ECONOMIC POTENTIAL OF NEWLY INTRODUCED CHICKEN STRAINS AT FARM LEVEL IN SELECTED AREAS OF TANZANIA

ROGERS ANDREW

A THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2020

EXTENDED ABSTRACT

In Tanzania, local chicken farming is an integral part of the rural economy with a high potential for poverty reduction and enhancing food security. However, despite its contributions to household economy and food security, local chicken productivity remains low because of low genetic potential, diseases and poor feeding. One of the options to increase local chicken production and productivity is the adoption of the chicken strains with high genetic potential. In that respect, African Chicken Genetic Gains project introduced Sasso and Kuroiler chicken strains for on-farm testing to evaluate their economic potential in different agro-ecological zones. The study attempted to contribute towards the knowledge base regarding the possibility of increasing chicken production and productivity for enhancing income of smallholder farmers in the country. This study adopted developmental research design whereby 202 farmers in 12 sites in three regions of Tanzania were involved. Farmers were earlier on provided with 6 six-week old chicks which had been vaccinated against Mareks, Newcastle, Infectious Bronchitis and fowl pox. The study was conducted in Dodoma, Morogoro and Njombe regions which differed agro-ecologically. Data used were obtained through weekly farmers' and extension officers' records, survey, secondary data, simulation exercises, interviews, focus group discussions and observations. The study applied a Farm Simulation Model; FARMSIM and Stochastic Efficiency with Respect to Function to establish economic viability of these strains relative to the local chickens. Second, it used an Adoption and Diffusion Outcome Prediction Tool to predict the potential rate of adoption of introduced chicken strains and contributing factors. Further, Stochastic Data Envelopment Analysis was used to determine technical, allocative and economic efficiencies of keeping introduced strains among selected farmers. Lastly, multivariate multiple regression model in the Just and Pope framework was applied to investigate the effect of controllable inputs on production and variability. The results indicate that keeping Sasso strain was the most economically viable business with the highest Net Present Value, Net Cash Farm Income and the highest probability of attaining economic return. Kuroiler was the second, followed by keeping local chickens without supplementation. Keeping local chickens with supplementations was the least economically viable enterprise. However, inclusion of risk behaviour of the farmers revealed that extremely risk-averse farmers preferred mostly keeping local chickens without supplementations whereas, extremely risk loving farmers preferred Sasso strain the most. The extremely risk-averse farmers would need to receive about TZS 388 620.0 and TZS 297 180.0 to be indifferent between keeping about 60 Sasso strain and Kuroiler strain respectively and local chickens without supplement. The results also indicate that the peak for adoption is likely to be 34, 29 and 38% after 8, 7 and 9 years in Bahi, Ifakara and Wanging'ombe sites respectively. The sensitivity analysis results indicate that, the adoption rate may increase up to 59, 49 and 57% and may decline to about 17, 16 and 21% in Bahi, Ifakara and Wanging'ombe respectively. Results show that there is significant inefficiency in both the Sasso and Kuroiler chicken keeping households. Further, farmers were technically, allocatively and economically inefficient with mean indices of 19.9%, 68.8% and 12.9% respectively. The likely cause of being inefficient was due under utilization of key input factors with exceptional to maize bran. Furthermore, the results indicate that there was production variability attributable to input factors. However, there was inconsistent effect since some inputs were both variability increasing and reducing; that is, reducing in production of birds but increasing in egg production for the same strain and vice versa. It is likely that the full potential of these strains requires inputs in a standardised form for reduced performance variability. The study recommends promotion and scaling up of these strains for improving the livelihood of smallholder farmers and increasing the sector's contribution to country's Gross Domestic Product. Moreover, the scaling up must be integrated with education on technical knowledge on good farming practices, feed

formulations, biosecurity and shelter for improved productivity and reduced variability. It is important to strengthen market integration for both inputs and outputs for improving economic efficiency and profit maximization. Lastly, further study has to be set for determining the farm level input mix with minimum effect on output variability.

DECLARATION

I, Rogers Andrew, do hereby declare to the Senate of Sokoine University of Agriculture, that this thesis is my own and original work done within the period of registration and that it has neither been submitted nor being concurrently submitted for degree award in any other institution.

Rogers Andrew — Date

(PhD. Agricultural Economics Candidate)

Above declaration is confirmed by:

Jeremia Makindara (PhD) — Date

(Supervisor)

Said H. Mbaga (PhD) — Date

(Supervisor)

Roselyne Alphonce (PhD) — Date

(Supervisor)

COPYRIGHT

ACKNOWLEDGEMENTS

Above all, I am thankful to God, the Almighty, for this achievement. I am also thankful to Sokoine University of Agriculture (SUA) for offering me the sponsorship and study leave.

I gratefully acknowledge the African Chicken Genetic Gains (ACGG) Project under the Bill and Melinda Gates Foundation (BMGF) funding for offering me research fund to accomplish fieldwork.

I am very grateful to my supervisors: Dr. Jeremia R. Makindara, Dr. Said H. Mbaga and Dr. Roselyne Alphonce, for their relentless support throughout my study. Their insightful feedback accelerated my research. Thanks to Professor. James W. Richardson and Dr. Jean-Claude Bizimana of Agricultural and Food Policy Centre (AFPC), Texas A & M University and Innovation Laboratory for Small Scale Irrigation (ILSSI) Project for granting the FARMSIM model for analysis. Sincere thanks are extended to the Commonwealth Scientific and Industrial Research Organization (CSIRO) for granting the Adoption and Diffusion Out-come Prediction Tool (ADOPT) for analysis.

I appreciate the rigorous comments and insights from discussant and referees in particular; Professor Aida Isinika and Professor Reuben Kadigi. Insights and encouragements from Dr. Adam M. Akyoo are also acknowledged. Thanks to all farmers, enumerators and field guides who participated in the on-farm testing and data collection. My postgraduate colleagues, with whom I shared study experiences, are also deservedly acknowledged.

Lastly but not least, special appreciation is accorded to my wife, my mother, my sisters, my brothers and my children for their patience, prayers and hope during my study.

DEDICATION

This successful completion of this doctoral thesis is dedicated to my beloved mother; Elizabeth Andrea, my hero, for all she has undertaken in my life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

ACGG	African Chicken Genetic Gain
ADOPT	Adoption Diffusion Outcome Prediction Tool
AE	Allocative Efficiency
AFNETA	Alley Farming Network for Tropical Africa
DADPs	District Agriculture Development Programmes
DEA	Data Envelopment Analysis
DMU	Decision Maker Unit
ECR	Ending Cash Reserves
EE	Economic Efficiency
FARMSIM	Farm Level Economic and Nutrition Analysis
GDP	Gross Domestic Product
ILRI	International Livestock Research Institute
ITFC	Improved Traditional Family Chicken
LS	Least Squares
ML	Maximum Likelihood
NCI	Net Cash Income
NLS	Non-Linear Least Squares
NPV	Net Present Value
OECD	Organisation for Economic Co-operation and Development
SCC	Expanded Specialized/Commercial Chicken
SDEA	Stochastic Data Envelopment Analysis
SERF	Stochastic Efficiency with Respect to Function
SFA	Stochastic Frontier Analysis
Simetar	Simulation and Econometrics to Analyse Risk

SSA	Sub-Sahara Africa
SUA	Sokoine University of Agriculture
TE	Technical Efficiency
TIC	Tropical Improved Chicken
TLMP	Tanzania Livestock Master Plan
TZS	Tanzanian Shilling
URT	Ministry of Livestock and Fisheries Development
URT	United Republic of Tanzania
US$	United States Dollar
USAID	United States Agency for International Development
VRS	Variable Return to Scale
€	Euro

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

In Tanzania, poultry farming plays an important role in both urban and rural settings in terms of food security, source of income and in meeting other social obligations such as dowry and rituals (Data Driven Insight, 2018). Chicken (*Gallus gallus domesticus*) production accounts for about 95% of poultry sector and plays an important role in the global economy whereby in 2018, over 13 million tons of poultry meat was exported globally (FAO, 2019). The entire Sub-Saharan Africa (SSA) accounts for less than 3% of poultry production in the world (Data Driven Insight, 2018). The largest share of SSA production is attributed to South Africa, which supplies 1.6% of global volumes, while Tanzania accounting for only 0.1% of global production volumes (OECD-FAO, 2019).

Keeping local chickens is an integral part of Tanzania’s rural economy whereby among the existing 4.7 million agricultural households in Tanzania, 3.7 million households keep chicken (FAO, 2019). The current population of chickens is estimated at 72 million, of which 40 million are indigenous chicken and the remaining 32 million are exotic poultry, which include 24 million broilers and 8 million layers (Match Maker Associates Limited (MMA) and Transcend Enterprises Limited, 2018). Chicken production contributes about 1.8% of the Gross Domestic Product (GDP) (Data Driven Insight, 2018). In 2018, the estimated monetary value of meat and eggs was TZS 874 billion and 364 billion respectively (MMA and Transcend Enterprises Limited, 2018).

However, despite the economic potential experienced, the local chickens’ contributions to household economy and food security have remained low. Key challenges include low genetic potential, diseases and poor feeding which consequently lead to low growth rate and low egg production with high mortality rates (Marwa *et al*., 2018; FAO, 2019). Low genetic potential of local chicken farming system in Tanzania has multifaceted effects to increased contribution of the sector to country's GDP, reaching the targeted egg and meat production and protein intake among rural dwellers. According to URT (2015), the weight of local chicken ranges between 1.6 and 2.0 kg at 20 weeks while annual average eggs produced per hen per year is 36. Therefore, due low productivity of the sector, Tanzania has continued being a net importer of chicken products. For example, by July 2018, Tanzania imported processed chicken products worthy €2 333 846 (MMA and Transcend Enterprises Limited, 2018).

Hence, in order to improve production and productivity of local chicken farming system in the country, the Government of Tanzania (GoT), Research Institutions and Development Partners introduced several interventions, which include: District Agriculture Development Programmes (DADPs), Transforming Traditional Poultry Keeping into a Commercial Venture (Rural Livelihood Development Company-RLDC under SWISSAID), Poultry Skills for Rural Livelihoods (Sokoine University of Agriculture (SUA), under USAID-Feed the Future Programme), Improvement of local chicken keeping practices (Uluguru Mountains Agricultural Development Project), just to mention a few. Some of these programmes aimed at upgrading genetic potential through cross-breeding programmes between local chickens and improved (exotic) ones. The aim was to combine desirable features from these two diverse genetic groups; that is, high productivity from exotic genotypes and high adaptability from local chicken genotype (African Chicken Genetic Potential (ACGG), 2016). However, such programmes became unsustainable due to unreliable supply, high costs of maintaining exotic breeding cocks, reduced broodiness and ability to evade predation (Tadelle *et al.,* 2000).

