THE EFFECT OF ROAD INFRASTRUCTURE ON COUNTY HORTICULTURAL PRODUCTION IN KENYA

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DECLARATION

I affirm this is my original work and to the best of my knowledge it has by no means been presented for the award of any degree in another university or institution.

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SIGNATURE..DATE 16/11/21

APPROVAL

This MA proposal has been forwarded for presentation with my approval as University Supervisor:

Prof. Damiano Kulundu

SIGNATURE..................................**DATE** 16/11/2021

DEDICATION

My willpower goes to my mum and dad for their organization help in cheering me and continously reminding me of the cost of time for the length it took on my studies. Their encouragement and wonderful recommendations ensured my carrying out this work. I recorgnize them greatly.

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Thank you.

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LIST OF ACRONYMS AND ABBREVIATIONS

AMG	Augmented Mean Group
FE	Fixed Effect
GDP	Gross Domestic Product
HCDA	Horticultural Crop Development Authority
KNBS	Kenya National Bureau of Statistics
R&D	Research and Development
RE	Radom Effect
SIDs	Small Island Developing States
SSA	Sub Saharan African
WDI	World Development Index

ABSTRACT

This study sought to investigate the effect of road connectivity on horticultural outcome at the county level. More specifically, the study aims at investigation the correlation between existing road connectivity and horticultural output at county level in Kenya using a panel data analysis. Data was sourced from various county government official reports for the period running from 2015-2019 comprising of all 47 county governments of Kenya. Using fixed effect model, the study finding reveals that there is evidence to link road connectivity and county horticultural production. However, we found a negative effect of road connectivity to county horticultural production contrary to other empirical work. Other key factors influencing horticultural production at the county level included rainfall amount, area under production and labour input. We recommend that farmers should increase the area under horticulture production and incur some input costs such as labour in an effort to increase horticultural production at the county level. It is also expected that with increased production, the multiplier effect of the value chain for horticultural products will be impactful.

Keywords: Road, transportation, infrastructure, County Government, horticultural production

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CHAPTER ONE

INTRODUCTION

1.1 Background

The economic value of road infrastructure in any economy cannot be underestimated (Ansar, A., et al., 2016; Farhadi, 2015; Vickerman, 2018; Coşar & Demir, 2016). A well-connected road network leads to accelerated economic growth and development by enhancing greater movement of goods/services/people within and without the country (McCombie & Thirlwall, 2016; Mörtberg, et al., .2017; Tuluy, 2016). The ultimate achievement of road connectivity is welfare improvement by linking the spatially separated areas from social contacts and interaction (Magris, et al., 2017). It also leads to access to employment, better health care, and education among other social amenities that enhance civilization and thus economic growth and development (Bloch, 2003).

On the contrary, insufficient road networking in any given region limits several economic activities such as Foreign Direct Investment and private investment as it is costly to invest in such areas (Buckley, et al., 2018; Seid, 2018; Crescenzi, et al., 2016). Transportation of produce to the market becomes costly and this negatively impacts on the producer as his/her produce loses the comparative advantage due to his/her product's high prices than the market prices to cover up the transportation cost (Meade, 2016; Dangelico, & Vocalelli, 2017; Ebata, 2017). Delays of perishable goods especially those produced in horticulture to the market as a result of insufficient road network may lead to huge losses to the producer and ultimately to a vicious cycle of poverty and low economic growth (Kekana, M. V. (2017; FATTY, 2019; Dev, & Sengupta, 2020). To curb all these, most African nations have prioritized road network construction as a form of opening up remote and marginalized areas to speed up economic growth (Benos, 2005).

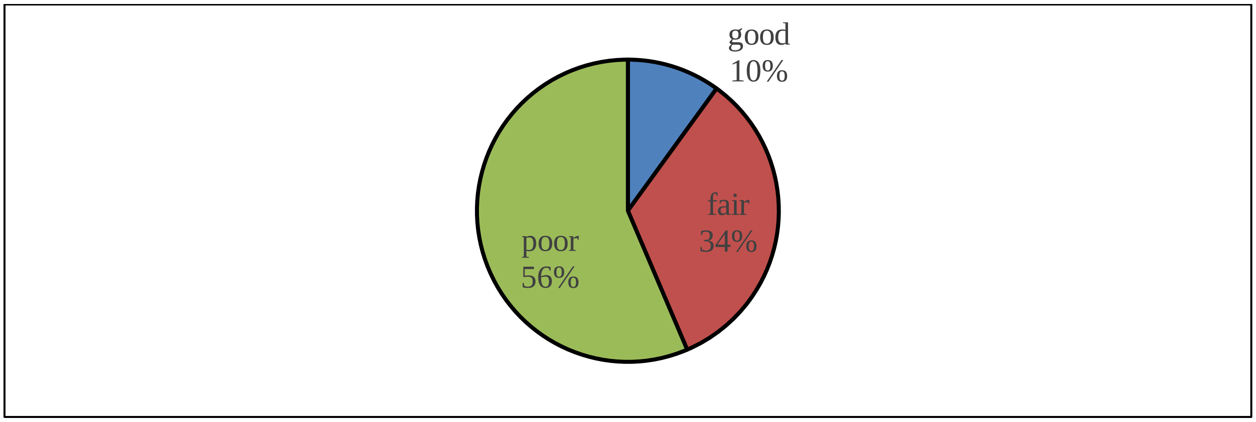
Road networking at times is an indicator to the level of economic development which has been linked to provision of sustainable economic growth through multiplier effect resulting from increased government spending (Vaslavskiy, & Vaslavskaya, 2019; Long, & Ji, 2019; Meersman, & Nazemzadeh, 2017). According to Gautam and Tripathi (2010), this sustained economic growth arises from the volume of private investments attracted by the opening up of the potential areas when the government constructs roads. However, he cautions that the positive impact of roads exists in a situation where the gains from such private investments outweigh the tax the government collects to fund the construction of such roads.

1.1.1 Review of Road Network in Kenya

This study defines road transport as those arteries that aid the flow of goods, persons, and information necessary for the economy (Guerrero-Ibanez, et al., 2015; Huang, et al., 2018). It is a system through which goods produced in a given part of the nation are circulated throughout the country (Meersman, H., & Nazemzadeh, M. (2017; Mfenjou, et al., 2018). From this definition, Kenya is still in need of this crucial road infrastructure since most of the roads are still unclassified and underdeveloped.

Kenyan road system is grouped into two broad categories: classified or unclassified with statistics from the Road Inventory and condition survey (KNBS, 2018) shows that poor roads account for over 50% of the total roads in Kenya with the fair and good take 34% and 10% respectively as shown in Figure 1. Out of the 39% of the classified roads in the country, 6% of these are international Trunk roads (categorized as class A), 4% are National Trunk Road (categorized as class B) while 43% are Minor roads (categorized as class E)

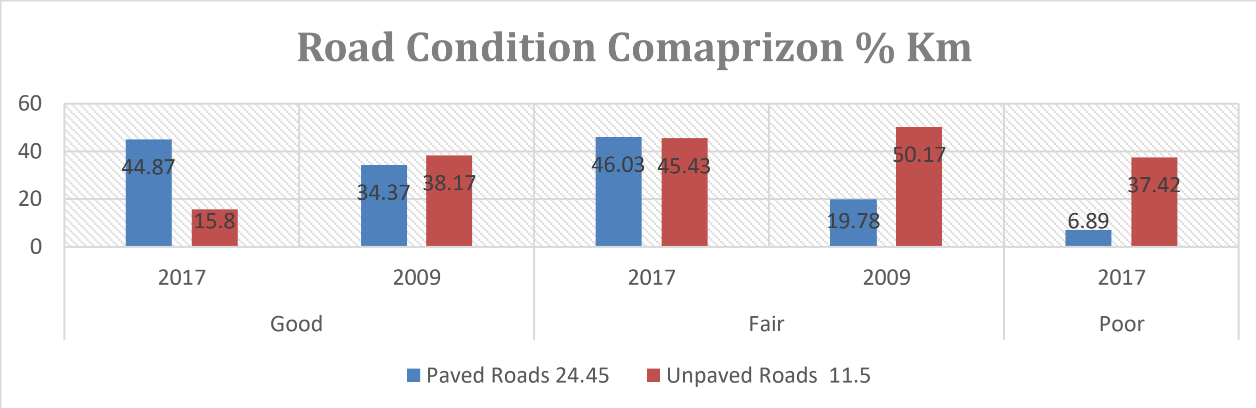
Figure 1: General road conditions in Kenya



