TECHNICAL EFFICIENCY, PROFITABILITY AND MARKET DIVERSITY AMONG SMALLHOLDER TOMATO FARMERS IN KIRINYAGA COUNTY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION

I dedicate this thesis to my wife Janeffer and daughter Nadia Claire.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

AEZs	Agro Ecological Zones
AFC	Agricultural Finance Corporation
ANOVA	Analysis of Variance
ASN	Ammonium Sulphate Nitrate
BCR	Benefit Cost Ratio
CAN	Calcium Ammonium Nitrate
CBK	Central Bank of Kenya
CD	Cobb Douglas
CRF	Capital Recovery Factor
DAP	Di-Ammonium Phosphate
DEA	Data Envelopment Analysis
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GM	Gross Margin
GoK	Government of Kenya
Ha	Hectares
Kg	Kilogram
Km	Kilometer
KES	Kenyan Shillings
MAP	Mono Ammonium Phosphate
MSc	Master of Science
M^2	Meter Squared
MD	Man-day
NACOSTI	National Commission for Science Technology and Innovation
NGOs	Non-Governmental Organizations
NPK	Nitrogen Phosphorus Potassium
LR	Likelihood Ratio
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Square
PhD	Doctor of Philosophy
SACCO	Savings and Credit Cooperative Organizations
SDI	Simpsons Diversity Index

SFPF	Stochastic Frontier Production Function
SPSS	Statistical Package for Social Sciences
SSA	Sub Saharan Africa
SSP	Single Super Phosphate
TC	Total Cost
TR	Total Revenue
TSP	Triple Super-Phosphate
TVC	Total Variable Costs
VIF	Variance Inflation Factor

DEFINITION OF TERMS

Allocative efficiency	The ability of smallholder farmers to combine available resources in optimal proportions based on the prevailing factor prices.
Farm size	In this study, farm size is the entire land owned by the tomato farmer.
Greenhouse	Greenhouse system was conceptualized as growing tomatoes under a structure covered with transparent materials that transmit light for the growth of the plants.
Land size	In this study, land size is the piece of land under tomato cultivation.
Market diversity	A strategy of expanding marketing outlets of a particular enterprise in order to reduce the risk of uncertainties, inefficiencies and unreliability in markets within a given period of time.
Open field	In this study, open field system was considered as a conventional method of commercial tomato production in the open-air space without any protection from the environment.
Producer	An economic unit that converts factors of production into outputs to meets human needs and wants.
Profitability	The ability of a farm business to generate adequate returns and reward the producer with surplus income generated from its economic use of resources.
Productivity	A measure of efficiency which is a proportion of total output and inputs used in production per hectare of cultivated land.
Smallholder farmer	A farmer who has land of utmost 2.0 hectares in size and chooses production assortments that meet household food security while generating cash flow from commercial crops.
Technical efficiency	The ability of a producer to achieve maximum output from the available resources and technology.

ABSTRACT

The horticultural sub-sector in Kenya contributes immensely to the country's development agenda. Particularly, vegetables are crucial in poverty alleviation with tomato production ranking among the most vibrant enterprises. The crop creates employment and is a source of income for smallholders in rural areas. Despite its potential, tomato production faces major challenges including unreliable markets, low adoption of modern production systems and production inefficiencies. This has been attributed to lack of adequate and reliable information to guide producers on measures of improving productivity through cost effective production systems and efficient markets systems. As a result, this study sought to evaluate technical efficiency, profitability and market diversity among smallholder tomato farmers in Kirinyaga County. The study applied a cross sectional survey design through multistage stratified and probability proportionate to size sampling procedures. Primary data were collected by administering structured questionnaires to a sample of 384 smallholder tomato farmers. Descriptive statistics were used to analyze socioeconomic characteristics and results revealed that majority of the respondents were males with the youth forming a large proportion. In addition, results revealed that respondents were moderately experienced and had adequate information regarding markets. The stochastic frontier production function of the Cobb Douglas form was used to estimate efficiency while Tobit regression model was applied to identify farm and farmer characteristics that influence technical efficiency. Results showed an average technical efficiency of 39.55% among respondents with greenhouse farmers being more technically efficient than open field farmers. This indicated that there is a possibility of improving technical efficiency by 60.45% through better utilization of resources and technologies. Household size, production systems, seed type and fertilizer were significant and positively influenced technical efficiency while land size had a negative and significant impact on technical efficiency. The input-output relationship showed that area under tomato cultivation and the quantity of fertilizer used were significant and positively influenced tomato yield. The profitability of both green house and open field production systems was evaluated using a combined analyses of gross margin and net profit. The capital recovery factor was applied to determine the amount of initial cost of investment recouped by farmers annually. In addition, the independent sample t-test was used to show the significant variations between costs and profitability of the two systems. Results showed that fixed and variable costs were statistically different while the greenhouse system had better returns compared to the open field system. The Simpsons' diversity index was used to evaluate the magnitude of diversity and producers had a mean diversity index of 47.71%. This implied presence of an opportunity to improve diversity scores by more than 50 percent if the quantities sold in each market outlet are improved. A one way ANOVA was used to assess connection between market diversity and farm prices. Results revealed that farm prices realized by the smallholder tomato farmers across different marketing outlets were not statistically different despite levels of market diversity being distinct. The study recommends that emphasis should be focused on policies that enhance production of certified seeds and provision of subsidized fertilizers since their continued application increases technical efficiency. In addition, policy interventions aimed at subsidizing costs of establishing greenhouses would serve as an incentive to motivate farmers use technologies in tomato production. Besides, enhancing contract markets would reduce the influence of intermediaries and guarantee market efficiency leading to improved farm prices hence increased returns.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Sub-Saharan Africa (SSA) accounts for about 13 percent (950 million people) of the global population (UN, 2015). This is anticipated to increase to 2.1 billion people by the year 2050 (OECD, 2018). Majority (75%) of the inhabitants in this region are small scale farmers with farms ranging from 0.2 to 3 hectares (ha) (Nyamwamu, 2016). The anticipated population upsurge signifies growing demand for adequate food and better living standards especially in rural areas. Conversely, agricultural production, the main source of sustenance for smallholders in developing countries has declined and remains below the global optimal levels (Najjuma, Kavoi & Mbeche, 2016). This shows a need to promote agriculture and ensure population growth keeps pace with food production and income generation (Chepng'etich, Nyamwaro, Bett & Kizito, 2015).

Achieving this goal necessitates an understanding on the efficacy of production and productivity in agriculture. In addition, Maniriho and Bizoza (2015) elaborated that smallholder farmers need to utilize resources efficiently by embracing production systems that increase yield and guarantee better returns. Equally, farmers need to understand the performance of these systems for informed production decisions as discussed by Wachira, Mshenga and Saidi (2014). Further, Fiszbein (2017) elucidated that farmers need to appreciate the market settings by exploring existing opportunities. This will ensure reduced inefficiencies, adequate flow of information and an expanded market offering rewarding farm prices.

Tomato (*Solanum Lycopersicum*) is an important vegetable belonging to the Solanaceae family and its importance in developing countries has been given a special mention (Al-Amri, 2013). Its production is practical on small scale and a major food crop among rural populations. In Kenya, the crop has a possibility to transform agriculture into a profitable venture and improve livelihoods among rural populations. This potential prompted this study that sort to evaluate technical efficiency, profitability and market diversity among smallholder tomato farmers in Kirinyaga County. The study related provision of research information regarding improving tomato productivity through cost effective production systems in an efficient and expanded market structure.

1.2 Agriculture and tomato production in Kenya

Sub-Saharan African (SSA) countries continue to rely on agriculture for food and economic expansion (Ochilo *et al*., 2019). In Kenya, the sector is a key economic pillar contributing 24 percent of the GDP and about 65 percent of total exports (Nyamwamu, 2016). In addition, 85 percent of the rural population depend on agriculture, either directly or indirectly (Yabs & Awuor, 2016). Tabe and Molua (2017) noted that smallholders dominate the sector underwriting about 70 percent of the total produce.

In Kenya, vegetables form the bulk of agriculture with about 80 percent of producers and 60 percent of total exports (Ochilo *et al.*, 2019). Karuku, Kimenju and Verplancke (2017) noted that vegetables form a vibrant enterprise that sustains rural populations but production among smallholders has recorded declining productivity over the years. Among the widely cultivated vegetables, tomato has a greater potential, ranking second after potato in terms of value and production (Ibitoye, Shaibu, & Omole, 2015). The country records an average of 410,033 tonnes from tomato production annually, placing Kenya among leading producers in SSA (Geoffrey *et al*., 2014).

Tomato farming provides income, improves livelihoods and creates employment opportunities among rural populations (Humphrey, 2017). Owing to this contribution, tomato farming remains important in rural areas especially among smallholders. Tomato is categorized among crops mostly grown in rain dependent open fields (Mitra & Yunus, 2018). However, the system is undermined by pest and disease infestations among other climatic conditions which adversely affect production (Mwangi *et al.*, 2015). Consequently, farmers encounter losses due to reduced yields and poor marketability of the produce. Erkie and Andualem (2018) noted that owing to the changing weather patterns, smallholders are progressively growing tomatoes in greenhouses. Nyamwamu (2016) explains that this has been achieved through numerous endeavors initiated by stakeholders (e.g. NGOs, extension agents, agrochemical dealers and through government programs) to improve tomato productivity in Kenya. Besides, the initiative included development of disease resistant varieties, effective pesticides, quality and subsidized fertilizers aimed at reducing costs of production in tomato farming.

1.3 Variations in tomato production and marketing

Globally, tomato production is estimated at 10 tons per hectare against the optimal production of 33.7 tons per ha (Mani, Hudu & Ali, 2018). In Sub-Saharan Africa, tomato productivity has remained low at 8.5 tons per hectare contrary to an optimal level of 20.51 tons per hectare (Masunga, 2014). In Kenya, area under tomato cultivation has gradually increased from 18,178 hectares (ha) in 2011 to 18,378 ha in 2015 and 20,111 ha in 2016 (Kumar *et al*., 2018). Kumar *et al*. (2018) also noted that productivity has been declining from 22.4 tons in 2011 to 17.9 tons in 2015 and 16.9 tons in 2016. In addition, 12 tons per hectare were recorded in 2018 against the country's potential yield of 30.7 tons per hectare (Ochilo *et al.*, 2019).

The low and declining productivity in tomato production may be attributed to failure of farmers to exploit available resources and technologies (Katungwe, Elepu, & Dzanja, 2017). Further, Mitra and Yunus (2018) argued that inadequate support by farmer institutions may lead to reduced productivity. Besides, Simwaka, Ferrer and Harris (2013) clarified that limitation of factors of production hinder farmers from improving production through use of more inputs. This is so despite efforts to promote tomato production by introducing modern technologies such as greenhouses, irrigation, certified seeds and improved fertilizers. This yield promoting parameters continue to record low adoption rates hence low productivity and profitability (Mani *et al*, 2018). Among smallholders, disparities in production may also arise from socio-economic and institutional characteristics. The existence of variations in production signify a need to examine technical efficiency in agriculture particularly in tomato production. This is so because technical efficiency remains a valuable tool in solving problems of low productivity among smallholders as explained by Tabe and Molua (2017).

Chepng'etich *et al*. (2015) debated that variations in agricultural production are caused by differences in scale of operation, operating environments and type of production systems. Mani *et al*. (2018) noted that to increase production, farmers need to efficiently utilize available production systems rather than adopt modern production technologies. This is so since improving productivity in the short run would be more cost effective through efficient utilization of existing production systems compared to introducing new technologies as argued by Wahid, Ali and Hadi (2017).

Further, Ochilo *et al*. (2019) argued that improving technical efficiency in tomato production, farmers would increase their yields thus benefit from the economies of scale. Further, farmers need to embrace production systems that are receptive to varying climatic settings to ensure improved tomato productivity and acclimatization to weather patterns. In Kirinyaga , tomatoes are mainly grown under open field but farmers are progressively adopting the greenhouses as noted by Wachira *et* a*l*. (2014).

Ndirangu, Mbogoh and Mbatia (2017) illustrated that, land available for agriculture has reduced due to urbanization and extensive soil degradation. Wanjiku (2015) also noted that increased human population and land fragmentation has gradually reduced land available for tomato production. Therefore, to achieve maximum output and returns, smallholder farmers need to embrace production systems that boost productivity (Moranga, Otieno & Oluoch, 2016). This informs that, it is necessary to encourage farmers embrace systems that are highly productive and that generate more profits (Puozaa, 2015). In embracing either greenhouse or open field production system, tomato farmers need to consider factors such as costs, environmental conditions and other factors that may impact on profitability (Wachira *et al.*, 2014). Despite this considerations, information on the performance of the two production systems (open field and greenhouse) remains scarce and variable.

Technological innovations though indispensable in realizing higher productivity, are not sufficient to guarantee efficient markets for agricultural produce (Saavedra, Figueroa & Cauih, 2017). Nevertheless, Mutayoba and Ngaruko (2018) argued that devising necessary marketing approaches has the potential to offer resourceful channels through which farmers would acquire better proceeds. Ruttoh, Bett and Nyairo (2018) noted that this can be attained since efficient markets increase the producer’s share in the consumer price. Moreover, Panda and Sreekumar (2012) posited that besides linking buyers and sellers, efficient markets provide dynamic strategies that promote product consumption. Though important, attention on marketing of high value vegetables such as tomatoes has been limited thus resulting to market imperfections (Moranga *et al*., 2016). This has hindered farmers from accessing emerging market opportunities and in most cases farmers get frustrated due to low produce prices (Hanadi, Mohammed & Salih, 2018). Panda and Sreekumar (2012) articulated that this traps smallholder farmers within certain constraints thus compelling them to continue operating in markets that offer unrewarding incomes.

Despite the substantial contribution of agriculture to economic development, the competitiveness of tomato markets in rural areas is still low (Ngenoh *et al*., 2019). Moranga *et al*. (2016) attributed this to inefficiencies which affect quality marketing thus hindering growth of the tomato industry. This indicates that farmers fail to make meaningful profits along the marketing system (Osondu *et al*., 2014). Abel *et al*. (2019) attributed this to the continued use of traditionally structured market systems that are characterized by high transaction costs, poor information systems and inefficiency in predicting trade linkages. Entangled with the perishable nature of the tomato crop, these traits lead to huge losses for the farmers. This can be inverted through formation of polies that support linkage of smallholders to output markets through channel expansion as explained by Mutayoba and Ngaruko (2015). In addition, Momanyi (2016) argued that there is a need for farmers to choose strategies that expand markets in order to reduce inefficiencies within a given period. Though deemed necessary in achieving an efficient marketing system that offer stable tomato farm prices, there is limited and inadequate information on market diversity and its relation to farm prices among farmers particularly in Kirinyaga and areas in similar agro ecological zones (AEZs).

1.4 Statement of the problem

Towards achieving vision 2030, the Kenyan government intends to transform the agriculture sector into a profitable venture in the economy. This revolution requires a major change that reduces output variations, use of appropriate production systems and use of better market oriented approaches. Tomato is one such crop that has the possibility to significantly promote the sector in wealth creation and poverty reduction. The crop is widely cultivated by smallholders and ranked second important after potato.

The future of the tomato is linked to its ability to thrive in small scale among rural populations. This potential has motivated research institutions to devise technologies that can boost tomato production. The government has also initiated numerous undertakings to improve tomato production and offer potential for growth among smallholder farmers. Despite these concerted efforts, there still exists a yield gap between the farmers' actual production levels and the maximum attainable output, hence technical inefficiencies. Reviewed literature shows that in Kenya, tomato optimal yield is approximately 30.7 tons per hectare, but farmers are only able to realize an average of 12 tons per hectare.

Tomato is among crops grown by smallholder farmers under the rain dependent open field system with slight irrigation. This system is prone to unpredictable rainfall patterns, increased disease and pest infestation. Owing to this conditions, smallholders are progressively growing tomatoes in greenhouses irrespective of the high initial investment costs. Though these systems exist, farmers are unable to account for the costs and returns for the entire economic life of their investments. This restricts available information on the performance of these systems among smallholder tomato farmers. Further, despite the value attached to tomato production in rural areas, farmers operate under traditionally structured markets that are inefficient in predicting trade linkages. This traps farmers within certain market constraints that hinder access to emerging market opportunities. As a result farmers continue to receive low and unreliable produce prices. This leads to market uncertainties and imperfections which affect quality marketing and flow of products. To invert this, there is a need to assess market diversity which has been deemed necessary in realizing resourceful markets that are efficient to offer stable farm prices.

However, efforts to promote tomato production have been hampered by lack of adequate and reliable research based information, which guides producers on measures of improving productivity through cost effective production systems and the realization of efficient markets. Results from previous studies conducted to evaluate tomato production and profitability have been found to be inconclusive in that they failed to assess the performance of production systems by conducting a cost analysis and their failure to assess the magnitude of market diversity. In addition, literature provided scanty information regarding the relation between farm prices and diversity in an expanded market structure. For this reason, the current study was conducted to examine tomato productivity and assess profitability by providing research based information regarding aspects that impact on technical efficiency, the profitability of tomato production systems, the magnitude of diversity in expanded markets and its relation to farm prices among smallholder farmers in Kirinyaga County.

1.5 Objectives of the study

1.5.1 General objective

The broad objective of this study was to assess technical efficiency, profitability and market diversity in tomato production among smallholder farmers in Kirinyaga County.

1.5.2 Specific objectives

The specific objectives were;

1. To determine the effect of selected socioeconomic factors on technical efficiency among smallholder tomato farmers in Kirinyaga County.
2. To evaluate profitability between open field and greenhouse production systems among smallholder tomato farmers in Kirinyaga County.
3. To evaluate tomato market diversity on farm prices among smallholder tomato farmers in Kirinyaga County.

1.6 Hypotheses of the study

The following hypotheses were tested:

1. The selected socioeconomic factors have no significant effect on technical efficiency among smallholder tomato farmers in Kirinyaga County.
2. The profitability between greenhouse and open field production systems does not differ significantly among smallholder tomato farmers in Kirinyaga County.
3. Market diversity has no significant effect on farm prices among smallholder tomato farmers in Kirinyaga County.

