outline Chapter 1, the aim of this chapter is to ascertain the determinants of road access improvement in Kenya from 2004-2012 and to test the hypothesis that the rehabilitation of rural roads was not politically motivated. We focus on political influence because road infrastructure improvement is a huge investment, and is often undertaken by central government which is made up of powerful politicians and technocrats. Because of the democratic space that the country has enjoyed during the period of our study, we do not expect any political variable to influence the implementation of road construction. Similarly, our development proxy variables are expected to remain insignificant. Following these claims, we hypothesize that

Hypothesis 5. *Other things remaining the same, the construction of roads is not influenced by political affiliation*

6.5 Data and Methods Methodology

In this section, we describe the data used in the study as well as our specification to determine the factors influencing road construction in Kenya between 2003-2012. We use the 2002 electoral and administrative boundaries that falls within our study region. In total, there are 97 communities in 35 constituencies in 15 districts.

6.5.1 Data

The data used in this study come primarily from the merged RePEAT and roads network data provided by the Ministry of Roads. As described in Chapter 2, we constructed time distance variables to the nearby market and to the nearby big towns as a measure of road improvement. First, we digitized 2004 maps and superimposed them on the to 2012 road network database to make a panel. Then we run the algorithm described in Chapter 2 to obtain our road access improvement variables.

The second data set comes from the former Electoral Commission of Kenya (ECK) and the current Independent Electoral and Boundaries Commission's (IEBC) databases. We use the data to construct political dummy variables namely: (a), being a member of parliament after the 2002 and 2007 general elections ; (b), whether the member of parliament's party was in power from 2003 to 2007 ; (c), whether the member of parliament became a minister after the 2002 and 2007 general elections.

The third set of data comes from the Constituency Development Funds Authority (CDF). Starting from the year 2003, each of the 210 constituencies have been allocated CDF to aid development in the constituencies[4]. The share of allocations were arrived at using a formula developed by the authority. These funds are managed by the constituency committees, who are elected or sometimes appointed by the member of

[4]We restrict our analysis to the original 210 constituencies as per 2002 electoral demarcation

parliament, with themselves being the chairpersons and fund signatories. The constituency development funds have no specific usage, but the projects deemed as vital in the constituencies are given priority. Since 2003, because the road networks were totally dilapidated, most of the constituencies decided to allocate a fair share of their funds towards the rehabilitation of roads under their jurisdictions. In areas where skirmishes were intense as a result of the 2007 post-election violence, many roads were extensively damage. When the coalition government had settled, the government rolled out massive repairs of roads in the country, mainly the highways and districts roads linking the highways to administrative headquarters.

The fourth type of data is the night light data obtained from National Oceanic and Atmospheric Administration (NOAA), and it has been described in detail in Chapter 2. This type of data has recently interested economists because of its high resolution and availability for longer periods (Bickenbach et al., 2013, Doll et al., 2006, Henderson et al., 2012). The data have been proven to proxy well for local developments projects of which their influences are localized (Nordhaus & Chen, 2012, Storeygard, 2013). Following the guidelines provided in Lowe (2014), we constructed our development proxy variable, namely the average number of pixels measured by digital numbers (DN). The grid we used to pool our zonal statistics measured 12 × 12 pixels (approximately 11.8 square km).

We also used population data extracted from the 1999 and 2009 population and housing census.

6.5.2 Descriptive statistics

We first present the summary statistics pertaining the CDF allocations, population densities and the share of president's votes in the 210 constituencies in Table 6.1. From

the year 2003 to 2007, the total amount of money that has been disbursed to the constituencies is USD 1.2 million. This amount has increased almost three fold from the year 2008 to 2012. The increase in the amount is as a result increased budgetary allocations owing to increase in the GDP. The increase in the amount was homogenous across the country's regions (Figure 4, panel (c)), depicting that no region was favoured, even those regions that are thought to be strongholds for the ruling party from 2003 to 2012. The constituency population density continues to grow at rate of 0.26 per annum on average.

The wining presidential candidate average vote share per constituency drop from 59% in 2002 to 43% , but the overall president vote share dropped to 46% in 2007. The 2007 general elections were closely contested, and immediately after the winner was announced, chaos spontaneously erupted in the country. The chaos only stopped after mediation from international community, to form coalition government, which resulted in bloated ministerial portfolio as shown by the rise in the probability of being a member of cabinet from 8% to almost 20%.

Next, we present the summary statistics of the areas covered by RePEAT survey in Table 6.2. Because of road improvement, the time distance to a nearby market and to a big town has been reduced by 30 percent and 18 percent on average respectively. As shown in figure Figure 4 panel (a), most of the improvement in roads to the nearby market was experienced in the Rift Valley region compared to all other regions. This is because in the Rift Valley regions, people still own very large tracks of land and as a result, markets are scattered and are serviced by earth roads. Because of the earth roads, upgrading to gravel surface reduce travel time by big margin. As for the time to nearby market, most improvements were experienced in the Eastern and Nyanza regions (Figure 4 panel (b)). In the Eastern region for example, the improvement was as a result

of re-tarmacking the Nairobi-Mombasa highway, which passes through the region. The cumulative CDF has increased by over 60 percent from period 2003-2007 to 2008-2012. Although not shown, the increase in the CDF were similar across all the regions. The population density has slightly increased, with a constituency average of 784 people per square kilometer in 2009.

The cumulative CDF is consistent with the national distribution as shown in Table 6.1. The 10 year population density growth is at 1.6, lower that the national constituency average.

As for the political variables, the share of votes for the winning presidential candidate were almost equal in 2002 and 2007. At 60%, we could allude that the region was progovernment. Thus, if the government is practices favouritism, these areas could easily benefit from more resource allocations, as a sign of appreciation for voting in the government. Although the national probability of becoming a Cabinet Member increased from 8% after the 2002 general elections to 18% after the 2007 general elections, the areas covered by the repeat survey was not favoured, as the probability increased from 4% to 8% depicting that the area was not favoured for cabinet posts.

About 40% of the districts covered in the RePEAT survey have Mombasa-Malaba highway passing through. This highway is an important economic infrastructure as it links the countries in East and Central Africa to port of Mombasa which is the gateway to near and other far East countries. As for the economic proxy variables, the mean light intensity increased from 0.92 digital numbers to 2.167 digital numbers on average. This shows that there has been expanded economic activities in the region. If the proxy variables captures well the economic activities, therefore we are able to capture all economic activities, including those that are implemented by government

but hard to obtain data. Thus, by comparing the voting patterns and the night lights, we are able to gauge if the areas that voted for the government got undue advantage of resource allocations.

6.5.3 Empirical Specification

The baseline equation we use is a simple Ordinary Least Squares (OLS) model, controlling for the initial conditions at the community and district levels. First, we estimate the factors influencing the cumulative allocation of CDF (**CDFAllocations$_{ij}$**) from 2003-2007 and from 2008-2012 in all the 210 constituencies using a variant of Equation (6.1). Then we estimate the factors influencing road rehabilitation in our study area.

The base equation is of the following form:

$$ChangeInTimeMrkt_{ij} = f\big(Timedistance04_{ij}, \mathbf{Population_{ij}}, \mathbf{PoliticalVariables_{ij}}, \mathbf{EconomicActivity_{icj}}, \mathbf{Geographical_{j}}\big), \tag{6.1}$$

where i indexes the constituency, j indexes districts while c indexes community centres.

Here, $ChangeInTimeMrkt_{ij}$ is the change in time distances to a nearby market (which is replaced by change in time distance to a big town when we run regression for the change in time to a big town), $Timedistance04_{ij}$ is the time to a nearby market in 2004 (which is replaced by time distance to a big town in 2004 when we run regression for the change in time to a big town). **PoliticalVariables$_{ij}$** include $Pvote02_{ij}$ and $Pvote07_{ij}$ which are the share of presidential votes in the constituency in the 2002 and 2007 general elections. $Cabinet02_{ij}$ and $Cabinet97_{ij}$ are dummies for being a Cabinet Member, and whether the Member of Parliament belongs to the ruling party

after the 2002 ($Rparty02_{ij}$). The government formed after the 2007 general elections was a coalition of parties, thus there was no distinct opposition party.

Other controls in the equation include (a) $\mathbf{Population_{ij}}$: 1999 constituency population density ($CDensity99_{ij}$), (b) economic activity variables ($\mathbf{EActivity_{icj}}$), proxied by night lights, (c) economic geography variables ($\mathbf{Geographical_{j}}$): whether Mombasa-Malaba highway passes through the district $disthighpass_j$ and whether the district borders international boundary $distborder_j$.

6.6 Estimation results and Discussions

6.6.1 Determinants of CDF allocations

By construction, the CDF was meant not to be influenced by the politicians. An independent governmental agency is task to share the allocations as per the rule depicted in Chapter 2. If indeed the rules of allocation were followed, we do not expect any of our political variable to influence the allocation of CDF.

Table 6.3 presents the results of the determinants of cumulative CDF allocations from 2003-2007. Column 1 present results without inclusion of political variables. As expected, the allocation of CDF favoured poor areas, represented by the negative coefficient of night light variable. Similarly, the coefficient of population density and the area of the constituency are all positive and significant, consistent with the CDF allocation criteria. When we include political variables in columns 2 to 4, non of them becomes indicating that politics did not play any significant role in CDF apportioning. When we drop the political variables and instead used the largest tribe variable in each district in column 5, the districts that are inhabited by Kisii's and Luhya as the majority show positive and significant coefficients. This therefore means that these areas have strong characteristics that satisfy allocation criteria. Naturally, these two tribes are not

very strong politically to warrant their elected leaders to divert resources to their districts. Indeed, the positive and significant coefficients captures poverty levels in the districts as these two regions have very high population densities and hence poverty is also high.

For the cumulative CDF allocations from 2008-2012, we present the results in Table 6.4. Column 1 present results without inclusion of political variables and the results mimic those in Table 6.3. However, when we include the political variables, all except presidential vote share after the 2007 elections are insignificant. Presidential vote share after the 2007 elections becomes negative and significate, denoting that in the areas that voted for winning presidential candidate, there was no undue increased allocation over and above the other constituencies. When we drop the political variables and control for ethnic composition, still Kisii and Luhya districts show positive and highly significant coefficients. However, these tribes are not had very power politicians in government to warrant resource diversities.

6.6.2 Determinants of improvement of roads to a nearby market

Roads to the nearby market play a vital role in ensuring that markets are intergraded thus reducing the time cost and price spread of commodities. However, the rehabilitation is an expensive undertaking which calls for substantial sum of money. This can provide an opportunity for the incumbent member of parliament to apportion part of the CDF to reward his/her voters. In Kenya, after the enactment of the Roads Act of 2007, the rural roads are managed by Kenya Rural Roads Authority (KURA) in conjunction with the CDF committee. Therefore, if indeed the rules of KURA and CDF committees are adhered to, we do not expect our political variables to influence the rehabilitation of infrastructure.

Table 6.5 presents the results of the determinants of change in road improvement to a nearby active market. Column 1 present the results without controlling for the local political variables and local development. Column 1 indicates that the road improvement to a nearby active market depends on the initial roads condition in 2004. Large change occurred mostly in areas where infrastructure was poor. It also indicates that the infrastructure was improved most where the population growth is high. This is consistent with the notion that roads could have been improved largely in areas with higher population densities.

When we control for the presidential vote share and being a cabinet member in columns 2 and 5, the political variables remain insignificant and no other variable changed its significance. This depicts the absence of political influence on the rehabilitation of the roads. When we control for all the political variables in the same model in column 6, the coefficients of our political variables of interest did not change in magnitude or significance, indicating their robustness.

When we use the district tribe composition as controls, the districts with Kalenjin tribe as majority experienced more improvement of roads. This improvement is not attributed to the fact that Kalenjins are more powerful in politics. The significant coefficient captures the fact that in the districts, people own huge tracts of land and thus markets are further apart. Most of the roads connecting markets in the region are dirt roads which are prone to damage by weather. The roads were upgraded to murram, a kind of dirt more firm than natural earth, thus enabling the roads to be accessible in all seasons. The vehicle density also in the regions is low, further enabling the roads to last longer.

Overall, our political variables are insignificant indicating that road access

improvement in the rural was short of political influence.

6.6.3 Determinants of improvement of roads to a nearby big town

Table 6.6 show the basic results of the determinants of improvement of roads to nearby big towns. Column 1 presents the results without controlling for political variables. It indicates that road access improvement depends on the road conditions in 2004, and it occurred mostly in areas further away from the big towns. Column 1 also indicates that the roads were rehabilitated in areas with vibrant economic activities as indicated by the positive coefficient of night lights. Furthermore, the coefficient of population density is negative indicating that improvement occurred mostly in densely populated areas. Similar improvement was experience in areas where Mombasa-Malaba road passes. The Mombasa-Malaba highway is maintained by the central government to enable goods transit from Mombasa port to landlocked countries in East and Central Africa. Thus this improvement is what the model is capturing.

When we control for political variables in columns 2 and 3, the coefficient of being a cabinet member becomes positive and significant indicating that in the areas that the cabinet ministers come from, road infrastructure to a nearby big town received more improvement. This is true in the sense that most roads linking to big towns are maintain by the central government and that the government made blanket rehabilitation for most of the roads. The outstanding improvement was the construction of the Thika supper highway which links the central part of Kenya to the capital city. The infrastructure is one of its kind in east and central Africa as it is a dual carriage linking Thika town, which is an industrial town to the City of Nairobi. The highway is the only gateway to the city from the central region, which was predominantly stronghold for the winning presidential candidate and of Kikuyu tribe. Thus the positive coefficient of presidential

vote share and that of Kikuyu tribe confirms this. However, the construction of Super Thika highway was to decongest the roads leading to Nairobi as it has been marred by very long traffick jams caused by lorries ferrying goods form Thika town. Thus the coefficient may just be capturing contemporaneous effect.

The magnitude and significance of the coefficients are not altered when we control for all the political variables in in column 6, depicting robust results. When we control for ethnicity, except for districts with Kalenjin and Kamba tribes , all other districts experienced road improvement to nearby big town as per the government directive. The reason why the Kamba districts and Kalenjin districts showed insignificant results is that, in 2012, most of the roads were still under rehabilitation.

Therefore, in summary, politics seemed to have not influenced the rehabilitation of roads in Kenya.

6.7 Conclusion

Corruption and misappropriation of public resources have hindered the progress of development, especially in developing nations. Resources allocated for public investment to alleviate poverty often end up in individuals pockets. This is worse off in undemocratic regimes, further exacerbating the already appalling poverty conditions (Burgess et al., 2013).

Over the past half century, Kenya has gradually moved towards full democracy by ushering in a system of multi-party governance in 1992. This, as many believe, will help in reducing the perceived rampant corruption in the public sector. The introduction of Constituency Development Funds (CDF) in the country in the year 2003 has helped in reducing widespread poverty levels in the rural areas, although there are still challenges of shoddy spending, especially towards the end of a fiscal year

(Gutiérrez-Romero, 2013).

Kenya has embarked on a expensive and expansive road rehabilitation project throughout the country aimed at increasing the productivity in all sectors of the economy, including agriculture, where smallholder farmers belong.

In this study, by using a carefully constructed data set, we have estimated the factors that determined the rehabilitation of roads from 2004 to 2012 in Kenya. These data fill the gap of data scarcity in evaluation the of determinants the of infrastructure improvement, especially in SSA. We find that population density and CDF allocations were the main drivers of rehabilitating roads to the nearby markets aprt from the initial road conditions. Our variables of interest, the political variables, were not significant, indicating that the improvement of roads was not influenced by politics. This corroborates what is contained in the literature about functioning democracies (Acemoglu & Robinson, 2000, Martinez-Bravo et al., 2012). Therefore, the findings stipulate the importance of having a working democratic space in order to implement programs that are targeted at alleviating poverty without influence the of political favoritism. The results are an important learning experience, especially in developing nations, to show that when democracy thrives, acceleration towards the eradication of poverty can be achieved faster.

Overall, our study sheds light on the importance of democracy in public infrastructure implementation. These results are encouraging and policy makers in developing nations can adopt. Although the road rehabilitation in Kenya was a success, whether this can be transferred to other public projects remains to be investigated as different infrastructure may need different approaches of intervention.

Chapter 7

Conclusion and Policy Implications

7.1 Introduction

There is no doubt that developing nations must increase their efforts to improve productivity in all sectors of the economy in order to reduce the widespread poverty, so that the World Bank target of reducing extreme poverty to under three percent by the year 2030 becomes a reality (World Bank, 2013). Among the interventions identified to have a greater impact on poverty alleviation is improving the road infrastructure (World Bank, 2007). Roads enable markets to integrate; therefore pushing the prices of goods and services to become favourable to consumers. Moreover, good roads enable smallholder farmers to access farm inputs easily as well as allowing them to market their produce in a timely manner. Integrated markets aid the transfer of new skills as a result of people interacting, therefore making it possible for the smallholder farmers to become aware of available opportunities to engage in non-farm sector in order to increase their incomes (Pinstrup-Andersen & Shimokawa, 2007).

Therefore, this dissertation attempts to empirically evaluate the impact of improving roads on adoption of yield enhancing technologies and market participation as well as on the welfare improvement of smallholder farmers in Kenya. The thesis also attempts to uncover the factors that determined the roads rehabilitation in Kenya. We use new, geo-referenced panel data collected as part of the RePEAT project in East Africa from 2004 to 2012. Other data were constructed using secondary data obtained from various sources including the National Oceanic and Atmospheric Administration (NOAA). The fundamental strength of our data was the geo-referencing, which made it possible to

merge the data to the exact location of the areas covered by the RePEAT survey to create a unique panel dataset.

The findings of the dissertation shed light on the interventions needed to address the challenge of tackling the wide poverty spread, especially in the developing world. This is important because the whole world is concerned about the ever rising poverty levels in developing nations, and especially those in SSA.

In the following sections, we summarize the empirical findings of the studies in the dissertation, and based on the findings, the chapter concludes by giving policy implications to enhance agricultural productivity, market participation, welfare improvement and the importance of democracy in alleviating poverty. These findings can be tailored to suit other developing nations, as Kenya is a more representative country for the developing nations.

7.2 Summary of findings

The literature review in Chapter 3 has shown that road improvement is pertinent to the economic development of a country. It has linked road improvement to agricultural productivity, market growth and poverty reduction in general. However, these studies have concentrated in East Asia and Latin America, and a number of them use cross-sectional data, which is prone to biases associated with the non-random placement of road infrastructure.

Chapter 3 also reviewed the literature on factors affecting public investments. There has been documented evidence that politicians in undemocratic regimes use public funds for their own benefits. This has led to the skewed distribution of public infrastructure, especially roads, in many developing nations. However, the literature on the evaluation of road access improvement is weak in Africa, in general. This has been attributed to

the scarcity of data that can enable such evaluation to be carried out. In the recent past, there has been revived drive to invest in road infrastructure in Africa, and of late, some data have started to trickle in from the implementing agencies. Therefore, this dissertation addressed that gap by using new panel data from Kenya. It also seeks to evaluate the factors influencing the road rehabilitation in Kenya.

7.2.1 Do smallholder farmers respond to road infrastructure improvement?

In Chapter 4, we provide an impact evaluation of the effect of road access improvement on agricultural development and market participation in Kenya. We find that in areas experiencing road access improvement, farmers have responded well by expanding their land for planting hybrid maize, increases the application of organic fertilizer in their farms as well as increase participation in marketing milk. This effect was particularly profound in the remote areas. Therefore, the results suggest that road access improvement has benefited smallholder farmers, especially those in isolated places. This implies that the recent road access improvement in Kenya is pro-poor.

On the contrary, we did not find any evidence linking road access improvement to participating in maize marketing and inorganic fertilizer application. As has been discussed in Chapter 4, we have attributed this to the following factors: the first being that inorganic fertilizer adoption in Kenya is not a new phenomena and its is likely that application thresholds have been achieved in our study area. For the maize marketing, the oversupply of maize in the market due to higher yields, hence driving market prices to unprofitable levels, and hence farmers opt out of marketing maize. The other plausible reason is that, the smallholder farmers are net consumers of maize and only produce for subsistence.

In summary, these findings corroborate the findings in the literature that road

improvement is pertinent to agricultural development, particularly on hybrid seed use and inorganic fertilizer application in isolated areas. The findings are useful in guiding policy-makers, who may have alternative poverty intervention strategies to choose from, while drafting interventions programs aimed at addressing poverty alleviation.

7.2.2 Does road improvement lead to poverty reduction?

As a result of the successful response by smallholder farmers to road infrastructure improvement, we investigate in Chapter 5 if the success has translated to the welfare improvement of the smallholder farmers. The improvement of smallholder farmers' welfare is a signal that poverty eradication is taking place.