Source: KNBS(2018)

Further evidence suggests that while the paved roads of ‘Good’ condition performed well in 2017 as compared to the base year 2007, an increase from 21.45% to 44.87%, those of poor roads condition had a marginal increase of 6. 87% over the same period. Equally, evidence suggests that unpaved roads of ‘Good’ condition improved greatly from 11.50% in 2007 (the base year) to 15.80% in 2017 with the unpaved roads of ‘poor’ condition decreasing from 50.17% in 2007 to 37.42%. However, there is concern over high number of roads that are unpaved and of poor condition as shown in Figure 2. That is, about 6.89% and 37.42% of the paved and unpaved roads were classified as poor in 2017 alone. Of interest improvement of paved roads with ‘good condition’ from 34.37% in 2009 to 44.84% in 2017. This can’t be said for the unpaved roads of ‘good condition’ as the data indicated that there was a significant decline from 38.17% in 2009 to about 15.8% in 2017. A similar trend is seen for those roads with ‘fair condition’ in which the paved roads increased from 19.78% in 2009 to 46.03% in 2017 while the unpaved roads declined from 50.17% to 45.43% between 2009 and 2017 respectively.

Figure 2: A summary of the overall road condition in 2009 and 2017



Source: Kenya Roads Board, 2018

The government of Kenya prioritizes expenditure in infrastructure with the share going to the trunk road transportation having a lion share. Available statistics from the KNBS in the period 2005-11 indicate that the expenditure on trunk roads has been rising steadily while those for the secondary raods follows. The least funded roads are the primary roads, most of which are in the rural farming areas. In recent times, government expenditure on roads still shows an increasing trend (say from 415.4 to 456.8 Billion Kenyan shillings) due to major road projects undertaken in 2019. A Similar trend was witnessed in 2020 with development expenditure increasing by about 15.5%.

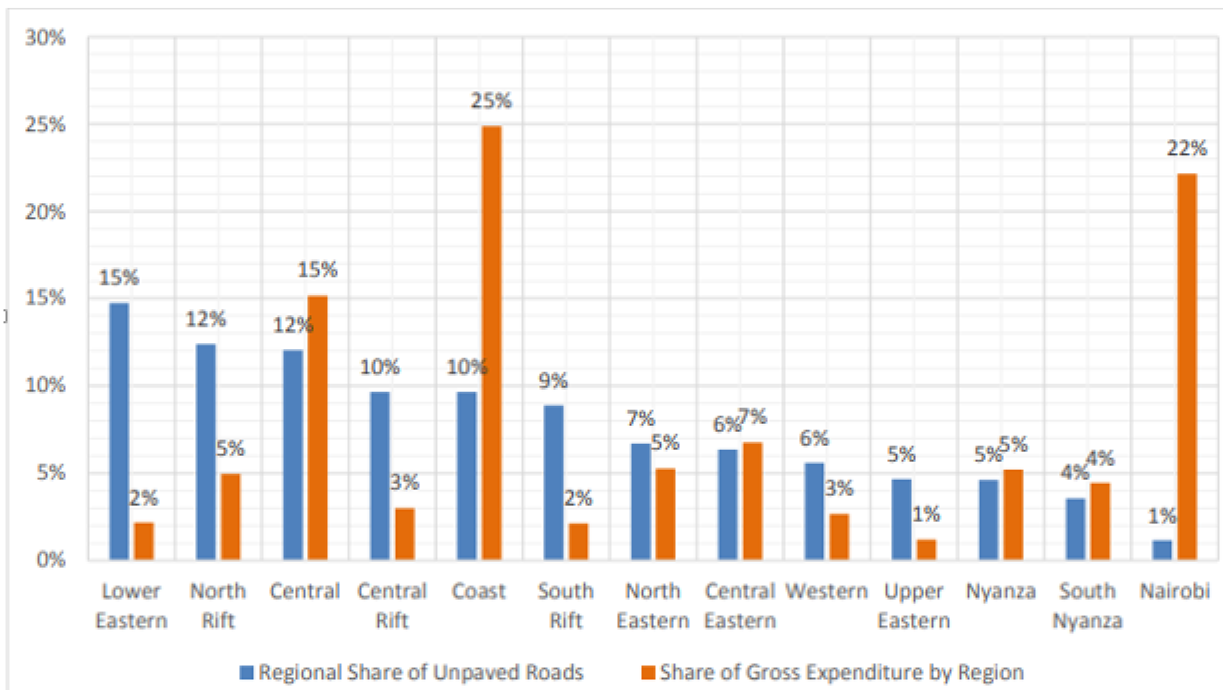
1.1.2 County Economic Performance and Road Transportation Network in Kenya

The County system of governance as per the Constitution of Kenya, 2010 was operationalized in 2013. This formed 47 counties that operate as their governments. Further, a Gazette Notice of January, 2016 transferred 121,456kms of roads to the County Government while 39,995kms of National Trunk roads remained with the National Government. County Governments have since actualized devolution with functions enumerated under the Fourth Schedule of the Constitution being devolved as well as resources from the National Government. Therein, each county government has a development plan and key among them is the improvement of road transport.

This is in recognition of the close relationship between the quality of roads and economic performance especially in agricultural production(Boopen, 2006).

Equally, looking at road access and budgetary by 2018, the Coast region led with about 25% followed closely by Nairobi Region (at 22%) while the central region was third (with 15%). We further observed that Upper Eastern regions of Isiolo and Marsabit were the lowest beneficially of the budegetary allocation to roads at 1%.