1.7 Justification of the study

Tomato is an extensively cultivated crop with potential to provide incomes, improve living standards and create employment among rural populations in developing countries. Spreading out the tomato enterprise can be achieved through adequate knowledge of factors that hinder realization of optimal production. Further high productivity can be attained by embracing highly productive and profitable production systems that are receptive to changing climatic conditions. The intensification of land demarcation and increased human population requires farmers to utilize existing production systems appropriately while embracing technologies that promote technical efficiency. In addition, it is necessary to assess the market system and the role of diversity in achieving fair farm prices. Although studies on marketing and production of tomatoes exist, literature relating measures of improving tomato productivity in an expanded market structure through cost effective production systems is limited.

This study provides information aimed at bridging the research gap by explaining matters regarding proficient use of resources and technologies among smallholder tomato farmers. The application of this knowledge will enable farmers achieve high levels of technical efficiency thus increased yields and quality of produce. Increased tomato yield guarantees the economies of scale benefit thus making tomato farmers more competitive due to reduced costs per unit of production. This will enable farmers operate in an expanded market structure thus reduced risks and losses. Consequently, farmers will be able to engage in different market platforms and explore markets with greater potential. Besides, with improved quality, tomato farmers are able to realize enhanced farm prices an aspect that leads to increased profitability.

Kirinyaga County was selected since it is a frontrunner of tomato production in Kenya. In addition, the County has an outstanding potential in tomato production due to availability of plenty viable farmland. In addition, the County portrays better productivity due to availability of sufficient irrigation infrastructures a condition that facilitates the implementation of both the greenhouse and open field production systems. Given the increased land fragmentation which has reduced farm sizes, tomato production continues to be an option for generating incomes among smallholder farmers in the region.

Information generated from this study will help smallholder tomato farmers to utilize resources efficiently. Policy makers will use this information in designing policies meant to improve efficiency, embrace profitable systems and approaches that promote efficient marketing aimed at realizing better prices and returns. This will result to sustainable resource management for food security and poverty alleviation, hence contribute towards achieving vision 2030 and in line with the Sustainable Development Goals (SDGs). Research institutions and extension agents will benefit from the findings as they formulate messages for use in Kirinyaga and other areas with tomato growing potentials. The study also pointed out gaps for further research that can improve tomato production among smallholders.

1.8 Scope of the study

The current study was carried out in Kirinyaga County where tomato farming is among the major agricultural enterprises. The County has been involved in initiatives conducted to promote tomato production in Kenya. The main issues in the study were socioeconomic features among respondents, technical efficiency, profitability of production systems, market diversity among farmers and farm prices. Structured questionnaires were used as tools for data collection and administered to a sample of 384 smallholder tomato households. The sample was selected through multi stage stratified and probability proportionate to size sampling techniques. This ensured accuracy and consistency of information which enriched attainment of the intended goal of the study. Quantitative and qualitative data were collected while descriptive statistics (means, percentages, frequencies) and econometric models were used in data analysis.

Mainly, the study relied on primary data from smallholder tomato farmers and focused on a twelve (12) month production period. This allowed the researcher gather adequate information pertaining tomato production particularly for the 2018/2019 season. The study area has an outstanding potential in farm viability and production infrastructures that promote the use of both open field and greenhouse production systems. This aspect makes the study findings relevant among smallholder tomato farmers in Kirinyaga County since an understanding of the production systems, will facilitate efficient resource utilization thus increasing technical efficiency hence increased yields. Similarly, analyzing data through chosen models provides information regarding the use of cost effective production systems and technologies that promote quality of tomato produce. This enables farmers realize enhanced prices at farm level leading to increased profitability. Besides, smallholders become more competitive owing to economies of scale benefits that result from increased yields.

CHAPTER TWO

LITERATURE REVIEW

2.1 Measures of technical efficiency

Farrell introduced measures of efficiency as being economic, allocative and technical (Najjuma, 2016). For a farm to be economically efficient it has to attain both allocative and technical efficiencies (Ndirangu *et al*., 2017). Zalkuw *et al*. (2014) explained that the determination of a farm's level of optimal production, involves the approximation of the production frontier. Further, Moranga *et al*. (2016) noted that the formulation of the frontier enables researchers to calculate technical efficiency, allocative efficiency and economic efficiency. Literature provides different approaches adopted to construct the frontier function. These methodologies are categorized into parametric and non-parametric approaches (Oladimeji & Abdulsalam, 2013).

2.1.1 Non-parametric approach of measuring efficiency

The non-parametric models of frontier estimation involves developing a functional relation between inputs and output from empirical observations without prior specifications (Erkie & Andualem, 2018). Data envelopment analysis (DEA) is the frequently used non-parametric approach (Ndirangu *et al*., 2017). The DEA model maximizes output per unit of input by determining the frontier of best practice using linear programming (Ajibefun, 2008). Mukhtar *et al*. (2018) noted that DEA is a deterministic model thus deviations in output from the frontier are not separated into inefficiency and random errors. Ndirangu *et al*. (2017) then indicates that this model is sensitive to errors and noises in the data. In addition, though not necessary to specify technology in DEA, hypothesis testing regarding the performance of the model is impossible due to the uncertainty in estimation of parameters (Adanguidi, 2019). In addition, the use of parametric models of statistics to analyze efficiency parameters generated by the non-parametric DEA model raises uncertainty issues. Erkie and Andualem (2018) explained that this ambiguity is addressed by allocating essential weights to inputs and outputs through linear programming to ascertain maximum efficiency. For that reason, DEA model is designed to maximize relative efficiency subject to the constraint that parameters attained are feasible for all others in the sample.

2.1.2 Parametric approach of measuring efficiency

The estimation of a production function using parametric approaches involves the description of a parametric function and minimizing the distance of the observed data from the frontier function (Ndirangu *et al.,* 2017). In estimating efficiency and the production technology, these approaches incorporates the cost, profit, revenue and possibly the production functions as is the case in this study (Ajibefun, 2008). The commonly used parametric model is the stochastic frontier production function (SFPF) (Abdul & Isgin, 2016). The stochastic models attributes deviations from the frontier function into inefficiencies and random errors thus more accurate and less sensitive to measurement errors in data (Weldegiorgis *et al.,* 2018). The SFPF allows hypothesis testing regarding the effectiveness of the model (Dessale, 2019). Further, it is possible to use parametric statistics in analyzing efficiency measures generated by the stochastic models (Erkie & Andualem, 2018). Similarly, this approach is a flexible technique in measuring the frontier production function, which provides a meaningful estimate of the measurement error. Conversely, parametric frontier functions require the definition of a specific functional form for the technology and the inefficiency error term (Ajibefun, 2008). In measuring technical efficiency of tomato production among smallholders in Kirinyaga County, the SFPF approach was applied. This was based on its advantage to provide a chance to distinguish the random noise from inefficiency and to calculate the standard error of efficiency measurement results. Among individual farms, technical efficiency was computed as a proportion of observed output against the maximum attainable output from a given set of resources.

2.2 Empirical studies on factors affecting technical efficiency

Masunga (2014) assessed production of tomatoes among smallholder farmers in Musoma Municipallity, Tanzania. The study reported that production in the area exceeded the projected level in Tanzania but was lower compared to the estimated levels in Africa and the global optimum. However, the study was not conclusive on the levels of technical efficiency and productivity. In Mymensingh district of Bangladesh, a study by Mitra and Yunus (2018) assesed the levels of technical efficiency and found that tomato farmers in the area had high levels of technical efficiency. The study further revealed that farmers could reduce their input utilization by a slight proportion and remain technically efficient. In addition, Mitra and Yunus (2018) noted that education, training and adoption were reported to positively influence efficiency while age had a negative impact. The study used the DEA approach but failed to consider economic factors such as farm size, farm inputs, land tenure, farm and off farm incomes which could affct the famers' efficiency levels.

A study in Oyo State in Nigeria on tomato producton found that technical efficiency of the farmers was below average. The study further revealed that education, experience and diversification infuenced efficiency (Adedeji *et* al., 2011). The SFPF was used to approximate technical efficiency of tomato farming in Adamwa state, Nigeria. Results showed that farmers operated below the frontier but the effect of market proximity and technology was not captured (Zalkuw *et al.*, 2014).

In Cameroon, Tabe and Molua (2017) used the Cobb Douglas (CD) production function to evaluate efficiency of smallholder tomato farmers. The study revealed that farmers were not fully technically efficienct though experienced farmers recorded high levels of technical efficiency. The results showed that education, age, adoption and practice of agronomic practices such as weeding, crop protection and fertilizer application positively influenced technical efficiency whereas proximity to extension services had a negative impression. However the aspects of farm and off farm incomes were not well articulated in this study.

A study in India found that irrespective of the farm size, tomato farmers continue to experience inefficiency problems (Murthy *et al.*, 2009). Land, land productivity and education levels were found to better explain technical efficiency among medium scale farmers who recorded the best measures of technical efficiency. On the other hand, smallholder farmers were found to be price efficienct (low production cost) with potential to expand production and productivity. This study by Murthy *et al*. (2009) adopted the non parametric DEA approach thus deviations from the frontier output were not seperarated into inefficiency and random errors. A research conducted in rural areas of Pakistan found that the mean technical efficiency for tomato growers was relatively high with most producers opearating in the increasing returns to scale (Khan & Shoukat, 2013). This study also revealed that formal and informal education increased technical efficiency. However, this research looked at the whole array of tomato growers and failed to indicate the actual contribution of smallholders who are the major producers among rural populations.

In Kenya, Najjuma (2016) compared technical efficiency of green house and open field tomato farmers in Kiambu County. The study noted that greenhouse farmers were more efficienct and that modern technologies were under-exploited an aspect that negatively affected productivity. The CD model results revealed that credit access did not show significant statistical differences on the tomato production system. In addition, Najjuma (2016) revealed that access to extension services, agricultural labor, size of land under tomato production and farmer experience had a statistical effect on the type of production system. Further, the study reported that increased use of certified seeds, persistent application of fertilizer and pesticides in appropriate proprtions positively influenced technical efficiency. Similarilty, increase in farm sizes, continued use of tractors in farm operations, improved access to financial credits, provision of extension services and enhanced availability of income reduced technical inefficiencies. Besides, the study suggested that similar studies be conducted in other counties to form a basis for comparison of the findings in differet parts of the Country. Based on this recommendation and that Najjuma (2016) made conclusions of technical efficiency regarding tomato production among farmers in Kiambu County, the current study replicated this study in Kirinyaga County.

2.3 Profitability analysis of production systems

In a comparative analysis of profitability among ground nut farmers, the Benefit Cost Ratio (BCR) was used to show profit efficiency of certified ground nut seeds and convectional ground production (Tasila, Mabe & Oteng, 2019). The BCR method was appropriate for this study since the goal was to describe benefits and costs derived by the producers. In comparing the profitability of cassava and maize enterprises, a study by Abdullahi, Orinya and Ajawuihe (2015) used enterprise budget method. This method is approporiate in that it enables farmers understand the need of farm budgeting though it posses budgeting frustrations in earlier years of operation. In Saudi Arabi, enterprise budgeting has been used to compare profitability of greenhouse vegetables which included tomatoes, cucumbers, green peppers, eggplant, okra, beans and squash. The by Al-Abdulkader (2004) revealed desirable enterprise environment of the selected crops and reported that tomatoes and cucumbers were the most profitable greenhouse enterprises. However, Kibirige (2014) explicated that enterprise budgeting is deprived by limitation of information since budgets make future predictions and it is difficult to accurately estimate markets, prices and yields of agricultural enterprises like tomato.

The breakeven analysis was used in Accra and Kumasi areas of Ghana to determine the feasibility of broiler production. Since breakeven point is realized where the total incomes equals the costs, performance of an enterprise below or above the breakeven point indicates varying inferences towards profitability (Mahama *et al.,* 2013). The breakeven method is used to determine the financial perfomance of individual farm enterprises like the production of fruits, cabbages and livestock thus not appropriate in comparing profitability between tomato production systems. In most studies, the analysis of profitability adopts the gross margin concept since it helps compute profits in the short run (Sekumade & Toluwase, 2014). Sekumade and Toluwase (2014) also indicated that it shows the ratio of gross profit to sales revenue in percentage form. A comparative study on the performance of improved maize seeds in Cameroon used the gross margins (Anokyewaa & Asiedu, 2019).

Further, a study by Ndungu, Macharia and Kahuthia (2012) analyzing the perfomance of vegetable production which included kales, cabbages and spinch in Kiambu and Kajiado Counties used gross margin method. From the results, kales reported a high gross margin compared to spinach (Ndungu *et al.,* 2012). Gross margin estimates returns of an enterprise within a specified period as explained by Wachira *et al*. (2014). Though this method does not consider fixed costs and capital costs, the method is valuable if fixed costs form a small portion of production costs especially in subsistence agriculture among smallholders as reported by Mitra and Sharmin (2019).

In Nakuru-North district of Kenya a study used both gross margins and net profit to compare profitability in tomato productin (Wachira *et al*., 2014). The results revealed that greenhouse growers recorded twice the income generated by their open field counterparts. Despite this study, litereature reviwed focused more on other agricultural enterprises with limited information on horticultural production. Besides, information regarding the profitability of vegetable production in rural areas remained scanty with limited scope regarding smallholder tomato farming. This necessitated the need for the current study which used Gross Margins and Net Profits to compare profitability of tomato farming in open field and greenhouse production systems among smallholder farmers in Kirinyaga County. The study used t-test to determine whether significant differences existed in the profitability of open field and greenhouse production systems in the study area.

2.4 Analysis of market diversity

A study on the impact of diversification among smallholders in vegetable production noted that lack of reliable markets and inappropriate infrastructures were the major obstacles towards market diversification in vegetable production (Joshi, Joshi & Birthal, 2006). In addition, the study indicated that high price volatility and yield risks were major aspects to consider in market diversity since they influenced farmers' profitability. A study conducted in Kilimanjaro analyzed the effects of price variations in agricultural production and marketing among Tanzanian farmers. The study reported that price fluctuations within the agricultural sector were a major challenge towards the achievement of the goals set by smallholders (Huka, Ruoja & Mchopa, 2014). Further this study revealed that these impediments resulted to loss of capital and farmers abandoning agriculture for more lucrative endeavors. The study by Huka *et al*. (2014) attributed this to the seasonality nature of most agricultural products which causes unequal distribution. As a result, prices tend remain low during a glut and high during scarcity hence the price fluctuations different production periods. Conversely, the study considered price fluctuations but failed to report on how this price variations were influenced by the choice of different market outlets.

A study in Kajiado County analyzed the market structure and conduct in tomato marketing using the Herfindahl-Hirschman indices (Ruttoh *et al.*, 2018). The study reported that markets were more diversified at retail and wholesale but specialized at the producer level. The study further used the Gini Coefficient to show that markets were biased in income distribution thus noted that tomato markets were imperfect (Ruttoh *et al.*, 2018). However, the Herfindahl-Hirschman indices fails to genuinely take into account the complexities of various markets in assessing competitiveness. In addition, Gini Coefficient assumes that a straight line distribution gives desirable outcomes which may not be the reality in scenarios where markets are dynamic.

A study in Giwa market, Kaduda state of Nigeria analyzed market expansion and price variations in tomatoes and used the Grand seasonal index. The study revealed that the commodity indexes in the market were highly flexible which resulted from minimal incentives among rural farmers and marketers of tomatoes (Mani *et al*., 2018). The results showed that tomato farmers experienced the highest price volatilities among other smallholder farmers. In addition the research noted that tomato farmers sold most of their produce at rural markets with little diversification to urban and international markets. Though the seasonal index allows for adjustments in forecasting, the indices cannot be measured accurately using statistical approaches. In addition, seasonal indices are computed on the assumption that changes in the markets are uniform but this supposition does not hold in agricultural markets (Mani *et al*., 2018).

In marketing agricultural products, diversification has been considered as a measure of spreading marketing risks instead of concentrating total risk on a particular channel (Erkie & Andualem, 2018). Diversity has been measured using a number of indices such as the margalef index. Tanah (2014) and Morris *et al*. (2014) noted that this index has no value limit and shows variation depending with the number of characters. Though the selected component can be compared in a wide range of characters, this index considers only a specific diversity components that shows sensitivity to the sample size. The Fisher alpha index shows the current and progressive distribution patterns of a character (Grabchak *et al*., 2017). The index is less sensitive to the sample size but does not provide information regarding the rare characters (Tanah, 2014), thus found to be inappropriate in this study.

The most common indexes in analyzing market patterns are Shannon-wiener and Simpson's indices. The former is used to measure uniformity and abundance but like the fisher index it does not analyze the exceptional characters. The Simpson's diversity index (SDI) ranges between 0 and 1 (McLaughlin *et al.*, 2016) and the level of diversity gradually increases as the index approaches 1 (Morris *et al.*, 2014). The SDI considers rare markets, measures uniformity, abundance (Erkie & Andualem, 2018) and takes into account the quantities sold in each outlet while determining the degree of diversity (Grabchak *et al.*, 2017). Based on this advantage, the current study used the Simpson's diversity index in computing the magnitude of market diversity among smallholder tomato farmers in Kirinyaga County.

2.5 Theoretical framework

The study was founded on the economic theory of production. The theory explains that efficiency concerns the relative performance of processes used in transforming a given input into output A producer is a decision making unit that transforms the productive resources into valuable goods and services that meet consumer needs (Snyder, Nicholson & Stewart, 2012). The producer utilizes available resources to produce a commodity that will be sold at a profit through input combinations that minimize cost.