Recently, Tanzania established the Tanzania Livestock Master Plan (TLMP) 2017/2018-2021/2022 with overall target of raising annual chicken meat production almost eightfold; from about 60 800 to 465 600 tonnes and egg production from about 3.0 to 4.2 billion by year 2021/22 (URT, 2017). The main pathways include: Improved Traditional Family Chicken (ITFC), Tropical Improved Chicken (TIC) and expanded Specialized/Commercial Chicken (SCC) with layers and broilers sub-systems. In addition, it considers interventions in the areas of animal health, genetics, marketing and processing being the cornerstone for increasing the contribution of the national poultry sector to GDP by 182% to nearly USD 324 million over the 2017–2022 period.

Thus, due to low production and productivity of local chicken farming systems, ACGG project supported the goals of the established Tanzania Livestock Master Plan by introducing to Tanzania, tropically improved chicken that have been found to be more economically potential in other areas. The ACGG project introduced new chicken strains, were tested at village level in Tanzania to assess their economic potential in different agro ecological zones. The introduced strains are Kuroiler and Sasso which have proven to be performing better than local strains in other countries. Kuroiler strain which is developed and marketed by Kegg Farms, weighs about 1.8–1.9 kg (hen) and 2.3–2.4 kg (cock) at 20 week age. The hen can produce about 150 eggs per year (World Society for the Protection of Animals, 2011). Sasso strain which originally was developed and marketed by Hendrix Genetics weighs 1.5-1.7 kg (hen) and 2.2-2.5 kg (cock) at 20 week age and can produce about 150 eggs per hen per year (Rodelio and Silvino, 2013). With this regard, ACGG aims at improving family chicken sub-system to increase production, productivity and through simulating farmers from an extensive farming system to a semi-intensive farming system. The ACGG is therefore trying to open more opportunities for investments in local chicken farming system in the country which will revamp the sector and related industries to become more productive and business oriented.

1.2 African Chicken Genetic Gain (ACGG) Project

The African Chicken Genetic Gains (ACGG) is an Africa-wide collaboration led by the International Livestock Research Institute (ILRI). As part of the wider 'LiveGene' initiative, the ACGG intended to test and makes available high producing, farmer-preferred genotypes of chicken to increase smallholder chicken productivity in Africa. The ACGG introduced chicken strains namely Sasso and Kuroiler to be tested at farm level in different agro-ecological zones in order to evaluate their economic potential. The project delivery systems included provision of pre-vaccinated chicks to farmers in diverse agro ecologies of Tanzania. The project intended also to catalyse public-private partnership to increase accessibility of these strains and associated services. On-farm testing approach was the method adopted by ACGG. Such an approach is in line with a shift in thinking away from looking at adoption as the delivery of an external, typically science-based innovation with farmers as potential end users of the technology (Roling and Jiggins, 1998). These approaches are sometimes more complex learning process which involve a wide range of actors such that at the end, farmers' adoption becomes a challenge (Roling and Jiggins, 1998). Furthermore, the absence of technologies, limited access to or the use of inappropriate technologies has been in part blamed for the lack of increase in productivity and persistent food insecurity in developing countries (Bizimana and Richardson, 2017).

In addition, the ACGG project responded to the fact that, the gateway to Africa's economic development hinges on innovation, diffusion and utilization of agricultural technologies (Langat *et al.*, 2013; Shaw, 2014). Lastly, targeting smallholder farmers, indeed, the project is in line with the Tanzania Livestock Master Plan (TLMP) 2017/2018-2021/2022 (URT, 2018). The TLMP aims at improving the sector so as it increases its contribution to GDP from TZS 256 billion to TZS 723 billion by 2022; thereby contributing significantly to closing the production consumption gap for meat by 2032 (URT, 2017). Accordingly, in its Master Plan, GoT targets small-scale poultry production systems to develop the sector. This is due to the established fact that investing in the current small-scale poultry enterprises will have more impact than increasing the number of large and industrial poultry farms (URT, 2018). In this regard, the ACGG project is one of the interventions in Tanzania aimed at finding ways of transforming the poultry sector through provision of preferred chicken strains and smoothen the delivery system to farmers and engagement of private investment to improving household income, food and nutrition security.

1.3 Problem Statement and Study Justification

Despite the importance of poultry in the Tanzanian economy, the sector is still at an infant stage both in the commercial and traditional production (Data Driven Insight, 2018; MMA and Transcend Enterprises Limited, 2018; FAO, 2019). Therefore, based on a poultry sector analysis (URT, 2017), there are three areas of concern with regard to chicken productivity enhancement: improvement in genetic breed, medication and management. In addition, the need to look for alternatives chicken strains does not only arise from low genetic potential of available local chicken but also due to the need to find ways through which the introduced strains can act as an investment stimulator among local chicken keepers.

Generally, the productivity of chickens in family poultry production systems in Tanzania is low, mainly due to low genetic potential, diseases, poor quality of feeds and feeding, inadequate technical and farmer support services (FAO, 2019). There are several efforts that have been in place to improve productivity in local chicken farming systems (URT, 2018). However, many of these efforts failed to deliver the intended impact because they tried to use high-producing genotypes created for intensive temperate feeding systems (ACGG, 2016; FAO, 2019). Thus, the ACGG's strategy aims to combines new genetics and enhanced delivery systems in finding ways to improve productivity (ACGG, 2016). In achieving its objectives, ACGG project distributed six weeks old and vaccinated chicks to selected farmers for purpose of on farm testing. Chicks distributed belonged to Sasso and Kuroiler chicken strains which are known to perform better in other countries like Ethiopia and India.

The economic performances of these chicken strains in other countries at local environment are somehow documented (World Society for the Protection of Animals, 2011; Rodelio and Silvino, 2013). However, information on the economic potential of these strains in Tanzania`s agro-ecological zones is limited. Moreover, the good performance of these strains in other countries cannot be guaranteed to Tanzania since their interaction with new agro-ecology may influence their productivity (Francis *et al.,* 1995). According to USAID (1988), even if new technologies and production methods appear to hold a promise for improving the income and nutrition of farmers, yet it is important to confirm the magnitude of such improvement at farm level.

Meanwhile, Sunding and Zilberman (2000) argue that, innovations require assessment for their technical feasibility to provide a base for their adoption. Moreover, in both economic and diffusion of innovations theories, farmers are presumed to be rational in making decisions based on available information, with a view to securing optimum result possible (Simon, 1959). Furthermore, according to AFNETA (1992), it is essential to evaluate new technologies in terms of viability, risk, sustainability and acceptance before incurring high costs of technology transfer.

Accordingly, assessment of agricultural technologies in terms of their technical and economic viability and their subsequent transfer and adoption to farming communities are all fundamental. This will ensure sustainable increase of incomes leading to economic growth and subsequent poverty reduction (Limbu, 1999). Finally, assessing the economic potential and impact of technology can assist in setting priorities, providing feedback to research programmes, guiding policy makers and those involved in technology transfer to have a better understanding of how introduced chicken strains are diffused and assimilated into farming communities, and provide evidence that clients may benefit from such research products (Mignouna *et al.*, 2011). It is therefore envisaged that the findings of this study will contribute to the body of knowledge on the introduced chicken strain and raise pertinent policy issues in relation to poultry sub-sector as described in the next paragraphs.

First, the study assessed the economic viability of the introduced chicken strain at farm level in selected areas of Tanzania. This is important because knowledge on the economic viability of technologies enables farmers to select superior technology (Miceikiene *et al*., 2015). According to Spicka *et al.* (2019), estimation of farm economic viability is more topical when redesigning the agricultural policy that should stabilise farm income and make agribusiness more viable and sustainable.

One of the reasons why the viability of agriculture is a critical farm policy issue is that, farmers are rational economic agents whose decisions to adopt new technology largely depend on how viability such technology is. According to Limbu (1999), studies on the economic viability of recommended agricultural technologies are meant to provide some insights into the extent to which the recommended technologies are profitable. With this regard, the study provides economic insights that should guide farmers' decision for adopting the strains towards increased chicken production and productivity.

Second, the study assessed the potential of adopting the introduced chicken strains among small scale farmers in the selected areas of Tanzania. The assumption is that, farmers will adopt a new technology only if the benefits or perceived utility of using the new technology outweighs the benefits of the current or old technology (Bizimana and Richardson, 2017). However, adoption of agricultural technologies may not be straightforward since farmers are economic agents who can only decide to adopt a new technology only if they are exposed to it (Foster and Rosenzweig, 2010). Nevertheless, the adoption of improved agricultural technologies and practices by farmers has often been less than expected, despite demonstrated benefits (Bizimana and Richardson, 2017; Thornton *et al*., 2017).

Likewise, in some developing countries, national governments, international agencies and several development organizations have attempted to make agriculture more productive and profitable by introducing agricultural technologies but with modest results (Yengoh *et al.*, 2010). Soule *et al.* (2000) provide experience that, even when technologies are appropriate for the biophysical setting, they are not always adopted because farmers consider a variety of factors when making a decision to adopt a particular technology.

Thus, whatever the introduced chicken strains are in terms of economic viability, biophysical adapted, assessment of the possible for adoption is inevitable. Therefore, the results of this study is expected to provide empirical information for a better understanding of the likelihood of the diffusion and adoption of introduced chicken strains to guide producer, researchers and policy makers in making prudent and informed decisions about allocating resources in scaling up the interventions.

Third, the study seeks to estimate the technical, allocative and economic efficiencies of keeping the introduced chicken strains at farm level among smallholder chicken keepers. According to Ghatak and Ingersent (1984), technological improvement is expected to create a larger output, increased both allocative and technical efficiencies and hence motivates the small farmer to invest. Consequently, farmers are supposed to make efficient use of the existing technology, that is, either to produce at a maximum level with given set of inputs or use the minimum level of inputs to produce a specific level of output (Minviel and Latruffe, 2016).