Figure 3: Share of unpaved roads per region by the year 2018

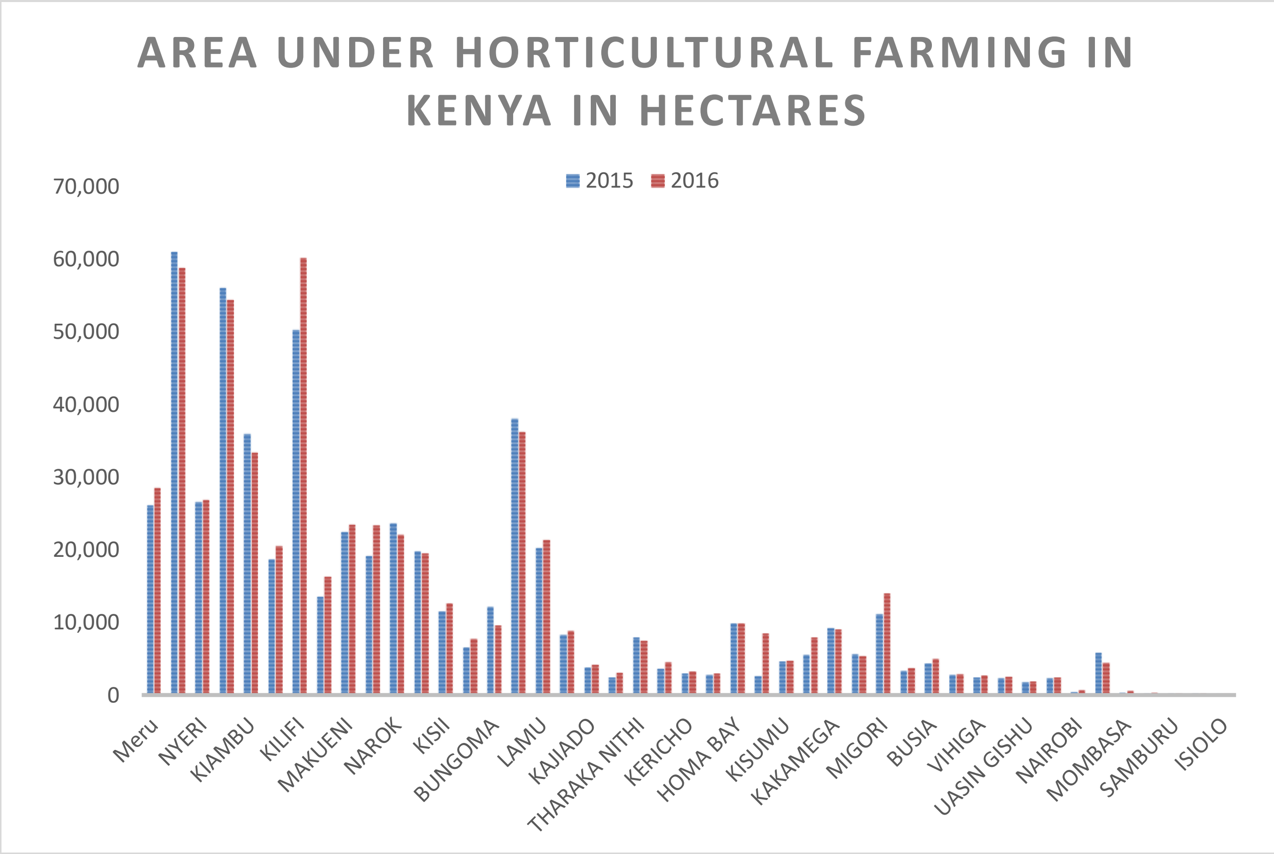


1.1.3 Horticultural in Kenya

Horticulture in Kenya has gained much publicity due to its foreign exchange earning to the country with an income generation of approximately 1 billion US dollars annually and the creation of 2million jobs.

In 2015, Horticultural Industry contributed up to 1.45% to the National GDP. It has remained Kenyan's main export and ranked among the top three foreign exchange-earners after tourism receipts as well as cash flows from tea. The weakening of the Kenyan shillings coupled with the road connectivity in various parts of the country has created a good incentive for the growing of horticultural crops as well as their export. A close look at the area under cultivation on horticulture across the forty-seven ounties reveals that majority of the counties have witnessed an increased land under horticulture (figure 4).

Figure 4: Area under horticultural farming in Kenya in hectares



Source: Horticultural Crop Development Authority

From Figure 4 above, counties such as Nyeri, Kilifi and Kisii allocated the highest areas under the production of horticulture while Nairobi, Samburu, and Isiolo were the least in land allocated to horticultural production respectively. There was a remarkable increase in the area under horticultural production between 2015 and 2016 in the counties of Meru, Kisii. Lamu and Kajiado. However, some other counties like Nyeri and Kilifi had a remarkable decline on the land allocated for the production of horticulture production. Notably, most of the counties have a slight increase or decrease in the land allocation for the production of horticulture. Intutively implying that on average, there was little or no incentives for farmers to allocate more land between this two period. Horticulture crop being a perishable good requires well-developed road infrastructure for faster movement to markets or factories for processing. Despite a wide acknowledgment of the value of road connectivity to horticultural development in Kenya, there exist a gap in the link between road connectivity and horticultural output in Kenya. Thus this study will fill this knowledge gap and form basis for further research.

1.2 Statement of the Problem

County road transport facilitates delivery of agricultural inputs and farm outputs to the markets. One such agricultural output, that has been significantly contributing to Kenya's foreign exchange earning is the horticulture sector. By opening up the county rural areas, we expect more output. With the statistics indicating that poor roads at 56% and only 10% of the roads are in good condition, vision 2030 could be challenging to achieve. Quality road network reduces man-hour loss for production through the elimination of frequent traffic jams; minimizes loss to investors by reducing accidents associated with bad roads, and leads to faster movements of raw materials to the industries as well as goods to the markets thus facilitating trade within and without the nation. Despite the important role of the roads in opening up areas for greater economic activities through increased crop production, few empirical studies exist to account for the real impact of roads connectivity on horticultural production at the county level in Kenya. The only study available linking road infrastructure and horticultural production in Kenya is a Master's thesis by Olwang,

(2019) on the "Responsiveness Of Horticultural Production To Infrastructure Development In Kenya". However, this study differs from this study on two fronts: First, this study will utlize panel data with more information as compared to the cross section data used by Olwang, (2019). Secondly, we use a more appropriate measure of road connectivity than their study that used expenditure in roads s a proxy which may suffer fungibility and the potential of suffering from endogeneity. Thus this study fills the knowledge gap by investigating the effect of road connectivity (proxied by distance of paved road) on horticultural production of the forty- seven counties in Kenya.

1.3 Research Questions

1. Does road connectivity in the county have any influence on their horticultural production in Kenya?
2. What policy implication can be drived from our study findings?

1.4 Objectives of study

1.4.1 General Objective

The main objective of this study is to investigate the effect of road infrastructural development on county horticultural production in Kenya.

1.4.2 Specific Objectives

1. To investigate the effect of road connectivity on county horticultural production in Kenya.
2. To offer policy recommendations based on the findings of the study.

1.5 Significant of Study

Given that road network in any country is vital for basically all economic activities, the study findings will be important in three folds: First, the findings will benefit the policymakers both at

National and County Governments especially where road transportation is the common form of transportation given its flexibility and cheap means of transportation. Secondly, the study findings will play a crucial role in availing valuable information on how the county governments can improve the country's main exports crops. Finally, the study findings will add to the frontier of knowledge and act as basis for further research in the academic body.

1.6 Organization of Study

Following introduction is Chapter Two which provides the theoretical literature review and empirical literature review in addition to the summary of the same. Chapter Three is the methodology and gives the conceptual framework, data type, the pre-test and statistical tests that were applied in the analysis.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The chapter is subdivided into three parts. Part 2.1 presents the theoretical literature review; part 2.2 is the empirical literature review while part 2.3 discusses the overview of the literature review

2.1 Theoretical Literature Review

From the classical economist to the neo-classical economist, the production of goods and services requires capital inputs and labor inputs. Road infrastructural expenditure has been cited as one of the main capital. For instance, Gramlich (1994) classified road infrastructure as capital expenditure or as a capital good. His main argument was that road infrastructure posed some traits of the public good of non-excluding and positive externalities.

However, road infrastructure may be viewed as a stock variable or a flow variable. For instance, if we view road infrastructure as a stock variable, then what we are concerned with is the kilometers of roads that have been constructed at a given period while in the context of a flow variable, we view road infrastructure as a net road infrastructure at a given period. Understanding this classification of road infrastructure is crucial since the measurement of variables has to have a distinction between cumulative and non-cumulative variables. For example, since GDP is a stock variable, we can then compare it with road infrastructure stock. Equally, viewing road infrastructure as a flow variable requires one to compare it GDP growth which is also a flow variable (Seethapalli et al, 2008)

2.1.1 Basic Growth Theory

According to this theory, economic growth can be viewed from the lens of production function where capital and labour units are the inputs. Despite many basic growth models stressing the key determinants of growth as physical capital, some other important determinants such as technology and human capital (measured by labour units) also play a key role. According to the basic growth theory, infrastructural development represents the supply-side of economic growth (that is, it may be regarded as direct input to economic growth). An increase in infrastructural stock is likely to increase economic growth (Boopen, 2006) through availing the movement of goods and services to the markets as well as raw materials (like labour) to the production sites. Thus improving the infrastructural development reduces the production costs and makes firm production profitable. This creates a good atmosphere for investment attracting both the local and international investors (Shi, & Sun, 2017).