The concept of agricultural productivity has been defined by Tabe and Molua (2017) as the ratio of total farm output and total inputs used in the farm production. Abate, Dessie and Mekie (2019) argued that the main intention of producers is to optimally achieve high levels of production. This can be attained through efficient utilization of resources and modern technologies which leads to improved produce quality and higher levels of technical efficiency hence increased yields. Consequently, Adeoye and Balogun (2016) noted that this will enable farmers benefit from economies of scale and realize enhanced product prices thus increased farm profitability. Besides, increased agricultural productivity and efficiency improves the well-being of the society as a whole. An increase in farm output may result from an increase in quantity of inputs with no change in output per unit of input. Second, may result from increased productivity of inputs with no change or a decrease in quantity of input and finally, from a combination of changes in inputs and productivity. This situation makes the concept of efficiency and profitability a central issue in production economics.

The economic theory of production provides basic guidance to the producers on how to allocate scarce resources towards optimizing the production of commodities. A production function relates inputs to outputs in a production process and shows the maximum attainable output from a set of resources (Debertin, 2012). The CD production function was used to estimate the frontier production in the current study. Combinations beyond the frontier are not feasible due to resource limitation but combinations below the frontier are technically inefficient (Ndirangu *et al*., 2017). Farms operating along the frontier production are technically efficient. Debertin (2012) reported that the concept of efficiency is applicable in the SFPF using econometric methods and where technical efficiency is measured against the frontier function.

Snyder *et al*. (2012) noted that the production theory explains that through adoption of improved systems, farms can remain at the same level of production with the utilization of smaller quantities of resources or use same amount of resources to produce more output. Debertin (2012) explained that technology increases the quality of inputs and is similar to an increase in resources. This theory assumes that farms or producers are profit maximizers operating in a perfectly competitive market structure (Wachira *et al*., 2014). This concept explained the response of smallholder tomato farmers' profitability to adoption of either open field or greenhouse tomato production systems. Further, the two production systems were assumed to be mutually exclusive.

2.6 Conceptual framework

From literature, the nexus concerning the independent and dependent variables was hypothesized in a conceptual framework. Literature explains that production in agricultural enterprises entails the transformation of inputs into outputs. In tomato production, inputs include land, labour, fertilizer, pesticides and seeds collectively used in different proportions to yield the desired output. The efficacy of input conversion is not only dependent on the quantity of resources used but also on production systems adopted by farmers, farm and farmer characteristics. Motivated by their intention to achieve efficient markets, farmers seek an expanded market system that enables them to diversify and explore various markets as a measure of reducing the risks, uncertainties and inefficiencies. This connection has been clarified below in **Figure 2.1**.

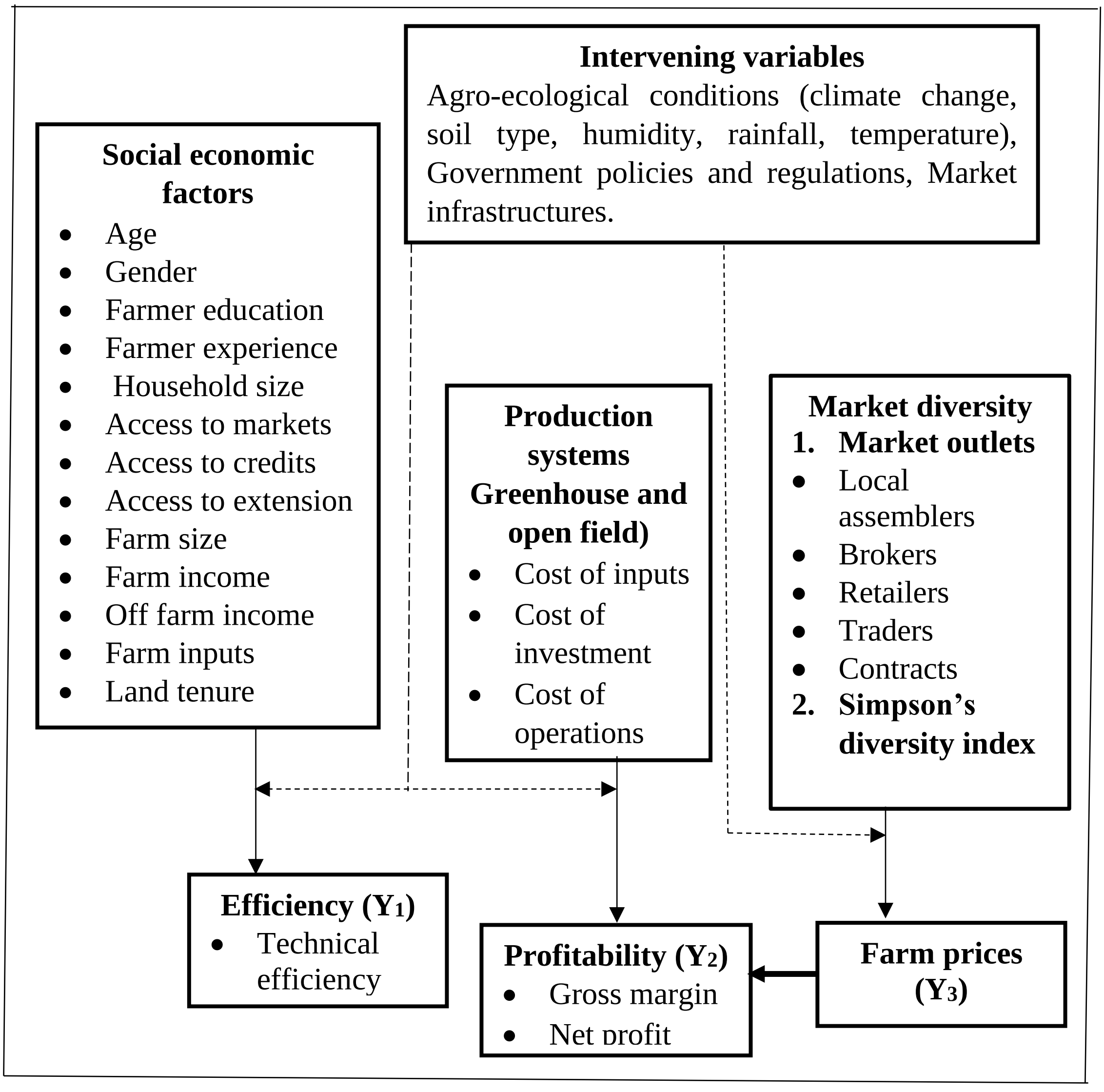

Figure 2. 1: Conceptual framework

2.7 Operationalization of variables

Table 2.1 summarizes variables used in this study and how each variable was measured.

Table 2. 1: Description of variables

Variable	Description	Measure
Technical efficiency	Yield per Ha	Deviation from frontier production
Profitability	Returns from tomato production	Gross margin, Net profit
Farm price	Level of the price	Kenyan shilling
Age	Age of the household head	Age in years
Gender	Gender of household head	0 = male, 1 = female
Education	Years spent while schooling	Number of years
Experience	Years in farming	Number of years
Market distance	Market proximity	Kilometers
Production system	System adopted	0= Open field, 1 = greenhouse
Access to credit	Credit availability	0 = No, 1 = Yes
Extension access	Availability of extension	0 =No, 1 =Yes
Fertilizer	Quantity of fertilizer used	Fertilizer in Kilograms
Input cost	Cost of inputs	Cost per unit per hectare
Labour	Type and source of labour Amount of labour used per hectare	Family/hired/both Number of man days per hectare
Type of seed	Type of seed used in production	0 = uncertified1 = Certified
Land tenure	Respondents having title deed	0=with title1 = Without title
Farmer groups	Membership to farmer groups	0 = No, 1= Yes
Household size	Number of family members	Number of persons
Farm size	Total land of respondent	Number of hectares (Ha)
Land size	land under tomato cultivation	Number of hectares (Ha)
Farm income	Income from farm activities	KES
Off farm income	Off farm employment income	KES
Diversity	Magnitude of diversity	Simpsons diversity index Number of markets

CHAPTER THREE

METHODOLOGY

3.1 Area of study

The research was carried out in Kirinyaga central and Mwea west sub counties which are the major tomato growing zones in Kirinyaga County. The County is located approximately 170 kilometers north east of Nairobi along the slopes of Mt Kenya. It lies between latitude $0^o1'$ and $0^o40'$, and latitudes 37^o and 38^o East (Odhiambo, 2012). Generally, Kirinyaga County lies between 1,158 metres and 5,380 metres above sea level in the South and at the slopes of Mt. Kenya, respectively. The County covers 1,478.1 square kilometers with Mt. Kenya forest covering 350.7 square kilometers. With Mt. Kenya on the northern side, its geographical nature greatly influences the landscape and other topographical features of the County. The area has three ecological zones; the lowland areas that fall between 1158 metres to 2000 metres above sea level, the midland areas that lie between 2000 metres to 3400 metres above sea level and the highland comprising areas falling between 3400 metres to 5380 metres above sea level. Kirinyaga central and Mwea west sub counties are located in the midland and low land zones, respectively (GoK, 2018).

The area receives bimodal rainfall with long rains in March through to May with quantities averaging 2,146mm while short rains occur in October through to December with quantities averaging from 1,212mm (GoK, 2018). The amount of rainfall declines from the high altitudes of Mt. Kenya towards the semi-arid zones in the eastern parts of Mwea constituency. On average, temperatures range from 8.1^oC to 30.3^oC in the lower zones during the hot season (Mwangi *et al*., 2015). In Kirinyaga County, agriculture is the major economic activity employing approximately 87 percent of the population. Tomato is among the most promising crops with the County underwriting about 14 percent of the total tomato production in the country. This ranks Kirinyaga as the front runner among other counties (Karuku *et al*., 2017). Tomato is mainly produced in small scale in rural areas of the County and contributes to income generation, household food security and creates employment opportunities (Masunga, 2014).

3.2 Research design

The study followed a cross sectional research survey design which saves time, resources and has high magnitude of precise and accuracy (Hoffmann *et al.*, 2018). The design allows data collection in a specific time and enables researchers describe groups within the population in respect to the outcome while estimating the extent of the results for a given population (Levin, 2006). In addition, the design also allows the application of both qualitative and quantitative methods of data analysis (MacKay & Schluger, 2015).

3.3 Target population and sample size

Smallholder farmers practicing tomato production in Kirinyaga County were the target of this study. Smallholder tomato households formed the sampling frame with the household head as the sampling unit. To get the sample size, the Cochran (1977) formula was used as applied by Narcisse (2017). The formula is applicable in scenarios where the population is greater than 10,000. The formula is presented and explained below:

$$n_o = \frac{z^2\ pq}{d^2} \tag{1}$$

where n is the desired sample size, z is the standard normal deviate (z-value) yielding the required confidence level, p is an estimate of the population proportion having the characteristics, q is equal to 1-p representing the proportion of the population without the characteristic, d is the degree of precision or the level of statistical significance. The study used a standard normal deviate of 1.96 and a statistical significance of 0.05 which corresponds to 95% confidence level. Since the proportion of the population was unknown, the study adopted an estimated proportion of 0.5 which assumes maximum heterogeneity, that is, 50/50 split. The sample size was calculated as shown below;

$$n = \frac{(1.96)^2\ (0.5)0.5}{(0.05)^2} = 384 \tag{2}$$

The sample size was 384 smallholder tomato households in Kirinyaga County.

3.4 Sampling technique

A multi stage stratified random sampling technique was used for the study. This approach is reasonable and pledges a perfect depiction of the target population (Masunga, 2014). The first stage was to select Kirinyaga County as the study area. The County leads in tomato production in Kenya and has high potential for tomato production. Kirinyaga central and Mwea west sub counties were purposively selected since they are the main areas where tomato farming is practiced in the County. From each sub county, wards were chosen based on the concentration of tomato production. Six wards were considered namely: Mutithi, Thiba, Kangai, Kandongu, Kerugoya south and Kanyeki-ine. The study targeted all farmers growing tomatoes in small scale from which the sampling frame was obtained. The research unit of analysis was the household head while the sampling frame constituted of two strata: - the first was smallholder farmers practicing tomato farming in open field and the second farmers using the greenhouse system in tomato production. For the greenhouse stratum, since the use of this technology was low a census survey was conducted to get an accurate figure with minimal errors. From the survey, a total of 78 greenhouse farmers were obtained and interviewed. Consequently, a probability proportionate to size sampling procedure was applied using the sampling frame to select 306 open field farmers who were interviewed during the study.

From each of the six randomly selected wards, administrative villages were selected making a total of 11 villages. The selection was based on the concentration of tomato production. Later, the village population considering number of households was used to determine the number of households interviewed. To achieve this, the village households as a proportion of the total number of household for all selected villages was used to determine the number of households to be interviewed in each village using the probability proportionate to size formula as applied by Wambua *et al*. (2019).

$$k = \frac{P}{M} * 306 \qquad (3)$$

Where: k = number of household heads to be interviewed from each ward, P= the number of households in each selected village, M= total number of households in the 11 villages. The first household to be interviewed was randomly selected while others were selected along the road transect at intervals determined by dividing the number of village households by number of households to be interviewed (P/k). **Table 3.1** shows the 11 selected villages, the number of households in each village and number of interviewed households in each village from among open field tomato smallholders.

Table 3. 1: Number of households selected for interview in each village

Sub-county	Wards	Villages	Population	No. of HH	No. of HH interviewed
Mwea west	Mutithi	Kabiriri	22,439	150	21
		Rukanga		268	37
	Thiba	Nguka	31,689	152	20
		Thiba		350	49
	Kangai	Kombuini	17,660	204	28
		Kathiga		190	15
		Mathigaini		106	25
	Kandongu	Nyagati	22,593	160	23
		Kiarukungu		96	20
Kirinyaga central	Kerugoya south	Gakoigo	11,257	152	35
	Kanyeki-ine	Kiamuthambi	24,050	390	33
Total			129,688	2218	306

3.5 Data collection

Both primary and secondary data were used in this study. Primary data was obtained by administering structured questionnaires to the sampled smallholder tomato farmers. The questionnaire comprised short and precise questions regarding efficiency, profitability and market diversity. In addition, the research engaged in a face to face encounter with the respondent to obtain in-depth information necessary to realize the goal of the study. Existing literature in publications, government annual reports and internet were a valuable source of secondary data for this study. This data was used for comparison with the field information and to enrich the findings of the questionnaire for the purposes of validating the survey.

3.6 Data analysis

3.6.1 Measurement of technical efficiency

In analyzing the first objective, the research adopted the SFPF approach of the Cobb Douglas functional form. The SFPF model approximates the production frontier by fitting observed data and minimizing their distance from the optimal level (Abdul & Isgin, 2016). In addition, the model distinguishes deviations from the frontier function into inefficiencies and random noises (Jarzębowski, 2013; Nguyen & Giang, 2009). Further the efficiency measures derived by this model can be analyzed using the parametric statistical models (Ndirangu *et al.*, 2017). The stochastic frontier approach equation was expressed as below:

$$Y_i = f(X, \beta) + e^{v-u} \quad (4)$$

The model was converted in logarithm form and depicted as shown below (equation 5):

$$\text{Ln } Y_i = \ln f(X, \beta) + V_i - U_i \quad (5)$$

Where: Ln is the natural logarithm, Y_i is tomato output of the i^{th} farmer, X is a vector of inputs of the i^{th} farmer, β is a vector of unknown parameters to be estimated, e is the random error, V_i is the distinctive error term that arises from measurement errors in input use and yield. It is associated with variations in output due to random exogenous variables, U_i is a non-negative random variable measuring technical inefficiency of an individual farmer. It shows the shortfall from the maximum achievable output (Y) due to output oriented inefficiencies.

In the current study, ln f(X, β) in equation five (5) was specified as a CD production function which provides suitable representation of any production technology used. Further, it is capable of holding multiple input modelling and efficient in managing multicollinearity, heteroscedasticity and correlation (Mitra & Yunus, 2018). Therefore, the stochastic frontier production of the CD functional form was expressed as:

$$\text{Ln } Y_i = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \ldots + \beta_n \ln X_n + V_i - U_i \quad (6)$$

Maximum likelihood producers were applied to estimate the frontier function which aided in the computation of technical efficiency. Technical efficiency was measured by comparing actual yield to the frontier production. That is, actual output (observed yield) of each farm was divided with the optimal output (frontier production) that the farmer would achieve with the specified input combinations. Individual farm's technical efficiency was computed as the ratio of observed output to the optimal production, constrained by the input levels. This was achieved using equation 7 as described by Narcisse (2017).

$$TE_i = \frac{Y_i}{Y_i^*} = \frac{[F(B,X) + (v_i + u_i)]}{[(B,X) + V_i)]} \quad (7)$$

Where; TE_i is the technical efficiency of the i^{th} farmer, Y_i represents observed output and Y_i^* represents frontier output.

The effect of farm and farmer characteristics on the observed technical efficiency levels was determined using the Tobit censored regression model. Since efficiency ranges from a minimum of 0 to a maximum of 1 (Mitra & Yunus, 2018), the Tobit censored regression model was found appropriate for this analysis since it is a limited dependent variable model (Chepng'etich *et al.*, 2015). The selected farm and farmer socio-economic factors were regressed against technical efficiency scores of each individual farm using the Tobit regression model which is empirically expressed as shown:

$$U_i = \alpha_0 + \sum_{j=1}^{n} \alpha_j X_{ij} + e_i \quad (8)$$

Censoring for the Tobit model on the left was done at 0 (zero) and at 1 (one) on the right (Olagunju & Ajiboye, 2010) as defined by the following measurement equation:

$$U = \begin{cases} 1 & \text{if } U_i^* \geq 1 \\ U* & \text{if } 0 \leq U_i^* \leq 1 \\ 0 & \text{if } U_i^* \leq 0 \end{cases} \quad (9)$$

where: i is the i^{th} smallholder tomato farmer, U_i is the efficiency scores of the i^{th} smallholder tomato farmer, U_i^* is the latent efficiency, $\alpha_o$is a constant, α_j are the parameters to be estimated, e_i is an error term that is independently and normally distributed with mean zero and common variance of δ^2, X_{ij} are variables representing the socioeconomic factors, that is, the farm and farmer characteristics.