This view is informed by concerns that, chicken production and productivity is very low in Tanzania albeit its importance of improving income and food to farmers and other actors in the value chain (URT, 2017). For instance, despite being one among very few livelihood strategies capable of supporting the poorest farming households in rural areas (Marwa *et al*., 2018), productivity is very low due to poor management and poor genetics (Data Driven Insights, 2018).

Allocative efficiency is estimated to measure the level to which a farm uses the best combination of a range of inputs considering the prevailing market prices (Mutoko *et al*., 2015). Accordingly, the product of Allocative and Technical efficiencies is used to evaluate the economic (overall) efficiency. Cooper *et al.* (2011) assert that, full efficiency takes place when a firm is functioning at such a point where no inputs or outputs can be better without deterioration of some other inputs or outputs. Therefore, improving the efficiency of chicken enterprises is important for poverty reduction among chicken value chain actors in Tanzania. The study provides empirical insights that should guide policies aimed at improving the economic efficiency of chicken production and inform strategies that contribute towards increased poultry production.

Lastly, the study aimed at analysing the effect of controllable inputs and management practices on performance variability of the introduced chicken strains. This is crucial since in agricultural production, risk in term of variability is an inherent part of the production process and plays an important role in both input use decisions and production of output (Kumbhakar, 2002 and Nalley and Barkley, 2007). Production variability also creates significant challenge in the design and implementation of technology (*De* Janvry, 1972 and Chavas and Shi, 2015). This is because, agricultural innovations are uncertain, resulting into variability in yields, which exposes farmers to production risk (Simon, 1959; Hurd, 1994; Khayyat and Heshmati, 2014). Consistently, variability in yield is not only explained by factors outside the control of the farmer such as weather, pests, diseases input and output prices alone, but also by controllable factors such as varying the levels of inputs (Antle, 1983). Hence, ignoring variability in the analysis can lead to wrong inferences on the technology and, in particular, can produce standard errors that are misleading by indicating much greater precision in estimation than it is (Koundouri and Nauges, 2005).

Moreover, whether variability is associated with the physical environment, farmers' management or the socio-economic environment, understanding the causes of variability in the performance of new technology leads to the identification of ways to reduce risk and increase acceptance among farmers (Boughton *et al*., 1990; Yang *et al*., 2016). Therefore, analysing the effect of controllable inputs on production variability is useful not only to farmers through increased knowledge about their input choices, but also for policy makers responsible in designing development strategies.

1.4 Study Objectives

1.4.1 Overall objective

The overall objective of this study is to assess the economic potential of newly introduced chicken strains at farm level in selected areas of Tanzania.

1.4.2 Specific objectives

The study pursued the following specific objectives:

i. To analyse economic viability of newly introduced chicken strains in selected areas of Tanzania in terms of Net Present Value, Net Cash Farm Income and probability distribution of economic gain;

ii. To analyse an *ex-ante* adoption of introduced chicken strains among smallholder farmers in selected areas of Tanzania;

iii. To estimate technical, allocative and economic efficiency of keeping introduced chicken strains among small holder chicken farmers in selected areas of Tanzania; and

iv. To analyse effect of controllable inputs on production and variability of the introduced chicken strains at farm level in selected areas of Tanzania.

1.5 Hypotheses and Research Questions

1.5.1 Hypotheses of the study

The study was guided by the following hypotheses**:**

i. Net Cash Farm Income of introduced chicken strains is similar to Net Cash Farm Income of available local chicken strains ($NCFI_l$=$NCFI_i$); Net Present Value of investing in keeping introduced chicken strain is similar to Net Present Value of investing in keeping available local chicken strains (PV_l=NPV_i); *i.e.* there no statistically significant difference in economic viability between keeping introduced chicken strains (i) and local chickens (l).

ii. Local chicken keepers are efficient in keeping introduced chicken strains.

iii. Controllable input factors do not statistically affect production and variability of introduced chicken strains.

1.5.2 Research questions

The study also was meant to answer the following research questions:

i. To what extent the introduced chicken strains are likely to be adopted by smallholder farmers?
ii. What are factors that may affect the adoption of the introduced chicken strains?

1.6 Shortcoming of the Study

The present study offers useful information on economic potential of introduced chicken strains at farm level in selected areas of Tanzania. Nonetheless, the study encountered some limitations as follows:

First, the developmental research design distributed a six weeks pre-brooded chicks to farmers and therefore, assessment did not include data for age below six weeks. This has an implication on the performance and mortality since mortality rate is always recorded higher in the age below six weeks in both local and commercial chicken farming. According to Sanka *et al.* (2020), mortality rate in poultry sector is higher in starter phase (0-6 weeks of age) than in grower phase (6-20 weeks of age).

Second, the analyses did not capture the feed resource base for the scavenging which is very important for local chicken production. For instance, some farmers may be found having more household scraps, because of their feeding habit which in turn become the potential feed supplements to introduced chicken strains. Also crop content, which varies according to seasonal, agricultural activities and location are very important. Others sources include: termites, worms and grasshoppers which are important sources of protein in local chicken farming in Tanzania. Although, the present study tried to capture the effect of scavenging by including location specificity in the model, yet it was not compressive enough to identify scavenging specific feed ingredient.

1.7 Literature Review

1.7.1 Chicken production and consumption in Tanzania

Poultry farming has long been based on traditional livestock practices and indigenous breeds operated by small-scale producers with a limited access to inputs and services (FAO, 2019). Local chicken production is practised in all region both in urban and rural areas whereby Tabora (2 636 692), Mbeya (2 524 782), Shinyanga (2 125 199), Mwanza (2 120 469), Morogoro (2 085 468), Geita (2 078 319), Dar es Salaam (1 827 337), Kilimanjaro (1 756 396), Mara (1 757 070), Tanga (1 756 396) and Simiyu (1 744 993) regions are main producers total chicken population in Tanzania (URT, 2017).

The population of chickens is estimated at 79.1 million, of which 38.5million are indigenous (backyard chicken) and the remaining 40.6 million are commercial poultry (MMA and Transcend Enterprises Limited, 2018). Table 1.1 below indicates the trend of meat and egg production for the past eight years. Production trend indicate declining for both meat and eggs in 2016/17 and hence putting Tanzania in a continued net import of the chicken products. According to MMA and Transcend Enterprises Limited (2018), supply of poultry meat and eggs estimates do not meet the market demand and hence, the country is importing significant volumes of processed chicken products (frozen chicken meat, eggs, hatchery (fertilized) eggs, etc.) primarily from the USA, Brazil, the UAE, and Russia and also from France, Turkey, Poland, and until 2018, China.

Table 1.1: Tanzania production of poultry products from 2011 to 2018

Year	Meat (tons)	Eggs (000')
2011/2012	84 524	3 494 584
2012/2013	87 408	3 725 200
2013/2014	54 360	3 899 568
2014/2015	99 540	4 153 800
2015/2016	104 292	4 353 182
2016/2017	63 597	2 758 000
2017/2018	78 110	3 156 692

Source: URT (2018)

According to Tanzania Livestock Master Plan-2018; successful poultry interventions would allow the sub-sector to move to improved farming of poultry with semi-scavenging crossbreeds and for substantial increases in the scale of specialized layer and broiler operations. The plan projected annual chicken meat and egg production in Tanzania to rise to 465 600 tons and 4.2 billion eggs, respectively. This would bring the production-consumption deficit for chicken meat from 130 000 to a surplus of 258 000 tons between 2017 and 2022. The combined interventions would result in increases of 666% and 40% respectively in chicken meat and egg production by 2022. Such accomplishments would enable Tanzania to meet the chicken meat and egg demand for its growing population, and produce a very significant surplus for domestic industrial use or export.

1.7.2 Economic viability

Economic viability is defined as the ability of the introduced chicken strains to generate higher and long term benefit (Spicka *et al*., 2019). Indicatively, economic viability is mainly measured by profitability, liquidity, stability and productivity (Latruffe *et al*., 2016). In summary, economic viability indicators include Net Cash Farm Income (NCFI), Net present value (NPV), gross margin, gross margin ratios, net profit, profitability ratios, profitability, net return and output-input ratio (Chaturvedi, 2013; Miceikiene *et al*., 2015; Mugweni and Muponda, 2015; Spicka *et al*., 2019). Specifically, economic viability of introduced chicken strains relative to available strains has been measured in terms of NPV, NCFI and, cumulative distribution and stoplight chart have been used to measure the distribution and probability such economic indicators. The stoplight chart is the chart presenting probabilities of getting different socio-economic outcomes using colour coded charts. The colour codes include green, yellow and red. Green represents the probability of getting the best outcome; yellow is the probability of getting moderate outcome and red is probability of getting the least socio-economic outcome (Bizimana and Richardson, 2017).

1.7.3 On farm test of new technology

The ACGG project introduced Kuroiler and Sasso chicken strains to evaluate their economic potential and acceptability in Tanzania's agro ecological zones and farming practices before scaling up the intervention (ACGG, 2015). On-farm test is commonly used as a means to ensure that technologies developed on-station or introduced are relevant to the problems and priorities of the targeted clients (AFNETA, 1992). According to De Janvry *et al.* (2016), it is important to note that diffusion of a new agricultural technology requires farmers to learn about its existence and the benefits of the technology. In addition, it is important to undertake a critical analysis of the technology since some technology packages may succeed or fail because of low yield, not being acceptable and the magnitude of risk farmers exposed to upon adoption (Boughton *et al.*, 1990). Petra and Kenneth (2006) also assert more reasons for on-farm testing of developmental research evaluation as follows; first, it makes possible to design a program that achieves some desired impacts at a minimum cost or it maximizes the impacts for a given cost. Second, it helps to avoid the high cost of implementing programmes on a large scale that are later found to be ineffective. Third, it provides an idea of the range of impacts to expect after the programme is implemented, which is useful for placement. Fourth, it is useful to study how the impacts would change if some parameters of the program were altered.

1.8 Theoretical Framework

A theory can be defined as a set of interrelated constructs or variables, definitions and prepositions that present a systematic view of phenomena (Creswell, 2010). The current study is guided by four theories namely rational choice theory (Cornish and Clark, 1986), the Rogers theory of diffusion of innovation (focusing on the perceived attributes of an innovation (Rogers, 2003), Bass Diffusion Model (Bass, 1969) and Production theory (Wolman, 1921). Details of each theory and how it has been applied are explained in subsequent subsections.