We find that smallholder farmers' income and consumption increased as a result of road access improvement. Particularly, we find that farm income, livestock income and non-farm income increased, thanks to improved road infrastructure. Of much interest is the increase in the livestock income and non-farm income. Many smallholder farmers in SSA do not have formal savings schemes for their increased income (Rosenzweig & Wolpin, 1993, Salami & Damilola, 2013). Instead, they invest in livestock rearing, which serves two purposes: first, animals like cows, goats and poultry provide direct food supply to the households to supplement that obtained from the farms. Secondly, the livestock acts as an insurance to smoothen consumption during lean times (Fafchamps et al., 1998).

Regarding non-farm income, we find that many smallholder farmers have started engaging in non-farm activities like operating small kiosks, bicycle repair shops and even brick making in an attempt to diversify their sources of income. This has been possible because good roads make market integration possible, bringing in new ideas and entrepreneurship skills, hitherto not available in the community.

These findings, therefore, suggest that road access improvement can directly improve income by providing direct employment to those participating in road construction, and indirectly through the creation of an environment that enables the diversification of activities for generating income.

On consumption, we find that smallholder farmers increased their expenditures due to the increased income. In particular, we find increased expenditures on staple food items and fresh food items. This was rather a unexpected result, in that Engels' law predicts that for income increases, a household is more likely to increase expenditures on non-food items. However, we found the contrary. We interpret this result to mean that farmers have not yet attained food self-sufficiency; hence, for any increase in income, they will increase expenditures on food items until a threshold has been reached. This result has also been found in a study in Ethiopia (Girma & Kedir, 2003).

Regarding the share of the composition of income and expenditures, none of them was found to have changed as a result of road access improvement. This is explained by the fact that farmers rarely shift their occupations when infrastructure has improved. They will only diversify farming techniques, engaging in activities like planting cash crops rather than seasonal crops. Therefore, the share of the composition of smallholder income and expenditures will remain constant for longer periods.

Therefore, these findings suggest that road access improvement reduces poverty by enabling smallholder farmers to increase income and expenditures, either directly or indirectly.

7.2.3 What are the determinants of road access improvement?

In Chapter 6, we evaluate the factors that might have influenced the implementation of road improvement in Kenya. From the literature review in Chapter 3, politicians

in a number of countries tend to influence the allocation of public funds to suit their own political ambitions, and that this is worse in undemocratic societies. Kenya has been ranked by the Transparency International (TI) as one of the corrupt countries, an allegation the government has vehemently opposed (Transparency International, 2013). In this dissertation, the rehabilitation of roads has provided us with an opportunity to determine the factors leading to its successful rehabilitation, against the backdrop of political interferences.

First, we examine if there was political interferences in the allocation of Constituency Development Funds (CDF). The CDF was the main source of funds for rural road rehabilitation during this period and if experience political interference, then roads rehabilitation could suffer the same fate. Results showed that there was no political influence on CDF allocation, proving that the criteria for CDF allocation was adhered to, as shown by the insignificant political variables as well as significant development proxy variables, constituency area, population density and population density growth rate.

Turning to improvement of roads in the rural areas, coefficient of our political variables remain insignificant across various model specifications. This shows that road infrastructure improvement was influenced by politics. On the road access improvement to a nearby big town, we also did not find any evidence to show that politics played part in infrastructure improvement.

Therefore, in conclusion, we have found that democracy is beneficial for public investments, especially on road improvement. This is a vital learning benchmark for other developing nations to emulate.

Overall, road infrastructure improvement has been found to be beneficial as far as

poverty alleviation is concerned. The empirical analysis we have presented in this thesis has demonstrated the need to invest in road rehabilitation in SSA.

7.3 Policy implications

Enhancing farmers' capability to reduce the prevalence of poverty by engaging in productive agricultural investments and non-farm activities is paramount. The results we found in Chapter 4 and Chapter 5 have shown that farmers respond to road improvement. In Chapter 6, we found that smallholder farmers' income and expenditure have increased as a result of road access improvement. The results in Chapter 7 show that democracy is beneficial for implementing public infrastructure like roads, providing an avenue for alleviating poverty.

Based on these studies, we would like to make specific policy recommendation in order to strengthen the quest to alleviate poverty in Kenya, and probably in SSA and Africa in general.

Our first policy recommendation concerns the improvement of roads, especially rural roads, in SSA. From the literature, the majority of the inhabitants dwell in the rural areas and most of them are poor (United Nations, 2008). Therefore, there is a need to increase funding for road improvement so that farmers benefit from the timely provision of farm inputs as well as market their farm produce in a timely manner . Because of the wide coverage of mobile phone networks in Kenya, farmers can further benefit by obtaining information on the prevailing market prices of farm outputs before taking them to the markets. The wide network coverage will reduce the information asymmetry, which is often capitalized by middle men to fleece farmers by seeking large margins of profits. Apparently, mobile phone network providers rely on good infrastructure to provide reliable services to their clients. Furthermore, farmers need to

be sensitized on crop differentiation. The improvement of roads can provide good marketing opportunities for farmers, but they will not benefit if all of them plant one type of crop. Thus, the government in partnership with the private sector, should initiate sensitization programs to enable farmers to identify their comparative advantage as far as crop differentiation is concerned. This will enable the farmers to increase their incomes from farm and non-farm activities, therefore alleviating poverty. Regions that are isolated from the rest of the country need the most intervention, as depicted by the farmers in remote areas responding to road access improvement by increasing maize yield. Therefore, priority be given to such areas. Lastly, our time distance variable is generated by taking into account all the road conditions to a nearby active market or a nearby big town, therefore making it difficult to recommend what type of roads are needed for bigger impact. We know from the survey that most of the roads in the rural areas are earth roads. Therefore, we are suggesting that these roads first be brought to motorable standards by upgrading them to gravel type. Maintaining the gravel type of roads using the Roads 2000 Programme adopted by the Kenyan government, which is is a labour intensive road construction technique, is more sustainable in the long term as basic materials and labor can be source locally. Further research need to be conducted in order to separate which roads actually provides the greatest impact and in which part of the country.

The second policy recommendation concerns the importance of democracy in fighting poverty especially in developing nations. The literature has been flooded with studies associating the poor implementation of public projects to interferences from politics. Our results have shown that in a democratic environment, the implementation of public investments can benefit the intended people. Therefore, disentangling the implementation of public infrastructure from influence of politics is beneficial. This

can be done through strengthening of institutions such as those implementing resource allocations. Furthermore, the decentralization of the construction of vital infrastructure to development like rural roads is necessary. This must be accompanied by public participation in the decision making process for the project to be owned by the community. Thus, other projects like irrigation and electrification in Kenya should follow suit.

In conclusion, we acknowledge the importance of road access improvement in rural SSA to improve agricultural productivity in order to alleviate poverty. Although we did not evaluate the distributive benefits of the impact of road access improvement, it is important to policy implementers to know how the benefits accruing from road infrastructure improvement is distributed in society. This will help in planning targeted intervention programs in a society, especially in those areas that have been isolated by poor infrastructure. This has been left for future research.

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Tables and figures

Tables used in Chapter 4

TABLE 4.1: DISTRIBUTION OF SAMPLED UNITS, REPEAT (2004-2012)

		2004		2012	
Region	District	Community	Households	Community	Households
Central	Kiambu	12	86	12	86
	Kirinyaga	6	41	6	41
	Maragua	3	23	3	23
	Murang'a	8	60	8	60
	Nyandarua	7	36	7	36
Eastern	Machakos	7	65	7	65
Nyanza	Kisii	7	61	7	61
	Nyamira	4	30	4	30
	Rachuonyo	7	61	7	61
Rift Valley	Nakuru	16	132	16	132
	Nandi	5	44	5	44
	Narok	3	14	3	14
Western	Bungoma	4	26	4	26
	Kakamega	4	23	4	23
	Vihiga	4	27	4	27
Total		97	729	97	729

TABLE 4.2: SUMMARY STATISTICS AND *ttest* FOR EQUALITY OF MEANS OF VARIABLES OF KEY VARIABLES: KENYA REPEAT 2004 AND 2012

	Year=2004			Year=2012			
Variables	Obs	Mean	Sd	Obs	Mean	Sd	MeanDiff
Household level							
Average education of household head(years)	729	6.63	4.48	729	6.75	4.37	0.122
Gender of household head(=1 for female)	729	0.21	0.41	729	0.28	0.45	0.075***
Average age of household head in years	729	55.33	13.8	729	61.71	14.01	6.380***
Mean adult education(years)	729	7.13	2.83	729	7.59	2.88	0.465***
Average household size	729	6.42	2.89	729	5.53	2.9	-0.893***
Percentage of households belonging to a self help group in 2012	-	-	-	729	0.46	0.5	0.462***
Percentage of households owning at least one mobile phone	729	0.12	0.32	729	0.93	0.25	0.813***
Average household asset value($\times 10^4$)	729	5.93	15.45	729	11.6	48.23	5.665***
Average land holding (Ha)	729	1.53	1.82	729	1.56	1.86	0.035
Average number of improved animals	729	1.32	1.93	729	1.4	1.78	0.081
Percentage of households producing milk	729	0.62	0.49	729	0.72	0.45	0.100***
Percentage of households selling milk	729	0.5	0.5	729	0.6	0.49	0.096***
Average milk sold monthly(liters)	729	71.32	130.33	729	103.19	199.61	31.871***
Proportion of milk sold	729	0.28	0.31	729	0.36	0.34	0.084***
Percentage of households cultivating maize	729	0.94	0.21	729	0.97	0.17	0.029***
Percentage of households selling maize	729	0.27	0.41	729	0.29	0.42	0.019
Proportion of maize sold	729	0.11	0.21	729	0.12	0.21	0.008
Average time to nearby market (minutes)	729	20.91	19.68	729	14.58	11.76	-6.331***
Proportion of land for planting Hybrid maize (Ha)	729	0.3	0.3	729	0.46	0.33	0.159***
Percentage of households using fertilizer	729	0.72	0.42	729	0.71	0.43	-0.011
Average inorganic fertilizer use(Kg/Ha, NPK equivalent)	729	44.78	50.84	729	46.61	48.63	1.836
Percentage of households using manure	729	0.56	0.44	729	0.54	0.46	-0.016
Average manure use(Kg/Ha)	729	1174.53	2050.36	729	1500.58	2431.98	326.048***
Average maize yield(Kg/Ha)	729	1317.82	1389.26	729	2083.09	1554.52	765.261***
Community level							
Percentage of mobile network coverage	97	0.62	0.49	97	1	0	0.381***
Average time to nearby big town (minutes)	97	95.27	46.39	97	78.16	37.17	-17.110***
Average community population density	97	671.38	881.29	97	1006.49	1300.05	335.112**

Significance level: ***p<0.01, **p<0.05,*p<0.1

TABLE 4.3: PAIRWISE CORRELATION BETWEEN ROAD ACCESS IMPROVEMENT AND FARMING VARIABLES

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
landhyvprop	-0.0373 *	-0.0841 ***	-0.0390 *	1						
lnqfertnpk	-0.121 ***	0.0667 **	0.00923	0.192 ***	1					
lnqmanure	-0.0330	-0.111 ***	0.00877	0.185 ***	0.316 ***	1				
lnyieldmaize	-0.00303	-0.200 ***	-0.0506 **	0.289 ***	0.334 ***	0.205 ***	1			
milkseller	0.0393 *	-0.135 ***	-0.00571	0.129 ***	0.180 ***	0.190 ***	0.147 ***	1		
milkpropsold	0.0363 *	-0.198 ***	-0.000965	0.140 ***	0.162 ***	0.239 ***	0.139 ***	0.886 ***	1	
maizeseller	0.0539 **	-0.0377 *	-0.0237	0.120 ***	0.106 ***	-0.0563 *	0.291 ***	0.0784 ***	0.0586 ***	1
maizeratio	0.0499 **	-0.0351 *	-0.0489 **	0.112 ***	0.119 ***	-0.0482	0.263 ***	0.0821 ***	0.0617 ***	0.868 *** 1

Notes:

1). Significance level: *** p<0.01, ** p<0.05, * p<0.1

2). Column (1) Log of centered time to nearby market (2) Log of centered time to nearby big town (3) Time interaction (4) Proportion of land under hybrid maize (5) lnqfertnpk - Log of NPK equivalent fertilizer(Kg/Ha) (6) lnqmanure - Log of organic manure (Kg/Ha) (7) lnyieldmaize - Log of maize yield (Kg/Ha) (8) milkseller- Dummy =1 if household sold milk (9) milkpropsold - Proportion of milk sold to harvested (10) maizeseller - Dummy =1 if household sold maize (11) maizeratio - Ratio of maize sold to harvested

TABLE 4.4: IMPACT OF ROAD IMPROVEMENT ON EXPANSION OF LAND FOR HYBRID MAIZE: KENYA, 2004-2012

Dependent Variable: *Proportion of maize land under hybrid maize*

VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.075**		−0.048	−0.301**	0.012	−0.099	0.016
	(0.043)		(0.141)	(0.017)	(0.837)	(0.214)	(0.823)
(b). Log centered travel time to big town		−0.188	−0.240**	−0.330	−0.659	−0.262*	−0.154
		(0.112)	(0.024)	(0.475)	(0.104)	(0.052)	(0.467)
(c). (a) × (b)			0.169***	−0.230	0.185	0.272***	0.218**
			(0.001)	(0.176)	(0.108)	(0.004)	(0.036)
Household level controls							
Gender of household head(=1 for female)	0.104***	0.102***	0.094**	0.153***	0.031	0.162*	0.025
	(0.004)	(0.006)	(0.013)	(0.002)	(0.639)	(0.068)	(0.736)
Average age of household head in years	−0.001	−0.001	−0.001	−0.016*	0.027*	−0.005	0.002
	(0.780)	(0.838)	(0.793)	(0.050)	(0.070)	(0.686)	(0.813)
Age of HH head squared	0.000	0.000	0.000	0.000	−0.000*	0.000	−0.000
	(0.882)	(0.934)	(0.926)	(0.101)	(0.054)	(0.767)	(0.766)
Average education of household head(years)	0.005	0.004	0.004	0.023**	0.002	0.007	0.002
	(0.294)	(0.365)	(0.333)	(0.022)	(0.845)	(0.307)	(0.886)
Education of male adults	−0.003	−0.002	−0.003	0.003	−0.004	−0.018**	0.005
	(0.579)	(0.655)	(0.617)	(0.714)	(0.723)	(0.024)	(0.766)
Education of female adults	0.006	0.006	0.005	0.003	0.014*	−0.002	0.011
	(0.242)	(0.214)	(0.307)	(0.779)	(0.069)	(0.784)	(0.450)
Average household size	0.005	0.005	0.006	−0.009	0.004	0.007	0.021*
	(0.466)	(0.446)	(0.348)	(0.588)	(0.791)	(0.514)	(0.079)
Number of male adults	0.013	0.011	0.012	0.045*	−0.007	0.023	−0.021
	(0.294)	(0.384)	(0.336)	(0.096)	(0.808)	(0.167)	(0.412)
Number of boys	0.008	0.007	0.009	0.084***	−0.010	−0.004	−0.019
	(0.522)	(0.577)	(0.479)	(0.004)	(0.704)	(0.858)	(0.354)
Ln(Per capita asset value(Kshs))	0.021	0.022	0.016	0.012	0.005	0.015	0.024
	(0.113)	(0.113)	(0.250)	(0.704)	(0.872)	(0.399)	(0.433)
Average land holding (Ha)	−0.009	−0.008	−0.007	−0.013	−0.026	0.009	−0.058
	(0.579)	(0.599)	(0.640)	(0.783)	(0.372)	(0.789)	(0.108)
Landholding squared	0.000	0.000	0.000	0.001	0.000	0.001	0.005
	(0.810)	(0.846)	(0.926)	(0.883)	(0.829)	(0.649)	(0.150)
Community level controls							
Log of community population density	0.075*	0.097**	0.056	0.193	0.029	0.024	0.161
	(0.094)	(0.042)	(0.134)	(0.173)	(0.411)	(0.717)	(0.236)
Other controls							
Season(short==2)	0.083***	0.083***	0.083***	0.098**	0.115*	0.172***	−0.029
	(0.000)	(0.000)	(0.000)	(0.034)	(0.053)	(0.000)	(0.352)
Constant	−0.421	−0.564*	−0.232	−0.937	−0.547	0.348	−1.140
	(0.132)	(0.070)	(0.354)	(0.294)	(0.259)	(0.551)	(0.134)
Observations	2,225	2,225	2,225	610	507	558	550
R-squared	0.163	0.161	0.170	0.278	0.281	0.187	0.072
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.5: IMPACT OF ROAD IMPROVEMENT ON INORGANIC FERTILIZER INTENSIFICATION(NPK EQUIVALENT, KG/HA): KENYA, 2004-2012

Dependent Variable: *Ln(NPK equivalent inorganic fertilizer(kg/ha))*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.068		−0.034	0.508	0.299	−0.159	−0.476
	(0.605)		(0.803)	(0.111)	(0.238)	(0.561)	(0.125)
(b). Log centered travel time to big town		−0.174	−0.229	2.491*	0.063	−0.489	0.502
		(0.641)	(0.576)	(0.093)	(0.962)	(0.427)	(0.563)
(c). (a) × (b)			0.190	0.475*	0.512	0.389	−0.437
			(0.328)	(0.054)	(0.231)	(0.248)	(0.314)
Household level controls							
Gender of household head(=1 for female)	0.025	0.025	0.020	0.000	0.053	0.224	−0.162
	(0.856)	(0.863)	(0.886)	(1.000)	(0.854)	(0.376)	(0.602)
Average age of household head in years	−0.025	−0.024	−0.024	0.034	−0.088*	−0.048	−0.009
	(0.185)	(0.192)	(0.197)	(0.355)	(0.063)	(0.283)	(0.730)
Age of HH head squared	0.000	0.000	0.000	−0.000	0.001**	0.000	0.000
	(0.132)	(0.137)	(0.140)	(0.487)	(0.035)	(0.280)	(0.625)
Average education of household head(years)	−0.007	−0.007	−0.006	−0.039	−0.008	0.011	−0.003
	(0.655)	(0.650)	(0.682)	(0.254)	(0.835)	(0.675)	(0.926)
Education of male adults	−0.026	−0.025	−0.026	0.032	−0.035	−0.070**	0.028
	(0.166)	(0.172)	(0.159)	(0.176)	(0.551)	(0.038)	(0.383)
Education of female adults	0.016	0.016	0.015	0.019	−0.038	0.007	0.057
	(0.214)	(0.210)	(0.258)	(0.349)	(0.146)	(0.722)	(0.259)
Average household size	0.042**	0.042**	0.044**	0.128**	0.004	0.073**	0.006
	(0.036)	(0.039)	(0.031)	(0.015)	(0.945)	(0.032)	(0.902)
Number of male adults	−0.026	−0.028	−0.027	−0.166**	0.005	0.004	−0.021
	(0.479)	(0.456)	(0.460)	(0.020)	(0.951)	(0.960)	(0.807)
Number of boys	−0.050	−0.050	−0.050	−0.179**	0.009	−0.092	−0.011
	(0.215)	(0.211)	(0.217)	(0.014)	(0.918)	(0.160)	(0.926)
Ln(Per capita asset value(Kshs))	0.006	0.004	0.001	0.023	0.032	−0.011	−0.040
	(0.890)	(0.917)	(0.973)	(0.749)	(0.769)	(0.886)	(0.623)
Average land holding (Ha)	−0.033	−0.032	−0.033	0.041	0.094	−0.092	−0.271
	(0.525)	(0.527)	(0.521)	(0.653)	(0.303)	(0.391)	(0.117)
Landholding squared	0.002	0.002	0.002	−0.001	−0.019*	0.007	0.035*
	(0.682)	(0.700)	(0.675)	(0.895)	(0.075)	(0.491)	(0.053)
Community level controls							
Log of community population density	−0.032	−0.010	−0.061	0.411	−0.279*	−0.116	0.052
	(0.821)	(0.945)	(0.700)	(0.348)	(0.061)	(0.701)	(0.901)
Other controls							
Season(short==2)	−0.109***	−0.110***	−0.110***	−0.126**	−0.037	−0.117*	−0.102
	(0.004)	(0.004)	(0.004)	(0.029)	(0.691)	(0.077)	(0.309)
Dummy for planted hybrid maize, =1	0.229***	0.231***	0.224***	0.223*	0.220	0.209	0.196*
	(0.001)	(0.001)	(0.001)	(0.056)	(0.332)	(0.142)	(0.077)
Dummy for farm is inter-cropped, =1	−0.060	−0.063	−0.061	0.012	−0.127	0.045	−0.362
	(0.620)	(0.608)	(0.610)	(0.961)	(0.778)	(0.768)	(0.286)
Constant	4.335***	4.198***	4.554***	−0.877	7.698***	5.959**	3.785
	(0.000)	(0.000)	(0.000)	(0.778)	(0.000)	(0.011)	(0.160)
Observations	1,605	1,605	1,605	421	362	495	327
R-squared	0.100	0.100	0.102	0.184	0.233	0.116	0.141
Number of hhid	636	636	636	153	158	200	125
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.6: IMPACT OF ROAD IMPROVEMENT ON ORGANIC FERTILIZER INTENSIFICATION(KG/HA): KENYA, 2004-2012