3.6.2 Analysis of profitability between open field and greenhouse systems

To achieve the second objective of the study, gross margins and net profit analyses were applied in comparing the profitability of open field and greenhouse tomato production systems in Kirinyaga County. Gross margin (GM) has been specified as a proxy used in the analyses of profitability (Mukherjee, Sarkar, & Sarkar, 2018). Gross margin is a farm management analytical tool used in capital budgeting and provides an estimate of the returns of a particular enterprise in a given period (Mitra & Sharmin, 2019). Despite this ability, gross margin only includes variable costs and dismisses fixed and capital costs. This necessitated the need to combine GM analyses with net profit (NP) which accounts for the fixed and capital costs while computing profitability (Wachira *et al*., 2014). Gross margin was computed as the difference between total revenue and total variable costs (Jagelavicius, 2013).

$$\mathrm{GM_i} = \mathrm{TR_i} - \mathrm{TVC_i} \tag{10}$$

Where GM is the Gross Margin; TR is the Total Revenue; TVC is the Total Variable Costs. In addition, i characterizes any of the production systems, that is, open field or greenhouse. Net profit was computed as total revenue less the total production costs (Husna & Desiyanti, 2016).

$$\Pi_\mathrm{i} = \mathrm{TR_i} - \mathrm{TC_i} \tag{11}$$

Where, TR is Total Revenue; TC is the Total Costs of production and Π is the net profit.

Total revenue was computed as the product of price and the quantity of output, that is, total revenue was quantified from the quantity of tomatoes marketed and the prevailing prices in the season under review. Total costs were obtained by summing up the total variable costs and the total fixed costs. Total variable costs were the sum of all costs of variable inputs (Debertin, 2012).

Variable costs included in this study were cost of inputs and costs of labor. To obtain the variable costs, the factor price was multiplied by the quantity of each particular input used in the production of tomatoes. These included inputs and labor costs such as seeds/seedlings, fertilizers, chemicals and transport among others. In addition, the initial cost of investment, interest on total variable costs and depreciation formed the fixed costs. Though majority of the smallholder farmers owned their pieces of land, cases where land had been rented were established and the cost of leasing the land included as a fixed costs.

The initial cost of investment (capital cost) was spread across the useful life of investments in tomato production using the capital recovery factor (CRF). The CRF is a compounding factor that considers interest rates and the economic life of an investment (Mccoy & Rubin, 2008). To determine the amount of initial cost recouped annually, the CRF was multiplied with the cost of initial capital (White & Cloud, 2008). The CRF was expressed as below:

$$\text{CRF}\ (\text{i}, \text{N}) = \frac{\text{i}(1+\text{i})^{\text{N}}}{(1+\text{i})^{\text{N}} - 1} \tag{12}$$

Where: *i* is the real interest rate and N is the number of years. Interest was achieved by charging a simple savings interest rate of 7.92 percent which was the average annual saving deposit interest rate for commercial banks in Kenya (CBK, 2018). In addition, an economic life of 5 years was used as the average period within which farmers expected to use acquired assets assuming a standard usage and preventive maintenance (Jadhav & Rosentrater, 2017). While calculating depreciation, a 10 percent scrap value was taken from the purchase price of the structures, buildings and equipment as indicated by Wachira *et al*. (2014). The depreciable expense of assets was assumed to be fixed during the useful life hence the straight line method of depreciation was appropriate in determining the portion of decrease in value (Mccoy & Rubin, 2008). The method is simple and frequently applied as it replaces the time function with the utilization function (Mert & Demir, 2016) and is expressed as shown;

$$\text{Depreciation} = \frac{\text{Asset price value} - \text{salvage value}}{\text{Expected economic life}} \tag{13}$$

To compare the performance of open field and greenhouse tomato production systems, gross margin and net profits were computed per unit of land under tomato cultivation in meters squared (M^2). This ensured consistency in comparison and was achieved by dividing gross margin and net profit by tomato acreage in meters squared. The mean gross margins and net profits were subjected to an independent sample t- test to determine whether profitability differences in open field and greenhouse tomato production systems were significant.

3.6.3 Assessment of market diversity among smallholder tomato farmers

The third objective of the study was achieved by assessing the number of outlets that smallholder farmers use in marketing tomato outputs. Diversity was articulated by the number of channels used with more outlets signifying increased diversity. However, this method was not conclusive in computing the magnitude of diversity among respondent since the market share of each outlet was not put into consideration. The study therefore adopted the Simpson's diversity index (SDI) to measure the degree of diversity among smallholder tomato farmers. This method was preferred due to its strength in considering rare markets, measuring consistency and large quantity (Erkie & Andualem, 2018). In addition, SDI takes into account the quantities sold in each outlet while computing diversity (Grabchak *et al.*, 2017). The value of the index ranges between 0 and 1 and the higher the value of the index the more the scale of diversity (Morris *et al.*, 2014). The Simpson's diversity index was calculated as presented below;

$$\mathrm{SDI} = 1 - \frac{\sum_{n=1}^{m} n(n-1)}{N(N-1)} \tag{14}$$

Where; SDI is the Simpson's diversity index, m is the number of market outlets, n is the quantity of tomato output sold in each market and N is the total quantity sold in all markets. The diversity scores were grouped into four categories namely; low, moderately low, moderately high and high levels of market diversity. Mean SDI and average prices were computed for each category and a one way ANOVA applied to test whether farm prices differed significantly within the diversity levels.

3.7 Regression diagnostics

The study employed Stata statistical software package version 13.0 to analyze the Cobb Douglas model. To establish that the model was suitable and met the assumptions of the Ordinary Least Squares (OLS), a couple of regression diagnostics were conducted. In this regard, heteroscedasticity and multicollinearity analytical tests were considered.

Heteroscedasticity is a scenario where the basic assumption of equal variance of residuals is violated in a regression model (Humphrey, 2017). It is a common concern in cross sectional data where the estimated parameters are unbiased though inefficient and invalid in making predictions about the dependent variable (Narcisse, 2017). In addition, the estimates of the variances are biased, leading to invalid tests of significance (Klein *et al*., 2016). The presence of heteroscedasticity in this study was tested by adopting the Breusch-Pagan-Godfrey test (Zaman, 2000), in STATA software using the hettest commands. Nevertheless, the model was further checked for adequacy to ensure that no needed variables were omitted. The results gave a Chi-square value of 0.6411 at 5 percent level of significance. This was greater than a p value of 0.05 showing the absence of heteroscedasticity thus the null hypothesis of constant variance was not rejected.

Multicollinearity is the existence of a linear connection between independent variables, that is, when explanatory variables appear to correlate (Humphrey, 2017). Estimation of parameters with the problem of multicollinearity causes extensive concerns because the projected coefficients are inaccurate. Solving this problem requires the identification and elimination of the variables that cause multicollinearity (Alhusseini & Odah, 2016). The presence of multicollinearity was ascertained using the variance inflation factor (VIF). Gujarati and Porter (1999) points out that multicollinearity exists if the VIF of predictor variables is less than one or greater than 10. The results presented in the results chapter indicated that none of the variables had a VIF less than 1 or greater than 10. Therefore it was concluded that the variables were not collinear hence absence of the multicollinearity in the data.

CHAPTER FOUR

RESULTS AND INTERPRETATION

4.1 Overview

This chapter presents the descriptive and inferential statistics from analysis of the data collected. Descriptive statistics on farm and farmer characteristics of the respondents are presented. Results on estimated parameters of stochastic frontier production function, technical efficiency scores and the censored Tobit regression analysis are also presented in this chapter. Further, results of the comparative analysis of the performance of open field and greenhouse systems are given and explained. Lastly, the results of the relationship between market diversity and prices are presented and interpreted.

4.2 Farm and farmer characteristics of respondents

In this research, 384 smallholder tomato farmers in Kirinyaga County were sampled and questionnaires administered as tools of data collection. The research intended to investigate the farm and farmer characteristics of the smallholder producers who practice tomato production in the County. From the sample, 79.7 percent (306 farmers) of the respondents used open field system of tomato production with only 20.3 percent (78 farmers) of the producers embracing the greenhouse system. This infers that in Kirinyaga County, the adoption of greenhouse technology in tomato production was still low among smallholder farmers. The low adoption could be attributed to limited knowledge on emerging innovations in tomato production and high initial capital cost required to establish greenhouse structures. The descriptive statistics on continuous and categorical characteristics among the respondents are given and compared between the two production systems in the subsequent subsections.

4.2.1 Analysis of continuous characteristics among respondents

Table 4.1 presents results of analysis of continuous characteristics of the smallholder tomato farmers in Kirinyaga County. The farm and farmer characteristics described in this subsection include age, credit, experience, household size, education and farm size. In addition, market distance was the only institutional characteristic described in this sub section.

Table 4. 1: Descriptive statistics on continuous factors

Description of Variables		Open field (n=306)		Greenhouse (n=78)		t test
		No	**%**	**No.**	**%**	
Age	21-35	181	59.2	35	44.9	-2.76***
(Years)	36-50	98	32.0	31	39.7	
	51-75	27	8.8	12	15.4	
Mean=37.03,Min=25,Max=75		**Mean=36.4**		**Mean=39.6**		
Credit	≤ 100000	302	98.7	46	58.9	-8.40***
(KES)	> 100000	4	1.3	32	41.1	
Mean=29930,Min=0,Max=500000		**Mean 9998**		**Mean 108121**		
Experience	1-8	138	45.1	78	100	21.2
(Years)	9-16	120	39.2	0	0	
	17-25	48	15.7	0	0	
Mean=9.06 ,Min=1.5,Max=25		**Mean=10.6**		**Mean=3.26**		
Household size	1-5	192	62.7	47	60.3	-0.34
(No.)	6-10	114	37.3	31	39.7	
Mean=5.14, Min=1,Max=10		**Mean=5.1**		**Mean=5.08**		
Education	None	15	4.9	0	0	23.3***
(Years)	1-6	0	0	0	0	
	7-12	232	75.8	8	10.3	
	13-18	59	19.3	70	89.7	
Mean=9.90,Min=0,Max=18		**Mean=8.74**		**Mean=14.49**		
Farm size	1-3	268	87.5	67	85.9	-0.29
(Ha)	3-5	36	11.7	11	14.1	
	5-7	1	0.4	0	0	
	7-9	1	0.4	0	0	
Mean=2.3,Min=1.6,Max=8.4		**Mean=2.29**		**Mean=2.32**		
Market distance	0-10	179	58.5	78	100	19.0***
(KMs)	11-20	96	31.4	0	0	
	21-30	31	10.1	0	0	
Mean=9.72,Min=2,Max=28		**Mean=11.1**		**Mean=4.25**		

Source: Field survey results, 2019; > Greater than (Above), ≤ Less than or equal to

The results reveal that respondents had a mean age of 37.03 years ranging from 25 years to 75 years. Majority (56.3%) of the respondents aged between 21 and 35 years indicating the predominance of young farmers engaged in tomato production. Further, 33.6 percent of the respondents were between 36 and 50 years with only 10.2 percent found to be between 50 to 75 years of age. This explains that majority of the sampled farmers were in their productive ages which constitutes a dynamic and suitable work force for agricultural production. The farmers were therefore expected to be more productive as young farmers have a high possibility to embrace new expertise and innovations for improved production and marketing of tomatoes. Age difference between open field and greenhouse systems differed significantly at 1 percent. This signifies that greenhouse farmers were significantly advanced in age compared to their open field counterparts. This shows that as tomato farmers progressed in age, they became more receptive to modern production technologies possibly due to experience, desire and probably established wealth that enabled them procure modern techniques.

Given the heavy financial needs of tomato production, respondents apportioned an average KES 29,930 of credit received in tomato production with KES 9,998 for open field and KES 108,121 for greenhouse farmers. This shows that tomato farmers were able to timely procure inputs and meet other production expenses. The large amount of credit used in greenhouse tomato production was necessitated by the high costs required to procure and establish greenhouse structures. Credit use in production differed significantly at 1 percent level of probability.

On average, the farmers had an experience of 9.06 years showing dominance of moderate experience in tomato production in Kirinyaga County. From the results, 56.3 percent of the respondents had experience in tomato production of up to 8 years with majority being greenhouse farmers. A proportion of 31.3 percent of respondents had an experience of between 9 and 16 years. However, only 12.5 percent of the respondents (15.7 open field farmers) had attained experience of 17 to 25 years in tomato production. The variations in number of years of tomato farming between systems differed significantly at 1 percent level with 10.6 years for open field and 3.26 years for greenhouse. This signifies that the involvement of farmers in open field production was essential in obtaining necessary experience regarding tomato production. This enabled smallholders understand tomato production and acquire knowledge on modern expertise. Besides, the results show that the use of greenhouses in the study area was still new with open field farmers partially migrating to using greenhouse systems. This would be attributed to the high initial costs of establishing greenhouses which required high investments thus compelling farmers to engage in open field systems of production during the initial stages.

In addition, the results showed that most of the households had 4 family members, with a household size ranging from 1 person and 10 persons for the large households. On average, 5.14 persons were reported per households with 5.1 members and 5.08 members for open field and greenhouse farmers. Besides, household sizes were not statistically different between farmers in either open field or greenhouse system. This signifies that household sizes in both systems were more less the same.

Globally, education has been identified as a key element in achieving sustainable development and poverty eradication. Majority (62.5%) of the respondents revealed that they had at least 7 years and a maximum of 12 years of education with majority (75.8%) being open field farmers. In addition, 89.7 percent of the greenhouse farmers and 19.3 percent of the open field farmers had a minimum of 13 years and a maximum of 18 years of schooling. This implies that majority of the greenhouse farmers had tertiary level education with majority of the open field farmers having primary or secondary education level. In addition, **Table 4.1** shows that 4.9 percent of open field farmers which comprised of 3.9 percent of the sample had zero years of education. This implies that the farmers never attained any form of formal education. Differences in years spent in school differed statistically at 1 percent level implying that greenhouse farmers were significantly more educated thus had enhanced skills and ability to better utilize market information and understand modern technologies.

The results also show that the respondents had a mean farm size of 2.30 ha with the largest farm being 8.40 ha and 1.60 ha for the smallest farm. This denotes adequate farms for agricultural production in Kirinyaga County. Farm size differences between open field and greenhouse farmers were not statistically significant. This shows that differences in farms owned by open field and greenhouse farmers were negligible thus uniform in size.

With regard to market distance, farmers were located at a range of 2 km to 28 Kms. The mean distance to the markets was found to be 9.72 km with majority of the respondents located less than 10 Kms from the market. Market distances between open field and greenhouse farmers differed significantly at 1 percent level with greenhouse farmers (4.25kms) closer to the markets than open field farmers (11.11kms). This elucidates that the former had adequate access to information regarding market outlets and market benefits on provision of inputs such as improved seeds and subsidized fertilizers.

4.2.2 Analysis of categorical characteristics among respondents

Table 4.2 gives a comparison of categorical variables between farmers using open field and greenhouse production system.

Table 4. 2: Descriptive statistics of categorical factors

Variables	**Sample (N=384)**		**Open field (n=306)**		**Greenhouse (n=78)**		**Chi sq.**	**Sig**
	No.	**%**	**No.**	**%**	**No.**	**%**		
Gender of the farmer								
Male	291	75.8	231	75.5	60	76.9	0.070	0.792
Female	93	24.2	75	24.5	18	23.1		
Group membership								
No	240	62.5	188	61.4	52	66.7	0.725	0.394
Yes	144	37.5	118	38.6	26	33.3		
Land tenure								
No	196	51.1	159	51.9	37	47.4	0.509	0.475
Yes	188	48.9	147	48.1	41	52.6		
Type of seed used								
Uncertified	167	43.5	167	54.9	0	0	76.94	0.000
Certified	215	56.5	137	44.8	78	100		
Access to extension								
No	300	78.1	245	80	55	70.5	3.319	0.068
Yes	84	21.9	61	20	23	29.5		
Access to market information								
No	26	6.8	22	7.2	4	5.1	0.418	0.518
Yes	358	93.2	284	92.8	74	94.9		

Source: Field survey results, 2019

From the results (Table 4.2), majority (75.8%) of the sampled households were male headed with only 24.2 percent being female headed, implying that men dominated tomato production in the study area. Comparable results were found within the production systems with only 24.5 percent and 23.1 percent of the open field and greenhouse farmers being females, respectively. Further, the relation between gender of the respondents and type of production system was not significant.

Concerning memberships to farmer groups, the results show that 62.5 percent of the respondents did not belong to any farmer group, while 37.5 percent of the respondents had group membership. Similar results were observed within systems with only 38.6 percent of open field and 33.3 percent of greenhouse farmers having group membership. This means that majority of the respondents had limited bargaining power in the market and potentially lacked information on how to mitigate the effects of market imperfections. Nevertheless, the affiliation between group membership and type of tomato production system used by the farmers was not statistically different. Conversely, majority (93.2 %) of the respondents were reported to receive market information, with only 6.8 percent not privy to the market information. This indicates that majority of the respondents had adequate information on market trends and other crucial information regarding both input and output markets. Relations between market information and either production system did not differ significantly.

Majority of the respondents (51.0%) were operating land that was either leased, communally owned or had permission to use by land owners. This indicates that majority of the farmers did not have title deeds to secure credits to enable them construct greenhouse structures. Within systems, majority (52.6%) of the greenhouse farmers had title deeds for their farms while majority (51.9) of the open field farmers operated farms without title deeds. This would be attribute to that farms used for tomato production by open field farmers were more likely leased, communal or had permission to use from the owners. On the other hand, the linkages between land tenure and productions systems were not statistically significant. This means land ownership did not influence the type of production system embraced by the smallholder farmers.

Further, quality of seeds used by the smallholders was not a problem with 56.0 percent of the farmers embracing improved (certified) seeds. This was attributed to that tomato production in Kirinyaga was dominated by youthful and receptive farmers to modern production techniques. Due to market proximity, greenhouse farmers used certified seeds more with only 44.8 percent of the open field farmers using certified seeds. Further, relations between seed type used by the respondents in either production system were statistically different. This means that the use of certified seeds among greenhouse farmers was higher compared to open field farmers. This was attributed to the need of greenhouse farmers to ensure quality and marketability of their produce due to their desire to maximize returns and recoup the high investment costs owing to the prolonged cultivation period of greenhouse varieties.