1.8.1 The rational choice theory

The rational choice theory (Cornish and Clark, 1986) is used to govern investigations on the economic viability and performance variability of introduced chicken strains, to provide information necessary for decision making based on the economic indicators. The theory claims that, economic behaviour is essentially rational behaviour in which decisions are made based on all available information with a view of securing the optimum result possible for each decision maker. The basic premise of the rational agent is assumed to take account of available information, probabilities of events, and potential costs and benefits in determining preferences, and to act consistently in choosing the self-determined best course of action (Grüne-Yanoff, 2012).

Feder *et al*. (1985) argues that, farmers' decisions in a given period of time and space are derived from maximization of expected utility or expected profit subject to resources constraints and risks associated with that investment. With this concern, the rational behaviour of these farmers is based on the information availability on any new agricultural technology. *De* Janvry *et al.* (2016), hypothesize that farmers with perfect information choose to allocate their resources between for example two crops, thus maximizing the returns. Under this hypothesis, it is expected that local farmers would decide to allocate the meagre resources they have on new chicken strains if and only if on farm testing reveals that the introduced strains increase return that supersede the variance relative to available chickens.

Problem-solving intervention for improving productivity of chicken keeping in Tanzania, on farm testing and empirical evaluation of the introduced chicken strains is activated to help farmers make a choice (adopt or reject) using information collected and the latter, This in turn, allows farmers to gather new information (Chowdhury, 1984). This is important since most of the adoption analyses assume fully informed rational decisions based on careful consideration of all the information available about a new technology (Brock and Barham, 2013).

1.8.2 Adoption theories

Diffusion of innovation theory (Rogers, 2003) and Bass Diffusion Model (Bass, 1969) were applied to guide assessment of the potential of adoption of introduced chicken strains. Diffusion of innovation theory by Rogers (2003) is based on the notion that, individuals will adopt an innovation if they perceive it to be more economic-efficient compared to the technology that will be replaced. There are four main interacting elements under the diffusion of innovations theory which include 1) an innovation, 2) communication, 3) over time and 4) among members of a social system. In addition, the theory classifies the rate of adoption based on a community based criterion into five categories: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%) and laggards (16%). Further, farmers consider adopting new technology by considering other attributes like; relative advantage, complexity, compatibility, or divisibility, costs relative to benefits and profitability (Kalaitzandonakes *et al*., 2018).

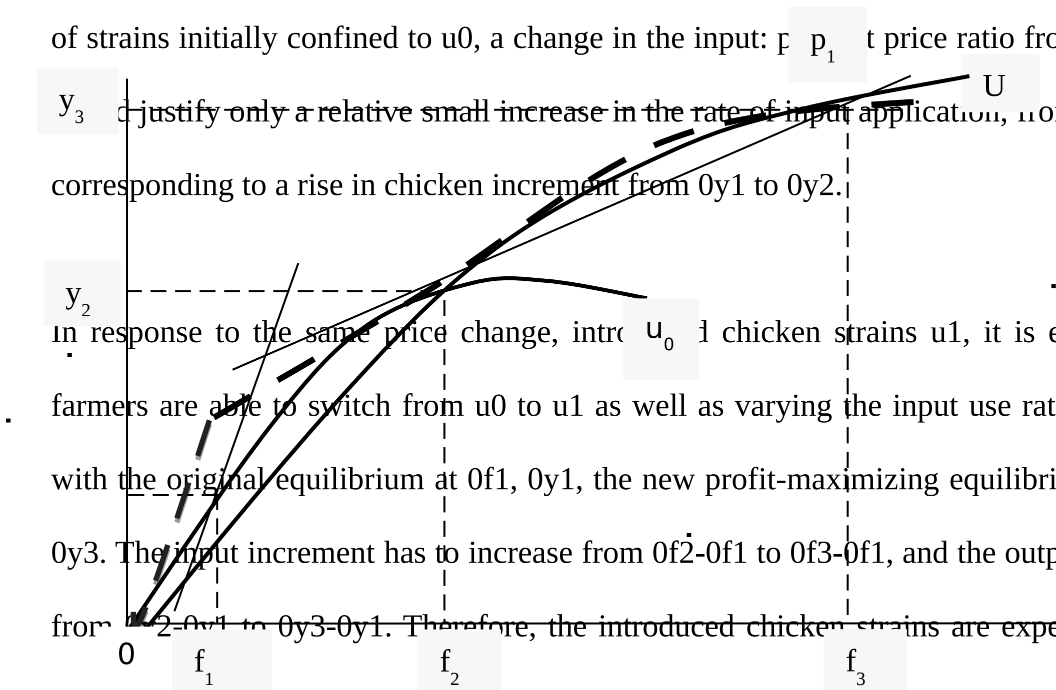
Moreover, according to Bass diffusion model, new products are adopted as a result of an interaction between users and potential users (Bass, 1969). The diffusion model gives many practical insights into how we can understand the diffusion and adoption of innovation. Bass (1969) sees technology spread as the outcome of two main factors: innovation which refers to the desire of people to try out new technologies, and imitation which refers to the influence of those that have tried out a technology thereby drawing in others who have not yet tried this technology to trying and using it.

In light of the introduced chicken strains it is necessary to address the question of the adoption in light of the model. This is because in most of the new technologies, their adoption rate still remains low (Bizimana and Richardson, 2017; Thornton *et al*., 2017). For that reason it is interesting to think within the framework of the technology diffusion and adoption (Ostojic, 2010). Therefore, the two theories have been combined to explain the likelihood of adoption of introduced chicken strains as it is detailed in chapter three of this thesis.

1.8.3 Theory of production

Production theory stipulates that, an increase in efficiency mean the use of inputs in suitable proportion to obtain maximum production at minimum cost. The theory is regarded as a tool used in the management of production, especially for optimizing existing production and planning new production (Foss, 1997). With respect to introduced chicken strains in Tanzania, Ghatak and Ingersent (1984) contend that, technological improvement in any kind of production process possesses two properties: first, a new production function is created such that any given quantity of resources yields a larger product. Second, is the proportions in which resources are combined to produce a given output at least cost. The assumption is that having good modern varieties that perform well under local conditions will lead to adoption and increase efficiency. In this case, other inputs which are converted into economically valuable outputs will increase, and productivity rises (Awotide *et al*., 2014). Therefore, agricultural technologies are critical in stimulating the transition from low productivity subsistence agriculture to a high productivity agro-industrial economy which is crucial for improving the welfare of farmers (World Bank, 2009). This is evidenced via the Green Revolution of Asian countries whereby high yielding varieties kick-started in investing in agriculture (World Bank, 2009).

A use of improved agricultural technologies and consequent change in resource allocation alter the structure of production (Ghatak, 1987). Figure 1.1 provides explanation on the impact of the improved variety on yield and how such variety responds to other inputs relative to existing variety. In order to shade light on the probable impact of the introduced chicken strains on poultry production and productivity, let consider Figure 1.1 as follows. Let the investment (set of inputs) measured along the horizontal axis and the dual poultry products along the vertical axis. The production functions represented by u0 and u1 are input response curves representing local chicken strains and introduced strains respectively. The points of tangency at p0 and p1 represent input-output ratios. With the farmer`s choice of strains initially confined to u0, a change in the input: output price ratio from p0 and p1 would justify only a relative small increase in the rate of input application, from 0f1 to 0f2, corresponding to a rise in chicken increment from 0y1 to 0y2.



In response to the same price change, introduced chicken strains u1, it is expected that farmers are able to switch from u0 to u1 as well as varying the input use rate. Compared with the original equilibrium at 0f1, 0y1, the new profit-maximizing equilibrium is at 0f3, 0y3. The input increment has to increase from 0f2-0f1 to 0f3-0f1, and the output increment from 0y2-0y1 to 0y3-0y1. Therefore, the introduced chicken strains are expected to have greater efficiency both in input usage (induced willing to invest) and in increased chickens and eggs production. In such sense, introduced chicken strains are expected to increase income through increased productivity and economic efficiency compared to existing chicken.

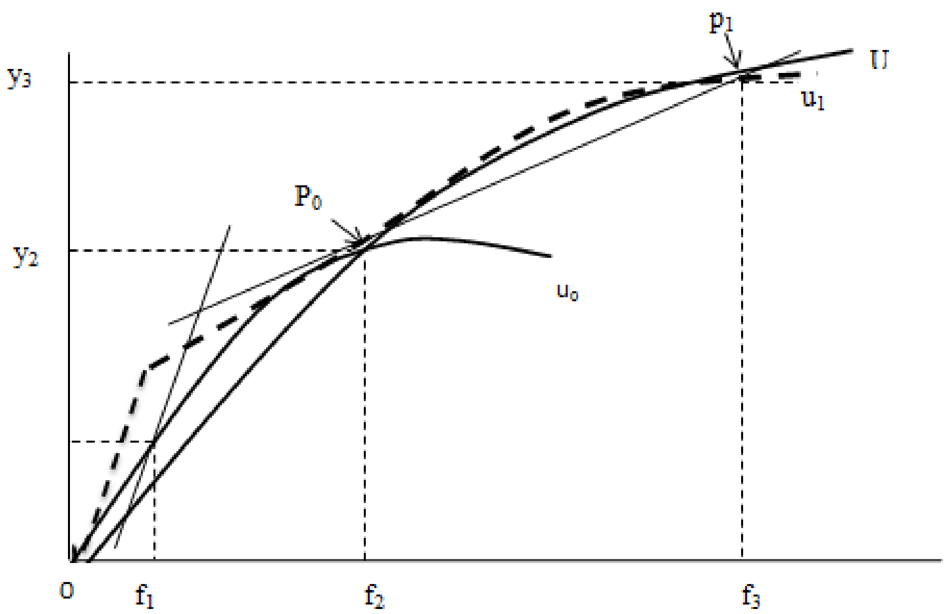


Figure 1.1: Perceived economic-efficiency improvement of introduced chicken strains
Source: Adapted from Ghatak and Ingersent (1984)

1.9 Empirical Review

1.9.1 Review of economic viability and adoption of agricultural technologies

An adoptable new technology always has more advantages than the previous practice that it would replace, at least when potential users have access to information about it (Bizimana and Richardson, 2017). Information on the economic importance of the technology has been the building block for farmers' decisions to adopt such innovations (Asfaw *et al.,* 2012). Different authors have worked on the economic viability of agricultural technology in both developing and developed world. Misaki *et al.* (2016) found that farmers consider information on economic importance of agricultural technology as a potential factor for their adoption decisions. Limbu (1999) analysed the economic viability of agricultural technologies in Tanzania and found that available information on the performance of these technologies was useful in the adoption process. Moreover, he noted that, technically, few producers were fully aware of the profitability potential of the recommended technologies, yet they did not adequately follow the breeders' recommendations. Further, farmers did not adopt because prices of inputs and products hampered adoption of technologies.