Dependent Variable: *Ln(Manure(kg/ha))*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.540***		−0.488***	−0.848*	−0.586*	0.312	−0.457**
	(0.003)		(0.005)	(0.082)	(0.095)	(0.660)	(0.048)
(b). Log centered travel time to big town		−1.664*	−1.440	2.040	−11.948***	−5.286**	−1.366
		(0.076)	(0.113)	(0.259)	(0.002)	(0.035)	(0.336)
(c). (a) × (b)			0.067	−0.685*	−1.232	1.176*	−0.871
			(0.837)	(0.069)	(0.156)	(0.075)	(0.238)
Household level controls							
Gender of household head(=1 for female)	0.046	0.009	0.001	0.054	−0.522	1.796**	−0.593
	(0.819)	(0.966)	(0.995)	(0.845)	(0.228)	(0.023)	(0.207)
Average age of household head in years	0.014	0.019	0.018	0.003	0.082*	−0.232	0.043
	(0.610)	(0.468)	(0.498)	(0.936)	(0.091)	(0.117)	(0.539)
Age of HH head squared	−0.000	−0.000	−0.000	−0.000	−0.001	0.002*	−0.000
	(0.643)	(0.469)	(0.482)	(0.543)	(0.113)	(0.099)	(0.637)
Average education of household head(years)	0.017	0.008	0.011	0.086**	−0.011	0.017	−0.081
	(0.562)	(0.785)	(0.705)	(0.020)	(0.849)	(0.816)	(0.378)
Education of male adults	0.006	0.010	0.009	−0.051	−0.001	−0.051	0.040
	(0.845)	(0.734)	(0.757)	(0.178)	(0.987)	(0.498)	(0.639)
Education of female adults	0.019	0.018	0.018	−0.023	0.079	0.098	0.050
	(0.541)	(0.546)	(0.551)	(0.589)	(0.110)	(0.300)	(0.565)
Average household size	−0.006	0.004	0.002	0.044	−0.085	0.110	−0.070
	(0.873)	(0.905)	(0.949)	(0.417)	(0.239)	(0.239)	(0.112)
Number of male adults	−0.038	−0.054	−0.051	−0.072	−0.096	0.401*	0.048
	(0.503)	(0.356)	(0.390)	(0.486)	(0.503)	(0.085)	(0.473)
Number of boys	0.056	0.038	0.053	−0.047	0.192	0.404	0.162
	(0.454)	(0.610)	(0.481)	(0.713)	(0.173)	(0.299)	(0.120)
Ln(Per capita asset value(Kshs))	0.083	0.100	0.077	0.171	0.014	0.078	0.063
	(0.371)	(0.282)	(0.411)	(0.231)	(0.925)	(0.796)	(0.800)
Average land holding (Ha)	−0.248***	−0.237***	−0.248***	−0.133	0.019	−0.635**	−0.440
	(0.002)	(0.003)	(0.003)	(0.418)	(0.879)	(0.028)	(0.105)
Landholding squared	0.009	0.008	0.009	0.014	−0.007	0.032	−0.016
	(0.200)	(0.256)	(0.224)	(0.444)	(0.459)	(0.120)	(0.543)
Community level controls							
Log of community population density	0.585**	0.719***	0.553**	−0.404	1.271***	0.859	0.521
	(0.015)	(0.001)	(0.013)	(0.612)	(0.000)	(0.178)	(0.450)
Other controls							
Season(short==2)	−0.061	−0.063	−0.065	0.049	0.063	−0.144	−0.267
	(0.446)	(0.433)	(0.424)	(0.729)	(0.447)	(0.624)	(0.102)
Dummy for planted hybrid maize, =1	0.234**	0.227**	0.221**	0.191	0.445***	0.010	0.103
	(0.013)	(0.017)	(0.016)	(0.390)	(0.008)	(0.971)	(0.592)
Dummy for farm is inter-cropped, =1	−0.314*	−0.316*	−0.329*	−0.317	−0.330	−0.364	0.229
	(0.075)	(0.083)	(0.064)	(0.235)	(0.488)	(0.384)	(0.137)
Constant	2.507	1.477	2.798	9.408*	1.449	5.492	1.588
	(0.179)	(0.368)	(0.115)	(0.074)	(0.573)	(0.390)	(0.787)
Observations	1,274	1,274	1,274	439	331	207	297
R-squared	0.150	0.145	0.154	0.134	0.226	0.454	0.372
Number of hhid	579	579	579	168	141	131	139
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.7: IMPACT OF ROAD IMPROVEMENT ON MAIZE YIELD(KG/HA), KENYA (2004-2012)

Dependent Variable: *Ln(Maize yield (kg/ha))*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	0.158		0.246	0.088	1.431**	−0.065	−0.235
	(0.475)		(0.292)	(0.915)	(0.019)	(0.675)	(0.160)
(b). Log centered travel time to big town		−0.723	−1.039*	1.864	−2.508	−0.878**	−0.058
		(0.184)	(0.064)	(0.496)	(0.335)	(0.039)	(0.951)
(c). (a) × (b)			0.503	0.864	0.606	0.021	0.129
			(0.200)	(0.354)	(0.436)	(0.908)	(0.664)
Household level controls							
Gender of household head(=1 for female)	0.088	0.051	0.046	−0.253	0.016	0.351	−0.103
	(0.613)	(0.772)	(0.793)	(0.469)	(0.976)	(0.156)	(0.579)
Average age of household head in years	0.015	0.016	0.016	0.098*	−0.001	−0.014	0.002
	(0.507)	(0.496)	(0.484)	(0.078)	(0.992)	(0.598)	(0.940)
Age of HH head squared	−0.000	−0.000	−0.000	−0.001*	0.000	0.000	0.000
	(0.686)	(0.637)	(0.636)	(0.098)	(0.830)	(0.498)	(0.770)
Average education of household head(years)	0.028	0.026	0.025	−0.071	0.091	0.026	−0.009
	(0.271)	(0.325)	(0.321)	(0.299)	(0.127)	(0.126)	(0.772)
Education of male adults	−0.020	−0.018	−0.018	−0.074	0.080	0.001	0.010
	(0.388)	(0.443)	(0.438)	(0.137)	(0.458)	(0.977)	(0.741)
Education of female adults	−0.014	−0.018	−0.017	−0.009	0.031	−0.002	−0.087**
	(0.586)	(0.479)	(0.491)	(0.853)	(0.623)	(0.928)	(0.025)
Average household size	0.010	0.012	0.014	−0.041	0.081	0.007	0.027
	(0.735)	(0.664)	(0.615)	(0.670)	(0.212)	(0.812)	(0.487)
Number of male adults	0.023	0.017	0.017	0.030	−0.084	0.017	0.055
	(0.627)	(0.721)	(0.729)	(0.829)	(0.540)	(0.742)	(0.250)
Number of boys	−0.124**	−0.122**	−0.122**	−0.331**	−0.202	0.093*	−0.066
	(0.023)	(0.024)	(0.024)	(0.045)	(0.336)	(0.093)	(0.269)
Ln(Per capita asset value(Kshs))	0.077	0.061	0.056	0.005	0.127	0.012	0.182
	(0.209)	(0.328)	(0.351)	(0.968)	(0.346)	(0.754)	(0.134)
Average land holding (Ha)	−0.152**	−0.151**	−0.149**	0.029	−0.260*	−0.094	−0.086
	(0.024)	(0.027)	(0.028)	(0.918)	(0.062)	(0.441)	(0.346)
Landholding squared	0.007	0.007	0.006	−0.021	0.012	0.005	0.000
	(0.114)	(0.131)	(0.145)	(0.579)	(0.158)	(0.622)	(0.976)
Community level controls							
Log of community population density	0.331	0.231	0.264	1.173	0.121	−0.089	1.336***
	(0.337)	(0.452)	(0.410)	(0.387)	(0.805)	(0.549)	(0.001)
Other controls							
Season(short==2)	−0.023	−0.027	−0.027	0.027	0.185	−0.192**	−0.112
	(0.840)	(0.813)	(0.815)	(0.920)	(0.619)	(0.013)	(0.178)
Dummy for planted hybrid maize, =1	0.077	0.065	0.062	−0.326	0.451	0.183	0.038
	(0.534)	(0.597)	(0.620)	(0.268)	(0.154)	(0.167)	(0.817)
Dummy for farm is inter-cropped, =1	0.444	0.427	0.439	−0.125	1.165	0.511***	0.622
	(0.171)	(0.181)	(0.172)	(0.795)	(0.135)	(0.001)	(0.316)
Constant	2.528	3.429*	3.241*	−2.972	0.935	7.329***	−4.002
	(0.228)	(0.067)	(0.098)	(0.740)	(0.789)	(0.000)	(0.146)
Observations	2,225	2,225	2,225	610	507	558	550
R-squared	0.279	0.279	0.281	0.296	0.412	0.121	0.257
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.8: IMPACT OF ROAD IMPROVEMENT ON PARTICIPATION IN MILK MARKET PARTICIPATION (LITERS SOLD): KENYA, 2004-2012

Dependent Variable: *Ln(Amount of milk sold as fresh (monthly, liters))*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.219		−0.153	0.215	−0.918**	−0.368	0.158
	(0.315)		(0.532)	(0.787)	(0.045)	(0.322)	(0.667)
(b). Log centered travel time to big town		−3.316***	−3.135***	−2.634	−3.595**	−4.904**	−0.172
		(0.000)	(0.001)	(0.526)	(0.046)	(0.018)	(0.886)
(c). (a) × (b)			−0.233	−0.337	−1.368	−0.156	0.509
			(0.478)	(0.687)	(0.104)	(0.648)	(0.297)
Household level controls							
Gender of household head(=1 for female)	−0.020	−0.159	−0.159	0.468	0.217	−1.036*	−0.111
	(0.923)	(0.477)	(0.479)	(0.284)	(0.601)	(0.055)	(0.756)
Average age of household head in years	−0.020	−0.019	−0.019	−0.017	−0.035	−0.049	0.006
	(0.509)	(0.544)	(0.541)	(0.760)	(0.618)	(0.491)	(0.906)
Age of HH head squared	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.497)	(0.632)	(0.638)	(0.969)	(0.678)	(0.585)	(0.933)
Average education of household head(years)	0.008	−0.006	−0.006	0.021	0.053	−0.037	−0.045
	(0.802)	(0.857)	(0.847)	(0.724)	(0.530)	(0.577)	(0.435)
Education of male adults	0.002	0.012	0.012	0.081	−0.046	−0.028	−0.053
	(0.940)	(0.709)	(0.712)	(0.316)	(0.602)	(0.629)	(0.282)
Education of female adults	0.013	0.006	0.005	0.049	−0.069	−0.029	0.178***
	(0.686)	(0.850)	(0.866)	(0.370)	(0.345)	(0.614)	(0.000)
Average household size	0.109**	0.115**	0.114**	0.053	0.149	0.201**	−0.006
	(0.021)	(0.014)	(0.014)	(0.654)	(0.249)	(0.022)	(0.939)
Number of male adults	−0.061	−0.100	−0.100	−0.008	−0.101	−0.213	0.045
	(0.464)	(0.209)	(0.211)	(0.962)	(0.526)	(0.200)	(0.708)
Number of boys	−0.107	−0.108	−0.108	0.305	−0.359	−0.445**	0.115
	(0.260)	(0.245)	(0.242)	(0.114)	(0.147)	(0.033)	(0.361)
Ln(Per capita asset value(Kshs))	0.381***	0.324***	0.326***	0.213	0.311	0.427***	0.106
	(0.000)	(0.001)	(0.001)	(0.344)	(0.135)	(0.007)	(0.532)
Average land holding (Ha)	0.068	0.105	0.103	0.870***	0.082	0.282	−0.206
	(0.524)	(0.316)	(0.326)	(0.008)	(0.637)	(0.276)	(0.451)
Landholding squared	−0.006	−0.008	−0.008	−0.129***	−0.001	−0.024	−0.002
	(0.430)	(0.252)	(0.266)	(0.004)	(0.871)	(0.195)	(0.951)
Community level controls							
Log of community population density	−0.135	−0.212	−0.239	0.998	0.124	−0.786***	0.600
	(0.555)	(0.275)	(0.262)	(0.292)	(0.638)	(0.010)	(0.339)
Constant	−0.127	1.033	1.220	−6.890	0.332	5.916*	−4.060
	(0.949)	(0.534)	(0.503)	(0.315)	(0.893)	(0.095)	(0.341)
Observations	1,426	1,426	1,426	349	343	412	322
R-squared	0.049	0.070	0.071	0.127	0.112	0.230	0.083
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.9: IMPACT OF ROAD IMPROVEMENT ON PROPORTION OF MILK SOLD: KENYA, 2004-2012

Dependent Variable: *Proportion of milk sold*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.054*		−0.047	0.012	−0.164**	−0.077	0.018
	(0.085)		(0.172)	(0.920)	(0.025)	(0.111)	(0.710)
(b). Log centered travel time to big town		−0.456***	−0.411***	−0.333	−0.190	−0.658**	−0.103
		(0.000)	(0.001)	(0.572)	(0.440)	(0.018)	(0.615)
(c). (a) × (b)			−0.048	−0.146	−0.137	−0.075	0.104
			(0.348)	(0.320)	(0.299)	(0.179)	(0.108)
Household level controls							
Gender of household head(=1 for female)	−0.006	−0.024	−0.024	0.026	0.044	−0.111	−0.019
	(0.828)	(0.408)	(0.393)	(0.684)	(0.474)	(0.102)	(0.667)
Average age of household head in years	−0.001	−0.001	−0.001	−0.002	−0.006	−0.006	0.005
	(0.838)	(0.879)	(0.870)	(0.830)	(0.597)	(0.508)	(0.520)
Age of HH head squared	0.000	0.000	0.000	0.000	0.000	0.000	−0.000
	(0.793)	(0.914)	(0.928)	(0.959)	(0.626)	(0.601)	(0.603)
Average education of household head(years)	−0.000	−0.002	−0.002	0.005	0.008	−0.011	−0.004
	(0.996)	(0.660)	(0.653)	(0.551)	(0.459)	(0.217)	(0.592)
Education of male adults	0.003	0.004	0.004	0.007	−0.003	0.005	−0.005
	(0.559)	(0.386)	(0.394)	(0.527)	(0.825)	(0.581)	(0.545)
Education of female adults	0.002	0.001	0.001	0.008	−0.014	−0.003	0.025***
	(0.663)	(0.755)	(0.818)	(0.333)	(0.170)	(0.687)	(0.002)
Average household size	0.015**	0.015**	0.015**	0.004	0.024	0.026**	0.001
	(0.028)	(0.020)	(0.021)	(0.818)	(0.199)	(0.022)	(0.921)
Number of male adults	−0.018*	−0.024**	−0.024**	−0.004	−0.017	−0.047**	−0.010
	(0.086)	(0.024)	(0.025)	(0.860)	(0.483)	(0.031)	(0.474)
Number of boys	−0.014	−0.015	−0.015	0.037	−0.046	−0.056**	0.012
	(0.263)	(0.243)	(0.243)	(0.201)	(0.195)	(0.032)	(0.375)
Ln(Per capita asset value(Kshs))	0.047***	0.040***	0.040***	0.024	0.042	0.055**	0.005
	(0.002)	(0.004)	(0.005)	(0.491)	(0.125)	(0.021)	(0.818)
Average land holding (Ha)	0.003	0.008	0.008	0.117***	0.011	0.022	−0.030
	(0.833)	(0.594)	(0.604)	(0.009)	(0.633)	(0.556)	(0.459)
Landholding squared	−0.001	−0.001	−0.001	−0.019***	−0.001	−0.002	0.000
	(0.571)	(0.375)	(0.390)	(0.002)	(0.644)	(0.545)	(0.931)
Community level controls							
Log of community population density	−0.007	−0.007	−0.020	0.179	−0.001	−0.082*	0.040
	(0.824)	(0.804)	(0.525)	(0.278)	(0.988)	(0.079)	(0.679)
Constant	−0.103	−0.023	0.065	−1.147	0.077	0.615	−0.362
	(0.707)	(0.924)	(0.795)	(0.310)	(0.805)	(0.174)	(0.587)
Observations	1,426	1,426	1,426	349	343	412	322
R-squared	0.074	0.089	0.093	0.153	0.138	0.219	0.075
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.10: IMPACT OF ROAD IMPROVEMENT ON MAIZE MARKET PARTICIPATION (KGS SOLD): KENYA, 2004-2012

Dependent Variable: *Ln(Maize sold, Kgs)*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.461		−0.460	−0.432	−0.905	−1.138**	−0.420
	(0.150)		(0.201)	(0.599)	(0.248)	(0.028)	(0.421)
(b). Log centered travel time to big town		2.774***	2.715***	5.393	−2.410	4.325***	5.031**
		(0.006)	(0.006)	(0.114)	(0.563)	(0.000)	(0.036)
(c). (a) × (b)			0.599	0.143	0.346	−0.291	1.200
			(0.160)	(0.872)	(0.695)	(0.615)	(0.118)
Household level controls							
Gender of household head(=1 for female)	0.516	0.661**	0.628**	1.089**	1.177*	−0.264	1.013
	(0.112)	(0.033)	(0.047)	(0.047)	(0.072)	(0.697)	(0.100)
Average age of household head in years	−0.053	−0.052	−0.053	−0.042	0.043	−0.060	−0.110
	(0.206)	(0.212)	(0.209)	(0.404)	(0.685)	(0.556)	(0.114)
Age of HH head squared	0.000	0.000	0.000	0.001	−0.001	0.000	0.001
	(0.305)	(0.250)	(0.265)	(0.364)	(0.504)	(0.599)	(0.118)
Average education of household head(years)	0.132***	0.143***	0.147***	0.236***	0.025	0.152**	0.140*
	(0.000)	(0.000)	(0.000)	(0.004)	(0.701)	(0.048)	(0.066)
Education of male adults	0.005	−0.002	−0.005	0.063	−0.107	0.120	−0.137*
	(0.909)	(0.961)	(0.910)	(0.269)	(0.389)	(0.103)	(0.077)
Education of female adults	−0.013	0.002	−0.008	0.054	−0.055	−0.054	0.087
	(0.740)	(0.969)	(0.830)	(0.452)	(0.430)	(0.432)	(0.286)
Average household size	−0.060	−0.068	−0.063	−0.081	0.089	−0.116*	−0.094
	(0.204)	(0.154)	(0.186)	(0.378)	(0.378)	(0.067)	(0.322)
Number of male adults	0.082	0.113	0.119	−0.183	0.051	0.171	0.298
	(0.370)	(0.231)	(0.196)	(0.240)	(0.804)	(0.372)	(0.123)
Number of boys	−0.070	−0.076	−0.069	0.085	−0.209	0.063	−0.194
	(0.523)	(0.498)	(0.530)	(0.726)	(0.550)	(0.758)	(0.142)
Ln(Per capita asset value(Kshs))	−0.065	0.009	−0.021	−0.192	−0.059	0.125	0.185
	(0.526)	(0.921)	(0.825)	(0.237)	(0.798)	(0.520)	(0.245)
Average land holding (Ha)	0.498***	0.458***	0.472***	−0.156	0.552**	0.840***	0.440
	(0.002)	(0.003)	(0.002)	(0.703)	(0.030)	(0.005)	(0.281)
Landholding squared	−0.032***	−0.029***	−0.030***	0.086	−0.037**	−0.046*	−0.028
	(0.002)	(0.003)	(0.001)	(0.146)	(0.018)	(0.060)	(0.369)
Community level controls							
Log of community population density	−0.698*	−0.347	−0.636	1.789**	−0.689	−1.424*	0.527
	(0.095)	(0.417)	(0.133)	(0.038)	(0.253)	(0.058)	(0.600)
Season(short==2)	0.065	0.172	0.173	0.430	0.666	−0.341	0.593**
	(0.791)	(0.467)	(0.473)	(0.228)	(0.272)	(0.605)	(0.043)
Constant	7.757**	4.532	6.713**	−8.521	6.059	11.079*	−1.060
	(0.014)	(0.139)	(0.032)	(0.164)	(0.171)	(0.074)	(0.886)
Observations	1,426	1,426	1,426	349	343	412	322
R-squared	0.110	0.116	0.125	0.264	0.215	0.188	0.161
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.11: IMPACT OF ROAD IMPROVEMENT ON PROPORTION OF MAIZE SOLD: KENYA, 2004-2012