Concerning availability of extension services only 21.9 percent of the farmers had at least one interaction with extension agents, while majority (78.1%) of the respondents had no access to extension services (Table 4.2). This implied that the bulk of the smallholder farmers were not well informed on the new and emerging technologies like greenhouses in tomato production. The relationship between extension access and production systems was not statistically significant.

4.3 Analysis of factors of production and tomato productivity

Table 4. 3: Descriptive statistics on factors of production and productivity

Variable	Sample				Open field	Green house	t-value	Sig
	Min	Max	Mode	Mean	Mean	Mean		
Land size (ha)	0.09	2.00	0.25	0.7096	0.6492	0.9464	-4.996	.000
Fertilizer (Kgs/ha)	18.5	1200	120	208.78	236.58	99.68	10.041	.000
Seeds (Grams/ha)	2.5	300	20	46.87	54.213	18.103	9.336	.000
Labor (Mds/ha)	35	2175	512	303.67	349.76	122.83	11.396	.000
Pesticides (litres/ha)	1	48	6	8.0	8.3438	6.6985	1.803	.072
Productivity Kgs/ha	0.56	23.5	16.68	8225	7046.5	12850	-7.935	.000

Source: Field survey results, 2019

Results given in **Table 4.3** reveal that the smallest size of land under tomato cultivation was found to be 0.09 ha while the largest portion of land was found to be 2.0 ha with majority measuring 0.25 and a mean of 0.7096. This indeed shows that the respondents were practicing tomato production in small scale in highly demarcated lands. The small land holdings show that tomato production faced competition from other agricultural undertakings as farmers attempted to diversify their sources of income. The land sizes differed significantly at 1 percent level between farmers in either production systems.

Data collected revealed that the most preferred pesticides in the study area were ridomil and milraz (fungicides), karate and bestox (insecticides) and oxy gold (herbicide). On average, the sampled farmers used 8.0 litres per hectare (ha) of pesticides. The application of pesticides was insignificant between open field and greenhouse farmers. In addition, an average of 46.88 grams of tomato seeds per ha were used in the study area. This was below the recommended levels of 75 grams to 150 grams of seeds per ha in the lowland and midland AEZs. The low seed rate could have resulted from the high costs of purchasing improved seeds and underutilization of the land set aside for tomato production. This clarifies that smallholder farmers did not achieve the required plant population per unit of land. The quantities of seeds used differed significantly between open field and greenhouse systems.

The commonly used fertilizers were DAP and NPK during land preparation and planting while urea and CAN were frequently used during top dressing. Further, respondents applied an average of 208.78 kilograms of fertilizers per ha to supplement the soil fertility. This average was below the required levels of approximately 1186 kilograms of per hectare showing that smallholder farmers applied fertilizers inefficiently. Given this inputs, an average of 8.225 tons per hectare of tomato output were realized but this productivity was far much below the maximum potential yield of 30.7 tons per ha. Further, 7046.5kgs/ha (7.046ton/ha) for open field and 12850 Kgs/ha (12.85tons/ha) for greenhouse farmers were recorded and differed significantly showing that greenhouses were highly productive compared to the open field system.

4.4 Estimation of technical efficiency in tomato production

This section presents results of parametric estimates of stochastic frontier production function parameters in log-linearized functional form. Technical efficiency measures determined from the SFPF are similarly presented. Subsequently, multiple regression results of factors affecting technical efficiency are given. The two limit censored Tobit regression in STATA software is applied to test the significance of factors that were hypothesized to impact on technical efficiency in tomato production.

4.4.1 Parametric estimates of frontier production function

The stochastic Cobb-Douglas functional form expressed in equation six (6) in chapter three was estimated using the maximum likelihood estimation procedure in STATA software and results shown in **Table 4.4**.

Table 4. 4: Results of maximum likelihood estimates of Cobb-Douglas stochastic frontier production function

Variable	Parameter	Coefficient	Std. error	z	P >|z|	VIF
Constant	β_0	1.7133	0.5244	3.27	0.001	
Land size	β_1	0.5917	0.0535	11.07	0.000***	1.120
Fertilizer	β_2	0.4761	0.0748	6.36	0.000***	1.262
Seed quantity	β_3	-0.1089	0.0508	-2.14	0.032**	1.130
Pesticides	β_4	0.0617	0.0579	1.07	0.287	1.266
Labour	β_5	-0.0336	0.0583	-0.58	0.564	1.062
Log likelihood		-447.5662			0.000***	
Wald chi square (5)		472.13			0.000***	
Lambda		10.7508	0.0923	116.42	0.000***	
Likelihood ratio (5, 5%)		15.1389			0.000***	
Sigma squared (σ^2)		2.097			0.000***	
Gamma (γ)		0.6876			0.000***	

Significance *** 1%, ** 5 %. Source: Field survey results, 2019

From **Table 4.4**, summing up the input coefficients, 0.987 was obtained as the return to scale. This was approximately one (1) signifying that in the study area tomato production expressed a constant return to scale. This implies that if the cost of tomato inputs in the study area increased by a certain proportion, the value of tomato produce would increase by the same proportion.

The CD results in **Table 4.4** revealed a sigma squared (σ^2) value of 2.097 that was significant at 1 percent level. This denotes a perfect goodness of fit with the CD stochastic production frontier model and correctness of the specified distributional assumption of the composite error term. The gamma parameter (γ) ranges between 0 and 1. A value of zero (0) denotes that there are no technical inefficiencies and that the ordinary least square would appropriately fit the data compared to the SFPF. As the value of gamma approaches one or equal to one (1) it demonstrates the suitability of the model. The value of γ was 0.6876 and differed statistically at 1 percent level showing that inefficiencies existed. This signifies that of the total variation in tomato output, 68.76 percent was due to technical inefficiencies.

Further, the significant values of Log likelihood (-447.56) and the Wald chi-square (472.13) shows that technical inefficiencies existed in the study area. Further, lambda (λ) had a value of 10.7508 that was significantly different from zero indicating that deviations between actual and predicted tomato output in the study area resulted from differences in production practices and not random variations.

The inefficiency assertion was confirmed by computing the likelihood ratio (LR) statistic which revealed a value of 15.1389, while chi-square value at 1 percent level of significance with 5 degrees of freedom was found to be 11.070. The critical value was smaller compared to the calculated value thus the null hypotheses that the stochastic production frontier model is not appropriate was not accepted. This reveals that the explanatory variables were not concurrently equal to zero and that the factors included in the model explained sources of efficiency differences.

The estimated parameters in the production function expressed positive and negative coefficients. This implies that if more inputs were applied in equitable proportions, tomato production would increase by the value of each positive coefficient and decrease by the value of each negative coefficient. The coefficients of land size and fertilizer quantity expressed positive and significant influence on tomato production at 1 percent level. The coefficient of seed type was negative and significant at 5 percent level.

Land size had a positive (0.5917) and significant coefficient. This results convey the potential of expanding tomato production among smallholders by increasing area under cultivation. This is explicated by that tomato output would increase by a factor of

0.5917 if land size is increased by 1 percent. Fertilizer had a positive and significant (0.4761) production elasticity. This denotes that by increasing quantity of fertilizer used in tomato production by 1 percent, tomato output in the study area would increase by a factor of 0.4761. On the contrary, type of seed had an inverse (-0.1089) and significant impact on tomato production. This denotes that an increase in use of uncertified seeds would decrease tomato output by a factor of -0.1089. In addition, the coefficients of labour and agrochemicals were insignificant. This implies that the observed deviations in tomato output in the study area were attributed to variations in quantities of land, fertilizer and seeds used in production. In addition, the coefficient of land had the greatest magnitude followed by the coefficient of fertilizer. This indicates that among tomato farmers in the study area, land and fertilizer were the most limiting resources.

4.4.2 Analysis of technical efficiency scores in tomato production

The estimated CD frontier production function in section 4.4.1 was used to determine the maximum achievable outputs at the given input levels. Afterwards, this was used to calculate technical efficiency scores. Technical efficiency of individual farmers was defined as a ratio of the observed output to the corresponding frontier output, restricted on the level of input used by the farmer as given in equation seven (7) in Chapter three of this thesis. **Table 4.5** gives the descriptive statistics on the technical efficiency scores for the sampled farms.

Table 4. 5: Descriptive statistics of technical efficiency scores

Description	Efficiency Range	Sample		Open field		Greenhouse	
		No.	%	No.	%	No.	%
Low	0 < to < 0.25	159	41.4	158	51.6	1	1.3
Moderately low	0.25 < to < 0.50	97	25.3	88	28.8	9	11.5
Moderately high	0.50 < to < 0.75	68	17.7	40	13.1	28	35.9
High	0.75 < to ≤ 1.00	60	15.6	20	6.5	40	51.3
Mean		0.3955		0.3148		0.7122	
Minimum		0.0363		0.0362		0.9462	
Maximum		0.9462		0.1536		0.9361	
Standard deviation		0.2667		0.2220		0.1763	

Source: Field survey results, 2019

The results revealed a mean technical efficiency of 0.3955 (39.55 percent). This suggest that there is a chance to increase technical efficiency among smallholder tomato farmers in Kirinyaga County by more than 60 percent if restrictions that make them inefficient are improved.

Greenhouse farmers had a higher technical efficiency than the open field farmers with 31.48 percent for open field and 71.22 percent for greenhouse. The results also revealed a standard deviation of 0.2667 for the sample, 0.2220 for open field and 0.1763 for greenhouse. This indicates that on average, deviation of technical efficiency scores from the mean value is about 27 percent for the sample, 22 percent for the open field and 18 percent for the greenhouse. This implies that technical efficiency among open field farmers is more spread out compared to the greenhouse farmers.

The minimum technical efficiency recorded was 0.0363 (3.63 percent) and a maximum of 0.9462 (94.62 percent) as depicted in **Table 4.5**. The wide range in the technical efficiency scores among tomato farmers in Kirinyaga County indicates that most of the smallholder farmers utilized available resources inefficiently and there still exists a possibility to improve technical efficiency levels. Majority of the respondents (41.4 %) had technical efficiency scores of less than 0.25 with 51.6 percent of open field and 1.3 percent greenhouse farmers in this category. This shows that inefficiencies existed among respondents with a sizeable proportion recording scores that were far much below the optimal levels.

Only 15.6 percent of the respondents had attained efficiency scores of above 0.75, with 51.3 percent greenhouse and 6.5 percent open field farmers. This shows that most of the open field farmers were below the potential levels of technical efficiency (TE=1). In addition, the results noted that 66.7 percent of the sampled tomato farmers had technical efficiency levels below 0.5. Majority (80.4%) of the open field farmers had efficiency levels below 50 percent with only 12.8 percent greenhouse farmers below this level. This implies that by increasing technical efficiency, 66.7 percent of the producers could increase tomato output by more than 50 percent with majority being open field farmers.

To test whether differences in technical efficiency between open field and greenhouse production systems were significant, the efficiency scores were subjected to a one way ANOVA as shown in **Table 4.6**.

Table 4. 6: One way ANOVA comparison of technical efficiency

Technical efficiency	Sum of squares	df	Mean squares	F	Sig
Between groups	9.816	1	9.816	215.098	0.000***
Within groups	17.433	382	0.046		
Total	27.249	383			

Source: Field survey results, 2019; ***Significance at 1%

From **Table 4.6**, technical efficiency differences were statistically different at 1 percent level of significance. This implies that greenhouse farmers in Kirinyaga County were more technically efficient than their open field counterparts. The plausible explanation is that farmers who use greenhouses used certified seeds (Table 4.2), and were significantly more educated thus easily understood the purpose of modern technologies in production (Table 4.1).

4.4.3 Tobit regression results on factors influencing technical efficiency

Assessment of the ability of producers to achieve maximum output given available resources and technology is an important aspect in constructing informed endorsements for policy formulation, review and implementation. It is therefore necessary to investigate characteristics that affect production efficiency as displayed by the Tobit regression results given in **Table 4.7** below.

The stochastic frontier approach defines that efficiency scores range from 0 to 1, hence making technical efficiency (dependent variable) a limited dependent variable. Due to this fact, the censored Tobit regression model (Limited dependent variable model) was applied as an appropriate investigative tool in determining characteristics that affect technical efficiency as given in equation eight (8) in chapter three. The selected characteristics were regressed against technical efficiency scores of each individual farm using Tobit regression model. Censoring for the Tobit model on the left was done at 0 (zero) and at 1 (one) on the right. The log likelihood ratio was 87.17 and was statistically significant at 5percent level demonstrating existence of inefficiency in the data set.

Table 4. 7: Socioeconomic characteristics influencing technical efficiency

Variable	Coefficient	Std. error	t	p>/t/	VIF
Age	-0.000835	0.001360	-0.61	0.540	1.72
Gender	-0.023283	0.023651	-0.98	0.326	1.07
Household size	0.019196	0.005652	3.40	0.001***	1.14
Group membership	0.028206	0.021185	1.33	0.184	1.19
Experience	0.000163	0.025128	0.06	0.949	2.37
Education	-0.003479	0.003729	-0.93	0.351	1.81
Type of system	0.446175	0.047588	9.38	0.000***	3.34
Land tenure	0.006994	0.091979	0.33	0.740	1.18
Seed type	0.043299	0.022004	1.97	0.050**	1.29
Off farm income	1.45e-06	1.01e-06	1.44	0.150	1.39
Farm income	7.92e-08	1.43e-07	0.55	0.580	1.27
Land size	-0.15262	0.022399	-6.81	0.000***	1.21
Fertilizer quantity	0.000754	0.000241	3.14	0.002***	1.25
Extension access	0.041649	0.025128	1.66	0.098	1.12
Market distance	-0.00291	0.002152	-1.35	0.178	1.56
Market information	0.078295	0.042304	1.85	0.065	1.17
Credit value	-2.98e-07	2.03e-07	-1.47	0.143	1.22
Constant	0.205409	0.091979	2.23	0.026	
Log Likelihood = 88.22***; Likelihood Ratio (LR) = 250.27***					

Significance at ***p<0.01, **p<0.05, *<0.1. Source: Field survey results, 2019

The Tobit regression results denoted a likelihood ratio of 248.16 while the critical value of chi-square at 5 percent level of significant with 17 degrees of freedom was 27.587. The critical value was less than the calculated value denoting that the null hypothesis that the censored Tobit regression model was not appropriate in determining characteristics that affect technical efficiency in the study area was not accepted.

The selected farm and farmer characteristics that were included in the efficiency model included social, economic and institutional factors. Household size, type of production system, land size and fertilizer quantity were found to be significant at 1 percent level. In addition, type of seed used in production differed statistically at 5 percent level. On the contrary age, gender, group membership, experience, land tenure, farm income, off farm income, market distance, value of credit used in tomato production, education, access to extension services and market information were found to be insignificant.

From **Table 4.7**, the coefficient for household size was positive 0.019196 and significant at 1 percent level. This implies that by increasing the size of the household by one household member, technical efficiency would increase by 1.91 percent. The coefficient of type of production system used in tomato production was positive 0.446175 and significant at 1 percent level. This demonstrate that if tomato farmers in the study area are increased by one greenhouse farmer, technical efficiency levels would increase by 44.61 percent. Similarly, quantity of fertilizer used had a positive (0.000754) and significant coefficient at 1 percent level. This points that by increasing fertilizer use in tomato production by a factor of one, technical efficiency would increase by a factor of 0.000754. The coefficient of type of seed used by the farmers was positive (0.043299) and significant at 5 percent level. This denotes that by increasing tomato farmers in the study area by one farmer using certified seeds, technical efficiency would increase by 4.32 percent. Further, land size had a negative (-0.15262) and significant coefficient at 1 percent level. This indicates that a 1 percent increases in the land under tomato production reduces technical efficiency levels by 0.15 percent.

4.5 Comparative analysis of open field and greenhouse production systems

This section presents results of the comparative performance of open field and greenhouse tomato production systems, using independent sample t test. This was achieved by evaluating the profitability of open field and greenhouse production systems. Profitability was compared using gross margin (GM) and net profit (NP).

Information regarding revenue generated, yields, price and costs incurred were analyzed from both categories of farmers. In this study, costs were categorized as variable costs and fixed costs. The cost of inputs and labor directly employed in tomato production were incorporated as variable costs and included seeds, pesticides, fertilizers, land preparation, planting, pruning, training, watering, harvesting and transportation. Variable costs were computed by multiplying the quantities of each input by the factor prices. Annual initial costs, depreciation of the structures and tools and interest on total variable costs (working capital) comprised the fixed costs. Though smallholder farmers were assumed to own land, land rents were included as fixed cost in scenarios where land had been leased.

Capital Recovery Factor (CRF) method was applied to determine the amount of initial cost of investment recouped by farmers annually. To obtain the amount of initial cost that farmers recoup annually, the CRF was multiplied with the cost of initial capital (White & Cloud, 2008). The CRF is a compounding factor that considers interest rates and the economic life of an investment. The CRF was computed as expressed in equation twelve (12) in chapter three on this thesis.

The straight line method was applied to estimate the depreciation of assets. A 10 percent salvage value was calculated on the purchase worth as explained by Wachira *et al*. (2014). The total depreciable cost was divided by the useful life of the assets to obtain the annual depreciation expenditure as expressed in equation thirteen (13) in chapter three of this thesis. Interests on total variable costs were calculated by charging a simple interest rate of 7.92 percent which was the average annual saving deposit interest rate for commercial banks in Kenya (CBK, 2018). This method was applied in most of the previous studies as explained by Wachira *et al*. (2014). In this study, costs were computed as shown in **Table 4.8** below.