Qaim (2001) analysed the effects of biotechnology on semi subsistence agriculture. The study focused on the *ex-ante* economic implications of transgenic virus and weevil resistant sweet potatoes in Kenya whereby it was found that both innovations were likely to bring about substantial growth in economic surplus to improve livelihood of farmers. Study conducted by Asfaw *et al*. (2012) in Ethiopia and Tanzania found that access to information and perception about the new cultivars were identified as a key determinant for both pigeon pea and chickpea technology adoption. One of their recommendations was for the government to take the lead in technology promotion and dissemination at the initial stages and in creating an enabling environment for effective participation of the private sector. Second recommendation was to include awareness campaigns for improved varieties, combined with improved local availability of improved seeds at reasonable prices. This approach offers the most promising policy mix to accelerate and expand adoption.

Based on the review above it is clear that the evaluation of the economic potential of introduced new chicken strains while still on farm testing is novel to provision prudent information for adoption decision. Information to be generated will policy discussion on the promotion and adoption of introduced strains for improving household income, food security and filling demand gap of poultry products in Tanzania.

1.9.2 Review of agricultural technology adoption

Rogers (2003) defines a rate of adoption as the relative speed with which an innovation is adopted by members of a social system. There is a wide collection of empirical literature on technology adoption in developing countries across a variety of topics (Shaw, 2014; Gupta *et al*., 2018; Mottaleb, 2018). Kalaitzandonakes *et al*. (2018) provided evidence that, the rate and pattern of adoption of innovations vary according to the type of crop, the location and characteristic of the specific innovation. There is evidence that adoption of new technologies contribute to poverty reduction in some African and Asian countries, but also instances in which they fail to benefit poor farmers (Gupta *et al*., 2018). In his review of the impact of agricultural technologies, Mottaleb (2018) revealed that, in reality, despite the visible benefits of many from the new agricultural technologies, including machinery and management practices, farmers either do not adopt them or it takes a long time to begin the adoption process and subsequent scaling up.

In Tanzania, several studies on adoption of agricultural technologies have been conducted (Namwata, 2010; Asfaw *et al*., 2012; Pedersen, 2012; Kahimba *et al.,* 2014). On average, these studies found adoption rate ranging between 23 and 65%. However, these studies nevertheless used describe statistics and either probit or logit regression models both of which, according to Pindiriri (2016), fall short of proper methodological approaches to the exploration of the drivers of technology adoption in agriculture as they overlook non-exposure and selection biases and have contributed little to the problem of designing innovation adoption and scaling up pathways.

1.10 Conceptual Framework

This study conceptualizes that, the performance of introduced improved chicken strains is a function of input use and agro-ecological differences. For the economic analysis of introduced strains, there compulsory information is required from strains, farmers and market. Determination of the economic potential of introduced chicken strains depends, amongst others, on the availability of the strains; that ACGG project provided to selected farmers for on-farm testing. During on farm testing, farmers are required to collect data on inputs used, number of eggs produced, mortality rate, adaptation, feeding and growth. In addition to the input required there are also prices of both inputs and outputs which are very essential in determining economic viability of introduced chicken strains, performance variability and efficiency of keeping introduced chicken strains. It is important to note that assessment of economic viability especially by using Net Present Value (NPV), Net Cash Farm Income (NCFI) and probability distribution requires discount rate and net of return for off-farm income. Thus, the study used an average discount rate of 10% from Bank of Tanzania as from 2009 to 2018. Further, the likelihood of adoption of the introduced chicken strains depends on the perceived attributes namely: relative advantage, compatibility, complexity, trialability and observability. Adoption and Diffusion Outcome Prediction Tool are used to collect data useful in *ex-ante* analysis of adoption of introduced chicken strains. Thus, farmers evaluate these traits empirically in the course of on-farm testing. The on-farm test in Tanzania intends to assess whether these perceived benefits will be realized at farm level in different agro-ecological zones in Tanzania. The relationship of key variables with regard to evaluation of economic potential of introduced chicken strains is presented in Figure 1.2.

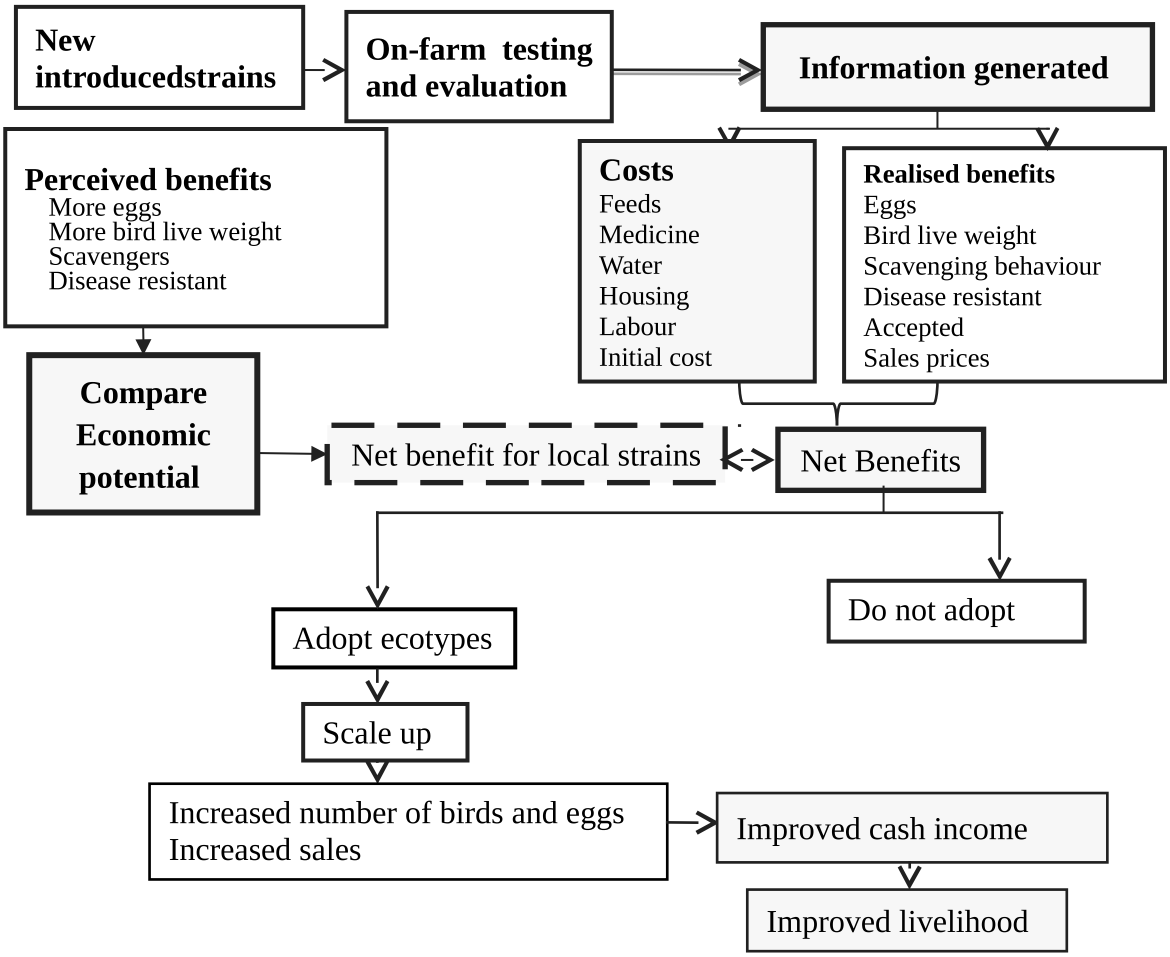


Figure 1.2: Conceptual framework of the study

1.11 Methodology

1.11.1 Developmental research design

Developmental design was applied to evaluate economic potential of introduced chicken strains. The design assumes a traditional model of skill in which the unit of analysis is taken to be the individual (AFNETA, 1992; Richey, 1994). According to Barrow and Röling (1989), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. The study design is in accordance to Thornton *et al.* (2017) that testing and dissemination of technology are at the core of development-oriented agricultural research. Selection of location for establishing on-farm testing sites was based on Tanzania's Agro Ecological Zones (AEZs) to present the general farming systems in Tanzania. The AEZs range from higher rainfall areas on the coast and highlands in the North, far West, South and Southwest, to arid and semi-arid areas in the interior of the country (URT, 2015). Accordingly, cropping patterns, climatic differences reflect biophysical characteristics for growth and stability of chickens.

On-farm testing for introduced chicken strains across different AEZs was meant to facilitate farmers and other actors' along the poultry value chain, evaluate the potential of the strains at farm level. Three assumptions underlie the design. First, selected farmers have had experience in keeping chickens so that the design does not add any fixed cost such as chicken house, feeding facilities and drinkers. In other words, on-farm testing used already available facilities. Secondly, time and labour spent in keeping introduced chickens and available local chickens were presumed similar and hence zero opportunity cost. Third, small-scale local farmers in Tanzania operate relatively similar in keeping chickens. Thus, any of AEZs fit for on-farm testing. According to ACGG (2015), households recruited to receive the chickens met the following criteria:

i. Chicken keeping households that had kept local chickens for a continuous period of at least two years prior to the baseline survey;
ii. Keeping at least 15 adult chickens but no more than 50;
iii. Willingness to accept 25 birds of randomly selected strain;
iv. Commitment to provide some supplemental feeds and
v. Willingness to participate in the project for a minimum of 72 weeks.

For setting the basic criteria for selecting farmers to participate in on-farm testing, the baseline survey was conducted. Baseline survey was conducted to identify legible population in central semi-arid, Eastern sub-humid, Southern Highlands, Lake zone and Southern humid to represent different agro-ecologies in the country. Specifically, first step involved selection of three regions which were Morogoro, Dodoma and Njombe to present AEZs. In each region, one district was selected purposely taking into account the availability of villages which had about 20 and above households that have least 15 adult chickens but no more than 50. Secondly, out of the qualified villages, four of them from each district were selected randomly from the long list of the villages. Subsequent stage involved randomly selection of households from the long list of households that met the set criteria. After random selection of qualified farmers, it followed provision of six-week pre-brooded chicks to these households whereby each farmer received 25 chicks. At this stage, each farmer received either Kuroiler or Sasso. Chicks received the recommended vaccination against Mareks, Newcastle Disease, Infectious Bronchitis and fowl pox before being distributed to farmers. Farmers continued keeping these strains based on their practices with some additional supplementation using locally available feeds and providing treatment and shelter under a semi-scavenging system (ACGG, 2016).