Dependent Variable: *Proportion of maize sold*							
VARIABLES	(1) Nearby market	(2) Nearby big town	(3) Full model	(4) 0 - 84	(5) 85 - 165	(6) 166 - 305	(7) Over 306
Variables of interest							
(a). Log centered travel time to nearby market	−0.040		−0.041	−0.055	−0.098	−0.080*	−0.053
	(0.196)		(0.239)	(0.572)	(0.246)	(0.068)	(0.260)
(b). Log centered travel time to big town		0.188*	0.192*	0.306	−0.054	0.220*	0.539**
		(0.076)	(0.079)	(0.319)	(0.931)	(0.068)	(0.027)
(c). (a) × (b)			0.033	0.035	0.054	−0.032	−0.003
			(0.443)	(0.735)	(0.606)	(0.561)	(0.953)
Household level controls							
Gender of household head(=1 for female)	0.040	0.050*	0.048	0.100**	0.127*	−0.056	0.080
	(0.179)	(0.081)	(0.101)	(0.035)	(0.071)	(0.418)	(0.161)
Average age of household head in years	−0.004	−0.004	−0.004	−0.005	0.007	−0.006	−0.007
	(0.387)	(0.394)	(0.386)	(0.407)	(0.524)	(0.502)	(0.280)
Age of HH head squared	0.000	0.000	0.000	0.000	−0.000	0.000	0.000
	(0.499)	(0.442)	(0.457)	(0.359)	(0.380)	(0.454)	(0.310)
Average education of household head(years)	0.011***	0.012***	0.012***	0.024***	0.005	0.004	0.015**
	(0.002)	(0.001)	(0.001)	(0.003)	(0.597)	(0.595)	(0.049)
Education of male adults	0.004	0.004	0.004	0.010*	−0.006	0.015*	−0.008
	(0.284)	(0.353)	(0.375)	(0.087)	(0.600)	(0.066)	(0.399)
Education of female adults	0.000	0.002	0.001	0.012	−0.013	0.004	0.004
	(0.924)	(0.728)	(0.855)	(0.218)	(0.118)	(0.560)	(0.557)
Average household size	−0.006	−0.007	−0.006	−0.014	0.008	−0.007	−0.009
	(0.142)	(0.110)	(0.128)	(0.111)	(0.388)	(0.229)	(0.250)
Number of male adults	0.000	0.003	0.003	−0.017	0.004	−0.006	0.018
	(0.957)	(0.774)	(0.730)	(0.367)	(0.863)	(0.758)	(0.250)
Number of boys	0.003	0.002	0.003	0.020	−0.008	0.018	−0.014
	(0.801)	(0.837)	(0.798)	(0.403)	(0.839)	(0.234)	(0.291)
Ln(Per capita asset value(Kshs))	−0.014	−0.008	−0.010	−0.025	−0.020	0.010	0.005
	(0.238)	(0.449)	(0.343)	(0.198)	(0.470)	(0.643)	(0.769)
Average land holding (Ha)	0.024*	0.022	0.023	−0.050	0.043*	0.069**	0.001
	(0.094)	(0.139)	(0.116)	(0.175)	(0.074)	(0.018)	(0.970)
Landholding squared	−0.001	−0.001	−0.001	0.013**	−0.002*	−0.004*	0.000
	(0.140)	(0.202)	(0.167)	(0.033)	(0.089)	(0.089)	(0.938)
Community level controls							
Log of community population density	−0.068*	−0.040	−0.063	0.175*	−0.066	−0.145**	0.041
	(0.081)	(0.304)	(0.112)	(0.061)	(0.207)	(0.037)	(0.651)
Season(short==2)	−0.007	0.001	0.001	0.016	0.115*	−0.089	0.043
	(0.797)	(0.973)	(0.971)	(0.661)	(0.056)	(0.195)	(0.104)
Constant	0.675**	0.428	0.597**	−0.873	0.485	1.021*	−0.079
	(0.023)	(0.126)	(0.041)	(0.169)	(0.262)	(0.060)	(0.905)
Observations	1,426	1,426	1,426	349	343	412	322
R-squared	0.084	0.086	0.091	0.224	0.186	0.154	0.124
Number of hhid	724	724	724	177	175	209	163
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.

TABLE 4.12: TOBIT FE HONORÉ (1992) OF THE IMPACT OF ROAD IMPROVEMENT ON VARIOUS OUTCOMES OF INTEREST

VARIABLES	(1) landhyvprop	(2) lnqfertnpk	(3) lnqmanure	(4) lnyieldmaize	(5) maizeratio	(6) milkpropsold
Variables of interest						
(a). Log centered travel time to nearby market	−0.025	−0.030	−0.488**	0.249	−0.074	−0.075
	(0.582)	(0.789)	(0.025)	(0.106)	(0.272)	(0.185)
(b). Log centered travel time to big town	−0.381**	−0.232	−1.440*	−1.045**	0.401*	−0.559***
	(0.019)	(0.580)	(0.063)	(0.021)	(0.066)	(0.000)
(c). (a) × (b)	0.298***	0.188	0.067	0.545**	0.074	−0.090
	(0.000)	(0.269)	(0.847)	(0.038)	(0.450)	(0.227)
Household level controls						
Gender of household head(=1 for female)	0.141**	0.020	0.001	0.038	0.098	−0.029
	(0.012)	(0.881)	(0.995)	(0.830)	(0.283)	(0.682)
Average age of household head in years	−0.004	−0.025	0.018	0.019	−0.008	−0.002
	(0.623)	(0.157)	(0.532)	(0.434)	(0.472)	(0.751)
Age of HH head squared	0.000	0.000*	−0.000	−0.000	0.000	0.000
	(0.751)	(0.097)	(0.508)	(0.556)	(0.583)	(0.900)
Average education of household head(years)	0.002	−0.006	0.011	0.026	0.022*	−0.003
	(0.782)	(0.695)	(0.666)	(0.364)	(0.052)	(0.748)
Education of male adults	−0.004	−0.026	0.009	−0.019	0.014	0.004
	(0.541)	(0.104)	(0.735)	(0.491)	(0.201)	(0.658)
Education of female adults	0.003	0.015	0.018	−0.014	0.006	0.002
	(0.591)	(0.349)	(0.545)	(0.544)	(0.594)	(0.701)
Average household size	0.016*	0.044*	0.002	0.012	−0.010	0.025**
	(0.071)	(0.055)	(0.949)	(0.712)	(0.406)	(0.031)
Number of male adults	0.008	−0.028	−0.051	0.015	0.005	−0.038**
	(0.606)	(0.427)	(0.424)	(0.784)	(0.811)	(0.026)
Number of boys	−0.001	−0.049	0.053	−0.119**	0.005	−0.026
	(0.964)	(0.245)	(0.486)	(0.047)	(0.863)	(0.235)
Ln(Per capita asset value(Kshs))	0.019	0.001	0.077	0.035	0.007	0.059***
	(0.252)	(0.983)	(0.358)	(0.626)	(0.815)	(0.006)
Average land holding (Ha)	−0.003	−0.031	−0.248***	−0.152**	0.048	0.022
	(0.860)	(0.536)	(0.004)	(0.017)	(0.130)	(0.442)
Landholding squared	−0.000	0.002	0.009	0.007	−0.002	−0.003
	(0.896)	(0.688)	(0.317)	(0.113)	(0.137)	(0.202)
Community level controls						
Log of community population density	0.070	−0.058	0.553***	0.273	−0.155***	−0.007
	(0.120)	(0.690)	(0.007)	(0.141)	(0.008)	(0.901)
Other controls						
Season(short==2)	0.159***	−0.112***	−0.065	−0.025	0.012	
	(0.000)	(0.004)	(0.347)	(0.737)	(0.875)	
Dummy for planted hybrid maize, =1		0.226***	0.221**	0.081		
		(0.001)	(0.026)	(0.460)		
intercrop		−0.060	−0.329*	0.459		
		(0.648)	(0.075)	(0.102)		
Observations	2,225	1,605	1,274	2,225	1,426	1,426
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.
4). Column (1)-Proportion of land under hybrid maize, (2)-ln(NPK equivalent inorganic fertilizer(kg/ha)), (3)-ln(Manure intensification (kg/ha)), (4)- ln(Maize yield (kg/ha)), (5)- Maize market participation, (6)- Milk market participation.

TABLE 4.13: IMPACT OF ROAD IMPROVEMENT WHEN INTERACTED WITH COMMUNITY MOBILE NETWORK AVAILABILITY

VARIABLES	(1) landhyvprop	(2) lnqfertnpk	(3) lnqmanure	(4) lnyieldmaize	(5) maizeratio	(6) milkpropsold
Variables of interest						
(a). Log centered travel time to nearby market	−0.069	0.010	−0.207	0.382	−0.051	−0.030
	(0.115)	(0.943)	(0.263)	(0.199)	(0.172)	(0.460)
(b). Log centered travel time to big town	−0.286***	−0.131	−1.727*	−0.506	0.223**	−0.442***
	(0.008)	(0.775)	(0.065)	(0.437)	(0.049)	(0.002)
(c). (a) × (b)	0.183**	0.139	−0.879**	0.108	0.051	−0.104
	(0.036)	(0.500)	(0.050)	(0.817)	(0.334)	(0.243)
Community mobile network availability(Available==1)	−0.068**	0.148*	0.045	0.263	−0.010	−0.006
	(0.049)	(0.095)	(0.811)	(0.165)	(0.733)	(0.856)
Community mobile network availability×(a)	0.003	0.017	−0.295*	−0.154	0.002	−0.021
	(0.951)	(0.849)	(0.062)	(0.492)	(0.908)	(0.575)
Community mobile network availability×(b)	−0.002	−0.074	−0.145	−0.660**	−0.048	0.018
	(0.968)	(0.625)	(0.715)	(0.017)	(0.285)	(0.779)
Community mobile network availability×(c)	−0.049	0.145	1.147***	0.262	−0.047	0.067
	(0.506)	(0.333)	(0.005)	(0.486)	(0.195)	(0.430)
Household level controls						
Gender of household head(=1 for female)	0.100**	0.024	−0.055	0.009	0.048	−0.027
	(0.011)	(0.865)	(0.771)	(0.955)	(0.102)	(0.371)
Average age of household head in years	−0.002	−0.025	0.020	0.018	−0.004	−0.001
	(0.759)	(0.192)	(0.428)	(0.425)	(0.385)	(0.865)
Age of HH head squared	0.000	0.000	−0.000	−0.000	0.000	0.000
	(0.870)	(0.139)	(0.371)	(0.530)	(0.461)	(0.924)
Average education of household head(years)	0.005	−0.006	0.013	0.025	0.012***	−0.002
	(0.311)	(0.702)	(0.660)	(0.292)	(0.001)	(0.645)
Education of male adults	−0.003	−0.025	0.010	−0.019	0.004	0.004
	(0.578)	(0.171)	(0.738)	(0.404)	(0.399)	(0.395)
Education of female adults	0.006	0.013	0.014	−0.016	0.001	0.001
	(0.246)	(0.317)	(0.642)	(0.530)	(0.806)	(0.833)
Average household size	0.005	0.045**	0.012	0.013	−0.007*	0.016**
	(0.398)	(0.031)	(0.741)	(0.650)	(0.100)	(0.019)
Number of male adults	0.012	−0.026	−0.056	0.013	0.003	−0.024**
	(0.339)	(0.487)	(0.344)	(0.788)	(0.752)	(0.024)
Number of boys	0.010	−0.051	0.058	−0.120**	0.004	−0.015
	(0.403)	(0.209)	(0.441)	(0.028)	(0.745)	(0.245)
Ln(Per capita asset value(Kshs))	0.016	−0.002	0.074	0.045	−0.011	0.040***
	(0.211)	(0.958)	(0.423)	(0.447)	(0.329)	(0.005)
Average land holding (Ha)	−0.008	−0.034	−0.236***	−0.147**	0.022	0.008
	(0.616)	(0.503)	(0.004)	(0.031)	(0.119)	(0.591)
Landholding squared	0.000	0.003	0.008	0.006	−0.001	−0.001
	(0.909)	(0.651)	(0.300)	(0.155)	(0.181)	(0.375)
Community level controls						
Log of community population density	0.062	−0.092	0.522**	0.241	−0.059	−0.022
	(0.100)	(0.527)	(0.012)	(0.446)	(0.140)	(0.482)
Other controls						
Season(short==2)	0.083***	−0.112***	−0.063	−0.028	0.002	
	(0.000)	(0.003)	(0.436)	(0.807)	(0.942)	
Dummy for planted hybrid maize, =1		0.226***	0.224**	0.060		
		(0.001)	(0.014)	(0.620)		
intercrop		−0.053	−0.315*	0.445		
		(0.656)	(0.077)	(0.165)		
Constant	−0.224	4.678***	2.921*	3.228*	0.587**	0.082
	(0.380)	(0.000)	(0.085)	(0.099)	(0.049)	(0.742)
Observations	2,225	1,605	1,274	2,225	1,426	1,426
R-squared	0.173	0.105	0.167	0.284	0.094	0.094
Number of hhid	724	636	579	724	724	724
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Time distance in minutes by motor vehicle; Robust standard errors clustered at community level; All equations include year × agrozone; Controls include household and village level regressors as described in data section.
4). Column (1)-Proportion of land under hybrid maize, (2)-ln(NPK equivalent inorganic fertilizer(kg/ha)), (3)-ln(Manure intensification (kg/ha)), (4)-ln(Maize yield (kg/ha)), (5)- Maize market participation, (6)- Milk market participation.

Tables used in Chapter 5

Table 5.1: Household and community level summary statistics.

Variables	year=2004			year=2012			
	Obs	*Mean*	*Sd*	*Obs*	*Mean*	*Sd*	*MeanDiff*
Panel A:Household level							
Characteristics							
Average education of household head(years)	729	6.63	4.48	729	6.75	4.37	0.122
Gender of household head(=1 for female)	729	0.21	0.41	729	0.28	0.45	0.075***
Average age of household head in years	729	55.33	13.8	729	61.71	14.01	6.380***
Mean adult education(years)	729	7.13	2.83	729	7.59	2.88	0.465***
Average household size	729	6.42	2.89	729	5.53	2.9	−0.893***
Percentage of households belonging to a self help group in 2012	729	0	0	729	0.46	0.5	0.462***
Percentage of households owning at least one mobile phone	729	0.12	0.32	729	0.93	0.25	0.813***
Per capita asset value ($\times 10^4$)	729	1.09	2.96	729	2.47	7.15	1.380***
Per capita land holding	729	0.36	0.49	729	0.38	0.48	0.025
Average time to nearby market (minutes)	729	20.91	19.68	729	14.58	11.76	−6.331***
Income							
Per capita income overall (Kshs)	729	23095.86	27462.79	729	63602.27	88028.42	40506.416***
Per capita farm income	729	6187.22	9312.99	729	22451.35	31835.85	16264.129***
Per capita livestock income	729	4770.27	9347.06	729	15697.41	32310.89	10927.137***
Per capita non-farm income	729	9602.13	18402.03	729	18969.03	44689.01	9366.907***
Per capita non-labor income	729	2536.24	6999.38	729	6606.83	28354.46	4070.593***
Expenditure							
Per capita overall expenditure	729	21089.91	20852	729	46968.9	36032.96	25878.995***
Per capita expenditure on staple food	729	3175.95	2386.44	729	23860.35	23556.06	20684.397***
Per capita expenditure on fresh food	729	2692.85	2265.31	729	7442.85	5973.87	4749.998***
Per capita expenditure on non-fresh food	729	2720.26	1867.78	729	2750.45	2684.12	30.187
Per capita expenditure on non food items	729	9716.28	15961.92	729	10270.63	18706.71	554.354
Per capita expenditure on contributions	729	2181.96	3623.74	729	1127.86	2772.76	−1054.099***
Per capita savings	729	601.89	1822.84	729	1516.76	3397.03	914.869***
Panel B: Community level							
Percentage of mobile network coverage	97	0.62	0.49	97	1	0	0.381***
Average time to nearby big town (minutes)	97	95.27	46.39	97	78.16	37.17	−17.110***
Community population density	97	671.38	881.29	97	1006.49	1300.05	335.112**

Significance level: *** p<0.01, ** p<0.05, * p<0.1

TABLE 5.2: CORRELATIONS BETWEEN ROAD ACCESS AND INCOME AND EXPENDITURE VARIABLES

	Centered log time distance in minutes (1)	(2)
	To market	To big town
Income		
Log per capita overall income	−0.0228	−0.102***
Log per capita from farm income	−0.0621*	−0.0380
Log per capita livestock income	0.0442	−0.0827**
Log per capita non-farm income	0.0570*	0.0327
Log per capita non-labor income	−0.00806	−0.0582*
Share of farm income	−0.0760**	0.0829**
Share of non-farm income	0.0345	0.0337
Share of livestock income	0.0697**	−0.0991***
Share of non-labor income	−0.0312	−0.0539*
Expenditure		
Log per capita overall expenditure	−0.109***	−0.111***
Log per capita expenditure on stable food	−0.159***	−0.107***
Log per capita expenditure on fresh food items	−0.110***	−0.138***
Log per capita expenditure on non-fresh food items	−0.00438	−0.0474
Log per capita expenditure on non-food items	0.0219	−0.0803**
Log per capita expenditure on contributions	0.0688**	0.0155
Log per capita expenditure on savings	−0.0164	−0.0859***
Share of expenditure on staple food	−0.157***	−0.0422
Share of expenditure on fresh food	−0.0309	−0.0533*
Share of expenditure on non-fresh food	0.0750**	0.0992***
Share of expenditure on non-food items	0.124***	0.0310
Share of expenditure on contributions	0.118***	0.0393
Savings share	−0.0143	−0.0671**

Significance level: *** p<0.01, ** p<0.05, * p<0.1

TABLE 5.3: REGRESSION ESTIMATES FOR PER-CAPITA INCOME AND BY SOURCE (PREFERRED MODEL ONLY), 2004-2012

VARIABLES	(1) lnpcincome	(2) lnpcfarminc	(3) lnpclvinc	(4) lnpcnonfarmincome	(5) lnpcnonlaborinc
Variables of interest					
(a). Log centered travel time to nearby market	−0.121	−0.192	−0.751*	−0.542	−0.688
	(0.304)	(0.356)	(0.088)	(0.230)	(0.128)
(b). Log centered travel time to big town	−1.901***	−3.222***	−3.736***	−5.945***	−5.860***
	(0.000)	(0.000)	(0.001)	(0.000)	(0.001)
(c). (a) × (b)	0.391**	0.573**	0.780	1.156*	−0.305
	(0.019)	(0.046)	(0.204)	(0.064)	(0.727)
Household level controls					
Household head gender(female==1)	−0.274**	−0.063	−0.504	−0.145	0.135
	(0.017)	(0.713)	(0.118)	(0.782)	(0.824)
Average household size	−0.074***	−0.073**	−0.061	0.000	−0.092
	(0.001)	(0.013)	(0.338)	(1.000)	(0.382)
Average number of men in a household	0.034	−0.001	−0.121	0.099	0.143
	(0.343)	(0.989)	(0.313)	(0.450)	(0.425)
Average number of boys	−0.034	−0.039	−0.145	0.069	−0.030
	(0.377)	(0.486)	(0.238)	(0.638)	(0.892)
Average household head age(years)	0.007	0.039	0.001	−0.305***	0.133
	(0.684)	(0.127)	(0.979)	(0.000)	(0.242)
Household head age squared	−0.000	−0.000*	0.000	0.003***	−0.000
	(0.725)	(0.091)	(0.996)	(0.000)	(0.645)
Average education attainment for men in a household	0.029**	0.022	0.040	0.134**	0.074
	(0.041)	(0.291)	(0.428)	(0.036)	(0.391)
Average education attainment for women in a household	0.049***	0.010	0.008	0.138**	0.035
	(0.001)	(0.589)	(0.868)	(0.038)	(0.699)
Member of self-help group	0.208**	0.017	−0.049	0.153	0.769
	(0.028)	(0.910)	(0.843)	(0.654)	(0.141)
Household per capita assets in 'Kshs	0.000***	0.000	−0.000	0.000	0.000
	(0.003)	(0.260)	(0.779)	(0.466)	(0.285)
Household per capita land holding (Ha)	0.522***	0.681***	0.345	−0.728	1.665***
	(0.000)	(0.000)	(0.204)	(0.176)	(0.002)
Community level controls					
Log of community population density	0.204	0.797**	0.692*	0.727*	1.817***
	(0.153)	(0.014)	(0.074)	(0.088)	(0.002)
Constant	8.202***	2.514	2.806	10.064***	−13.421***
	(0.000)	(0.259)	(0.334)	(0.003)	(0.009)
Observations	1,457	1,455	1,430	1,190	1,042
R-squared	0.458	0.510	0.420	0.356	0.488
Number of hhid	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-lnpcincome: ln(percapita overal income) (b)- lnpcfarminc: ln(percapita farm income) (c)-lnpclvinc: ln(percapita livestock income) (d)-lnpcnonfarmincome: ln(percapita non-farm income) (e)-lnpcnonlaborinc: ln(percapita non-labor income)