Table 4. 8: Cost analysis in tomato production among smallholder farmers

Cost and returns	Open field system			Greenhouse system		
	Unit price	Quantity	Total (KES)	Unit price	Quantity	Total (KES)
Total revenue	35.5	70461	249852	36.4	12850	467483
Variable costs						
Labour (Man days/ha)	275	350	96250	280	115	32200
Pesticides (Litres/ha)	1000	9	9000	740	7	5180
Fertilizer (Kgs/ha)	76	240	18000	60	100	6000
Seeds (Kgs/ha)	285	50	14250	210	20	4220
Total variable cost			137500			47600
Gross margins			112352			419883
Fixed costs			**Average cost**			**Average cost**
Capital recouped (KES per annum)			4390			93290
Interest on capital (KES per annum			1390			29560
Depreciation (Annual depreciable expense)			3160			67190
Variable costs interest (KES per annum)			9060			3770
Land (Rent per ha of land annually)			2600			0
Total fixed costs			20600			193810
Total costs			158100			241410
Net profit			91752			226073

4.6 Relative profitability between open field and greenhouse production systems

Gross margin and net profit analysis of the two systems were evaluated to realize the second objective of this study. To guarantee uniformity in the use independent t-test to compare the significant performance of the two production systems, yield, costs, gross margin and net profit were computed and converted per meter squared. The comparative results are presented in **Table 4.9** below.

Table 4. 9: Relative profitability analysis between tomato production systems

Variable	Production system	Mean	Std. Dev	Min	Max	t- ratio	Sig.
Yield (KGs/M^2)	Open field	0.7047	0.587	0.06	2.35	-8.41	.000***
	Greenhouse	1.2850	0.533	0.31	2.16		
Price (KES/KG)	Open field	35.46	4.35	20.00	63.00	1.61	.108
	Greenhouse	36.38	5.25	18.00	55.00		
Total revenue (KES/M^2)	Open field	24.98	21.32	1.83	90.88	-8.31	.000***
	Greenhouse	46.62	20.33	10.08	92.88		
Variable costs (KES/M^2)	Open field	13.75	13.89	1.76	78.24	5.67	.000***
	Greenhouse	4.76	3.17	1.43	18.68		
Gross margins (KES/M^2)	Open field	11.23	21.18	-55.38	76.67	-12.40	.000***
	Greenhouse	41.86	19.00	8.65	87.25		
Fixed costs (KES/M^2)	Open field	2.06	1.94	0.24	12.78	-17.27	.000***
	Greenhouse	19.38	17.17	4.09	77.85		
Total costs (KES/M^2)	Open field	15.81	15.64	2.02	86.72	-3.95	.000***
	Greenhouse	24.14	20.04	5.55	96.53		
Net profit (KES/M^2)	Open field	9.17	21.79	-62.36	75.99	-5.15	.000***
	Greenhouse	22.48	19.99	-46.03	64.75		

Source: Field survey results, 2019; *** Significance at 1 %.

From the results, the mean yields are 0.7047 kg/m^2 and 1.2850 kg/m^2 for open field and greenhouse production systems, respectively. Though harvesting in this production systems is distinct and these systems embrace different tomato varieties, greenhouse producers were found to be more productive than the open field producers. Thirty one percent of open field farmers grew Rio Grande tomato variety, followed by 26.2 percent who grew Onyx F1. In greenhouse system, 64.2 percent of the farmers grew Anna F1, followed by 12.8 percent who grew Prostar F1 tomato variety. The results also revealed that 23.0 percent of greenhouse farmers grew open pollinated tomato varieties like Rio Grande (11.5%), Onyx (6.4%) and Cal J (5.1%). Among open field farmers, Ansal F1 (16.3%), Strike F1 (9.8%) and Rambo F1 (8.2%) were also common varieties. In addition, some open field farmers (8.5%) grew hybrid variety Anna F1. The yield differences between the two production systems differed significantly at 1 percent level.

Though farmers in these systems operate in similar markets, their mean market prices were KES 35.46 and KES 36.38 for the open field and green house, respectively. However, the price differences were insignificant. The mean total revenues were KES 24.98/m^2 and KES 46.62/m^2 for open field and greenhouse systems, respectively. This shows that greenhouses generate more income than the open field system hence has the potential to compensate for extra investment costs incurred. The differences in value of output were statistically different at 1 percent level.

The mean variable costs were KES 13.75/m^2 and KES 4.76/ m^2 for open field and green house, respectively. The results denote that in the short run period of production, greenhouse producers incurred less compared to the open field farmers. In greenhouse farming, seeds, watering and nursery management formed a large proportion of the variable costs, while in the open field system pesticides such as fungicides, insecticides and herbicides formed a substantial proportion. The differences in the variable costs between the two production systems were significant at 1 percent level.

The mean gross margins for the open field and greenhouse farmers were KES 11.23/m^2 and KES 41.86/m^2, respectively. The differences between the gross margins were significant at 1 percent level. The mean fixed costs were KES 2.06/m^2 and KES 19.38/m^2 for open field and greenhouse, respectively. This illustrates that in the long run period of production, the costs of establishing a greenhouse venture were almost 10 times the costs of establishing an open field enterprise. The high fixed costs in greenhouses were attributed to high cost of constructing the greenhouse structure while in the latter the cost of leasing land formed a sizeable proportion of the fixed costs. This variations in fixed costs between the two systems differed statistically at 1 percent level. The mean total costs were found to be KES 15.81/m^2 and KES 24.14/m^2 for open field and greenhouse farmers, respectively. This shows that in the entire tomato production process, greenhouse producers incurred almost twice the cost of open field farmers. This was explained by the high cost of establishing the structures. The mean total costs for the two systems were arrived at by dividing the total costs with land size in meters squared. Alternatively the mean total costs would be obtained by summing up the means of variable costs and fixed costs for the two systems. The differences in the total costs between open field and greenhouse were significant at 1 percent level. The average net profits were KES 9.17/m^2 and KES 22.48/m^2 for open field and greenhouse farmers, respectively. The differences in net profits were significant at 1 percent level. This means that the greenhouse system of tomato production was more profitable than the open field system as shown by the gross margins and net profits.

4.7 Assessment of market diversity and farm prices among tomato farmers

In agriculture, market diversity outlines strategies of increasing market outlets of a particular product in a manner mitigating the possibility of uncertainties, inefficiencies and unreliability associated with specialized marketing over a given period of time. From the study area, fresh tomatoes were marketed mainly through six channels namely; sale to local assemblers, sale to retailers, sale to wholesalers, sale to middlemen and sale to contract markets. Further, direct marketing which involves sale from the farm to ultimate consumers existed but was constrained by inadequate labour and affordability of capital among respondents.

The computation of market diversity among smallholder farmers involves parameters such as number of participants, volume of produce handled, price and number of channels. The consideration of number of channels used requires more outlets express high market diversity with few outlets indicating low diversity.

Table 4.10 shows the distribution of farmers and the number of channels used to market tomatoes. Results reveal that majority (41.7%) of the smallholder farmers were marketing tomatoes through three channels, this means that most of the farmers experienced moderate market expansion. In addition, 37.8% of the respondents were spread in two outlets while 13.0% sold their produce in four channels. Besides, 0.5% of the respondents had engagements in five outlets with only 2.8% having an affiliation with other marketing channels. This results specify that smallholder farmers in the study area were able to highly expand their fresh tomato markets.

Table 4. 10: Descriptive analysis on the number of marketing channels

Number of outlets	Frequency	Percentage	Cumulative percentage
1	16	4.2	4.2
2	145	37.8	42.0
3	160	41.7	83.7
4	50	13.0	96.7
5	2	0.5	97.2
6	11	2.8	100.0
Total	384	100	

Source: Field survey results, 2019

Besides, more than half (58%) of farmers were able to reduce risk of losses brought about by the perishability of tomatoes during a glut by selling in at least three channels while 42% enriched their market linkages by supplying their fresh tomatoes in utmost two channels. This implies a possibility to achieve high diversity levels if trade relations existing among tomato farmers in rural area are improved by mitigating effects of uncertainty and inefficiency.

Results in **Table 4.11** display the aspect of market diversity in regard to number of participants in specific channels. Besides, the results show the mean prices realized in each outlet during the production period of the study. Results in **Table 4.11** show that respondents were more concentrated in channels with the engagement of brokers, retailers and local assemblers. In addition, wholesalers involved a sizeable proportion of tomato farmers with contract markets and direct marketing fairly attractive in the study area. Generally, farmer to contract markets and farmer to wholesale channels recorded highest prices followed by brokers and local assemblers. The retailer channel and direct markets recorded lowest prices while prices attained in markets ranged from KES 15 to KES 75 per kilogram of fresh tomato sold.

Table 4. 11: Average price for a kilogram of tomatoes per market outlet

Marketing channel	Freq.	Mean price	Std. Dev	Min	Max	F-test
Farmer → Local assemblers	316	34.17	4.45	25	50	6.173***
Farmer → Wholesalers	97	38.07	4.55	30	50	
Farmer → Contract markets	51	44.40	2.79	40	50	
Farmer → Retailers	233	33.45	5.62	15	65	
Farmer → Brokers	335	37.38	4.63	25	75	
Farmer → Consumers	40	30.45	5.85	15	45	

Source: Field survey results, 2019

In addition, results denote that the average prices achieved in different channels differed significantly at 1 percent level of probability. This show that there was a stable price competition between participants in different channels. However, contract markets attracted a high average price compared to other markets but fewer participant sold their produce in this channel. This was attributed to inadequacy of information regarding market contracts and benefits attached. Local assemblers had a potential to attract more farmers despite having a low average price possibly due to reduced transaction costs. Higher prices reported by farmer broker channel were not attractive to producers most likely because participants failed to establish mutual trust in trade.

Figure 4.1 shows the flow of tomatoes from the farm through various channels to intermediaries, marketing agents and to the ultimate consumers. Results reveal that, majority (37%) of the produce was sold through brokers who play a significant role of linking farmers to potential customers. In most cases, trade between farmers and brokers was executed at farm level though farmers do not fully benefit since the channel has limited transparency in price setting strategies.

Some farmers sold their produce to local assemblers accounting for 25% of the total marketed produce. The assemblers later sold to rural markets with farmers incurring less costs since the produce is collected at the farm. Further, 20% of the produce was sold to retailers who sell fresh tomato produce in small scale at open air markets, stalls and urban centers. This channel is characterized by ease in customer availability since it involves door to door hawking. The wholesale channel was characterized by existence of brokers and product exchange at rural markets. The channel collected 9% of the fresh tomatoes but was constrained by market unreliability.

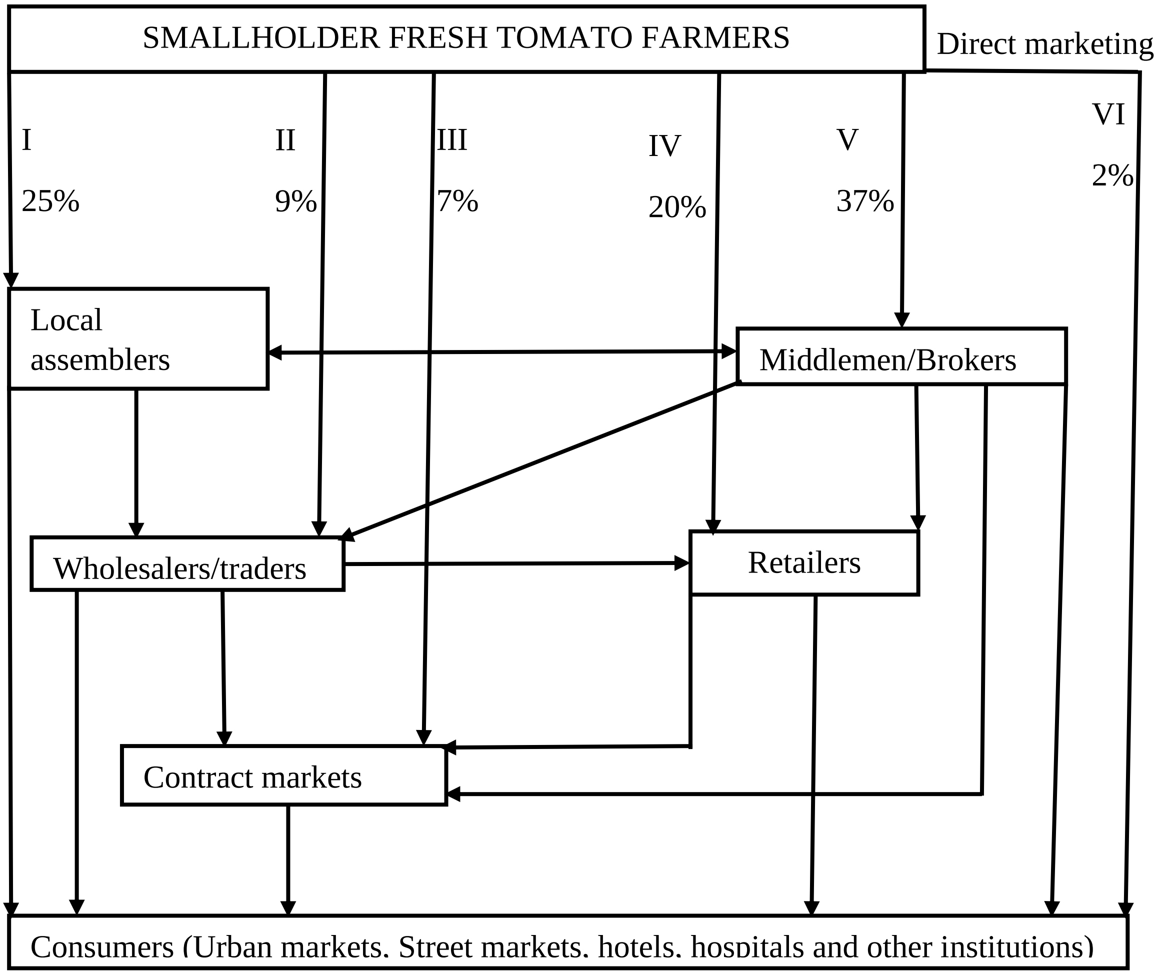

Figure 4. 1: Marketing channels of fresh tomato among smallholder farmers

Besides, some farmers engaged in contract markets which involved an agreement between farmers and marketing firms for the production and supply of tomatoes normally at determined prices. The contract bargain embraces that the purchaser provides a degree of production support through supply of inputs and provision of technical advice. However, the channel was least preferred in the study area due to existence of information asymmetry among participants and limited availability of extension services which plays a crucial role of educating farmers. In addition, since contract markets handle small quantities, farmers were displeased with this outlet since it involves extra contractual obligations in regard to quantity and quality which is determined by buyers. In Kirinyaga County, fresh tomato contract markets were mainly offered by learning institutions, hospitals, supermarkets and hotels but the channel absorbed only 7% of the total produce.

Farmers' direct marketing of fresh tomatoes was widely neglected despite being a certain niche that plays a distinctive role in establishing high quality markets among agribusiness enterprises. This approach entails farmers working as producers as well as retailers and has a growing importance in providing farmers with greater net returns. However, only 2% of the total produce was marketed through this channel. This could be accredited to farmers having difficulties defining their place in competition, analyze their own strengths and weaknesses thus unable to realistically meet market demands.

4.8 Analysis of the magnitude of market diversity in tomato marketing

To take into account the proportion of output sold through chosen market channels, Simpsons Diversity Index (SDI) was computed. The index is strengthened by considering rare markets, large quantities and measuring consistency. This was necessary to aid in the computation of the intensity of diversity among smallholders.
In addition, SDI accounts for the number of marketing channels and the proportion of output sold through each chosen channel. The SDI ranges from 0 to 1 with a value of zero showing no diversity and a value of one indicating maximum diversity. The SDI was computed as expressed in equation fourteen (14) in chapter three of this thesis. **Table 4.12** displays the distribution of SDI in four different categories of diversity.

Table 4. 12: Descriptive analysis on market diversity

Description	Level of SDI	Frequency	Percentage	Cum. Percent
Low	0 to <0.25	44	11.5	11.5
Moderately low	0.25 to < 0.50	160	41.7	53.1
Moderately high	0.50 to < 0.75	179	46.7	99.7
High	0.75 to 1.00	1	0.3	100.0
SDI	Mean = 0.4771		Min = 0	
	Std. Dev = 0.1825		Max = 0.77	

Source: Field survey results, 2019

Results show that SDI scores of the farmers ranged from a minimum of 0 to a maximum of 0.77. This wide range in diversity implies that smallholder tomato farmers were not reasonably distributed across all available marketing channels. The mean diversity index was 0.4771 (47.71%) showing that on average smallholder farmers practicing tomato production in Kirinyaga County had a moderately low level of market diversity. This result elucidates that there exists an opportunity to improve diversity among respondents by more than 50% if constraints that hinder farmers from exploring existing markets are minimized. The results also show a standard deviation of 0.182 suggesting that the diversity indices were spread around the mean with an average distance of 18.2 percent from the mean score. In addition, more than half (53.1%) of the smallholder farmers had a market diversity index below 50 percent. This indicates that there exists a chance to increase market diversity among smallholder farmers in the study area by more than 50 percent if quantities sold in each market outlet are improved.

Table 4.13 shows one way ANOVA results. Market diversity is the independent variable while farm prices are the dependent variable.

Table 4. 13: Results of one way Analysis of variance

Description	Sum of squares	df	Mean squares	F	Sig
Between groups	13.165	3	4.388	0.210	0.889
Within groups	7924.668	380	20.854		
Total	7937.833	383			

Source: Field survey results, 2019

Results in **Table 4.13** show that the relationship between market diversity and tomato prices in the study area was insignificant. The insignificant relation could be ascribed to poor assimilations in producer markets thus low competitiveness among smallholder farmers. This clarifies that average farm prices realized farmers in the study area were not statistically different across marketing channels despite differences in levels of market diversity. This could have resulted from the engagement of different market participants in various nodes in the flow of tomatoes from the producer to different markets. A possible explanation is that prevailing market pricing strategies were independent of approaches intended to expand tomato markets in the study area. That is, substantial price changes in tomato markets were not ascribed to differences in intensities and magnitudes of diversity, despite existence of chances to further diversify.