1.11.2 Description of the study sites

The study was conducted in three regions namely Dodoma, Morogoro and Njombe where on farm testing were in Bahi, Ifakara and Wanging`ombe respectively. Dodoma Region is located in the Central part of the country on Latitude: -6° 00' 0.00' S and Longitude: 36° 00' 0.00' E. The region is bordered by Manyara region to the North, Singida region to the West, Iringa region to the South and Morogoro Region to the Southeast. It is primarily semi-arid and covers an area of 41 311 square kilometres. The region lies at altitude of 1 125M above sea level. Annual rainfall is about 500 to 700 mm and annual average temperature of about 22.6°C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1°C (Climatic Data Org, 2016). Major crops include drought tolerant such as family of sorghum, groundnuts, sunflower, and some maize. Four villages namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa were selected.

Morogoro region is administratively divided into six districts, namely Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo. The region lies between Latitude 5º58' and 10º0' to the South of the Equator and Longitude 35º25' and 35º30' to the East. It is bordered by seven other regions: Arusha and Tanga regions to the North, Pwani region to the East, Dodoma and Iringa to the West and Ruvuma and Lindi to the South. Morogoro region lies at an altitude of about 525 M above sea level. The annual rainfall ranges from 600 to 1 200 mm with average annual temperature of about 25ºC. The zone is characterized by an average annual rainfall of 1 160 mm with average temperature of 16°C. There are typically two distinct long and short rainy seasons of March–May and November–January/February, respectively, but rain sometimes falls uninterrupted from October to March. The Udzungwa and extensive river system have deposited rich alluvial sediments in the valley (Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara district. The on farm test sites were located in four villages: Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe region lies between Latitude 08º40' and 10º32' South of the Equator and between Longitude 33º47' and 35º45' east of Greenwich and an altitude of about 2 000M above sea level. The region borders Iringa region in the North, Morogoro region in the East and Ruvuma region in the South. It also borders the Republic of Malawi via Lake Nyasa and part of Mbeya region in the North-west and West. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1 160 mm with average temperature of 18.6°C (Climatic Data Org, 2016). On-farm, test sites were located in four villages namely Ujindile, Uhambule, Msimbazi and Ufwala. Maize, sunflower, pulses and horticultural production dominate farming system of the sites.

1.11.2 Data sources

Data used in this study were mainly collected from farmers participated in the ACGG. A total of 202 participants from 12 villages were involved in the study. Out of the total famers, 111 farmers were provided Sasso strain whereas 91 farmers were being given Kuroiler chicken strain. Data used were collected through: a) household survey, (b) on-farm weekly data records (c) secondary data especially prices of inputs and discount rate (d) simulation exercises, (e) Key Informant Interview, (f) Focus Group Discussions and (g) observation.

Face-to-face interviews were conducted to a farmer who was involved in on-farm testing. The survey questionnaire was structured into five main sections covering broad issues such as household characteristics and composition, household other animals keeping enterprise and main sources of income, chicken keeping enterprises, crop production and Adoption and Diffusion Prediction Tools cattle output, inputs, services and markets. Furthermore, weekly data from households under support from extension officers for 72 weeks was useful in collecting data on eggs production, chickens exit (sales, consumption, diseases, symptoms and other cause of death) and weight gain. The research reviewed various documents such as published data and research reports to gather necessary information in relation to trend of discount rate and exchange rate. Discount rate used was an average discount rate of Bank of Tanzania for a period between 2009 and 2018 (BOT, 2015; BOT, 2018). Average feed prices were computed using prices reported by farmers, after validation with extension officers and inputs retailers in the specified location.

In addition, in order to ascertain the likelihood of the adoption of the introduced chicken strains, in-depth interviews with extension officers at ward and district levels and focus group discussions (FGDs) with farmers were conducted. The use of participatory research methods such as FGDs is geared towards planning and conducting the research process with those people whose life-world and meaningful actions are under study (Bergold and Thomas, 2012).

Twelve FGDs, each comprising of 12 ACGG participants and none participants across three sites were held between September and December 2017. The FGDs were conducted using a check-list (Appendix 2).

1.11.4 Data analyses

To achieve the first objective; analysis of economic viability of newly introduced chicken strains in selected areas of Tanzania, data obtained from on farm testing, historical data and simulation exercises were analysed using Farm Level Economic and Nutrition Analysis (FARMSIM) and Stochastic Efficiency With Respect to Function (SERF). Details of these models are given in chapter two of this thesis.

To achieve the second objective, data collected through household survey, Key Informant Interviews and Focus Group Discussions were subjected to the Adoption and Diffusion Outcome Prediction Tool (ADOPT) for *ex-ante* analysis of adoption of introduced chicken strains among smallholder farmers in selected areas of Tanzania. The analysis aimed at assessing the potential of adopting the introduced chicken strains among small scale farmers in the selected areas of Tanzania. The set questions for Adoption and Diffusion Outcome Prediction Tool presented appendix 2 were used to capture information related to ex-ante prediction of adoption as detailed in chapter three of this thesis.

Further, Stochastic Data Envelopment Analysis was used to determine the technical, allocative and economic efficiency of keeping introduced strains among selected farmers. To achieve this objective, a survey was conducted to collect covering broad issues related to chicken enterprise such as: strains of chicken kept, the number of chickens, number of eggs sold, hatched, ready for selling, number of chicks/chicken sold and ready for sale, amounts and prices of feeders, brooder, chicks, eggs, feeds, medicines, vaccines and labour. Other data included were number of chicken/chicks died and number of eggs. Description and analytical procedures of the Stochastic Data Envelopment Analysis is presented in chapter four of this thesis.

Finally, to achieve the fourth objective covering effect of input of performance and variability of introduced chicken strains, a multivariate multiple regression model according to Just and Pope Framework was applied. The specification of the multivariate multiple regression model is presented in chapter five of this thesis.

1.12 Organization of the thesis

This thesis is organized into six chapters. The introduction chapter has laid out the research issues, introduced the African Chicken Genetic Gain project, rationale, shortcoming of the study, methodology, theoretical review and conceptual framework for the study. Chapter Two provides a discussion on economic viability of newly introduced chicken strains relative to local chickens. Chapter discusses an *ex ante* analysis for adoption of the introduced chicken strains by using Adoption Diffusion Outcome Prediction Tool (ADOPT). Chapter Four presents a publishable manuscript on the technical, allocative and economic efficiency of keeping introduced strains among chicken keepers. In Chapter Five, another publishable manuscript focuses on the effect of inputs on performance and variability of the introduced chicken strains at farm level in selected areas of Tanzania. Finally, chapter six presents a summary key findings, tested hypotheses, research questions addressed, conclusions, recommendations and suggestions for future research.

References

ACGG. (2016). African Chicken Genetic Gain project profile. pp 2.

ACGG. (2015). Site Selection Framework. pp 6.

AFNETA. (1992). Alley Farming Training Manual Volume 1. [http://biblio.iita.org/ documents] site visited on 21/11/2016.

Alders, R. G., Spradbrow, P. B. and Young, M. P. (2009). Village chickens, poverty alleviation and the sustainable control of Newcastle disease. Proceedings of an international conference held in Dar es Salaam, Tanzania, 5–7 October 2005. ACIAR Proceedings No. 131, 235pp. [www.aciar.gov.au] site visited on 08/02/2019.

Antle, J. M. (1983). Testing the Stochastic Structure of Production: A flexible Moment based Approach. *Journal of Business and Economic Statistics* 1(3): 192-201. [doi: 10. 1080/07 350 015.1983.10509339] site visited on 08/02/2019.

Asfaw, S., Shiferaw, B., Simtowe, F. and Lipper, L. (2012). Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Journal of Food Policy* 37: 283–295. [www.elsevier.com/ locate/foodpol] site visited 12/05/2020.

Awotide, B. A., Diagne, A., Awoyemi, T. T. and Nakelse, T. (2014). Impact of Seed Certification on Allocative Efficiency and Willingness-To-Pay for Certified Improved Rice Seed in Nigeria: A Local Average Treatment Effects (LATE) Approach. [https://editorialexpress.com/cgi] site visited 18/01/ 2019.

Barrows, R. and Röling, N. (1989). Extension Science: Information Systems in Agricultural Development. *American Journal of Agricultural Economics* 71(3): 833-834. [https://doi.org/10.2307/1242055] site visited 20/10/2020.

Bizimana, J. and Richardson, J. W. (2017). Agricultural Technology Assessment for Smallholder Farms in Developing Countries: An Analysis using a Farm

Simulation Model (FARMSIM). Working Study February 2017. [DOI: 10.13140/RG.2.2.15949.23526] site visited on 24/10/2018.

Bergold, J. and Thomas, S. (2012). Participatory Research Methods: A Methodological Approach in Motion. Qualitative Social Research. [http://www.qualitative-research.net/] site visited on 11/10/2018.

BOT. (2018). Annual Report 2018/19. pp 264. [https://www.bot.go.tz/] site visited on 27/04/2019.

BOT. (2015). Annual Report 2014/15. pp264. [https://www.bot.go.tz/] site visited on 27/04/2019.

Boughton, D., Crawford, E., Krause, M. and de Frahan, B. H. (1990). Economic Analysis of On-Farm Trials: A Review of Approaches and Implications for Research Program Design. The Department of Agricultural Economics at Michigan State University under the Senegal Agricultural Research II Project.[http://citeseerx. ist.psu.edu/viewdoc/] site visited on 18/01/ 2017.

Brock, C. C. and Barham, B. L. (2013). Milk is Milk': Organic Dairy Adoption Decisions and Bounded Rationality. *Journal of Sustainability* 5: 5416-5441. [doi:10.3390/ su5125416] site visited on 27/04/2019.