TABLE 5.4: REGRESSION ESTIMATES FOR SHARE OF INCOME BY SOURCE (PREFERRED MODEL ONLY), 2004-2012

VARIABLES	(1) shfarm	(2) shnonfarm	(3) shlvinc	(4) shnlb
Variables of interest				
(a). Log centered travel time to nearby market	−0.039	0.011	−0.010	0.023
	(0.214)	(0.760)	(0.709)	(0.497)
(b). Log centered travel time to big town	−0.071	−0.145	−0.082	0.092
	(0.489)	(0.131)	(0.332)	(0.414)
(c). (a) × (b)	0.025	0.079	0.022	−0.048
	(0.584)	(0.115)	(0.611)	(0.358)
Household level controls				
Household head gender(female==1)	0.029	−0.001	−0.025	0.041
	(0.380)	(0.975)	(0.351)	(0.180)
Average household size	−0.015**	0.006	−0.002	−0.005
	(0.021)	(0.447)	(0.637)	(0.355)
Average number of men in a household	0.005	0.014	−0.011	−0.016
	(0.584)	(0.267)	(0.260)	(0.161)
Average number of boys	0.014	0.000	−0.010	−0.004
	(0.307)	(0.988)	(0.321)	(0.741)
Average household head age(years)	0.001	−0.009	−0.005	−0.008
	(0.859)	(0.156)	(0.314)	(0.206)
Household head age squared	−0.000	0.000	0.000	0.000**
	(0.869)	(0.168)	(0.242)	(0.026)
Average education attainment for men in a household	0.001	0.006	−0.006*	−0.004
	(0.864)	(0.352)	(0.082)	(0.402)
Average education attainment for women in a household	−0.009**	0.005	−0.001	0.009*
	(0.038)	(0.367)	(0.727)	(0.077)
Member of self-help group	−0.038	−0.031	−0.011	0.039
	(0.107)	(0.296)	(0.528)	(0.142)
Household per capita assets in 'Kshs	−0.000	−0.000	0.000	0.000
	(0.409)	(0.738)	(0.671)	(0.761)
Household per capita land holding (Ha)	−0.008	−0.097***	0.012	0.023
	(0.756)	(0.003)	(0.626)	(0.485)
Community level controls				
Log of community population density	0.034	0.009	0.006	0.025
	(0.369)	(0.790)	(0.833)	(0.523)
Constant	0.227	0.524*	0.375	0.043
	(0.403)	(0.064)	(0.116)	(0.878)
Observations	1,455	1,208	1,433	1,072
R-squared	0.145	0.087	0.049	0.141
Number of hhid	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Income composition share (a)-shfarm: farm income (b)-shnonfarm: non-farm income (c)-shlvinc: livestock (d)-incomeshnlb: non-labor income

TABLE 5.5: REGRESSION ESTIMATES FOR PER-CAPITA EXPENDITURE AND BY TYPE (PREFERRED MODEL ONLY), 2004-2012

VARIABLES	(1) lnpctexpend	(2) lnpcexstaple	(3) lnpcexfresh	(4) lnpcexnonfresh	(5) lnpcexnonfood	(6) lnpcexcontri	(7) lnpcsavings
Variables of interest							
(a). Log centered travel time to nearby market	−0.199**	−0.623***	−0.296***	0.223***	0.110	0.177	−0.096
	(0.012)	(0.001)	(0.004)	(0.005)	(0.247)	(0.156)	(0.668)
(b). Log centered travel time to big town	−1.046***	−2.377***	−2.067***	0.724**	−0.649	1.488**	−1.809**
	(0.000)	(0.001)	(0.000)	(0.023)	(0.127)	(0.011)	(0.034)
(c). (a) × (b)	0.068	0.367	0.171	0.075	0.021	−0.041	0.132
	(0.591)	(0.205)	(0.359)	(0.442)	(0.885)	(0.844)	(0.707)
Household level controls							
Household head gender(female==1)	0.032	0.223	0.031	−0.137*	−0.166	−0.152	−0.242
	(0.671)	(0.108)	(0.778)	(0.082)	(0.134)	(0.344)	(0.353)
Average household size	−0.116***	−0.125***	−0.104***	−0.122***	−0.101***	−0.081***	−0.087**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.039)
Average number of men in a household	0.054**	0.025	0.007	0.021	0.083**	−0.056	−0.028
	(0.015)	(0.526)	(0.785)	(0.287)	(0.015)	(0.230)	(0.695)
Average number of boys	−0.002	−0.018	−0.007	0.047*	0.000	−0.019	−0.151*
	(0.954)	(0.703)	(0.852)	(0.088)	(1.000)	(0.740)	(0.078)
Average household head age(years)	−0.016	−0.021	−0.008	0.017	0.003	−0.048*	0.014
	(0.141)	(0.301)	(0.601)	(0.176)	(0.858)	(0.084)	(0.735)
Household head age squared	0.000*	0.000*	0.000	−0.000*	−0.000	0.000	−0.000
	(0.060)	(0.082)	(0.383)	(0.090)	(0.811)	(0.413)	(0.667)
Average education attainment for men in a household	0.011	0.022	0.006	−0.008	0.020	0.010	0.029
	(0.196)	(0.145)	(0.741)	(0.391)	(0.137)	(0.655)	(0.347)
Average education attainment for women in a household	0.028***	0.037**	0.021*	−0.000	0.032**	0.020	0.026
	(0.004)	(0.014)	(0.071)	(0.970)	(0.033)	(0.340)	(0.380)
Member of self-help group	0.139**	0.321***	0.121	−0.043	0.006	−0.399***	1.595***
	(0.025)	(0.001)	(0.146)	(0.460)	(0.947)	(0.003)	(0.000)
Household per capita assets in 'Kshs	0.000	0.000	0.000*	0.000***	−0.000	−0.000	0.000
	(0.751)	(0.292)	(0.063)	(0.000)	(0.792)	(0.901)	(0.212)
Household per capita land holding (Ha)	0.217***	0.223*	0.313***	0.246***	0.115	0.046	−0.179
	(0.007)	(0.055)	(0.000)	(0.003)	(0.320)	(0.808)	(0.516)
Community level controls							
Log of community population density	0.087	0.532***	0.211	−0.145**	−0.153	−0.492***	0.132
	(0.351)	(0.003)	(0.125)	(0.043)	(0.144)	(0.004)	(0.584)
Constant	9.933***	5.350***	7.032***	8.810***	9.670***	12.299***	4.479**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.014)
Observations	1,458	1,458	1,458	1,457	1,452	1,431	1,363
R-squared	0.591	0.694	0.568	0.243	0.115	0.283	0.345
Number of hhid	729	729	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-lnpctexpend: ln(percapita overall expenditure) (b)-lnpcexstaple: ln(percapita staple food) (c)-lnpcexfresh: ln(percapita fresh food) (d)-lnpcexnonfresh: ln(percapita non-freshh food) (e)-lnpcexnonfood: ln(percapita non-food) (f)-lnpcexc

TABLE 5.6: REGRESSION ESTIMATES FOR SHARE OF EXPENDITURE BY TYPE (PREFERRED MODEL ONLY), 2004-2012

VARIABLES	(1) shstaple	(2) shfresh	(3) shnonfresh	(4) shnonfood	(5) shcontri	(6) shsave
Variables of interest						
(a). Log centered travel time to nearby market	−0.125***	−0.014	0.044***	0.074***	0.019***	0.001
	(0.000)	(0.164)	(0.000)	(0.007)	(0.004)	(0.895)
(b). Log centered travel time to big town	−0.284**	−0.138***	0.142***	0.124	0.134***	0.015
	(0.050)	(0.001)	(0.000)	(0.269)	(0.000)	(0.342)
(c). (a) × (b)	0.026	0.012	0.002	−0.030	−0.010	0.000
	(0.622)	(0.566)	(0.872)	(0.460)	(0.433)	(0.985)
Household level controls						
Household head gender(female==1)	0.063**	−0.003	−0.016	−0.042	0.003	−0.008
	(0.014)	(0.817)	(0.149)	(0.109)	(0.737)	(0.161)
Average household size	−0.004	0.004	−0.001	0.002	−0.000	−0.000
	(0.410)	(0.130)	(0.531)	(0.586)	(0.936)	(0.657)
Average number of men in a household	−0.002	−0.008**	−0.001	0.013*	−0.001	−0.001
	(0.783)	(0.017)	(0.838)	(0.092)	(0.680)	(0.526)
Average number of boys	−0.004	−0.001	0.004	0.000	0.001	−0.004*
	(0.635)	(0.910)	(0.237)	(0.967)	(0.659)	(0.056)
Average household head age(years)	−0.004	0.001	0.004**	0.003	−0.005**	−0.000
	(0.277)	(0.648)	(0.021)	(0.512)	(0.011)	(0.833)
Household head age squared	0.000*	−0.000	−0.000***	−0.000	0.000**	0.000
	(0.075)	(0.610)	(0.007)	(0.355)	(0.039)	(0.969)
Average education attainment for men in a household	0.002	−0.000	−0.002*	0.001	−0.000	−0.001
	(0.529)	(0.909)	(0.100)	(0.742)	(0.851)	(0.177)
Average education attainment for women in a household	0.002	−0.002*	−0.003**	0.002	−0.000	0.001
	(0.373)	(0.086)	(0.019)	(0.450)	(0.911)	(0.478)
Member of self-help group	0.049***	0.003	−0.022***	−0.034**	−0.034***	0.039***
	(0.007)	(0.711)	(0.008)	(0.033)	(0.000)	(0.000)
Household per capita assets in 'Kshs	−0.000	0.000	0.000**	−0.000	−0.000	0.000*
	(0.914)	(0.269)	(0.011)	(0.277)	(0.295)	(0.057)
Household per capita land holding (Ha)	0.001	0.017*	0.012	−0.027	−0.004	0.003
	(0.972)	(0.088)	(0.243)	(0.178)	(0.619)	(0.571)
Community level controls						
Log of community population density	0.097***	0.021	−0.021**	−0.075***	−0.020**	−0.000
	(0.004)	(0.129)	(0.041)	(0.004)	(0.012)	(0.951)
Constant	−0.311	0.020	0.200**	0.724***	0.363***	0.044
	(0.141)	(0.838)	(0.018)	(0.000)	(0.000)	(0.433)
Observations	1,458	1,458	1,457	1,452	1,431	1,363
R-squared	0.591	0.098	0.456	0.355	0.446	0.180
Number of hhid	729	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-shstaple: Share of staple food (b)-shfresh: Share of non-staple food (c)-shnonfresh: Share of non fresh food (d)-shnonfood: Share of non-food (e)-shcontri: Share of contributions (f)-shsave: Share of savings

Tables used in Chapter 6

TABLE 6.1: SUMMARY STATISTICS FOR 210 CONSTITUENCIES

Variable	Mean	Std. Dev.
Cumulative CDF (2003-2007, USD 2012, $\times 10^3$)	1274.558	146.071
Cumulative CDF (2008-2011, USD 2012, $\times 10^3$)	3390.357	416.112
Population density (cons, 1999)	619.278	2064.417
Population density (cons, 2009)	784.186	2617.417
Share of president's vote in constituency (2002)	0.591	0.283
Share of president's vote in constituency (2007)	0.433	0.34
Cabinet Member(=1, 2003-2007)	0.086	0.281
Cabinet Member(=1, 2008-2012)	0.181	0.386
Member of ruling party(=1, 2003-2007)	0.629	0.484
N	210	

TABLE 6.2: SUMMARY STATISTICS FOR 98 COMMUNITIES COVERED BY REPEAT SURVEY

Variable	Mean	Std. Dev.
Time distance in minutes to nearby active market (2012)	14.485	6.838
Time distance in minutes to nearby active market (2004)	21.423	11.416
Time distance in minutes to nearby big town(2012)	78.771	33.7
Time distance in minutes to nearby big town(2004)	95.949	42.738
Cumulative CDF (2003-2007, USD 2012, $\times 10^3$)	1292.259	138.224
Cumulative CDF (2008-2011, USD 2012, $\times 10^3$)	3386.302	350.752
Population density (cons, 1999)	395.932	237.662
Population density (cons, 2009)	459.541	268.657
Share of president's vote in constituency (2002)	0.603	0.273
Share of president's vote in constituency (2007)	0.61	0.363
Cabinet Member(=1, 2003-2007)	0.041	0.199
Cabinet Member(=1, 2008-2012)	0.082	0.275
Member of ruling party(=1, 2003-2007)	0.765	0.426
Mombasa-Malaba highway passes the dist(=1)	0.408	0.494
District shares international boundary (Shares=1)	0.051	0.221
Minimum light intensity (DN,2004)	0	0
Maximum light intensity (DN,2004)	11.837	12.115
Total sum of light intensity (DN,2004)	1247.296	1643.887
Mean light intensity (DN,2004)	0.927	1.421
Minimum light intensity (DN,2012)	0	0
Maximum light intensity (DN,2012)	21.347	15.866
Total sum of light intensity (DN,2012)	3157.224	3263.755
Mean light intensity (DN,2004)	2.167	2.65
N	98	

TABLE 6.3: FACTORS INFLUENCING ALLOCATION OF CONSTITUENCY DEVELOPMENT FUND (CDF) IN KENYA, (2003-07)

Dependent Variable: *Log of cumulative CDF (2003-2007)*					
VARIABLES	(1)	(2)	(3)	(4)	(5)
Log mean light intensity (2004)	−0.0131***	−0.0132***	−0.0132***	−0.0132***	−0.00431
	(0.00242)	(0.00243)	(0.00243)	(0.00243)	(0.00267)
Population growth rate (yearly)	−0.250*	−0.253*	−0.252*	−0.253*	−0.235**
	(0.127)	(0.133)	(0.130)	(0.133)	(0.119)
Log population density (cons, 1999)	0.201***	0.201***	0.201***	0.201***	0.172***
	(0.0158)	(0.0161)	(0.0166)	(0.0169)	(0.0162)
Log area (cons, sqkm)	0.215***	0.215***	0.215***	0.215***	0.201***
	(0.0165)	(0.0167)	(0.0170)	(0.0174)	(0.0148)
Share of president's vote in constituency (2002)		−0.00200		−0.00164	
		(0.0220)		(0.0363)	
Member, rulling party (2003-07)			−0.00183	−0.000279	
			(0.0116)	(0.0200)	
Cabinet Member(=1, 2003-2007)		−0.00520		−0.00516	
		(0.0246)		(0.0251)	
Ditrict tribe over 50% =Kalenjin					−0.0604***
					(0.0133)
Ditrict tribe over 50% =Kamba					−0.0184
					(0.0222)
Ditrict tribe over 50% =Kikuyu					−0.122***
					(0.0135)
Ditrict tribe over 50% =Kisii					0.0638***
					(0.0142)
Ditrict tribe over 50% =Luhya					0.0286*
					(0.0167)
Ditrict tribe over 50% =Luo					−0.0374
					(0.0230)
Ditrict tribe over 50% =Meru					−0.0409**
					(0.0203)
Ditrict tribe over 50% =Others					−0.0760***
					(0.0235)
Constant	16.05***	16.05***	16.05***	16.05***	16.36***
	(0.187)	(0.188)	(0.193)	(0.199)	(0.182)
Observations	210	210	210	210	210
R-squared	0.497	0.497	0.497	0.497	0.669

Notes:
1). Reporting standard errors in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Robust standard errors clustered at constituency level

TABLE 6.4: FACTORS INFLUENCING ALLOCATION OF CONSTITUENCY DEVELOPMENT FUND (CDF) IN KENYA, (2008-12)

Dependent Variable: *Log of cumulative CDF (2008-2011)*					
VARIABLES	(1)	(2)	(3)	(4)	(5)
Log mean light intensity (2004)	−0.0136***	−0.0106***	−0.0106***	−0.0107***	−0.00728**
	(0.00248)	(0.00271)	(0.00270)	(0.00276)	(0.00282)
Population growth rate (yearly)	0.360***	0.378***	0.378***	0.372***	0.333**
	(0.135)	(0.135)	(0.135)	(0.139)	(0.131)
Log population density (cons, 1999)	0.202***	0.194***	0.194***	0.195***	0.186***
	(0.0166)	(0.0166)	(0.0166)	(0.0176)	(0.0175)
Log area (cons, sqkm)	0.224***	0.218***	0.218***	0.219***	0.220***
	(0.0172)	(0.0170)	(0.0170)	(0.0176)	(0.0166)
Share of president's vote in constituency (2007)		−0.0520***	−0.0521***	−0.0514***	
		(0.0136)	(0.0137)	(0.0143)	
Member, rulling party (2003-07)				−0.00356	
				(0.0130)	
Cabinet Member(=1, 2008-2012)		0.00110		0.00157	
		(0.0160)		(0.0161)	
Ditrict tribe over 50% =Kalenjin					−0.0129
					(0.0127)
Ditrict tribe over 50% =Kamba					0.0125
					(0.0224)
Ditrict tribe over 50% =Kikuyu					−0.0735***
					(0.0135)
Ditrict tribe over 50% =Kisii					0.0980***
					(0.0130)
Ditrict tribe over 50% =Luhya					0.0653***
					(0.0164)
Ditrict tribe over 50% =Luo					−0.0320
					(0.0202)
Ditrict tribe over 50% =Meru					−0.0586***
					(0.0192)
Ditrict tribe over 50% =Others					−0.0337
					(0.0236)
Constant	16.93***	17.05***	17.05***	17.04***	17.08***
	(0.196)	(0.197)	(0.197)	(0.204)	(0.201)
Observations	210	210	210	210	210
R-squared	0.517	0.536	0.536	0.536	0.658

Notes:
1). Reporting standard errors in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Robust standard errors clustered at constituency level

TABLE 6.5: DETERMINANTS OF CHANGE IN TIME DISTANCE TO A NEARBY MARKET IN KENYA (LOGS), 2004-2012

Dependent Variable: *Change in log time distance to nearby market(minutes, 2004-2012)*							
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log travel time to market (2004)	−0.185*	−0.176*	−0.181*	−0.179*	−0.183*	−0.176*	−0.268**
	(0.102)	(0.0993)	(0.104)	(0.100)	(0.0941)	(0.0979)	(0.114)
Log mean light intensity (2004)	−0.0347	−0.0323	−0.0294	−0.0350	−0.0288	−0.0256	−0.118
	(0.0638)	(0.0712)	(0.0760)	(0.0666)	(0.0605)	(0.0837)	(0.0770)
Population growth rate (yearly)	−9.510**	−10.32**	−9.641**	−9.976**	−10.73**	−11.54**	−2.698
	(3.857)	(4.471)	(3.831)	(4.379)	(4.294)	(4.685)	(4.975)
Log population density (cons, 1999)	−0.198	−0.214	−0.192	−0.184	−0.155	−0.130	0.0313
	(0.228)	(0.229)	(0.245)	(0.229)	(0.245)	(0.258)	(0.222)
Log area (cons, sqkm)	−0.241	−0.238	−0.235	−0.209	−0.193	−0.132	−0.370
	(0.248)	(0.252)	(0.259)	(0.258)	(0.256)	(0.282)	(0.232)
Mombasa-Malaba highway passes the dist(=1)	0.0861	0.0747	0.0875	0.0670	0.0911	0.0574	0.0706
	(0.118)	(0.119)	(0.133)	(0.121)	(0.113)	(0.149)	(0.117)
Share of president's vote in constituency (2002)		−0.0874				0.0809	
		(0.241)				(0.420)	
Share of president's vote in constituency (2007)			−0.0330			0.0342	
			(0.203)			(0.240)	
Member, rulling party (2003-07)				−0.0783		−0.152	
				(0.154)		(0.272)	
Cabinet Member(=1, 2003-2007)		0.168				0.144	
		(0.175)				(0.198)	
Cabinet Member(=1, 2008-2012)			0.0226			0.0331	
			(0.123)			(0.146)	
Party affiliation(PNU=1, 2008-2012)					−0.0902	−0.115	
					(0.143)	(0.148)	
Ditrict tribe over 50% =Kalenjin							0.523*
							(0.289)
Ditrict tribe over 50% =Kamba							0.409
							(0.267)
Ditrict tribe over 50% =Kikuyu							0.232
							(0.267)
Ditrict tribe over 50% =Kisii							−0.331
							(0.331)
Ditrict tribe over 50% =Luhya							−0.276
							(0.298)
Ditrict tribe over 50% =Others							0.454
							(0.306)
Constant	2.904	3.024	2.851	2.688	2.440	1.989	2.278
	(2.723)	(2.713)	(2.901)	(2.749)	(2.856)	(3.051)	(2.554)
Observations	98	98	98	98	98	98	98
R-squared	0.385	0.393	0.386	0.390	0.396	0.413	0.562