According to this basic growth model, road infrastructure and economic growth are linked in five different ways. Firstly, road transport can be viewed as a factor of production especially when it is considered under the category of physical capital. In this aspect, an increase in the stock of roads will likely increase the general output thus greater economic growth. Secondly, road infrastructure can complement other factors of production. For instance, a well-connected road transportation network reduces transportation costs and as has been said by scholars such as Collier and Gunning (1999), poor road transport networking has been the main reason for African's poor economic performance. Thirdly, road infrastructure can be seen as a stimulus to factor accumulation. For instance, both physical and human capital are important in the production process. An inadequate road network is likely to reduce the accumulation of human capital in an area thus reducing the pace at which production takes place. Contrary, a good road network encourages the movement of people to access education as well as to work thus leading to the accumulation of this vital factor of production. Fourthly, road infrastructure can be stimuli to accumulation of aggregated demand. This is what most scholars have termed the “the demand side of road infrastructure” for instance, when roads are constructed or even repaired, their expenditure adds on GDP through increased demand of goods and services- what Keynes referred to as a stimulus to boost aggregate demand during the recession period. Lastly, we can view road infrastructure as a tool of industrial policy. For example, the government through its decentralization strategy may construct a road in the rural area to attract private investors to set up an industry in such areas which ultimately improves the productivity of the area.

2.1.2 Solow Growth Model

This is one of the neoclassical models that postulate that economic growth is a result of capital accumulation. Following a Cobb-Douglas production function, the Solow growth model is given as $Y_t = AK_t^{\alpha} N_t^{1-\alpha}$

Where Y_t is the aggregate output

A is capital effectiveness (or technological progress as some scholars call it), K is capital stock

And N is population growth representing the labour.

According to the Solow-Swan model, total factor effectiveness arises when we account for the residual of capital accumulation on economic growth. An increase in the factor of production can be translated as an improvement in technological progress or on infrastructural development such as road connectivity (Solow 1956).

2.2 Empirical Literature Review

There is no doubt that infrastructural development particularly road transport plays is fundamental in economic growth. A reflection from special empirical attention indicates it has attracted different scholars throughout the world. Although effect of transportation infrastructure on economic growth has been done with studies revealing a positive impact of transport infrastructure on economic growth, most of the studies have failed to disaggregate transportation to the road, rail, air and water transportation and choose to aggregate all these modes of transport. Equally, as the study mentions some of the prominent empirical literature in this section, one thing that stands out is that none of them have investigated the impact of roads stock at the county level in Kenya. Thus, this study hopes to fill this gap.

Relating quality of road with improved competitiveness of farm produce, Ellis (2001) revealed that the sure pathway through which this is realized was through a reduction in transportation of cost and faster movement of products to the market. Using data from Zambia to compare farm transport prices and road roughness, this study showed that poor-quality roads had twice as high prices as those with high quality. Their conclusion suggested that the loss in comparative advantage due to poor quality roads trickled down to low quantity produced of the farm produce. A similar study in Tanzania revealed that, in a stretch beyond a fifty-Kilometre section of road, an additional roughness of road would increase truck charges by 16% (Ninnin, 1997). In some studies, the poor accessibility of some farmland has been found to have an adverse effect on agricultural output through the credit channel. For instance study by Hine et al., (1983) in Ghana, revealed that farmers in areas that had accessibility challenges were less likely considered for loaning by a major lender. Two plausible reasons for the observation are: (i) remoteness of farmland for measurement as evidence for collateral and (ii) costly follow-ups due to the high cost of accessing the farmland

In their study in South Africa on constraints of subsistainble agriculture, Chakwizira *et al.* (2010) revealed that the poor state of the rural road connectivity significantly influenced subsistainble agriculture. Further, their study found out that areas with poor road connectivity had an impact on agricultural output price at the market that made them uncompetitive over areas with good road connectivity. A plausible explanation for their finding could lie in the ability of improved road connectivity on access to widespread markets, and reduced time in moving the farm produce.

Further, empirical evidence suggests that road connectivity significantly influences agricultural production (Bergquist, (2017); Iimi, (2019); Inoni and Omotur, (2009) and Shamdasani, 2016). In particular, while using a one-time cross section survey of 47 countries from developing countries found positive and significant influence of road connectivity on agricultural output. However, this study was too broad, assumed homogeneity of countries, and was not specific on the type of road connectivity such as paved from those unpaved.

Some authors have also tried to link road connectivity to agricultural productivity (Samanta, 2015; Iimi et al., 2019 and Fan and Zhang, 2004) in which they have revealed a positive association. For instance, Fan and Zhang (2004) used a panel data analysis to show that investment in road connectivity increased agricultural productivity in Thailand. However, their measure of road connectivity using expenditure remains highly misleading since the allocation is highly susceptible to fungibility (a situation where the allocations may be diverted to other uses other than what they were meant for).

This study corrects this by investigating the influence of road connectivity on horticultural production through use of the length of kilometer of paved roads, which is more observable than allocation. In another study in Greece that sought to determine the influence of road connectivity on agricultural production, Manasan and Chatterjee (2003) found out that an additional one percent increase in road connectivity from the farm to the nearest road led to a 0.38% increase in the agricultural output.

Intuitively, this implies that relaxation in road connectivity may adversely affect the agricultural output production of a given crop. Although their study looks similar to this study, it lacks a comparison between paved and unpaved roads which could have a different influence on agricultural production. Equally, their study used time series data while our study will utilize a panel data analysis that has more information over a time series.

In yet another study by Goyal & Nash (2017), public expenditure on research and development toiled to agriculture plays a significant influence in determining cross-country variations in the productivity of agriculture. However, such expenditures remains highly mismeasurement of road connectivity and as such, may suffer from endogeneity. Intuitively, expenditure allocations in most of developing countries are rarely used for the construction of these roads as the money is either diverted to other uses or is embezzled and thus, measuring road connectivity using the distance of paved or unpaved roads could be a correct measure, which this study explores. In other studies, agricultural productivity is a sure pathway through which road connectivity reduces poverty in remote inaccessible areas. For instance, a study by Hine and Willilo (2015) holds that agricultural productivity is highly associated with accessibility to roads which ultimately increases the household income through the sale of produce and empowerment of such households. Similarly, Hine et al. (2016) argue that accessibility of the community necessitated by good transport services can improve people’s livelihood through diversification of economic activities in rural areas.

Existing literature indicates a symbiotic relationship between agricultural sector performance and road infrastructure, citing that such a relationship is very instrumental for rural poverty alleviation (Banjo et al., 2012). This study noted that returns on transport investment particularly in rural areas depend on various factors that include amounts of production, marketing, and related transport and processing needs, the size of farms, and their commercial orientation. This argument was reinforced by Hine and Bradbury (2016) in a case study of Central Kenya. Organized co-operatives provided accessible milk collection centers especially for farmers operating small-scale farms to the market.

Shamdasani (2016) investigated the role of improvement on roads on rural household's agricultural decision-making for the case of India. The study employed difference-in-ifference framework on panel-level data. The results indicate that those households close to improved roads tend to diversify their crop portfolio than those that are way from improved roads. In addition, the study observed that accessibility to improved road infrastructure enables households to enhance the utilization of complementary inputs. Furthermore, Shamdasani reports that paved roads increase accessibility to the market, which implies a paradigm shift from subsistence to market-based agriculture. The study concluded that great hurdle to investment in agriculture is poor road network in rural areas.

However, Asher and Novosad (2016) conducted a similar study from which they find that the development of roads in the rural areas, affected agricultural production negatively. Specifically, the study noted that due to improved roads, most people in the rural set up shift their labour from agriculture to wage labour. However, those results are limited in that, the authors used distance from the household to the nearest town as a proxy to rural road connectivity as opposed to the distance from the house to the nearest road. This implies that their study was more focused on closeness to urban areas than road network development. The current study employed distance between household and the road which is believed to be a good measure for road network development than Asher and Novosad study. However, much of the study done has focused on road connectivity and economic growth. To begin, we start with Saidi, et al., (2018)who while investigating the influence of transport and communication investments on economic growth using cross sectional data of different countries, revealed existence of positive influence of such investment on the countries under study. Equally, Zhang & Sun, (2019) in their study of the causality between different capitals and economic growth using a semiparametric smooth coefficient approach in China, revealed that faster economic growth was driven by an improvement of both physical capital and human capital.