Chaturvedi, B. K. (2013). Economic Viability of Milk Producing Units with intervention of Marketing Strategy in Rural Areas of Uttar Pradesh, India. *International Organization of Scientific Research Journal of Agriculture and Veterinary Science* 6(5): 1-6. [http://www.Iosrjournals.org] site visited on 31/07/2017.

Chavas, J. and Shi, G. (2015). An Economic Analysis of Risk, Management and Agricultural Technology. *Journal of Agricultural and Resource Economics* 40(1): 63–79. [http:// www.waeaonline.org/] site visited on 13/11/2018.

Chowdhury, T. E. (1984). Technological Diffusion in Agriculture: Theories and Evidence. *The Bangladesh Development Studies* 12(3): 75–85. [www.jstor.org/stable/ 40795204] site visited on 5/05/ 2020.

Cooper, W. W., Seiford, L. M. and Zhu, J. (2011). *Handbook on Data Envelopment Analysis*. Springer, Berlin, German. 164pp.

Cornish, D. B. and Clarke, R. V. (1986). *Introduction. In Cornish, Derek; Clarke, Ronald V., eds. The Reasoning Criminal*. New York: Springer-Verlag. 145pp.

Creswell, J. W. (2010). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, 2nd edition. Sage Publication, Thousand oaks, London and New Delhi. 246pp. [www.ceil-conicet.gov.ar] site visited 17/10/2017.

Data Driven Insights (2018). Structure and profitability of poultry value chains in Tanzania. First draft, 20 November 2018. [https://cgspace.cgiar.org/] site visited on 05/05/2020.

De Janvry, A., Macours, K. and Sadoulet, E. (2016). Learning for adopting: Technology adoption in developing country agriculture. Policy briefs from the workshop organized by Ferdi and SPIA on June 1 and 2, 2016, in Clermont-Ferrand. [https://cas.cgiar.org/] site visited on 30/04/2020.

De Janvry, A. (1972). Optimal levels of fertilization under risk: the potential for corn and wheat fertilization under alternative price policies in Argentina. *American Journal of Agricultural Economics* 54: 1-10. [https://doi.org/10.2307/ 1237728] site visited on 24/04/2020.

Dibba, L., Fialor, S. C., Diagne, A. and Nimoh, F. (2012). The Impact of NERICA Adoption on Productivity and Poverty of the Small-Scale Rice Farmers in the Gambia. *Journal of Food Security* 4 (2): 253–265. [https://link. springer. com/article/10.1007/s1] site visited on 8/05/2020.

FAO. (2019). Poultry Sector – The United Republic of Tanzania .FAO Animal Production and Health Livestock Country Reviews. No. 12. Rome. [http://www.fao.org/3/ca5750en/ca5750en.pdf] site visited on 8/05/2020.

Feder, G., Just, R. and Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. World Bank Staff Working Papers Number 542. [https://www.researchgate.net/] site visited on 30/04/2020.

Foss, N.J. (1997). The classical theory of production and the capabilities view of the firm. *Journal of Economic Studies* 24(5): 307-323. [https://doi.org/10.1108/01443589710175825] site visited on 22/04/2020.

Foster, A. D. and Rosenzweig, M. R. (2010). Microeconomics of technology Adoption. Economic Growth Centre Discussion Article No. 984. Yale University: New York (2010). [doi.org/10.1146/102308.124433] site visited on 3/12/2018.

Francis, C., Mundy, V., Janke, R. and King, J. (1995). Alternative Approaches to On-Farm Research and Technology Exchange. [http:// digitalcommons. unl. edu] site visited on 29/11/2016.

Ghatak, S. and Ingerset, K. (1984). Agriculture and Economic Development. Johns Hopkins University Press, Baltimore. *American Journal of Agricultural Economics* 67(2): 451-452. [http://econpapers. repec.org] site visited on 16/08/2016.

Ghatak, S. (1987). Limits to agricultural project evaluation under structural adjustment in developing countries. *Project Appraisal* 2(2): 107-112. [DOI: 10.1080/02688867.1987.9726609] site visited on 26/11/2020.

Gupta. A., Kagin, J., Taylor, J. E., Filipski, M., Hlanze, L. and Foster, J. (2018). Is technology change good for cotton farmers? A local-economy analysis from the Tanzania Lake Zone. *European Review of Agricultural Economics* 45(1): 27–56. [doi:10.1093/erae/jbx022] site visited on 12/05/2020.

Grüne-Yanoff, T. (2012). Paradoxes of Rational Choice Theory. In: Sabine Roeser, Rafaela Hillerbrand, Per Sandin, Martin Peterson (eds.). *Handbook of Risk Theory*. pp. 499–516. [doi:10.1007/978-94-007-1433-5_19] site visited on 16/08/2016.

Hurd, B. H. (1994). Yield Response and Production Risk: An Analysis of Integrated Pest Management in Cotton. *Journal of Agricultural and Resource Economics* 19(2): 313-326. [http://www.cpahq.org/] site visited on 22/11/2017.

Kahimba, F. C., Mutabazi, K. D., Tumbo, S. D., Masuki, K. F. and Mbungu, W. B. (2014). Adoption and scaling-up of conservation agriculture in Tanzania: Case of Arusha and Dodoma regions. *Journal of Natural Resources* 5: 161-176. [http://dx.doi.org/10.4236/nr.2014.54016] site visited on 12/08/2018.

Kalaitzandonakes, N., Grigoroudis, E., Carayannis, E. G. and Rozakis, S. (2018). *Innovation and Technology Transfer in Agriculture.* In the book of *From Agriscience to Agribusiness: Theories, Policies and Practices in Technology Transfer and Commercialization*. pp. 490. Springer ebook. [https://link. Springer.com/book/10.1007%2F978-3] site visited on 29/04/2020.

Koundouri, P. and Nauges, C. (2005). On Production Function Estimation with Selectivity and Risk Considerations. *Journal of Agricultura1 and Resource Economics* 30(3): 597-608. [https://core.ac.uk/] site visited on 22/10/2016.

Khayyat, N. T. and Heshmati, A. (2014). Production Risk, Energy Use Efficiency and Productivity of Korean Industries. Discussion Study Series 8081, March 2014. Institute for the Study of Labour, Germany. [http://ftp.iza.org/ dp8081.pdf/] site visited on 25/11/2018.

Kumbhakar, S. C. (2002). Specification and estimation of production risk, risk preferences and technical efficiency. *American Journal of Agricultural Economics* 84 (1): 8–22. [https://doi. org/10.1111/ 14] site visited on 23/02/2019.

Langat, B. K., Ngéno, V. K., Nyangweso, P. M., Mutwol, M. J., Kipsat, M. J., Gohole, L. and Yaninek, S. (2013). Drivers of Technology Adoption in a Subsistence Economy: The Case of Tissue Culture Bananas in Western Kenya. A Study Presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013: Hammet, Tunisia. [http://ageconsearch. umn.edu/] site visited on 24/12/2018.

Latruffe, L., Diazabakana, A., Bockstaller, C., Desjeux, Y., Finn, J., Kelly, E. and Uthes, M. S. (2016): Measurement of sustainability in agriculture: A review of indicators. *Studies in Agricultural Economics* 118(3): 123–130. [https://hal. archives-ouvertes.fr/hal-01512168/document] site visited on 18/01/2020.

Limbu, F. (1999). Agricultural Technology Economic Viability and Poverty Alleviation in Tanzania. The Structural Transformation Policy Workshop. ECAPAPA, Tegemeo Institute, and Michigan State University, 27-30 June 1999. Sarena Hotel, Nairobi, Kenya.

Match Maker Associates Limited and Transcend Enterprises Limited, 2018 (2018). Poultry Subsector in Tanzania. A Quick Scan. [www.agroberichtenbuitenl and.nl] site visited on 22/05/2019.

Marwa, L. J., Mbaga, S. H., Mutayoba, S. K. and Lukuyu, B. (2018). The productivity and management systems of free range local chickens in rural areas of Babati District, Tanzania. Livestock Research for Rural Development. [http://www.lrrd. org/lrrd30/8/leon30134.html] site visited on 22/05/2019.

Miceikiene, A., Savickiene, J. and Petkute, E. (2015). Tendencies in Variation of Economic Viability of Farms in Lithuania. *European Scientific Journal* 11(4): 95-109. [eujournal.org/index.php/esj/article] site visited on 31/07/2017.

Minviel, J. J. and Latruffe, L. (2016). Effect of public subsidies on farm technical efficiency: a meta-analysis of empirical results. *Journal of Applied Economics*

49 (2): 213-226. [DOI:10.1080/00036846.2016.1194963] site visited on 05/05/2020.

Misaki, E., Apiola, M. and Gaiani, S. (2016). Technology for Small Scale Farmersin Tanzania: A Design Science Research Approach. *The Electronic Journal of Information Systems in Developing Countries* 74(4): 1-15. [doi/pdf/ 10.1002/j.1681-4835.2016.tb00538.x] site visited on 11/05/2020.

Mottaleb, K. A. (2018). Perception and adoption of a new agricultural technology: Evidence from a developing country. *Technology in Society* 55: 126-135. [https://www.sciencedirect.com/] site visited on 05/05/2020.

Mugweni, L. and Muponda, G. (2015). Establishing the Economic Viability of Small Scale Dairy Farming In Zimbabwe: A Case Study of Marirangwe and Chikwaka Small Scale Farming Areas. *International Journal of Economics, Commerce and Management* 3(8): 448-466. [http:// ijecm. co.uk/wp-content/uploads/2015/08/ 3827.pdf] site visited on 31/07/2017.

Mutoko, M. C., Ritho, C. N., Benhim, J. and Mbatia, O. L. (2015). Technical and allocative efficiency gains from integrated soil fertility management in the maize farming system of Kenya Technical and allocative efficiency gains from integrated soil fertility management in the maize farming system of Kenya. *Journal of Development and Agricultural Economics* 7(4): 143–152. [https://doi.org/10.5897/JDAE2015.0633] site visited on 24/09/ 2020.

Nalley, L. L. and Barkley, A. (2007). The Impact of the CIMMYT Wheat Breeding Program on Wheat Yields in Mexico's Yaqui Valley, 1990–2002: Implications for the Future of Public Wheat Breeding. Selected Study Prepared for Presentation at the American Agricultural Economics Association Annual Meeting, Portland. July 29–August 1. 2007. [http://ageconsearch.umn.edu] site visited on 8/12/2016.