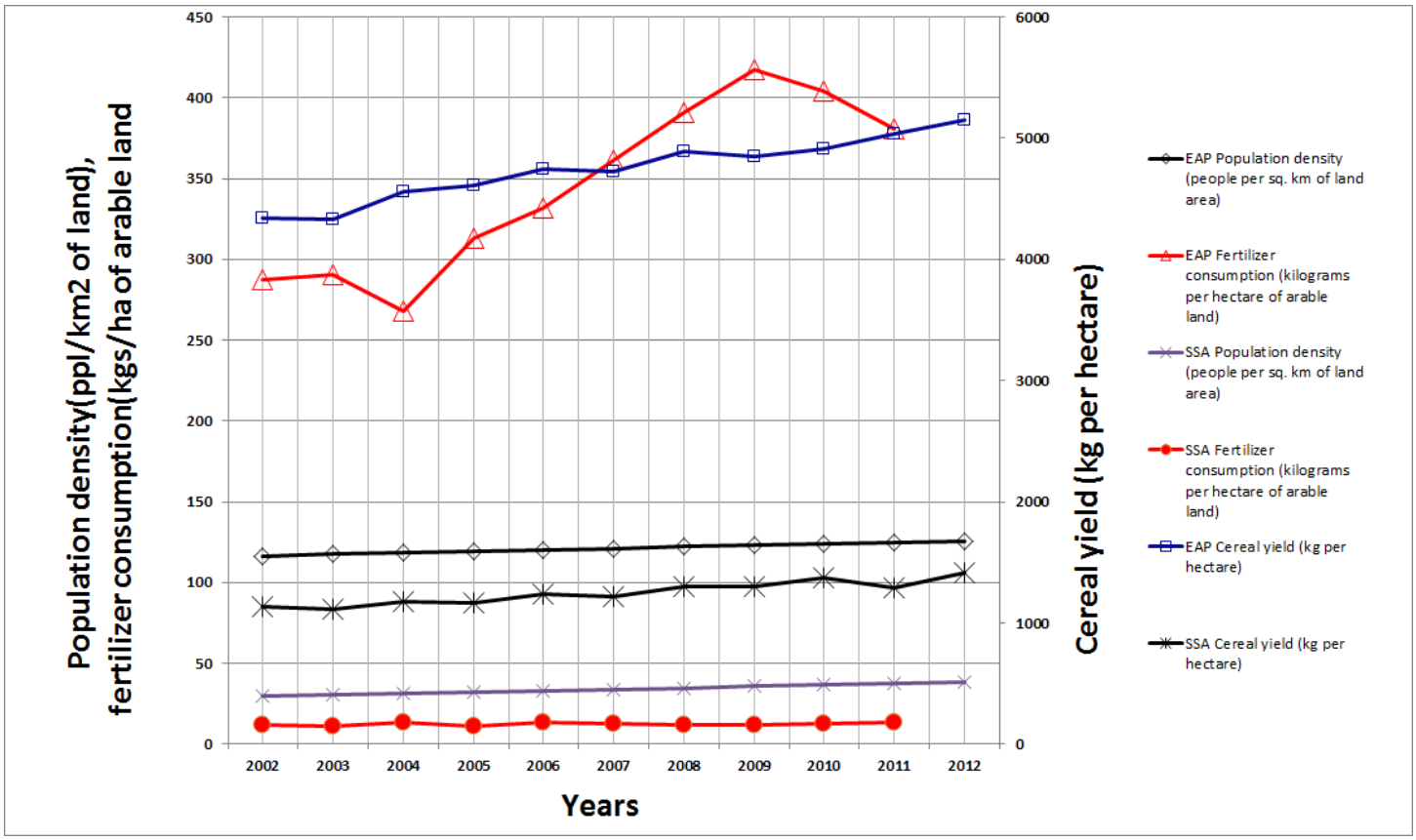
Notes:
1). Reporting standard errors in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Robust standard errors clustered at constituency level

TABLE 6.6: DETERMINANTS OF CHANGE IN TIME DISTANCE TO A NEARBY BIG TOWN IN KENYA (LOGS), 2004-2012

Dependent Variable: *Change in log time distance to nearby big town(minutes, 2004-2012)*							
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Log travel time to big town (2004)	−0.0921***	−0.110***	−0.117***	−0.0953***	−0.110***	−0.118***	−0.114***
	(0.0239)	(0.0220)	(0.0286)	(0.0259)	(0.0275)	(0.0295)	(0.0350)
Log mean light intensity (2004)	0.0336**	0.0326**	0.00734	0.0329**	0.0269*	0.00659	0.0140
	(0.0132)	(0.0120)	(0.0168)	(0.0138)	(0.0143)	(0.0157)	(0.0120)
Population growth rate (yearly)	0.708	0.231	0.918	0.639	1.209	0.245	−1.488
	(1.236)	(1.089)	(0.879)	(1.278)	(1.002)	(0.791)	(1.041)
Log population density (cons, 1999)	−0.122**	−0.135**	−0.107**	−0.120**	−0.142**	−0.103*	−0.127**
	(0.0584)	(0.0587)	(0.0490)	(0.0577)	(0.0625)	(0.0507)	(0.0486)
Log area (cons, sqkm)	−0.0803	−0.0801	−0.0879*	−0.0757	−0.104	−0.0785	−0.0447
	(0.0582)	(0.0590)	(0.0518)	(0.0559)	(0.0616)	(0.0519)	(0.0371)
Mombasa-Malaba highway passes the dist(=1)	−0.0827*	−0.0955**	−0.0771**	−0.0862*	−0.0899**	−0.0757**	−0.0549
	(0.0438)	(0.0419)	(0.0368)	(0.0431)	(0.0406)	(0.0322)	(0.0378)
Share of president's vote in constituency (2002)		−0.0439				−0.0694	
		(0.0435)				(0.0693)	
Share of president's vote in constituency (2007)			0.122**			0.133**	
			(0.0449)			(0.0540)	
Member, rulling party (2003-07)				−0.0109		0.0221	
				(0.0326)		(0.0592)	
Cabinet Member(=1, 2003-2007)		0.128***				0.0718**	
		(0.0276)				(0.0308)	
Cabinet Member(=1, 2008-2012)			0.0448			0.0504	
			(0.0325)			(0.0321)	
Party affiliation(PNU=1, 2008-2012)					0.0401	−0.0203	
					(0.0333)	(0.0261)	
Ditrict tribe over 50% =Kalenjin							0.0149
							(0.0810)
Ditrict tribe over 50% =Kamba							−0.0370
							(0.0653)
Ditrict tribe over 50% =Kikuyu							0.135***
							(0.0370)
Ditrict tribe over 50% =Kisii							0.190***
							(0.0418)
Ditrict tribe over 50% =Luhya							0.172***
							(0.0369)
Ditrict tribe over 50% =Others							0.135**
							(0.0546)
Constant	1.472**	1.660**	1.433**	1.457**	1.775**	1.397**	1.285**
	(0.662)	(0.665)	(0.628)	(0.658)	(0.738)	(0.662)	(0.517)
Observations	98	98	98	98	98	98	98
R-squared	0.516	0.562	0.635	0.517	0.538	0.663	0.759

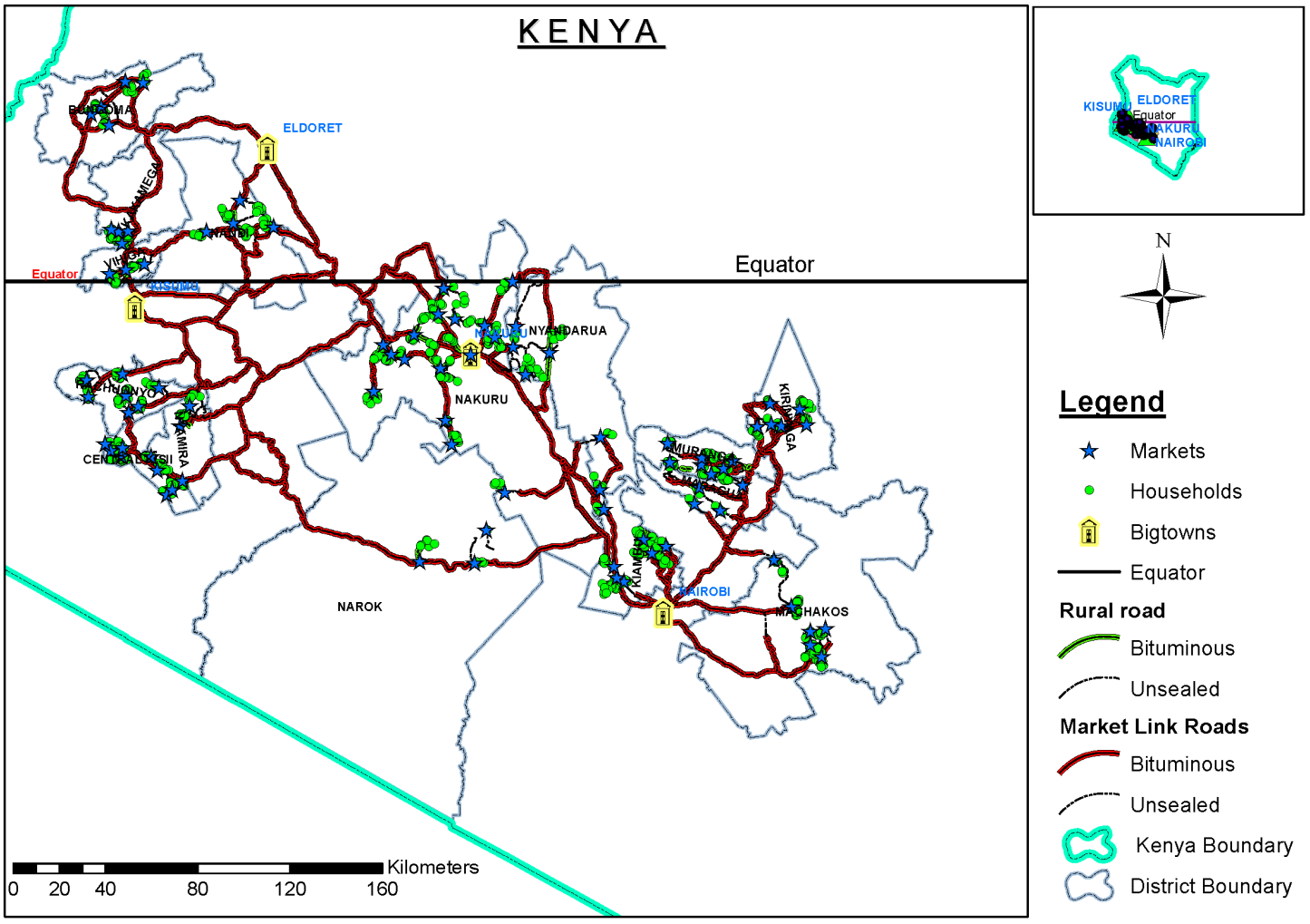
Notes:
1). Reporting standard errors in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Robust standard errors clustered at constituency level

Figures



Source: World Development Indicators, updated May 2014

FIGURE 1: CEREAL YIELD, FERTILIZER CONSUMPTION AND POPULATION DENSITY IN SUB-SAHARAN AFRICA(DEVELOPING ONLY) COMPARED TO EAST ASIA (DEVELOPING ONLY), 2002-2012.



Source: Authors depiction.

FIGURE 2: MAP OF THE STUDY AREA, REPEAT 2004-2012.

FIGURE 3: VISIBLE IMPROVED ROAD IN KARACHUONYO DISTRICT. *Left photo shows the road in 2005 while the right photo shows the road in 2009. Map courtesy of Google® Maps(0°20′29.66”S34°48′41.26”E)*

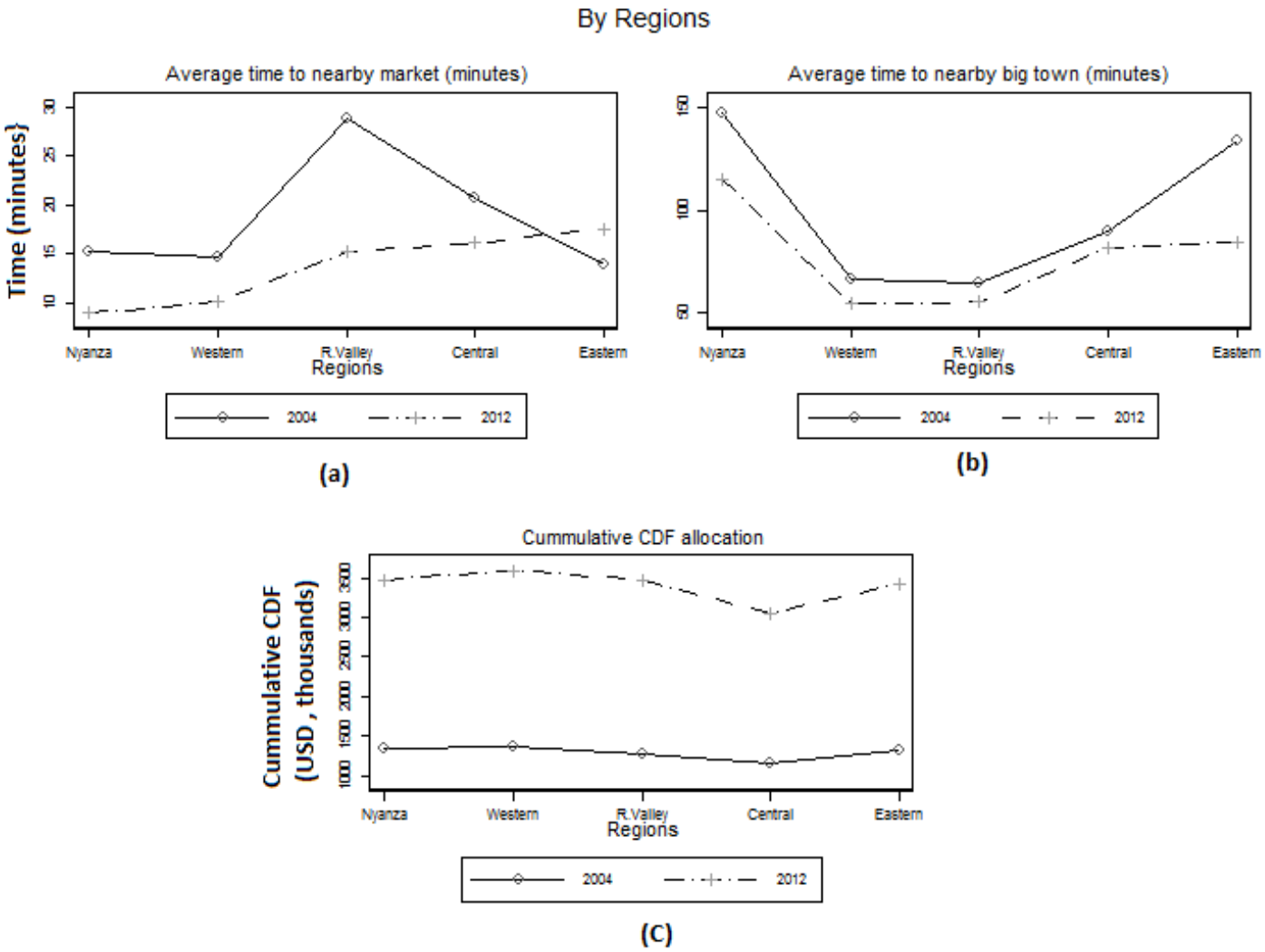


FIGURE 4: ROAD IMPROVEMENT AND CUMULATIVE CDF BY REGIONS. (A) IMPROVEMENT OF ROADS TO A NEARBY MARKET (B) IMPROVEMENT OF ROADS TO A NEARBY BIG TOWN (C) CUMULATIVE CDF ALLOCATIONS.