CHAPTER FIVE

SUMMARRY, DISCUSSION, CONCLUSION, RECOMMENDATIONS

5.1 Summary of the findings

This section gives a summary of results presented in chapter four. Majority of the respondents (79.7%) used open field system of production with only 20.3 percent embracing the greenhouse system. Respondents had an average age of 37.03 years ranging from 25 to 75 years. Age differed significantly between open field and greenhouse farmers. From the results, more men (75.8%) engaged in tomato production compared to women (24.2%). On average, 5.14 persons were reported per household ranging from 1 to 10 persons. The respondents had a mean of 9.09 years of education and ranged from zero to 18 years with greenhouse farmers significantly more educated. Experience ranged from 1.5 to 25 years with an average of 9.06 with open field farmers significantly more experienced. Majority (51.0%) of the farms lacked title deeds with 56 percent of farmers using certified seeds and operating farms averaged at 2.30 ha. Farm differences were not significant but seed type differed significantly between the two systems. Extension was limited with only 21.9 percent of the respondents having contact with experts. Market distance averaged at 9.72 km with majority of the respondents' located 10 km from the market with greenhouse farmers significantly nearer the markets. Majority (93.2%) of the respondents had no access to market information. Respondents apportioned an average of KES 29,930 of formal credit in tomato production with greenhouses receiving more due to the high investment costs.

The stochastic CD production function was used to estimate technical efficiency using maximum likelihood procedures. The input output relationship, showed positive coefficients of land size (0.5917) and fertilizer quantity (0.4761) that differed significantly at 1 percent level. Seed quantity had a negative (-0.1089) coefficient and differed significantly at 5 percent level. Pesticides and labour were insignificant. The input coefficients gave a returns to scale parameter of one (1) denoting a constant returns to scale. Mean technical efficiency was 39.55 and ranged from 3.63 percent to 94.62 percent. Majority of the respondents (41.4 %) had efficiency scores less than 0.25 with only 15.6 percent attaining scores above 0.75. The results noted that 66.7 percent of the respondents had technical efficiency levels below 0.5, while 33.3 percent attained efficiency levels of 50 percent and above.

The Tobit regression results indicated that the coefficients of household size (0.018771), type of system (0.421952) and fertilizer (0.000784) positively influenced technical efficiency and were significant at 1 percent level. The coefficient of land size was negative (-0.15078) and significant at 1 percent level. In addition, the coefficient of seed type (0.04481) had a positive impact on technical efficiency and significant at 5 percent level. Further, the Tobit model revealed a log likelihood ratio of 88.22 that was statistically significant at 5 percent level demonstrating existence of inefficiency in the study area. This was ascertained by the LR of 250.27 that was significant and greater than the chi square critical value (27.587) at 17 degrees of freedom.

The comparative analysis of costs between open field and greenhouse tomato production systems found the costs to be statistically significant at 1 percent level. The analyses of profitability between open field and greenhouse systems showed that yields, revenue, gross margins and net profits between the two systems were statistically different at 1 percent level. The prices realized between farmers in these systems were insignificant. Gross margins were KES 11.23/M^2 and KES 41.86/M^2 for open field and greenhouse, respectively. In addition, the net profits achieved were KES 9.16/M^2 and KES 22.48/M^2 for open field and greenhouse, respectively. The results showed that the former had better returns among smallholder tomato producers in the study area.

Farmers were found to sell they output in six markets namely; local assemblers, wholesalers/traders, contract markets, middlemen/brokers, retailers and direct sale to consumers. Majority (41.7%) of the respondents marketed tomatoes through three channels, with 0.5 percent managing to market in five channels while only 2.8 percent sold in all the available outlets. The Simpsons Diversity Index (SDI) was computed and summarized in four categories namely; low, moderately low, moderately high and high. The mean SDI was 0.4771 and ranged from 0 to 0.77. Majority (53.1%) of the smallholder farmers had an SDI below 50 percent. Further, prices across different marketing channels differed significantly at 1 percent level of probability with contract markets recording high average prices. A one way ANOVA was conducted to show the link between market diversity and farm prices. The ANOVA results revealed that farm prices realized by the sampled farmers across different marketing channels were not statistically different despite variations in levels of market diversity.

5.2 Discussions

5.2.1 Farm and farmer characteristics of the respondents

The mean age of farmers was 37.03 years with 56.2 percent of the respondents in the age bracket of 21 to 35 years. This explains that tomato productivity in the study area was expected to increase since majority of the respondents were in their productive ages hence expected to adopt modern technologies of tomato production. This was in line with the results of Ibitoye *et al*. (2015) who found that tomato production in Kogi state of Nigeria was dominated by farmers in the age bracket of 21 to 40 years. Majority (75.8%) of the sampled households were male headed with only 24.2 percent headed by females. The high involvement of men in tomato production was attributed to the labour intensive nature of the enterprise. In addition, by the fact that most of the respondents were men shows that the African culture that men take the lead on matters that touch on family activities was practical in the study area. These results agreed with Nguetti *et al*. (2018).The results show that, sampled farmers had an average household size of 6 persons ranging from 1 to 10 persons. Narcisse (2017) noted that, large households were appropriate since they provide readily available family labour in executing farm activities thus achieving production at least cost.

On average, respondents had a mean of 9.90 years of schooling with 3.9 percent having not attained any form of formal education. In addition, 56.6 percent had primary level education with 39.5 percent having gone past secondary education level. This denotes that a sizeable proportion of the respondents could be expected to quickly understand modern technologies toward increasing productivity. Further, Chepng'etich *et al*. (2015) explained that education enhances the skills and ability of farmers to offer standard supervision and better utilize market information. Majority (62.5%) of the respondents were not members of farmers groups thus had limited bargaining power in formulating market policies on provision of technical assistance. Ntabakirabose (2017) noted that farmers who belong to farmer associations, clubs or related organizations are more advantaged in accessing improved inputs, technologies and information on mitigating market imperfections.

The adoption of greenhouse system in tomato production among respondents was low at 20.3 percent. This was attributed to the fact that majority of the farmers were not members of social groups which helps mobilize farmers towards achieving extension services that educate on modern production technologies and innovations (Masuku &

Sihlongonyane, 2015). Further, almost half of the respondents operated farms with title deeds that farmers used as collateral to access formal loans. Mukhtar *et al*. (2018) noted that formal loans facilitated the timely acquisition of improved inputs such as fertilizers and certified seeds that farmers cannot afford from their own resources.

Majority of the farmers were located less than 10 km from the market. This enabled efficient access to market information with a large portion of the respondents' privy to trends in both input and output markets. The plausible explanation is that markets play an important role in the provision of extension services, credit information, farm inputs and an outlet of the farmers' produce. These results were in line with those of Shettima, Amaza and Iheanacho (2015) and Ayerh (2015). Sapkota *et al*. (2017) clarified that information equips farmers with technical knowledge and skills on markets trends.

5.2.2 Farm size, factors of production and productivity

Farm size ranged from 1.6 ha to 8.4 ha and averaged 2.3 ha but was not statistically different between open field and greenhouse farmers. Land under tomato cultivation averaged 0.70 ha with a range of 0.09 ha to 2.0ha and differed significantly between open field and greenhouse farmers. Further, majority of the respondents noted that their tomato acreage measured 0.25 ha. The plausible explanation is that land among respondents was highly demarcated and practiced tomato farming in small scale. In addition, tomato production faced competition from other agricultural endeavors hence the small land sizes. This result was in line with the findings of Najjuma (2016). On average, 208.78 kilograms of fertilizer were used per ha with open field farmers using significantly more quantity per ha. Najjuma *et al*. (2016) explained that tomato production requires 1186 kilograms of fertilizer per ha. This compared with the amounts used in Kirinyaga shows that farmers applied fertilizers inefficiently. This results coincided with the findings of Tabe and Molua (2017).

The application of pesticides in the study area averaged 8.0 litres per hectare. This was far much above the required levels of 3.0 litres per hectare. The plausible explanation is that farmers lacked knowledge on pesticide application. In addition, agro chemical companies indicate labels in technical languages that farmers cannot understand while dealers do not sufficiently educate the farmers on appropriate dosage of the chemicals. This finding agreed with a study conducted by Nguetti *et al*. (2018). Differences in pesticides use between open field and greenhouse farmers were not significant. Farmers achieved an average tomato yield of 8.225 tons per hectare. This was below the optimal yield of 30.7 tons per hectare as indicated by Wachira *et al*. (2014).

The average productivity was significantly different between production systems with the greenhouse farmers (12850.47 kilogram per hectare) more productive than open field farmers (7046.57 kilograms per hectare). However, this productivity remained low compared to 23 tons per hectare for open field and 161 tons per hectares for greenhouse system as explained by Van der Spijk (2018). This deviation in output shows existence of technical inefficiencies in tomato production among smallholder farmers in the study area. This is possibly due to inefficient utilization of available resources, low adoption of modern technologies and inadequate institutional support.

5.2.3 Technical efficiency score

The willingness of smallholder farmers to improve their innovative abilities, enhances their production efficacy and unleashes the potential of agriculture to respond to future challenges (Tavva *et al*., 2017) To attain better production intensities in tomato production, there is a need to improve technical efficiency levels, exploit economies of scale and adopt new technologies among smallholder producers (Abdul & Isgin, 2016).

Based on the results in **Table 4.5**, smallholder tomato farmers in Kirinyaga County recorded a low technical efficiency of 39.55 percent. This was below a mean technical efficiency of 74 percent reported by Ayerh (2015) in Ashanti region of Ghana. Similarly, Khan and Shoukat (2013) found the technical efficiency of tomato farms in northern Pakistan to be 65 percent. On the contrary, Zalkuw *et al.* (2014) estimated a mean technical efficiency of 37.79 percent of tomato production in the Adamawa state of Nigeria. Greenhouse farmers were more technically efficient than open field farmers with 71.22 percent and 31.48 percent for the two systems, respectively. The results negated the findings of Najjuma (2016) who reported a mean technical efficiency of 40.43 for open field and 33.71 for greenhouses. This demonstrates existence of substantial effects of inefficiency which hindered attainment of the frontier production (Narcisse, 2017). As explained by Humphrey (2017), there exists a tremendous opportunity to increase tomato production by 60.45 percent for the sample, 68.52 percent for open field and 28.78 percent for greenhouse farmers without additional resources and adoption of more technologies if technical efficiency is increased.

5.2.4 Socioeconomic characteristics influencing technical efficiency

Based on the results displayed in **Table 4.7**, the two limit censored Tobit regression in STATA was applied to test the significance of factors that influenced technical efficiency in tomato production. Five (5) factors were found to influence technical efficiency and significant. These factors were household size, type of production system, fertilizer quantity, seed type and land size. Some factors influenced technical efficiency in the expected directions while other characteristics assumed contrary directions.

The existence of a positive and significant affiliation between the size of household and technical efficiency was a remarkable result. It denotes that as the household size expanded, technical efficiency among smallholder tomato farmers in the study area increased. This infers that farmers with large household sizes are more technically efficient compared to farmers whose household sizes are small. This results were informed by the need of producers with big households, to meet their subsistence thus endeavor to achieve higher outputs. Similar results were conveyed by Ayerh (2015), Mukhtar *et al*. (2018) and Ibitoye *et al*. (2015). These researchers argued that since tomato production is labour intensive, large household sizes afford labor endowments necessary in executing farm decisions. In addition, with large households, adequate labour will be available for allocation to farm activities hence, augmented levels of technical efficiency. On the contrary, Chepng'etich *et al.* (2015) and Narcisse (2017) conveyed that household size had a negative influence on technical efficiency. These researchers debated that since households were important sources of family labor, which is associated with production inefficiency (low productivity per unit of family labor), its increase at farm level would reduce technical efficiency.

The positive and significant coefficient of the production system dummy inferred that technical efficiency increased if the smallholder farmers in the study area embraced greenhouse system of tomato production. This concurred with the anticipations of the study. The plausible explanation is that growing tomatoes under the greenhouses enhances quadruple production and enables farmers to cultivate the crop over a long period of time thus increasing yields. In addition, weather patterns and other conditions that hinder productivity in open field system, are largely controlled in the greenhouses, hence reducing crop stress and promoting early maturity. Further, majority of the farmers grow only one crop under the greenhouses, thus reducing nutrient competition. Additionally, mono-cropping enables farmers allocate adequate time and resource in the crop activities hence augmented productivity. These results concurred with the findings of Wabomba (2015) and Wachira *et al*. (2014). On the contrary, the results drew a discrepancy with the findings of Najjuma (2016) who reported that open field system of tomato production in Kiambu County had greater influence on technical efficiency compared to the greenhouse system.

Type of seed used exhibited a positive and significant relation with technical efficiency. This suggests that by farmers using certified seeds technical efficiency among the sampled farmers increased. This was ascribed to the notion that majority (56.0%) of the smallholder farmers used improved seeds (certified) in tomato production. This is reasonably due to efforts made in research to generate certified tomato seeds in the study area. In addition, majority (93.2%) of the tomato farmers in the study area were well informed on improved planting material due to high access of market information. In addition, a sizeable proportion of the respondent (65.6%) had access to formal loans hence, were able to easily procure certified seeds. The results agreed with Simwaka *et al*. (2013), Tasila *et al*. (2019) and Mukhtar *et al*. (2018) who argued that research has shown a positive affiliation between improved planting materials and productivity. Conversely, the results differed with the findings of Abdul and Isgin, (2016).

The area under cultivation (land size) had a significant inverse relationship with technical efficiency. This denotes that technical efficiency decreased with increase in land under tomato production in Kirinyaga County. These results substantiates that farmers with small land sizes were more technically efficient contrary to their associates with large plots of land. The reasonable justification is that, farmers with small land sizes could be part of the farmers who depend on their farms for occupation. This therefore inspires them to give farming greater attention for higher yields hence more efficient despite the size. These results are in conformity with the outcomes presented by Mukhtar *et al*. (2018) who argued that producers with small land sizes were more industrious and combined resources prudently hence minimizing inefficiencies. Additionally, farmers with huge farms engage in assorted agricultural enterprises(e.g. production of French beans, kales, cabbages, livestock keeping, dairy farming) which compete with tomato production for time and limited resource (Linh *et al.*, 2017).

In addition, Dessale (2019) argued that the managerial effectiveness diminished with increase in tomato acreage (land size) as farmers unsuccessfully performed important crop husbandry practices hence reducing technical efficiencies. On the contrary, Ibitoye *et al*. (2015) and Chepng'etich *et al*. (2015) reported a direct relationship between area under cultivation and technical efficiency due to the involvement of hired labor which offers high productivity and the desires of large farms to maximize production since they may have foregone other crops with tomato production.

Interestingly, fertilizer quantity displayed a significant and positive relationship with technical efficiency. This positive effect symbolizes that increased fertilizer application increased technical efficiency among smallholder tomato producers in Kirinyaga. In addition, the positive influence shows that the nutritional composition of fertilizers upgraded soil fertility an element that is of utmost importance in tomato production. This shows that tomato farmers were privy to the nutritional requirements of their soils thus applied fertilizers suitably and in the right proportions. The results agreed with the findings of Shettima *et al*. (2015). On the contrary, this results negated those of Wabomba (2015) who reported a negative effect of fertilizer use on technical efficiency and attributed this effect to inadequate information among farmers.

5.2.5 Profitability analysis of tomato production systems

The results illustrated on **Table 4.9** shows that the greenhouse system (1.2850kg/M^2) generated almost twice the output of open field system (0.7047M^2) per unit of land in meters squared. This indicates that greenhouse system was more productive than the open field system. This is so despite the two systems embracing distinct harvesting procedures and tomato varieties. The plausible explanation is that, the greenhouse production system enables extended cultivation of crops thus ensuring increased production. In addition, due to the lengthy growing season in the greenhouse, harvesting lasts longer, thus giving higher yields than the open field system. Further, tomatoes in the open field system are predisposed to adverse climatic conditions, pest and disease infestation factors that are majorly controlled in the greenhouse system, thus the significant yield variations. The findings concurred with those of Ansary *et al*. (2019), Alobwede, Leake and Pandhal (2019) and Singh *et al*. (2017).

The realized gross margins were KES 11.23/ M^2 and KES 41.86/M^2 for open field and greenhouse production systems, respectively. The gross margins were positive for the two production systems. In addition, the greenhouse system was more profitable than the open field system in the long run period of production though both systems had varying levels of variable costs. The plausible explanation is that the producers were able to reasonably spread their production costs, hence adequately compensated all the costs associated with tomato production. This was in line with the findings of Haque *et al*. (2015). On average, the net profits were KES 9.17/M^2 and KES 22.48/M^2 for open field and greenhouse production systems, respectively. The net profits were positive for both systems. In the short run period of production, returns of greenhouse system were almost fourfold that of the open field system. The possible explanation is that, in the entire production system, open field and greenhouse systems of tomato production were able to recuperate their total costs. This results concurred with the findings of Turemis (2017) and Chauhan *et al*. (2017).

As depicted by the gross margins and the net profits, the greenhouse system was more efficient and profitable than the open field system in tomato production among smallholder tomato farmers in Kirinyaga County. This explains that, the adoption of modern technologies such as greenhouse in tomato production, would enable farmers generate higher yields hence better returns. This results concurred with the studies of Wachira *et al*. (2014) and (Van der spijk, 2018).

On the contrary, the results drew a distinction with the findings of Najjuma (2016) who described that the use of open field system in Kiambu was more profitable and efficient compared to the greenhouse system in tomato production. The researcher accredited the findings to effects of mixed farming among smallholder farmers and the low uptake of technologies which led to the under exploitation of the greenhouse system. In addition, the results differed with the findings of Antoine *et al*. (2017) who compared Lake Water-fed Pond and Above Ground Tanks systems of fish production and found that the former was more profitable compared to the latter. The researcher contended that modern was not permanently profitable as demonstrated by the theory of industrialization if subsidies in establishing modern technologies were not accessible.