Peter et al., (2015) while investigating the causality between road stock and the output of a nation using cross-regional found out unidirectional causality running from improvement in road stock to the output. Same study done by Tolcha et al.,(2020) using sub-Sahara African data also found the same unidirectional causality running from road investment to economic growth but was experiencing a diminishing marginal rate of return. This means to him, as the road investment increases, so do to the output but this relationship continues to a certain point where an increase in road investment does not effect on output (optimal point) and that beyond this point, an extra coin on investment, will have a negative effect on the output.

While trying to compare between developing nations and developed nations where an increase in road stock will have the highest impact on economic growth, Saidi & Hammami (2017) examined 100 different countries from the two categories. They used variables that were proxy of road infrastructure as a stock variable such as length of paved roads and provision of electricity. Their study showed that there was no evidence of a shortage of such physical stock in the countries under study and that the question should not be on the effect of increasing such physical stock on economic growth but rather the tradeoff between these types of physical stock since they were found to have a positive impact on economic growth.

Le, T.H (2016) in his analysis of the role played by transport capital on economic growth of selected countries of both the Sub Saharan African Countries and the Developing States using panel data analysis, revealed that that road transport capital was positively influencing economic growth of the sampled nations. However, comparing the magnitude of the contribution in the two regions, the study concluded that road capital had a greater contribution in SSA countries than in the SIDs.

However, some studies have revealed a negative effect of road stock on economic growth (Bakhsh, et al., 2017; Khan, et al., 2018 and Damania et al., 2018). For instance, a study by Ng, et al., 2017). in Germany investigated the effect of the length of paved roads (as a proxy of road stocks). This study revealed that other exogenous factors were more relevant than the growth of road stock in determining total factor productivity growth differences between eastern and western parts of Germany.

2.3 Overview of Literature

The literature has revealed that there is evidence linking road connectivity to increased agricultural output. Being the backbone of much inaccessible farmland in the rural areas, road connectivity provides a respective assurance for the supply and delivery of farm inputs and outputs to the markets. In particular,the increased road network in remote areas has greatly increased the agricultural output. Nevertheless, the only study that has been done in Kenya had limited information given that it relied on cross sectional data and had used expenditure allocation as a proxy of road connectivity (which we believe could have some endogeneity issue raising from estimation error due to fungibility). Horticulture is one of Kenyan's promising sectors in foreign exchange earning and hence a need for the country to know the drivers of its output. Further, from the literature, measurements of road connectivity using budgetary expenditure allocations are highly misleading and could lead to measurement errors and perhaps endogeneity problems due to its fungibility. This study, therefore, addresses these challenges by using more robust measures of road connectivity infrastructure development and focusing on horticulture production as opposed to agricultural production in general as well as a panel data analysis approach which has the advantange of having more information, more variability, and more efficient than time series or cross sectional data analysis approaches.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

The chapter presents the theoretical framework, empirical model and model specification, estimation technique, definition and measurement of variables, estimation issues, and data source.

3.2 Theoretical Framework

The theoretical foundation of this study emanates from the hypothesis that road connectivity increases horticultural production, after controlling for other factors. This effect is assumed to occur through a reduction in transport costs of goods and services, which increases the profit margins for horticulture crops (depending on demand and supply elasticities). A reduction in transport overheads reduces the costs of inputs, and the regained resources may be used for R&D, improved or innovation in general. Consequently, there is a possibility of compositions of production effects, since reduced transport costs may improve the competitiveness of horticulture crops both locally and internationally.

Following this hypothesis, this study adopts Nicholson and Snyder (2008) specification with slight modification and assumes a Cobb-Douglas production function of the following form:

$$Y_t = A_t K_t^{\beta} F_t^{\alpha} L_t^{1-\beta-\alpha} \quad \ldots\ldots 1$$

Where Y = Horticulture output , A = Technical progress, K = Capital stock, F = Infrastructure/road connectivity, L = Labour force, t = time period. Given that capital is enhanced by infrastructure just the same way infrastructure is influenced by capital, then the equation is represented in respective marginal products which are expressed as follows:

$$\frac{\partial Y_t}{\partial F_t} = \alpha A_t K_t^{\beta} F_t^{\alpha-1} L_t^{1-\beta-\alpha} > 0 \ldots\ldots 2$$

$$\frac{\partial Y_t}{\partial K} = \beta A_t K_t^{\beta-1} F_t^{\alpha} L_t^{1-\beta-\alpha} > 0 \ldots\ldots 3$$

In a theoretical interpretation, equation 2 implies that marginal gains of road connectivity to horticultural production is increasing. However, if we proceeded to find the second-order condition, the marginal gains will be declining. In a nutshell, the marginal gains of additional road connectivity will be increasing horticultural production at the county levels up to some optimal point beyond which, any additional road connectivity will not lead to any improvement in the horticulture production.

3.3 Empirical Model

This study adopts Edeme et al (2020) methodology and specifies the relationship as an augmented mean group estimator (AMG) in panel form. This is represented as follows:

$$lnHp_{it} = \propto_0 + \propto_1 ln\, Rd_{it} + \propto_2 lnHland_{it} + \propto_3 lnLab_{it} + \propto_3 lnRainF_{it} + \propto_3 lnIrr_{it} + \propto_3 lnA\_crop_{it} + \varepsilon_{it} \ldots\ldots 7$$

Where, $\propto_0$ is the intercept/constant term. Hp_{it} represents horticultural output(Fruits, Vegetables, and Flowers) for the ith County at period t. Rd_{it} is the road connectivity which is measured as the total kilometers of paved existing roads in the ith County at time t. $Hland_{it}$ is the size of land in acre under production of horticulture crop of ith county at period t. Lab is the number of workers in the horticultural farm of the ith county at period t. $lnRainF_{it}$ is the mean annual rainfall in millimeters received by the ith county at period t.. lnA_crop_{it} is the alternative cash crop being grown in the ith county at period t. $\boldsymbol{\varepsilon}$ is the error term of the stochastic model, while $\propto_i$ are the parameters of the models.

3.4 Definition and measurement of variables

This subsection explains how each of the variables in the model was measured and the source of its data:

3.4.1 Horticultural Production

The horticultural output of fruits, vegetables and flowers for the 47 counties was the dependent variables. The unit of measure was tonnes of the produce per year per county obtained from the Ministry of Agriculture, Livestock, and Fisheries.

3.4.2 Road Connectivity

This refers to the total kilometres of paved roads in the respective counties used as a proxy for road connectivity. Data was obtained from the Counties, Ministry of Transport and Infrastructure offices, and KNBS statistical abstracts. According to Solow's neoclassical model, an increase in physical capital results increases crop output. Since road connectivity is part of physical capital, an increase in road connectivity is likely to positively impact on county horticultural production.

3.4.3 Land Size Under Production

Measured in terms of the hectacres under the production of horticultural produce (specifically, Fruits, Vegetables and Flowers). This is one of the inputs in horticultural production. We anticipated a positive relationship between the size of land under production and the horticultural production. The data was obtained from the Horticultural crop development authority (HCDA).

3.4.4 Labour

Refers to the number of people hired to work in the horticultural sector within the counties. Since this data was challenging to find per county, the study make use of the number of workers working per county as a proxy of labour force in the farms. Although this mighty have been biased upwards for counties with more workers and biased downwards in counties with fewer workers, we expected the net effect to be zero and a positive relationship between labour and horticultural output production.