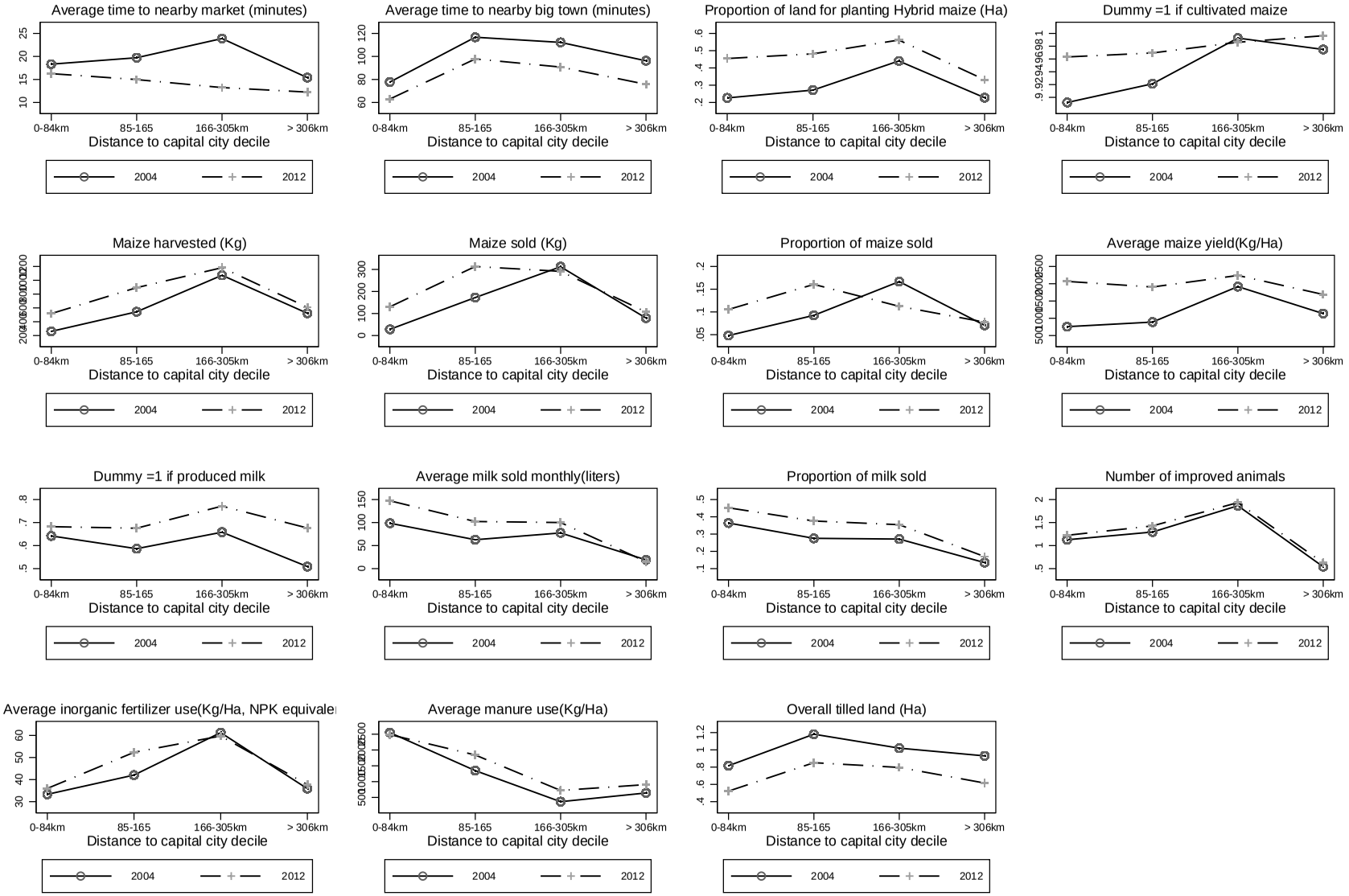


FIGURE 5: GRAPH OF SELECTED OUTCOME VARIABLES BY DISTANCE DECILES TO CAPITAL CITY, NAIROBI

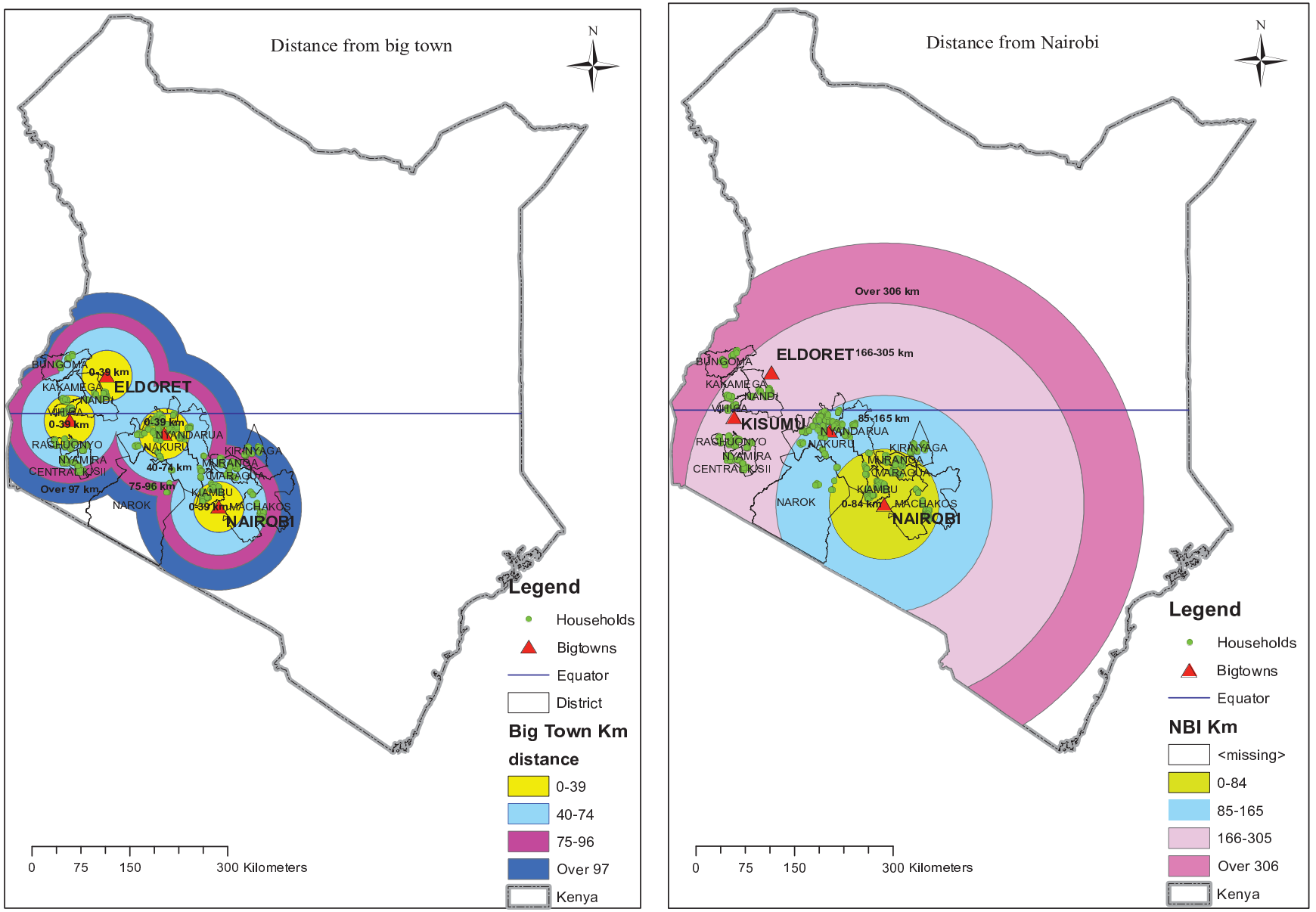
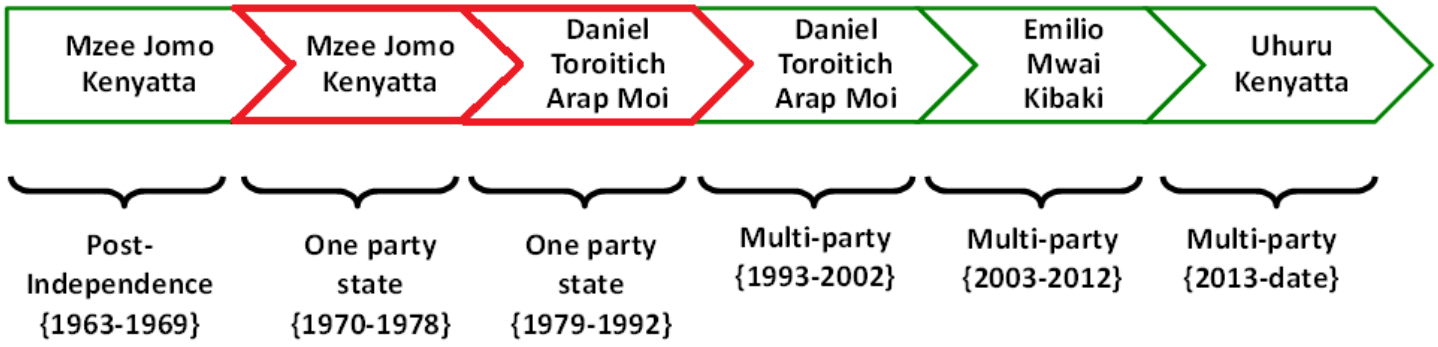


Figure 6: Euclidean distances approximation to show placement of our sampled households. Left figure shows distances measured from the center of a big town while the right figure shows distances from the capital city, Nairobi

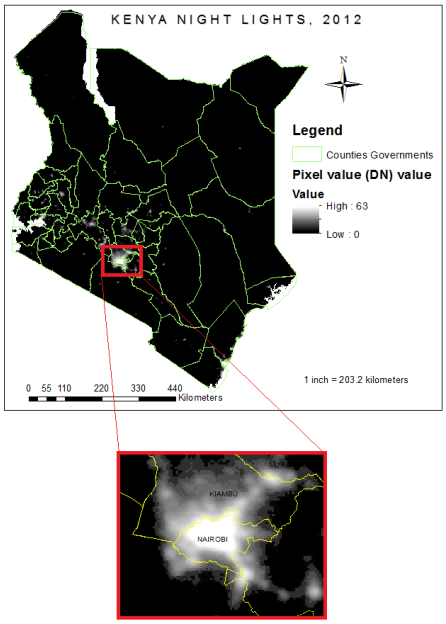


Source: Adapted from Burgess et al. (2013). Colored section is the author's modification.

FIGURE 7: REGIME CHANGE IN KENYA FROM 1963-2013

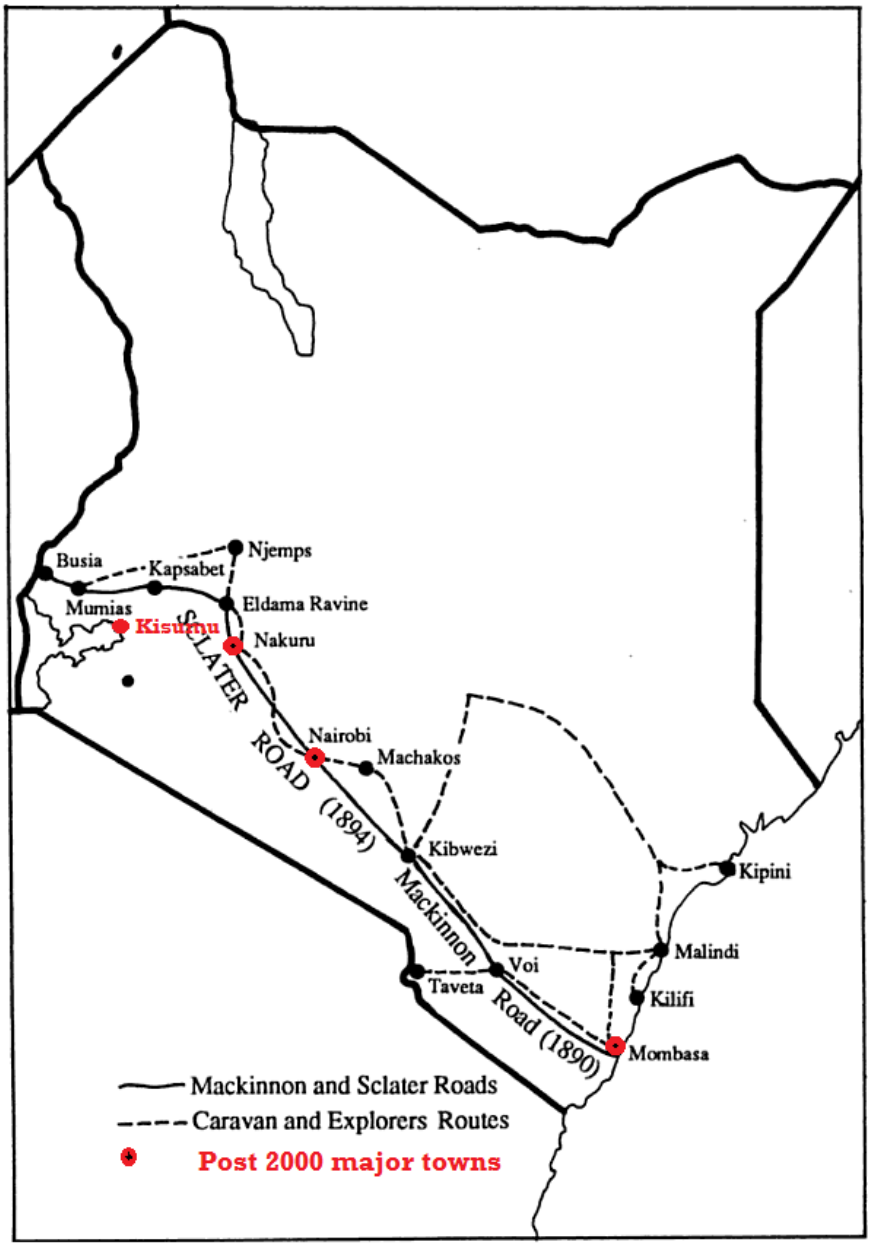
Source: National Oceanic and Atmospheric Administration (NOAA)

FIGURE 8: NIGHT LIGHTS IN KENYA AS SEEN FROM SPACE IN 2004 (LEFT MAP) AND IN 2012 (RIGHT MAP).



Source: National Oceanic and Atmospheric Administration (NOAA)

FIGURE 9: DIGITAL NUMBERS (DN) FOR THE PIXELS USED IN THE RASTER FILES.



Source: Adapted from Ochieng' & Maxon (1992). Colored section is the author's modification.

FIGURE 10: CARAVAN ROUTES, MACKINNON AND SCLATER ROADS BEFORE 1900.

Appendices

Appendix A

TABLE A.1: SPEEDS ASSIGNED TO ROAD SECTIONS (KM/H)

	Road condition					
	Excellent	Good	Fair	Poor	Very poor	Under construction
Surface type						
Premix	80	70	50	35	30	20
Surface Dressing	80	70	50	35	30	20
Brick	80	70	50	35	30	20
Concrete	80	70	50	35	30	20
Set Stone	80	70	50	35	30	20
Concrete Block	80	70	50	35	30	20
Gravel	50	50	35	20	5	5
Sand	50	50	35	20	5	5
Earth	40	30	25	10	5	5
Natural	40	30	20	5	5	5
Track	5	5	4	3	3	3
Unknown	5	5	4	3	3	3

Source: Traffic Act, Kenya and from authors projections

TABLE A.2: REGRESSION ESTIMATES FOR PER-CAPITA INCOME COMPOSITION WHEN INTERACTED WITH COMMUNITY MOBILE NETWORK AVAILABILITY.

VARIABLES	(1) lnpcincome	(2) lnpcfarminc	(3) lnpclvinc	(4) lnpcnonfarmincome	(5) lnpcnonlaborinc
Variables of interest					
(a). Log centered travel time to nearby market	0.017	−0.185	−0.461	−0.452	−0.755
	(0.904)	(0.434)	(0.461)	(0.420)	(0.211)
(b). Log centered travel time to big town	−1.751***	−2.911***	−4.052***	−4.842***	−5.216**
	(0.000)	(0.000)	(0.004)	(0.004)	(0.023)
(c). (a) × (b)	0.194	0.447	−0.155	1.324	−0.020
	(0.508)	(0.230)	(0.900)	(0.220)	(0.988)
Time to market× network availability	−0.119	−0.032	−0.406	−0.119	0.292
	(0.320)	(0.717)	(0.448)	(0.796)	(0.619)
Dummy ==1 if mobile network is available in the community	0.204	0.295*	0.022	0.453	0.494
	(0.138)	(0.059)	(0.945)	(0.366)	(0.477)
Time to big town× network availability	−0.012	−0.279	0.443	−0.775	−0.253
	(0.965)	(0.292)	(0.525)	(0.377)	(0.832)
Time interaction× network availability	0.227	0.169	0.953	−0.543	0.115
	(0.373)	(0.515)	(0.405)	(0.586)	(0.922)
Household level controls					
Household head gender(female==1)	−0.300***	−0.043	−0.808*	−0.167	0.195
	(0.007)	(0.809)	(0.062)	(0.754)	(0.758)
Average household size	−0.073***	−0.062*	0.049	−0.006	−0.089
	(0.001)	(0.086)	(0.564)	(0.955)	(0.412)
Average number of men in a household	0.035	0.016	−0.195	0.097	0.143
	(0.333)	(0.770)	(0.190)	(0.444)	(0.431)
Average number of boys	−0.036	−0.083	−0.228	0.072	−0.043
	(0.343)	(0.217)	(0.127)	(0.620)	(0.845)
Average household head age(years)	0.007	0.029	0.022	−0.309***	0.142
	(0.647)	(0.335)	(0.706)	(0.000)	(0.202)
Household head age squared	−0.000	−0.000	−0.000	0.003***	−0.000
	(0.662)	(0.246)	(0.678)	(0.000)	(0.583)
Average education attainment for men in a household	0.029**	0.019	−0.006	0.136**	0.076
	(0.048)	(0.425)	(0.912)	(0.032)	(0.390)
Average education attainment for women in a household	0.049***	0.005	−0.045	0.145**	0.032
	(0.001)	(0.815)	(0.432)	(0.030)	(0.716)
Member of self-help group	0.206**	0.007	0.066	0.157	0.761
	(0.032)	(0.964)	(0.811)	(0.645)	(0.148)
Household per capita assets in 'Kshs	0.000***	0.000	0.000	0.000	0.000
	(0.002)	(0.252)	(0.646)	(0.423)	(0.280)
Household per capita land holding (Ha)	0.516***	0.629***	0.346	−0.763	1.686***
	(0.000)	(0.000)	(0.288)	(0.151)	(0.002)
Community level controls					
Log of community population density	0.193	0.440	0.474	0.774*	1.735***
	(0.163)	(0.284)	(0.220)	(0.071)	(0.003)
Constant	8.117***	4.800	3.807	9.497***	−13.622***
	(0.000)	(0.112)	(0.208)	(0.005)	(0.010)
Observations	1,457	1,455	1,430	1,190	1,042
R-squared	0.463	0.388	0.145	0.359	0.489
Number of hhid	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-lnpcincome: ln(percapita overal income) (b)-lnpcfarminc: ln(percapita farm income) (c)-lnpclvinc: ln(percapita livestock income) (d)-lnpcnonfarmincome: ln(percapita non-farm income) (e)-lnpcnonlaborinc: ln(percapita non-labor income)

TABLE A.3: REGRESSION ESTIMATES FOR SHARE OF COMPOSITION OF INCOME WHEN INTERACTED WITH COMMUNITY MOBILE NETWORK AVAILABILITY.

VARIABLES	(1) shfarm	(2) shnonfarm	(3) shlvinc	(4) shnlb
Variables of interest				
(a). Log centered travel time to nearby market	−0.073**	0.025	0.012	0.015
	(0.029)	(0.618)	(0.738)	(0.708)
(b). Log centered travel time to big town	0.024	−0.173	−0.069	0.152
	(0.845)	(0.259)	(0.487)	(0.309)
(c). (a) × (b)	0.130*	0.032	0.025	−0.039
	(0.064)	(0.740)	(0.664)	(0.625)
Time to market× network availability	0.043	−0.035	−0.006	0.042
	(0.135)	(0.400)	(0.847)	(0.245)
Dummy ==1 if mobile network is available in the community	0.028	−0.031	−0.017	0.017
	(0.475)	(0.495)	(0.511)	(0.725)
Time to big town× network availability	−0.072	−0.024	0.024	0.015
	(0.307)	(0.752)	(0.573)	(0.856)
Time interaction× network availability	−0.136**	0.019	0.007	−0.032
	(0.039)	(0.840)	(0.878)	(0.645)
Household level controls				
Household head gender(female==1)	0.034	−0.006	−0.042	0.062**
	(0.306)	(0.904)	(0.198)	(0.048)
Average household size	−0.016**	0.005	−0.007	−0.001
	(0.015)	(0.491)	(0.189)	(0.855)
Average number of men in a household	0.006	0.013	−0.002	−0.008
	(0.532)	(0.323)	(0.806)	(0.476)
Average number of boys	0.014	0.002	−0.004	−0.007
	(0.298)	(0.900)	(0.665)	(0.558)
Average household head age(years)	0.001	−0.010	0.000	−0.001
	(0.881)	(0.111)	(0.961)	(0.849)
Household head age squared	−0.000	0.000	−0.000	0.000
	(0.878)	(0.120)	(0.988)	(0.334)
Average education attainment for men in a household	0.000	0.006	−0.004	−0.007
	(0.914)	(0.373)	(0.345)	(0.111)
Average education attainment for women in a household	−0.009**	0.005	−0.002	0.007
	(0.048)	(0.377)	(0.645)	(0.161)
Member of self-help group	−0.039*	−0.030	0.006	0.048*
	(0.099)	(0.314)	(0.781)	(0.088)
Household per capita assets in 'Kshs	−0.000	−0.000	0.000	0.000
	(0.323)	(0.712)	(0.463)	(0.227)
Household per capita land holding (Ha)	−0.007	−0.105***	−0.024	0.038
	(0.782)	(0.002)	(0.425)	(0.241)
Community level controls				
Log of community population density	0.038	0.008	−0.059*	0.022
	(0.326)	(0.819)	(0.077)	(0.557)
Constant	0.180	0.582**	0.661**	−0.154
	(0.511)	(0.038)	(0.026)	(0.605)
Observations	1,455	1,206	1,192	1,043
R-squared	0.153	0.092	0.032	0.147
Number of hhid	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Income composition share (a)-shfarm: farm income (b)-shnonfarm: non-farm income (c)-shlvinc: livestock (d)-incomeshnlb: non-labor income

TABLE A.4: REGRESSION ESTIMATES FOR PER-CAPITA EXPENDITURE COMPOSITION WHEN INTERACTED WITH COMMUNITY MOBILE NETWORK AVAILABILITY.