5.2.6 Market diversity and farm prices among tomato farmers

Table 4.13 shows the results that describe the relation between market diversity and farm prices. From the results, there were no significant differences in average farm prices that resulted from differences in market diversity despite farmers having numerous outlets. This means that no price differences existed due market diversity and that though market expansion is paramount in ensuring an efficient flow of products, producer prices are independent on the magnitude of market diversity. This explains that selling tomato output in different marketing channels is not a guarantee for better prices among smallholder farmers.

The results concurred with the findings of Abate *et al*. (2019). The researchers argued that though an efficient market is a prerequisite for stable producer prices, farmers retailing their produce in different outlets receive prices that do not differ between channels. The plausible explanation is that market participants engage in different channels at different nodes of the supply chain hence the unwavering prices. In addition, the results concurred with a study by Kissoly, Faße and Grote (2018). These researchers discussed that, despite smallholder farmers in rural areas embracing different marketing outlets, the promotional approaches involved do not guarantee better producer prices.

Similarly, the results coincided with the conclusion of Dabkienė (2016), Mutayoba and Ngaruko (2015). The researchers attributed price variations to the number of intermediaries involved in each channel but not the level of diversity. This signifies that farmers in close proximity to the markets achieve better prices compared to their counterparts operating in channels with a set of intermediaries. This was reinforced by Grabchak *et al*. (2017) who debated that, smallholder farmers are often confronted by multiple market constraints that brand them as price takers despite increased tactics to broaden their markets. Le (2019) argued that market diversity offers a broad platform to generate sales which earns income and minimizes risks that lead to spoilage and consequent losses of fresh products often occurring during a glut. Bellon *et al*. (2020) further revealed that high levels of market expansion (at least 0.7) would reduce participants along marketing systems and instead encourage collective marketing. This would empower farmers to explore rare markets and consequently realize the benefits of market diversity (Sen *et al*., 2017).

However, the results contradicted the finding of Faysse and Onsamrarn (2018). This researchers debated that, market diversity encourages joint marketing which offers competitive prices compared to individual farmers marketing their own products in a specialized market channel. This accredited the certainty that collective management of markets connects producers to cooperatives which increases their bargaining power and mitigates the effects of market uncertainties. This findings were strengthened by Biggeri *et al*. (2018) who noted that market diversity promotes the emergent of strategies that increase access to high value output markets among smallholder farmers. Similarly, Tura and Hamo (2018) explained that market diversity is associated with the changes experienced by farmers in identifying resourceful marketing channels that offer better prices for their products.

5.3 Conclusions

This section gives a conclusion based on the hypothesis and the results of the study. The results reveal that that out of the selected seventeen (17) factors, five (5) factors affected technical efficiency either negatively or positively. These factors were household size, type of production system, type of seed used, fertilizer quantity and land size. Household size, type of production system and fertilizer were significant at 1 percent level of probability and had a positive influence on technical efficiency. Type of seed used influenced technical efficiency negatively and was significant at 5 percent level of probability. Based on these findings, the research failed to accept the first null hypotheses that, the selected socioeconomic factors have no effect on technical efficiency among smallholder tomato farmers in Kirinyaga County.

The mean gross margins for the open field and greenhouse farmers were KES 11.23/m^2 and KES 41.86/m^2, respectively. The differences between the gross margins were found to be statistically significant at 1 percent probability level. In addition, the average net profits were KES 9.17/m^2 for open field and KES 22.48/m^2 for greenhouse farmers. The differences in net profits were found to be statistically different at 1 percent probability level. This shows that the profitability of open field and greenhouse differed significantly. Therefore the study rejected the second hypotheses that, profitability between greenhouse and open field production systems does not differ significantly among smallholder tomato farmers in Kirinyaga County.

The influence of market diversity on farm prices was articulated by the number of marketing channels that farmers choose to sell their tomato output and the quantity of output sold in each channel. The results reveal that, there are no statistical differences in the farm prices realized by the smallholder farmers across the marketing channels despite differences in market diversity levels. Therefore, the study failed to reject the third hypotheses that, market diversity has no effect on farm prices among smallholder tomato farmers in Kirinyaga County.

5.4 Recommendations

1. The use of certified seeds and application of fertilizers in tomato production were found to positively influence technical efficiency. This would increase tomato yield and enable farmers benefit from the economies of scale. The study therefore recommends that farmers should embrace certified seeds which are disease resistant and possess high yielding potential. In addition, since certified seeds are disease resistant, their application will reduce production costs due to low use of pesticides and ensure better returns. Further, research institutions should intensify the production of certified seeds while the government should ensure affordability and equitable supply among smallholders. Consequently, farmers should apply fertilizers at recommended levels of 1,186 Kgs per hectare since this will enrich soil fertility and enhance tomato production per unit of land. Additionally, extension experts should educate farmers on appropriate fertilizer application practices while the government and other stakeholders should develop strategies that guarantee fertilizer subsidies as this will reduce input costs and ensure higher returns.
2. The use of greenhouses was found to positively influence technical efficiency and more profitable in tomato production among smallholders. However, embrace of greenhouses in the study area remained low due to high initial investment costs. This study recommends that policy makers should develop strategies aimed at subsidizing cost of greenhouses since this will be an incentive to lure farmers use modern technologies. In addition, smallholders should engage in farmer groups as a way of enriching their bargaining power and ensure collective acquisition of cost effective modern technologies. The government should thus develop policies that promote farmer groups and protect their synergies from exploitation.
3. Prevailing market prices have been found to be independent of variations in market diversity across different channels. This is associated with the weak market linkages and increased number of participants between farmers and potential markets thus, reduced proceeds among smallholder farmers. This study recommends a need by the government to develop and implement policies that promote contract markets which have a potential to directly link farmers and buyers. This will reduce the influence of intermediaries and guarantee marketing efficiency hence enhanced

farm prices. Further, smallholder farmers should acquaint with the basics of contract marketing since this will enrich their bargaining efforts and mitigate the effects of constraints that brand them as price takers.

5.5 Proposed further research

For further research, the study suggests the following:

The scope of this study focused on the tomato enterprise mainly grown by farmers in small scale in Kirinyaga County. However, farmers in Kirinyaga grow other crops like coffee, tea, maize and French beans. Therefore, future studies can focus on the analysis of technical efficiency of all the crops grown in the county while capturing emerging technologies used in their production and the discrepancy that exists between the producer and consumer prices. Given that livestock production has a great potential to thrive in Kirinyaga, future studies can encompass livestock enterprises in this analysis.

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APPENDICES

Appendix 1: Interview schedule

Introduction

This interview schedule has been purposely prepared to help the researcher in collecting data on efficiency, profitability and market diversity among smallholder tomato farmers in Kirinyaga County. Please note that any information given herein will be treated with utmost confidentiality.

INTERVIEW SCHEDULE NUMBER: [ ]

A) GENERAL INFORMATION

Date: ____

Enumerator's Name: __________________________________

County: ____

Constituency: _______________________________________

Location: ____

Ward: _______________________________________

Village: ____

Type of farmer (√)

1. Greenhouse tomato farmer (...) 2. Open-field tomato Farmer (...)

B) Background information

1. Gender of smallholder farmer. a) Male ( ) b) Female ( )
2. What is the size of your household? ……....................
3. Number of years spent in school………………………
4. What education level did you attain? ……………........
5. Age of the smallholder farmer in years………………. Years
6. Which of the following activities form your major occupation

Activity	Farming	Trading	Formal employment	Casual employment
Tick appropriately				
Years in the activity				

7. What other agricultural activities do you engage in? a. Cash crop ( ) b. Dairy farming ( ) c. rice farming ( ) d. Other horticultural farming ( ) specify …………………
8. What is the type of the main road connecting you to the nearest market? 1. Tarmac [ ] 2. Marram [ ] 3. All weather road [ ]
9. Was it in a good condition in the last season? 1. Good [ ] 2. Poor [ ]
10. What is the main source of water in your farm? 1. River [ ] 2. Well [ ] 3. Roof catchment [ ] 4. Borehole [ ] 4. Piped water [ ] 5. Pond ( ) 6. Other (specify) …………………
11. What is your estimated annual farm income? ____________KES. per year.

C) **Information on factors that affect technical efficiency in tomato production**

Extension contact

1. Do you receive extension services and training on tomato production? a. yes [ ] b. No [ ]
2. If yes, from which body? a. County extension officers [ ] b. NGOs [ ] b. Farmer organization [ ] c. Research institutions [ ] d. Media [ ] e. Others (specify) ………………..
3. How often did you receive the services? …………………….

Farmer experience

4. For how long have you grown tomatoes? ………….....
5. What type of seed did you use? 1. Certified ( ) 2. Uncertified ( )
6. When you started what area did you have? (Ha) ………………
7. How many trainings have you attended on tomato farming? a. none [ ] b. one [ ] c. two [ ] d. three and above [ ]
8. How do you compare your production now and when you started? 1. Increased [ ] 2. Decreased [ ] 3. Constant [ ] 4. Others (specify)……………………..
9. How do you rate the performance of your tomato enterprise? 1. Good profit [ ] 2. Satisfactory profit [ ] 3. Inadequate profit [ ] 4. No profit [ ] 5. Negative profit [ ] 6. Not sure [ ]

Farmer Organization Membership

10. a) Do you belong to any farmer group? 1. Yes [ ] 2. No [ ]

b) If yes, which type of organization a. Self Help group (…) b. Cooperative Society (…) c. Welfare group (…) d. Farmer group (…) e. Other (Specify) (…) …………….

d) For how many years have you been in the organization? ……………………

11. How do you benefit from these organizations? 1. Market information [ ] 2. Credit [ ] 3. Seeking market and linking you to buyers [ ] 4. Input provision [ ] 5. Farmer training [ ] 6. Others (specify)………………………..

Credit access

12. Did you try to acquire any type of credits in the last season? 1. Yes [ ] 2. No []
13. If yes in from B11 above, did you receive the credit? a. Yes ( ) b. No ( )
14. If yes in in B12 above, from which body? Fill table below.

Source of credit	Type of credit 1. Cash 2. Input	Value of the credit KES.
Farmer groups		
Banks		
Micro finance		
SACCO		
AFC		

15. Did you use all the credit in tomato production? a. Yes ( ) b. No ( )
16. How did you use the credit? a. Other agricultural purpose ( ) b. Nonagricultural ( ) c. Household consumption ( ) d. Tomato production [ ] e. others ( ) specify ………………….
17. What proportion of the credit was used for tomato production? KES ……………
18. Did you experience difficulties getting the credit? a. Yes [ ] b. No [ ]
19. If you didn't receive the credit, what could be the reason why you did not get credit? a. Lack of collateral [ ] b. High interest rates [ ] c. don't know [ ] d. Outstanding loan [ ] e. Do not trust the lenders [ ] f. High interest rates [ ] g. Others (specify)…………………….

Market access

20. What is the distance from your farm to the nearest tomato market? ………….. Km
21. Have you been receiving information concerning tomato markets? 1. Yes [ ] 2. No [ ]
22. If yes, what is the source of the information? 1. Extension officers [ ] 2. Farmers' cooperatives [ ] 3. Agrochemical Company [ ] 4. Stockiest [ ] 5. Other farmers [ ] 6. Media [ ] 7. Buyer's field staff [ ] 8. Others (specify)……………………….
23. How often do you get the market information? 1. Daily [ ] 2. Weekly [ ] 3. Monthly [ ] 4. Others specify……………………

D) Information on the production systems.

Questions 1 to 6 for green house tomato farmers.

Questions 7 and 8 for pen field tomato farmers.

1. Which year did you start growing tomatoes under the green house? ……….
2. How did you acquire the green house? a. Ministry of Agriculture (…) b. Non-Governmental Organization (Specify) (…) _______ c. Inputs supplier (specify) (…) ________ d. Own initiative (…) e. Other (Specify) (…) ____________
3. What is the size of your greenhouse structure? a. 60 M^2 [ ] b. 90 M^2 [ ] c. 120 M^2 [ ] d. 150 M^2 [ ] e. 180 M^2 [ ] f. others [ ] specify …………
4. Number of plants in the structure. ……………….. Plants.
5. What is the cost of the initial investment in establishing a greenhouse structure? KES………………….
6. What is your main water source for your tomato greenhouse? **(√)** 1= Roof catchment (...) 2=Well (...) 3= Borehole (...) 4= Roadside runoff (...) 5= Piped (...) 6= ponds (…) 7= other (specify) (...) _______________
7. What are your reasons for not growing greenhouse tomatoes? a= Inadequate capital (…) b= Inadequate knowledge (…) c= Inadequate labor (…) d= Poor prices (...) Not beneficial (…) e= Inadequate water (…) f= Inadequate market (...) g= High production costs (...) h= Low yields (...) i= High Marketing costs (...) j= other (specify) (...) ____
8. What is the cost of the initial investment in establishing open field tomato production? KES……………………
9. What variety of tomatoes did you plant in your farm?………………………..….

E) Cost information for tomato production

1. Kindly provide information on the variable costs incurred in tomato production in the table below.

Type of variable cost	Units of measure	Price per unit (KES)	Quantity used
Land rent (If rented)	Ha		
Certified Seeds	Grams		
Seedlings	Number		
Nursery management	Man days		
Land preparation	Man days		
Herbicides	Litres		
Planting	Man days		
Disinfectants	Grams		
Insecticides	Grams		
Herbicides	Grams		
Fungicides	Grams		
Watering	Man days		
Sisal twine	Rolls		
Training	Man days		
Pruning	Man days		
Weeding	Man days		
Foliar spraying	Man days		
Top dressing	Man days		
Harvesting	Man days		
Grading and sorting	Man days		
Packing	Large box		
Produce transport	Large box		
Others			

2. Amount of fertilizer and foliar used. Please fill table below for main tomato plot or green house.

Plot	Acres	Fertilizer Type (use codes)	Unit of buying (use codes)	Unit price in KES	Fertilizer quantity used
BASAL					
a.					
b.					
TOP DRESSING					

a.					
b.					
FOLIAR					
a.					
b.					

3. **Basal, Topdressing and Foliar Fertilizer type codes:** 0=None 1=DAP 2=MAP 3=TSP 4=NPK (20:20:0) 5=NPK (17:17:0) 6=CAN (26:0:0) 7=ASN (26:0:0) 8=UREA (46:0:0) 9= SSP 10=Manure 11=Foliar feeds 12=NPK (20:10:10) 13=DAP + CAN 14=Compost 15=NPK (23:23:0) 16=NPK (17:17:17) 17= other (specify) _______________
4. **Unit of buying & unit of using codes:** 1. 50 Kg bag 2. 25 Kg bag 3. 10 Kg bag 4. Litre 5. Half Litre 6. Kgs 7. Grams 8. Debe 9. W/barrow 10. Others (Specify)
5. Where do you source the fertilizer? 1. Small traders [ ] 2. Stockiest [ ] 3. Company [ ] 4. Farmer /neighbor [ ] 5. Farmer group [ ] 6. Relative or friend [ ]

F. Information on input utilization in tomato production

Land utilization

1. What is the size of your entire land in hectares? …………………..
2. What is the size of farm allocated for tomato production? ……….. Ha.
3. How did you acquire the land? a. Inherited [ ] b. Purchased [ ] c. Rented [ ] d. permission to use [ ] e. Other (specify) ……….
4. Specify the type of land tenure.

Land owned with title	Land owned without title

Labor input in tomato production

5. What is the main source of labor in tomato production a. Family labor [ ] b. Hired labor [ ] c. Both family and hired labor [ ]
6. How many units of labor worked in the tomato field in the last season?

Type	Male	Female	Total
Hired labor in man days			
Family labor in man days			
Total			

7. What is the cost of labor per man day? KES …………
8. Are there times you experience labor shortages in the farm? a. Yes [ ] b. No [ ]

If Yes, for which specific activities?

a. Land cultivation [ ] b. Planting [ ] c. Weeding [ ] d. Spraying [ ] e. Pruning [ ]

f. Training [ ] g. Others { } (specify) ……………………

9. How do you overcome these challenge? 1. Hiring [ ] 2. Relatives [ ] 3. Was not able to overcome the challenge [ ] 4. Other specify …………………

F) Tomato production

1. What quality of tomatoes formed the largest portion of your harvest? 1. Grade 1 (Large) [ ] 2. Grade 2 (Medium) [ ] 3. Grade 3 (Small) [ ] 4. Grade (very small) [ ]
2. What quantities of tomatoes did you harvest from your farm? Kindly fill the information in the table below.

Type of farmer	Plot/ unit size (Ha)	Variety grown	Marketable output harvested (Kgs)	Unmarketable output harvested (Kgs)	Total quantity (Kgs)

3. In how many market outlets did you sell your farm produce? ……………
4. Specify the quantities sold and prices in these market outlets.

Market outlet	**Quantities**	**Price**
Farm gate		
Direct marketing		
Brokers/ Middlemen		
Traders		
Contract markets		
Farmer organization		

5. What were the highest and the lowest prices per quantity unit for your tomatoes during the year (May 2018-May 2019)?

a. High price (KES) ____________per__________________ (Output unit)

b. Low price (KES) ____________per__________________ (Output Unit)

6. Which months do you record the highest and the lowest tomato prices?

a. Months high _________________________________

b. Months low _________________________________

Appendix 2: NACOSTI research authorization permit

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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NACOSTI, Upper Kabete
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NAIROBI-KENYA

Ref: No. **NACOSTI/P/19/35693/31853**

Date: **30th July, 2019.**

Thomas Mbogo Mwangi
University of Embu
P.O. BOX 6-60100
EMBU.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Efficiency, profitability and market diversity among small holder tomato farmers in Kirinyaga County."*** I am pleased to inform you that you have been authorized to undertake research in **Kirinyaga County** for the period ending **29th July, 2020.**

You are advised to report to **the County Commissioner, and the County Director of Education, Kirinyaga County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

GODFREY P. KALERWA., MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kirinyaga County.

The County Director of Education
Kirinyaga County.

National Commission for Science, Technology and Innovation is ISO9001:2008 Certified