3.4.5 Rainfall amount

Availability of reliable rainfall in the horticultural growing area is key for high yield. To count for this, we constructted a metric on rainfall variation using historical data from the Metrological weather station across the 47 counties and merged it with the horticultural produce. We expected that counties with unreliable rainfall to have a negative impact on horticultural production and vice versa. The average annual rainfall amount was utilized.

3.4.6 Alternative Cash Crop

Horticulture crops remain the main export earner to Kenyan economy and are closely followed by tea and coffee. However, the earning from other cash crops such as coffee and tea during the booms or the volatility of prices of horticulture crop has some farmers substitute it to these crops. Thus alternative crops in the county was key in influencing its output as it competes for the same limited farmland. A negative association between horticulture output and alternative crops was expected.

Table 1: Summary of variables and measurement

Variable	Depiction	Expected Effect	Sources of Data
Dependent variable			
Hp_{it}	This is the total output of horticultural crops(Fruits, Flowers and Vegetables), which is measured in tonnes per year per county		Ministry of Agriculture, Livestock, and Fisheries
Independent and Intervening variables			
Rd_{it}	This is the total kilometres of paved roads existing in the respective counties. This is measured in kilometres.	Positive	County, Ministry of Transport and Infrastructure Offices/KNBS
$Hland_{it}$	This is the size of land in hectares under production for horticulture crop of ith county at period t.	inconclusion	Horticultural Crop Development Authority
Labt	This is the number of employed persons in the horticultural sector in the counties. Since this data is challenging to find per county, the study will use the workers	Positive	Various County Reports

	working per county as a proxy of labour force in the farms		
RainF	This is average annual rainfall amount in each county measured in milimetre per year	Positive	County level Meteorological Station
A_crop	This is a dummy variable of alternative cash crops which assumes 1 if there are alternative crops in areas of producing horticulture or zero otherwise	Negative	County, Ministry of agriculture, KNBS

3.5 Data Source and Type

The study used secondary data from county government offices and reports for the period running from 2015-2019 comprising of all 47 county governments of Kenya. Some data were obtained from the World Development Index (WDI) and Horticultural Crop Development Authority. This period was choosen since it is the time data on horticultural production was disaggregated into county level and is readily available.

3.6 Estimation and Testing Techniques

The study applied the panel data estimation approach due to its several benefits over both cross sectional and time-series data sets. According to Baltagi (2008), both time-series and cross section studies do not control for unobserved heterogeneity thus increases the risk of obtaining biased findings. Thus, panel data was used to control for these county and time-invariant variables of which a time-series study or a cross sectional study cannot, (Baltagi, 2008). To estimate this model, a poolability test to test whether both the alpha and beta are constant or not was run.and the F-statistic used to make judgment. If we fail to reject the null hypothesis (that is if the p-value is large) we stop there and conclude that pooled panel is the suitable model for the dataset. BUT if the p values of the F test are small, we reject H0 and conclude that at least one of the alphas is different. Thus required to perform the Hausman test to choose between the FIXED effect model and the RANDOM effects model. Hausman test (1978) as a post- estimation test chooses between fixed effect (FE) model or random effect (RE) model that was appropriate for our data set. It tests whether the unique errors are correlated with the regressors; the null hypothesis is that they are not (Greene, 2008). This study base decision is made considering the resulting p-value. Therefore, on conducting the test, if the P-value exceeds 5% significance level, it will imply that the individual level effects are best modeled using the random effects method. In other words, if the null hypothesis cannot be rejected, then random effect is preferred because it is a more efficient estimator. Thus, upon specifying the random effects model, the results shall be ready for discussion, (Hausman, 1978).

Fixed Effects (FE) assumes omitted effects specific to cross sectional units which are also constant over time while the Random Effects (RE) assumes the omitted effects are random variables. Further, fixed effects model is said to impose testable restrictions on the parameters of the reduced form model as indicated by Chamberlain (1984) suggesting that one should check the validity of these restrictions before adopting the fixed effects model. On the otherhand, Mundlak (1978) argued that the random effects model makes assumptions of exogeneity of all the regressors with the random individual effects.

3.7 Diagnostic test

3.7.1 Correlation Matrix

Two reasoning informed our computation of the correlation matrix: to reveal the pattern of the variables of interest and second, to test whether a linear regression analysis is possible for our analysis. In the pattern case, our interest was to check whether the variables are positively or negatively correlated. In the diagnostic check, theoretically if the variables were highly correlated then linear regression estimates may have been unreliable.

3.7.2 Multicollinearity test

Two or more independent (explanatory) variables are said to be collinear if there exist a linear association between them. If the variance of parameter estimates is inflated leading to provision of incorrect magnitude of coefficient estimates and signs therefore wrong conclusions.Variance inflation factors were used to check for its presence. If found to be there, one among the correlated variables is dropped, retained if not highly correlated or sample size is increased (Gujarati, 2003).

3.7.3 Heteroscedasticity test

Heteroscedasticity takes place where variance of the error term is not constant. Its presence renders inference testing inapplicable. To test heteroskasticity in our study, we applied the Breusch-Pagan-Godfery test. According to this test, heteroskasticity would have been present when the P value is less than 0.05 in which the null hypothesis of homoscedasticity is rejected and if found to be there, robust standard error used (Gujarati, 2003).

3.7.4 Poolability test

The first step in choosing the appropriate model in a static panel data was to choose between a pooled OLS models against the fixed effect panel model. To do this, we ran a poolability test. This is an F test that helps us to decide whether all fixed effects are jointly equal against at least one fixed effect. That is, the null hypothesis is that all apha i's are equal against an alternative hypothesis that suggests at least one alpha i's is different.

3.7.5 Hausman Test for Fixed and Random Effect

We carried out this test to determine which of the two models (between random effect and fixed effect model) is suitable for our data set. In this test, the null hypothesis of alpha i is UNCORRELATED with the explanatory variables against alpha i is CORRELATED with the explanatory variables is tested.

CHAPTER FOUR

DATA ANALYSIS, RESULTS, AND DISCUSSION

4.1 Introduction

This sub-section gives the data analysis, outcomes and discussion of findings. We explored our data set through a descriptive statistics and then presented diagnostic tests (such as correlation matrix, multicollinearity test and heteroscedasticity test). Further, pre-estimation tests (such as unit root test) and post-estimation tests such as poolability test and Hausman Test for deciding between pooled OLS versus fixed effect models or fixed effect versus random effect models were carried out and the appropriate model chosen.

4.2 Descriptive statistics

To begin with, the descriptive statistics for the main variables used in the analysis were computed as indicated in Table 2. The summary for the overall in years. The statistics revealed that, in 2015, the mean of the dependent variable (horticultural production) was about $1.39\text{X}10^7$ tonnes with a high standard deviation of $9.19X10^7$. This high standard deviation reflect the horticultural production desparities among the counties under study. In 2016, we observe that horticultural production, increased to $1.42X10^7$ tonnes for the sample however, there was a successful reduction in horticultural production in 2017,2018 and 2019 respectifully. Plausible reasons for this sustained reduction in the horticultural production could lie on the risks which were associated with the Kenyan's disputed general election (2017/2018) which had to go for a run off as well as flactualtion on world prices for horticultural produces in the country's traditional markets such as the European Union.

On average, the annual rainfall amount for the overall sample was found to be about 1096 mm/year in 2015, 1134 mm/year in 2016, 1191 mm/year in 2017, 1321 mm/year in 2018 and 1419 mm/year in 2019. Given that different horticultural crops have different optimal rainfall amount required for their production, this amount of rainfall can play both a positive and negative impact. In this respect, we expect that the impact of rainfall to be either negatively or postively assocated with the horticultural production.

On average, the area under horticultural production flactuaed under the period under study. For instance, there was a slight increase in the area under production from approximately 9291.033 ha in 2015 to 12533.55 ha in 2017. There was a slight reduction in coverage to 11864.21ha in 2018 and a recovery to approximately 12659.43ha in year 2019.