VARIABLES	(1) lnpctexpend	(2) lnpcexstaple	(3) lnpcexfresh	(4) lnpcexnonfresh	(5) lnpcexnonfood	(6) lnpcexcontri	(7) lnpcsavings
Variables of interest							
(a). Log centered travel time to nearby market	−0.122	−0.494**	−0.243**	0.202***	0.042	0.109	−0.018
	(0.125)	(0.012)	(0.023)	(0.007)	(0.701)	(0.430)	(0.944)
(b). Log centered travel time to big town	−1.047***	−2.408***	−1.794***	0.396	−0.664	1.575**	−1.658*
	(0.001)	(0.003)	(0.000)	(0.191)	(0.142)	(0.013)	(0.094)
(c). (a) × (b)	0.061	0.331	0.328	0.130	0.164	0.480	0.518
	(0.766)	(0.409)	(0.168)	(0.357)	(0.411)	(0.110)	(0.276)
Dummy ==1 if mobile network is available in the community	0.066	0.131	0.228**	−0.113	−0.040	0.122	0.123
	(0.366)	(0.365)	(0.011)	(0.117)	(0.659)	(0.403)	(0.650)
Time to market× network availability	−0.090	−0.130	−0.021	0.025	0.078	0.113	−0.118
	(0.164)	(0.239)	(0.793)	(0.651)	(0.314)	(0.294)	(0.572)
Time to big town× network availability	0.169	0.320	0.021	0.398***	0.014	0.397	0.207
	(0.294)	(0.365)	(0.916)	(0.002)	(0.927)	(0.104)	(0.682)
Time interaction× network availability	−0.047	0.020	−0.235	0.056	−0.139	−0.566**	−0.658
	(0.788)	(0.955)	(0.231)	(0.632)	(0.396)	(0.032)	(0.179)
Household level controls							
Household head gender(female==1)	0.015	0.196	0.016	−0.130*	−0.153	−0.141	−0.285
	(0.842)	(0.153)	(0.880)	(0.093)	(0.177)	(0.372)	(0.286)
Average household size	−0.116***	−0.124***	−0.105***	−0.121***	−0.102***	−0.082***	−0.103**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.001)	(0.018)
Average number of men in a household	0.055**	0.027	0.010	0.021	0.084**	−0.051	−0.023
	(0.014)	(0.497)	(0.675)	(0.284)	(0.014)	(0.276)	(0.744)
Average number of boys	−0.002	−0.020	−0.008	0.045*	0.001	−0.021	−0.139
	(0.952)	(0.659)	(0.823)	(0.097)	(0.990)	(0.708)	(0.103)
Average household head age(years)	−0.017	−0.021	−0.009	0.017	0.003	−0.048*	0.024
	(0.117)	(0.279)	(0.566)	(0.174)	(0.871)	(0.083)	(0.562)
Household head age squared	0.000**	0.000*	0.000	−0.000*	−0.000	0.000	−0.000
	(0.050)	(0.076)	(0.362)	(0.096)	(0.830)	(0.399)	(0.482)
Average education attainment for men in a household	0.011	0.023	0.005	−0.007	0.020	0.011	0.038
	(0.192)	(0.137)	(0.754)	(0.479)	(0.134)	(0.631)	(0.209)
Average education attainment for women in a household	0.027***	0.036**	0.020*	−0.002	0.032**	0.019	0.032
	(0.004)	(0.016)	(0.067)	(0.860)	(0.033)	(0.365)	(0.259)
Member of self-help group	0.151**	0.337***	0.128	−0.035	0.005	−0.372***	1.655***
	(0.013)	(0.000)	(0.118)	(0.538)	(0.953)	(0.006)	(0.000)
Household per capita assets in 'Kshs	0.000	0.000	0.000**	0.000***	−0.000	0.000	0.000
	(0.566)	(0.211)	(0.038)	(0.000)	(0.758)	(0.987)	(0.182)
Household per capita land holding (Ha)	0.209***	0.209*	0.308***	0.241***	0.121	0.050	−0.165
	(0.009)	(0.067)	(0.000)	(0.003)	(0.292)	(0.793)	(0.523)
Community level controls							
Log of community population density	0.104	0.549***	0.228	−0.143*	−0.150	−0.460***	0.176
	(0.246)	(0.002)	(0.106)	(0.053)	(0.160)	(0.008)	(0.434)
Constant	9.826***	5.207***	6.796***	8.893***	9.673***	12.037***	3.871**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.023)
Observations	1,458	1,458	1,458	1,457	1,453	1,432	1,378
R-squared	0.596	0.698	0.575	0.253	0.116	0.294	0.357
Number of hhid	729	729	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-lnpctexpend: ln(percapita overall expenditure) (b)-lnpcexstaple: ln(percapita staple food) (c)-lnpcexfresh: ln(percapita fresh food) (d)-lnpcexnonfresh: ln(percapita non-freshh food) (e)-lnpcexnonfood: ln(percapita non-food) (f)-lnpcexc

TABLE A.5: REGRESSION ESTIMATES FOR SHARE OF COMPOSITION OF EXPENDITURES WHEN INTERACTED WITH COMMUNITY MOBILE NETWORK AVAILABILITY.

VARIABLES	(1) shstaple	(2) shfresh	(3) shnonfresh	(4) shnonfood	(5) shcontri	(6) shsave
Variables of interest						
(a). Log centered travel time to nearby market	−0.089**	−0.011	0.032***	0.052*	0.016**	−0.000
	(0.020)	(0.316)	(0.001)	(0.071)	(0.037)	(0.951)
(b). Log centered travel time to big town	−0.278*	−0.089*	0.110***	0.113	0.117***	0.015
	(0.080)	(0.058)	(0.006)	(0.335)	(0.000)	(0.406)
(c). (a) × (b)	−0.012	0.018	0.013	−0.024	0.006	−0.005
	(0.869)	(0.546)	(0.587)	(0.604)	(0.699)	(0.661)
Time to market× network availability	−0.040*	0.003	0.014*	0.020	0.002	0.001
	(0.080)	(0.796)	(0.090)	(0.184)	(0.767)	(0.831)
Time to big town× network availability	0.036	−0.034	0.020	−0.040	0.029**	−0.012
	(0.530)	(0.108)	(0.301)	(0.354)	(0.029)	(0.137)
Time interaction× network availability	0.027	−0.008	0.005	−0.005	−0.018	0.006
	(0.671)	(0.741)	(0.806)	(0.900)	(0.220)	(0.496)
Household level controls						
Household head gender(female==1)	0.056**	−0.004	−0.013	−0.037	0.004	−0.008
	(0.029)	(0.757)	(0.255)	(0.151)	(0.683)	(0.186)
Average household size	−0.004	0.004	−0.001	0.002	−0.000	−0.000
	(0.426)	(0.145)	(0.570)	(0.608)	(0.909)	(0.677)
Average number of men in a household	−0.002	−0.008**	−0.001	0.013*	−0.001	−0.001
	(0.791)	(0.023)	(0.814)	(0.097)	(0.701)	(0.496)
Average number of boys	−0.004	−0.001	0.004	0.001	0.001	−0.004*
	(0.613)	(0.871)	(0.256)	(0.921)	(0.642)	(0.060)
Average household head age(years)	−0.004	0.001	0.004**	0.003	−0.005***	−0.000
	(0.259)	(0.609)	(0.019)	(0.517)	(0.009)	(0.788)
Household head age squared	0.000*	−0.000	−0.000***	−0.000	0.000**	0.000
	(0.072)	(0.545)	(0.007)	(0.359)	(0.030)	(0.939)
Average education attainment for men in a household	0.002	−0.000	−0.002	0.001	−0.000	−0.001
	(0.533)	(0.863)	(0.139)	(0.755)	(0.883)	(0.154)
Average education attainment for women in a household	0.002	−0.002*	−0.003**	0.003	−0.000	0.001
	(0.404)	(0.087)	(0.014)	(0.412)	(0.873)	(0.466)
Member of self-help group	0.051***	0.002	−0.023***	−0.037**	−0.033***	0.038***
	(0.003)	(0.822)	(0.008)	(0.023)	(0.000)	(0.000)
Household per capita assets in 'Kshs	0.000	0.000	0.000**	−0.000	−0.000	0.000*
	(0.888)	(0.267)	(0.013)	(0.227)	(0.326)	(0.071)
Household per capita land holding (Ha)	−0.002	0.017*	0.012	−0.025	−0.004	0.003
	(0.916)	(0.081)	(0.225)	(0.211)	(0.563)	(0.514)
Community level controls						
Log of community population density	0.099***	0.019	−0.022**	−0.077***	−0.018**	−0.001
	(0.004)	(0.157)	(0.033)	(0.004)	(0.023)	(0.898)
Dummy ==1 if mobile network is available in the community	0.029	0.031**	−0.020**	−0.031	−0.008	−0.003
	(0.280)	(0.028)	(0.026)	(0.157)	(0.256)	(0.589)
Constant	−0.338	0.002	0.219***	0.752***	0.360***	0.050
	(0.117)	(0.985)	(0.010)	(0.000)	(0.000)	(0.386)
Observations	1,458	1,458	1,457	1,452	1,431	1,363
R-squared	0.597	0.108	0.463	0.362	0.450	0.185
Number of hhid	729	729	729	729	729	729
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
1). Reporting pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-shstaple: Share of staple food (b)-shfresh: Share of non-staple food (c)-shnonfresh: Share of non fresh food (d)-shnonfood: Share of non-food (e)-shcontri: Share of contributions (f)-shsave: Share of savings

TABLE A.6: TOBIT FE (HONORE(1992)) REGRESSION ESTIMATES FOR PER-CAPITA INCOME.

VARIABLES	(1) lnpcincome	(2) lnpcfarminc	(3) lnpclvinc	(4) lnpcnonfarmincome	(5) lnpcnonlaborinc
Variables of interest					
(a). Log centered travel time to nearby market	−0.121	−0.246	−0.829**	−0.542	−0.644
	(0.218)	(0.174)	(0.031)	(0.188)	(0.202)
(b). Log centered travel time to big town	−1.901***	−3.268***	−3.823***	−5.945***	−5.948**
	(0.000)	(0.000)	(0.002)	(0.000)	(0.012)
(c). (a) × (b)	0.391***	0.569**	0.695	1.156**	−0.320
	(0.005)	(0.035)	(0.198)	(0.048)	(0.717)
Household level controls					
Household head gender(female==1)	−0.274**	−0.041	−0.770*	−0.145	0.132
	(0.017)	(0.827)	(0.084)	(0.774)	(0.823)
Average household size	−0.074***	−0.066**	0.010	0.000	−0.089
	(0.000)	(0.046)	(0.918)	(1.000)	(0.424)
Average number of men in a household	0.034	0.010	−0.168	0.099	0.126
	(0.331)	(0.854)	(0.257)	(0.487)	(0.540)
Average number of boys	−0.034	−0.070	−0.206	0.069	−0.032
	(0.441)	(0.310)	(0.249)	(0.671)	(0.888)
Average household head age(years)	0.007	0.031	0.018	−0.305***	0.135
	(0.707)	(0.286)	(0.766)	(0.000)	(0.230)
Household head age squared	−0.000	−0.000	−0.000	0.003***	−0.000
	(0.754)	(0.231)	(0.735)	(0.000)	(0.654)
Average education attainment for men in a household	0.029**	0.021	0.007	0.134**	0.074
	(0.035)	(0.387)	(0.899)	(0.024)	(0.439)
Average education attainment for women in a household	0.049***	0.006	−0.024	0.138**	0.041
	(0.000)	(0.747)	(0.671)	(0.023)	(0.640)
Member of self-help group	0.208**	0.024	−0.010	0.153	0.801*
	(0.016)	(0.865)	(0.976)	(0.636)	(0.097)
Household per capita assets in 'Kshs	0.000***	0.000	0.000	0.000	0.000
	(0.002)	(0.260)	(0.907)	(0.421)	(0.257)
Household per capita land holding (Ha)	0.522***	0.644***	0.355	−0.728	1.721***
	(0.000)	(0.000)	(0.287)	(0.178)	(0.001)
Community level controls					
Log of community population density	0.204*	0.562**	0.550	0.727*	1.861***
	(0.065)	(0.039)	(0.131)	(0.090)	(0.001)
Observations	1,457	1,455	1,430	1,190	1,042
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Income composition share (a)-shfarm: farm income (b)-shnonfarm: non-farm income (c)-shlvinc: livestock (d)-incomeshnlb: non-labor income

TABLE A.7: TOBIT FE (HONORE(1992)) REGRESSION ESTIMATES FOR SHARE OF COMPOSITION OF INCOME.

VARIABLES	(1) shfarm	(2) shnonfarm	(3) shlvinc	(4) shnlb
Variables of interest				
(a). Log centered travel time to nearby market	−0.040	0.010	0.017	0.070
	(0.189)	(0.797)	(0.679)	(0.583)
(b). Log centered travel time to big town	−0.066	−0.149	−0.058	0.212
	(0.554)	(0.309)	(0.628)	(0.531)
(c). (a) × (b)	0.023	0.090	0.046	−0.202
	(0.632)	(0.129)	(0.424)	(0.302)
Household level controls				
Household head gender(female==1)	0.031	−0.009	−0.055	0.074
	(0.406)	(0.855)	(0.248)	(0.160)
Average household size	−0.017**	0.006	−0.009	−0.000
	(0.020)	(0.539)	(0.284)	(0.978)
Average number of men in a household	0.008	0.013	−0.003	−0.028
	(0.518)	(0.347)	(0.813)	(0.249)
Average number of boys	0.019	−0.000	−0.009	−0.024
	(0.216)	(0.982)	(0.580)	(0.464)
Average household head age(years)	0.002	−0.010	0.001	−0.005
	(0.718)	(0.164)	(0.904)	(0.566)
Household head age squared	−0.000	0.000	−0.000	0.000
	(0.754)	(0.210)	(0.950)	(0.112)
Average education attainment for men in a household	0.001	0.007	−0.006	−0.014
	(0.850)	(0.269)	(0.339)	(0.152)
Average education attainment for women in a household	−0.009**	0.005	−0.002	0.015
	(0.044)	(0.342)	(0.674)	(0.138)
Member of self-help group	−0.042	−0.035	0.008	0.122**
	(0.119)	(0.277)	(0.812)	(0.037)
Household per capita assets in 'Kshs	−0.000	−0.000	0.000	0.000
	(0.619)	(0.728)	(0.521)	(0.574)
Household per capita land holding (Ha)	−0.009	−0.120***	−0.020	0.101**
	(0.758)	(0.006)	(0.614)	(0.029)
Community level controls				
Log of community population density	0.045	0.005	−0.086*	0.024
	(0.180)	(0.890)	(0.060)	(0.723)
Observations	1,455	1,206	1,192	1,043
HH FE	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). Income composition share (a)-shfarm: farm income (b)-shnonfarm: non-farm income (c)-shlvinc: livestock (d)-incomeshnlb: non-labor income

TABLE A.8: TOBIT FE (HONORE(1992)) REGRESSION ESTIMATES FOR PER-CAPITA EXPENDITURE

VARIABLES	(1) lnpctexpend	(2) lnpcexstaple	(3) lnpcexfresh	(4) lnpcexnonfresh	(5) lnpcexnonfood	(6) lnpcexcontri	(7) lnpcsavings
Variables of interest							
(a). Log centered travel time to nearby market	−0.199***	−0.623***	−0.296***	0.223***	0.110	0.180	−0.095
	(0.002)	(0.000)	(0.000)	(0.001)	(0.234)	(0.185)	(0.651)
(b). Log centered travel time to big town	−1.046***	−2.377***	−2.067***	0.724***	−0.649*	1.483***	−1.813**
	(0.000)	(0.000)	(0.000)	(0.002)	(0.060)	(0.002)	(0.026)
(c). (a) × (b)	0.068	0.367**	0.171	0.075	0.021	−0.035	0.130
	(0.515)	(0.047)	(0.259)	(0.458)	(0.884)	(0.865)	(0.674)
Household level controls							
Household head gender(female==1)	0.032	0.223*	0.031	−0.137*	−0.166	−0.149	−0.251
	(0.656)	(0.077)	(0.794)	(0.083)	(0.128)	(0.358)	(0.320)
Average household size	−0.116***	−0.125***	−0.104***	−0.122***	−0.101***	−0.082***	−0.089*
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.003)	(0.057)
Average number of men in a household	0.054**	0.025	0.007	0.021	0.083**	−0.056	−0.028
	(0.025)	(0.544)	(0.813)	(0.376)	(0.018)	(0.242)	(0.693)
Average number of boys	−0.002	−0.018	−0.007	0.047*	0.000	−0.018	−0.152
	(0.956)	(0.717)	(0.862)	(0.094)	(1.000)	(0.751)	(0.108)
Average household head age(years)	−0.016	−0.021	−0.008	0.017	0.003	−0.049*	0.014
	(0.152)	(0.257)	(0.600)	(0.170)	(0.837)	(0.083)	(0.746)
Household head age squared	0.000*	0.000*	0.000	−0.000*	−0.000	0.000	−0.000
	(0.060)	(0.052)	(0.387)	(0.088)	(0.783)	(0.408)	(0.677)
Average education attainment for men in a household	0.011	0.022	0.006	−0.008	0.020	0.009	0.029
	(0.253)	(0.138)	(0.724)	(0.429)	(0.168)	(0.676)	(0.396)
Average education attainment for women in a household	0.028***	0.037**	0.021*	−0.000	0.032**	0.020	0.026
	(0.003)	(0.013)	(0.073)	(0.972)	(0.025)	(0.323)	(0.371)
Member of self-help group	0.139**	0.321***	0.121*	−0.043	0.006	−0.399***	1.598***
	(0.016)	(0.001)	(0.092)	(0.452)	(0.946)	(0.001)	(0.000)
Household per capita assets in 'Kshs	0.000	0.000	0.000**	0.000***	−0.000	−0.000	0.000
	(0.772)	(0.287)	(0.046)	(0.000)	(0.796)	(0.910)	(0.216)
Household per capita land holding (Ha)	0.217***	0.223**	0.313***	0.246***	0.115	0.053	−0.176
	(0.002)	(0.027)	(0.000)	(0.001)	(0.283)	(0.779)	(0.531)
Community level controls							
Log of community population density	0.087	0.532***	0.211**	−0.145**	−0.153	−0.492***	0.123
	(0.222)	(0.000)	(0.027)	(0.049)	(0.134)	(0.001)	(0.611)
Observations	1,458	1,458	1,458	1,457	1,452	1,431	1,363
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-lnpctexpend: ln(percapita overall expenditure) (b)-lnpcexstaple: ln(percapita staple food) (c)-lnpcexfresh: ln(percapita fresh food) (d)-lnpcexnonfresh: ln(percapita non-freshh food) (e)-lnpcexnonfood: ln(percapita non-food) (f)-lnpcexc

TABLE A.9: TOBIT FE (HONORE(1992)) REGRESSION ESTIMATES FOR SHARE OF COMPOSITION OF EXPENDITURE.

VARIABLES	(1) shstaple	(2) shfresh	(3) shnonfresh	(4) shnonfood	(5) shcontri	(6) shsave
Variables of interest						
(a). Log centered travel time to nearby market	−0.156***	−0.013	0.051***	0.093***	0.031*	0.002
	(0.000)	(0.187)	(0.000)	(0.000)	(0.072)	(0.867)
(b). Log centered travel time to big town	−0.358***	−0.144***	0.151***	0.143*	0.195***	0.025
	(0.000)	(0.001)	(0.000)	(0.079)	(0.000)	(0.463)
(c). (a) × (b)	0.047	0.012	0.002	−0.009	0.002	−0.004
	(0.248)	(0.530)	(0.888)	(0.805)	(0.945)	(0.790)
Household level controls						
Household head gender(female==1)	0.060**	−0.002	−0.018	−0.045*	0.010	−0.010
	(0.019)	(0.870)	(0.155)	(0.085)	(0.531)	(0.435)
Average household size	−0.005	0.004	−0.001	0.002	0.000	−0.001
	(0.392)	(0.135)	(0.509)	(0.727)	(0.974)	(0.488)
Average number of men in a household	−0.002	−0.008**	0.001	0.015*	0.001	−0.001
	(0.809)	(0.039)	(0.886)	(0.067)	(0.890)	(0.690)
Average number of boys	−0.008	−0.000	0.007	−0.000	0.005	−0.006
	(0.459)	(0.950)	(0.116)	(0.980)	(0.419)	(0.115)
Average household head age(years)	−0.004	0.001	0.005**	0.004	−0.008***	−0.001
	(0.265)	(0.644)	(0.015)	(0.285)	(0.007)	(0.719)
Household head age squared	0.000**	−0.000	−0.000***	−0.000	0.000**	0.000
	(0.050)	(0.593)	(0.004)	(0.219)	(0.026)	(0.844)
Average education attainment for men in a household	0.001	−0.000	−0.002	0.002	−0.001	−0.002
	(0.727)	(0.845)	(0.203)	(0.487)	(0.846)	(0.161)
Average education attainment for women in a household	0.003	−0.002*	−0.003**	0.003	0.001	0.001
	(0.381)	(0.083)	(0.035)	(0.400)	(0.711)	(0.527)
Member of self-help group	0.052**	0.004	−0.024**	−0.033*	−0.057***	0.059***
	(0.011)	(0.692)	(0.016)	(0.075)	(0.000)	(0.000)
Household per capita assets in 'Kshs	−0.000	0.000	0.000	−0.000	−0.000	0.000
	(0.982)	(0.177)	(0.125)	(0.289)	(0.432)	(0.390)
Household per capita land holding (Ha)	−0.011	0.016	0.018	−0.033	0.009	0.004
	(0.602)	(0.136)	(0.163)	(0.112)	(0.621)	(0.631)
Community level controls						
Log of community population density	0.104***	0.020	−0.024**	−0.083***	−0.035**	−0.004
	(0.000)	(0.101)	(0.030)	(0.001)	(0.014)	(0.770)
Observations	1,458	1,458	1,457	1,452	1,431	1,363
HH FE	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Year × Agrozone dummy	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*

Notes:
pval in parentheses
2). Significance level: *** p<0.01, ** p<0.05, * p<0.1
3). (a)-shstaple: Share of staple food (b)-shfresh: Share of non-staple food (c)-shnonfresh: Share of non fresh food (d)-shnonfood: Share of non-food (e)-shcontri: Share of contributions (f)-shsave: Share of savings