Further, our study statistics reveals that our main variable of interest (paved roads in Km) was averagely between 42.50 km and 51.1 km per year for the overall sample. We also observe that in 2015, 2016 and 2019, there was a high standard deviation implying that in these years, the disparity in road connectivity among the counties was large than in 2017 and 2018. This disparities could be due to prioritizing of some areas than other areas.

Limited farm inputs such as labour and land was at least theoretically expected to have substitute effect horticulture production in the counties. The study findings shows that, the mean average land under other cash crop between 316.21 ha and 39002 ha. where 2015 recorderd the highest land under other cash crop production while 2019 had the least.

Lastly, on average, the labour population for the overall sample was approximately 4000 workers through out the five year period. However, a large standard deviation of above 2500 means some counties have more labour than others.

Table 2: Descriptive Statistics

Variable	Obs	2015	2016	2017	2018	2019
Horticulture production (Tonnes)	47	1.39e+07 (9.19e+07)	1.42e+07 (9.40e+07)	4597434 (2.97e+07)	158976.7 (192774.6)	161493.2 (200176.9)
Rainfall (mm/year)	47	1095.904 (778.9078)	1133.851 (700.566)	1190.702 (664.9082)	1321.064 (715.4956)	1418.855 (793.9875)
Horticultural production area (hectare)	47	9291.033 (9737.782)	10591.21 (11900.03)	12533.55 (15316.05)	11864.21 (14918.5)	12659.43 (15240.08)
Paved road (km)	47	51.0617 (107.4237)	49.16739 (56.1731)	43.71277 (28.16295)	42.49745 (27.84399)	47.4866 (42.4464)
Cash crop production (Tonnes)	47	117662 (144407.5)	449532.3 (320037.1)	295643.9 (290847.3)	864810.1 (2353475)	845851.3 (1334482)
Cash crop production (hectare)	47	39002.15 (100039.9)	22483.92 (56608.82)	3918.328 (8108.765)	6284.74 (26076.72)	316.2128 (426.3554)
Labor population (numbers)	47	4009.277 (2743.76)	4111.213 (2733.21)	4103.915 (2771.709)	4247.766 (2824.297)	4183.723 (2863.044)

Source: Author's computation

4.3 Diagnostic Tests

4.3.1 Correlation Matrix

Two reasoning informed our computation of the correlation matrix: to reveal the pattern of the variables of interest and second, to test whether a linear regression analysis is possible for our analysis. In the pattern case, our interest was to check whether the variables are positively or negatively correlated. In the diagnostic check, theory suggest that if the variables are highly correlated then linear regression estimates may be unreliable. In our case presented in Table 3, we observe that all the variables of interest have a low correlation of less than 50%. This implies that linear regression estimates can be relied upon. Further the finding shows that all the regressors are positively correlated with horticultural production (depended variables) except other cash crop production. In other words, an increase in these variables except cash crop production, increased horticultural production .

Table 3: Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) rainfall	1.000						
(2) hort_area	0.090	1.000					
(3) hort_prod	-0.111	0.048	1.000				
(4) paved_roadkm	0.117	0.073	0.027	1.000			
(5) cash_crop_prod~s	0.046	-0.010	-0.023	0.014	1.000		
(6) cash_crop_area~a	0.030	0.012	0.085	-0.028	-0.054	1.000	
(7) labor_pop	0.006	0.022	0.021	0.050	-0.038	0.017	1.000

Source: Author's computation

4.3.2 Multicollinearity test

Two or more independent (explanatory) variables are said to be collinear if there exist a linear association between them. If the variance of parameter estimates is inflated resulting to provision of incorrect magnitude of coefficient estimates and signs consequently wrong conclusions.Variance inflation factors had been used to test for its presence. If present, one among the correlated variables is dropped, retained if not highly correlated or sample size is increased (Gujarati, 2003). From the result in Table 4, both the individual Variance Inflation Factor (VIF) and the mean VIF were less than the threshold 10. Thus, multicollinearity was not a serious problem in our data set.

Table 4: VIF Multicollinearity Test using Varience inflation factor

	VIF	1/VIF
Rainfall	1.024	.976
Paved roadkm	1.021	.979
Hort area	1.013	.987
Cash crop prod ton~s	1.007	.993
Cash crop area ha	1.005	.995
Labor pop	1.005	.995

4.3.3 Heteroscedasticity Test

Heteroscedasticity happens once variance of the error term is not constant. Its presence renders inference testing inapplicable. To test heteroskasticity in our study, we applied the Breusch-Pagan-Godfery test. According to this test, heteroskasticity will be present when the P value is less than 0.05 in which the null hypothesis of homoscedasticity is rejected. If found to be there, robust standard error is used (Gujarati, 2003). From our study result in Table 5, the P-value of 0.000 was smaller than the threshold 0.05. We thus rejected the null hypothesis of homoscedasticity and concluded that there was presence of heteroscedasticity.

Table 5: Breusch-Pagan / Cook-Weisberg test for heteroscedasticity

```
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity
        Ho: Constant variance
        Variables: fitted values of hort_prod
        chi2(1)      =   249.37
        Prob > chi2  =   0.0000
```

4.3.4 Poolability test

The first step in choosing the appropriate model in a static panel data is to choose between a pooled OLS models against the fixed effect panel model. To do this, we ran a poolability test. This is an F test that helps us to decide whether all fixed effects are jointly equal against at least one fixed effect. That is, the null hypothesis is that all apha i's are equal against an alternative hypothesis that suggests that at least one alpha i's is different. If we fail to reject H0 (that is if p-value is large) we stop there and conclude that pooled panel is appropriate model for the dataset. But if the p values of the F test are small, we reject H0 and conclude that at least one of the alphas is different and thus we proceed to either fixed effect or random effect using the Hausman test.

From Table 6, the probability of 0.000 is small enough to reject the null hypothesis and concluded that either fixed effect model or random effect model could be suitable models for our data set.

Table 6: Chow's Poolability test

F test that all (46, 175) = 3.40	Prob > F = 0.000

4.3.5 Hausman Test for Fixed and Random Effect

We carried out this test to determine which of the models was suitable for our set of data. In this test, the null hypothesis of alpha i is UNCORRELATED with the explanatory variables against alpha i is CORRELATED with the explanatory variables is tested. The result from Table 7 the finding (prob = 0.043) revealed we reject the null hypothesis and apply the fixed effect model for our data set.

Table 7: Hausman (1978) specification test

	Coef.
Chi-square test value	11.48
P-value	.043

4.4 Fixed Effect Regression Results

Tables 8 shows the result from a fixed effect model, which was found to be appropriate for our dataset after rejecting the null hypothesis of alpha i being UNCORRELATED with the explanatory variables against alpha i CORRELATED with the explanatory variables in the Hausman test in the preceding section.

Table 8: Fixed-effects regression

VARIABLES	(1) Fixed effect model	(Roberstness check) Random effect model
ln_rainfall	0.419***	0.458***
	(0.00955)	(0.00775)
ln_hort_prod	0.507***	0.525***
	(0.00228)	(0.00237)
ln_paved_roadkm	-0.0162***	-0.0231***
	(0.00402)	(0.00434)
ln_cash_crop_prod_tonnes	0.0102***	0.0136***
	(0.00215)	(0.00233)
ln_cash_crop_area_ha	-0.00995***	-0.000817
	(0.00160)	(0.00174)
ln_labor_pop	0.595***	0.267***
	(0.0194)	(0.0120)
Constant	-4.897***	-2.798***
	(0.176)	(0.110)
Number of countryid	47	47
R-squared	0.662	

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.5 Findings/Discussions

Results reveals that our main variable of interest (road connectivity as proxied by paved roads per year in Km) was found to have a negative association with horticultural output. In particular, under ceteris paribus, an increase of one kilometre in road connectivity reduced horticultural output marginally by about 1.62%. This is contrary to our expectation and the plausible reason for this could be partly due to aggregation problem or due to extrapolation that we were forced to do where data was lacking, as fixed effect models require strongly balanced panel data. This finding differs from other empirical work by Raballand, et al., (2010) and Turner, (2014) who had found a positive and significance association between road connectivity and horticultural production.

Rainfall amount was found to have a significant and positive association with horticultural production. For instance, holding all other factors constant, an annual rainfall increase led to a 41.9% increase in horticultural production. Intuitively, this implies rainfall is a key determinant of horticultural crop. In most of the Kenyan horticulture production, rose flowers and vegetables forms the largest produce. These rose flowers grows well in sufficient rainfall amount and if not enough, production is done through greenhouse. This finding support and confirm with the work by Alwanga,(2019) who found a positive association of rainfall on horticultural production in kenya. That is, increase in the amount of rainfall increased production to some optimal level beyond which, an additional rainfall was destructive. Similary, our findig support McKeown, et al., (2005) work that found a direct association between rainfall amount and the horticultural output.

There is also enough evidence to support that increase in horticultural production areas increases horticulture output. For instance, a one percentage increase in horticultural production area led to about 50.7% increase in horticultural output, while all other elements are held constant. However, an increase by one percentage in the area under other cash crops, played a counterproductive role to horticulture output. For instance, holding all other factors constant, an additional rise in area under other cash crop reduced horticultural output marginally by about 0.1%. This was expected given that most of the arable land is limited and therefore, other cash crops plays a substitute role in competing for the limited land.

The number of labour units employed in the horticultural production was found to have a positive and a significant effects on horticulture output. For instance, holding all other factors constant, an additional labour input increased horticultural output by about 59.5%. This finding is in line with microeconomic theory.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter provides a summary of the key findings from our study. From this, we then present possible policy implication to the beneficiary of the findings and lastly, we suggest possible areas for further studies given the limitations of our study.

5.2 Summary of finding

Motivated by development of the feeder roads and 'county' roads and the fact that the value of sufficient road networking in agricultural production as well as economic activities cannot be underestimated, this study sought to investigate the effect of road connectivity in the county horticultural prodution in Kenya. Using a panel data (2015-2019) from various GoK sources (such as KNBS statistical abstracts, Kenya Roads Board, Kenya Rural Roads Authority(KeRRA), Kenya Metrological department and other sources like FAO, the study analysed the data using a static panel fixed effect model after confirming using Hausaman test

The finding reveals that there is evidence to link road connectivity and county horticultural production. That is, road connectivity was found to be negatively statistically signifcant in influencing horticultural production contrary to our prediction. Further, we found that rainfall had a significant and positive association with horticultural production implying that sufficient rainfall was key in horticulatural producing area.

Further, there was evidence supporting the production area under either horticulture or other cash crops improving horticultural production at the county level. Intutivelly implying that some horticultural crops could be growing better on shaded regions from strong sunlight and winds. Lastly, the fact that labour has a positive and significant influence on horticultural production, means that the cost of inputs were likely to be high in the growing areas. hence there is a need for elaborate subsidy strategy to assist the farmers increase their production of horticultural produce.

5.3 Conclusion

In conclusion, our study found there was evidence linking road connectivity to agricultural output (particularly horticultural production) at the county level. In particular, the study finding reveals that an increase in road connectivity by kilometer has a counter productive impact on horticultural output. In addition, there is enough evidence to support area under production as a possible boost to horticultural production at the county level. Lastly, rainfall variability is found to have a non desirable influence on horticultural production at the county level.

5.4 Recommendations

We recommend the county governments through their relevant departments and agencies to prioritize on incentives that will encourage high horticultural production such as initiating irrigation to avail enough water for planting, as rainfall was a significant influencer of production, encourage farmers to increase production areas through subsidizing some farm inputs to cut down cost of production, as well as subsiding labour to the large scale horticultural producers (may be through tax incentives). This is important since facilitating horticultural production will earn the country's foreign exchange and further a positive change in economic growth.

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Appendix 1: Stata Output for fixed effect model

```
. xtreg ln_hort_area ln_rainfall ln_hort_prod ln_paved_roadkm ln_cash_crop_prod_tonnes ln_cash_crop_area_ha ln_labor_pop [fwe
> ight= countryid], fe

Fixed-effects (within) regression               Number of obs     =     28,008
Group variable: countryid                       Number of groups  =         47

R-sq:                                           Obs per group:
     within  = 0.6622                                         min =          3
     between = 0.7228                                         avg =        4.8
     overall = 0.6965                                         max =          5

                                                F(6,27955)        =    9133.87
corr(u_i, Xb)  = -0.0213                        Prob > F          =     0.0000

------------------------------------------------------------------------------------------
            ln_hort_area |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------------------+----------------------------------------------------------------
             ln_rainfall |   .4191566   .0095455    43.91   0.000     .4004469    .4378663
            ln_hort_prod |   .5072466   .0022833   222.16   0.000     .5027713     .511722
         ln_paved_roadkm |  -.0161532   .0040179    -4.02   0.000    -.0240285   -.0082779
ln_cash_crop_prod_tonnes |   .0102184   .0021452     4.76   0.000     .0060137    .0144232
    ln_cash_crop_area_ha |  -.0099536   .0015989    -6.23   0.000    -.0130874   -.0068197
            ln_labor_pop |   .5948056   .0193598    30.72   0.000     .5568595    .6327517
                   _cons |  -4.897243   .1756633   -27.88   0.000    -5.241552   -4.552935
-------------------------+----------------------------------------------------------------
                 sigma_u |  .72023041
                 sigma_e |  .54931383
                     rho |  .63223163   (fraction of variance due to u_i)
------------------------------------------------------------------------------------------
F test that all u_i=0: F(46, 27955) = 755.81                 Prob > F = 0.0000
```

Appendix 2: Stata output for Robustness check (Random effect model)

```
. xtreg ln_hort_area ln_rainfall ln_hort_prod ln_paved_roadkm ln_cash_crop_prod_tonnes ln_cash_crop_area_ha ln_labor_pop [iwe
> ight= countryid], mle

Fitting constant-only model:
Iteration 0:   log likelihood =   -47344.5
Iteration 1:   log likelihood = -47333.334
Iteration 2:   log likelihood = -47333.269

Fitting full model:
Iteration 0:   log likelihood =  -31341.22
Iteration 1:   log likelihood = -31142.749
Iteration 2:   log likelihood = -31140.892
Iteration 3:   log likelihood = -31140.891

Random-effects ML regression                    Number of obs     =        226
Group variable: countryid                       Number of groups  =         47

Random effects u_i ~ Gaussian                   Obs per group:
                                                              min =          3
                                                              avg =        4.8
                                                              max =          5

                                                LR chi2(6)        =   32384.76
Log likelihood  = -31140.891                    Prob > chi2       =     0.0000

------------------------------------------------------------------------------------------
            ln_hort_area |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------------------+----------------------------------------------------------------
             ln_rainfall |   .4579468   .0077473    59.11   0.000     .4427624    .4731312
            ln_hort_prod |    .524581   .0023659   221.73   0.000      .519944    .5292179
         ln_paved_roadkm |  -.0231126    .004336    -5.33   0.000     -.031611   -.0146142
ln_cash_crop_prod_tonnes |   .0135979   .0023276     5.84   0.000     .0090358    .0181599
    ln_cash_crop_area_ha |  -.0008173   .0017355    -0.47   0.638    -.0042188    .0025843
            ln_labor_pop |   .2666082   .0120305    22.16   0.000      .243029    .2901875
                   _cons |  -2.797759   .1096112   -25.52   0.000    -3.012593   -2.582925
-------------------------+----------------------------------------------------------------
                /sigma_u |   .5652263   .0069699                      .5517293    .5790536
                /sigma_e |   .6230833   .0029973                      .6172362    .6289857
                     rho |   .4514267   .0068767                      .4379792    .4649303
------------------------------------------------------------------------------------------
LR test of sigma_u=0: chibar2(01) = 6223.82            Prob >= chibar2 = 0.000
```