Namwata, B. M. L., Lwelamira, J. and Mzirai, O. B. (2010). Adoption of improved agricultural technologies for Irish potatoes (*Solanum tuberosum*) among farmers in Mbeya Rural district, Tanzania: A case of Ilungu ward. *Journal of Animal and Plant Sciences* 8(1): 927- 935. [http://www.m.elewa.org] site visited on 19/08/2018.

Odame, H., Kimenye, L., Kabutha, C., Alemu, D. and Oduori, L. H. (2013). Why the low adoption of agricultural technologies in Eastern and Central Africa? Association for Strengthening Agricultural Research in Eastern and Central Africa.116pp. [https://www.asareca.org/sites/] site visited on 16/03/2020.

OECD-FAO. (2019). Agricultural Outlook 2019-2028. 50pp. [http://www.fao.org/3/I 9166e/i9166e_Chapter1.pdf] site visited on 16/03/2020.

Ostojic, I. (2010). Bass innovation diffusion model and its application in policy analysis for adoption of renewable energy technologies. Modelling and Simulating Social Systems with MATLAB. Project Report. [http://webarchiv.ethz.ch/soms/] site visited on 16/03/2020.

Pedersen, K. E. (2012). Factors affecting the adoption of improved banana technologies in Northern Tanzania. Published by Rockwool Foundation Research Unit. [https://www.rockwoolfonden.dk] site visited on 16/09/2016.

Petra, T. and Kenneth, I. W. (2006). *Ex Ante* Evaluation of Social Programs. PIER Working Study No. 06-022. Available at SSRN: [http://dx.doi.org/10.2139/ ssrn.931393] site visited on 16/09/2016.

Pindiriri, C. (2016). Breaking the Tradition Trap: Assessing Drivers of Modern Technology Adoption by Smallholder Farmers in Hurungwe District, Zimbabwe. African Economic Conference held in Abuja, Nigeria. 5-7 December 2016. [https://www.afdb.org] site visited on 12/01/2018.

Qaim, M. (2001). A prospective evaluation of biotechnology in semi-subsistence agriculture. *Journal of Agricultural Economics* 25: 165-175. [10.1111/j. 1574-0862.2001.tb00197.x] site visited on 21/10/2018.

Rodelio, B. C. and Silvino, Q. T. (2013). Sustainable Organic Farming in the Philippines. [http://wwwafaci.org] site visited on 18/10/2016.

Rogers, E. M. (2003). *Diffusion of Innovations* (5th ed.). The Free Press, New York, USA. 551pp.

Roling, N. and Jiggins, J. (1998). Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty. Cambridge: Cambridge University Press. pp. 283 –311.

Sanka, Y. D., Mbaga, S. H., Mutayoba, S. K., Katule, A. M. and Goromela, S. H. (2020). Evaluation of growth performance of Sasso and Kuroiler chickens fed three diets at varying levels of supplementation under semi-intensive system of production in Tanzania. *Journal of Tropical Animal Health Production* 52(6):3315-3322 [https://doi.org/1 0.1007/s11250-020-02363-x] site visited on 12/10/2020.

Shaw, C. S. (2014). Agricultural Technology Adoption in West Africa. A Thesis for Award Degree of Master of Science of Texas A&M University. 131pp.

Simon, H. A. (1959). Theories of Decision-making in Economics and Behavioural Science. *American Economic Review* 49(3): 253-283. [http://pages. stern.nyu. edu/~dbackus/Exotic/] site visited on 20/02/2017.

Soule, M. J., Tegene, A. and Wiebe, K. D. (2000). Land tenure and the adoption of conservation practices. *American Journal of Agricultural Economics* 82(4): 993-1005. [https://naldc.nal.usda.gov/download/29687/PDF] site visited on 18/04/2017.

Spicka, J., Hlavsa, T., Soukupova, K. and Stolbova, M. (2019). Approaches to estimation the farm-level economic viability and sustainability in agriculture: A literature review. *Agricultural Economics–Czech* 65: 289–297. [https://doi.org/10.17221/269/2018-AGRICECON] site visited on 14/01/2020.

Sunding, D. and Zilberman, D. (2000). The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector. pp 105. [http://www.jstor.org] site visited on 24/10/2016.

Suri, T. (2011). Selection and Comparative Advantage in Technology Adoption. *Econometrica* 79(1): 159-209. [https://doi.org/10.3982/ECTA7749] site visited on 12/05/2020.

Tadelle, D., Alemu, Y. and Peters, K. J. (2000). Indigenous chickens in Ethiopia: genetic potential and attempts at improvement. *World Poultry Science. Journal* 56: 45-54. [http://journals.cambridge.org/action] site visited on 19/10/2015.

Thornton, P. K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S. and Campbell, B. M. (2017). Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Journal of Agricultural Systems* 152: 145-153 [DOI:10.1016/j.agsy.2017.01.005] site visited on 06/05/2019.

URT. (2019). *Livestock and Fisheries Commodity Value Chain Briefs: Brief* No. 4. pp 12. [https://www.mifugouvuvi.go.tz/uploads/] site visited on 30/11/ 2020.

URT. (2018). Annual Agriculture Sample Survey: Crop and Livestock Report 2016/17.

URT. (2017). Tanzania Livestock Master Plan. Dar es Salaam. 2017/2018 – 2021/2022. 127 pp. [https://www.mifugouvuvi.go.tz/] site visited on 05/05/2020.

URT. (2015). Tanzania Climate Smart Agriculture Programme: 2015-2025. [http://www.kilimo.go.tz] site visited on 09/11/2016.

URT. (2014). Agriculture Climate Resilience Plan 2014-2019. pp 89.

URT. (2012). National Sample Census of Agriculture Small Holder Agriculture. Volume III: Livestock Sector National Report. [http://www.kilimo.go.tz.] site visited on 10/10/2016.

USAID. (1988). Animal Product Options in the Marketplace. Committee on Technological Options to Improve the Nutritional Attributes of Animal Products National Academy Press Washington, D.C. 1988. 383pp. [www.bookzz.org] site visited on 19/10/2016.

Wolman, L. (1921). The Theory of Production. *American Economic Review* 11(1): 37-56. [https://www.jstor.org/stable/1828032] site visited on21/05/2020.

World Bank. (2009). Agriculture and Rural Development. Agribusiness and Innovation Systems in Africa. The International Bank for Reconstruction and Development. The World Bank 1818 H Street NW, Washington DC 20433. [www.world bank .org] site visited on 20/10/2016.

World Society for the Protection of Animals. (2011). Enhancing rural livelihoods and nutrition through higher welfare poultry production in India. [http://www. wspa. Org] site visited on 20/10/2016.

Yang, Z., Mugera, A. W. and Zhang, F. (2016). Investigating Yield Variability and Inefficiency in Rice Production: A Case Study in Central China. *Journal of Sustainability* 8(7): 1-11. [http://www.mdpicom] site visited on 18/12/2018.

Yengoh, G. T., Armah, F. A. and Svensson, M. G. (2010). Technology adoption in small-scale agriculture. *Science, Technology and Innovation Studies* 5(2): 111-131. [DOI: 10.17877/DE290R-8685] site visited on 16/07/2018.

CHAPTER TWO

2.0 ECONOMIC VIABILITY OF NEWLY INTRODUCED CHICKEN STRAINS AT VILLAGE LEVEL IN TANZANIA: FARMSIM MODEL SIMULATION APPROACH

Rogers Andrew[1], Jeremia Makindara[2], Mbaga S. H[3], Roselyne Alphonce[4]

1. Department of Policy, Planning and Management, Sokoine University of Agriculture, Morogoro, Tanzania

2. Department of Business Management, Sokoine University of Agriculture, Morogoro, Tanzania

3. Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania

4. Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania

Correspondence: Rogers Andrew, Email: randrew@sua.ac.tz

Abstract

Local chicken farming is an integral part of Tanzania's rural economy. However, despite its contributions to household economy and food security, local chicken productivity remains low because of low genetic potential, diseases and poor feeding. One of the options to increase local chicken productivity is the adoption of chicken strains with high genetic potential. In that respect, the Africa Genetic Gain project introduced Sasso and Kuroiler chicken strains for on-farm test purposes. Developmental design involved provision of 25 six weeks old chicks to farmers in 12 sites in three regions. The study was carried out in Dodoma, Morogoro and Njombe regions in Tanzania to assess the effects of agro-ecological differences on the performance of these strains. The chicks were vaccinated against Mareks and Newcastle diseases at the hatchery; then against Infectious Bronchitis (IB) at 0, 7 10, 16 and 21 days. The Newcastle Disease vaccine was repeated after 10 and 21 days using LaSota vaccine. After 6 weeks, the chicks were again vaccinated against fowl pox ready for supply to farmers. A farm Simulation Model (FARMSIM) and Stochastic Efficiency with Respect to Function (SERF) were applied to access economic viability of these strains relative to local chickens. FARMSIM is a Monte Carlo Simulation Model that simultaneously evaluates a baseline and an alternative farming technology. To simulate using FARMSIM, Simulation and Econometrics to Analyse Risk (Simetar©), an excel add-in is needed as a simulating engine. Data were obtained through survey, farmers' records and simulation exercises. The results indicate that keeping Sasso strain was the most economically viable enterprise with the highest Net Present Value, Net Cash Farm Income and the highest probability of attaining economic return. Kuroiler was the second, followed by keeping local chickens without supplement and local chicken with supplement was the least economically viable enterprise. However, inclusion of risk behaviour revealed that extremely risk-averse farmers preferred mostly keeping local chickens without supplement whereas extremely risk loving farmers preferred the most Sasso strain.

It is recommended that the introduced chicken strains should be promoted to increase household income and improve people's livelihoods. However, scaling up the introduced chicken strains must be integrated with education on technical know-how for good farming practices, feed formulations, medication and shelter construction for improved productivity and reduced variability of performance among the introduced chickens.

Keywords: Economic Viability, FARMSIM, Simetar, Introduced Chicken Strains, Farm Level

2.1 Introduction

A local chicken farming is an integral part of Tanzania's rural economy. About 3.8 million households keep chickens, and the country has an estimated 35.5 million local chickens and 24.5 million improved chicken breeds (United Republic of Tanzania (URT), 2015). Additionally, the sector contributes about 1% of the national Gross Domestic Product (GDP). In 2013, the estimated monetary values of meat and eggs were US$ 874 billion and 364 billion respectively (Komwihangilo, 2015). Low genetic potential of Tanzania`s local chickens has continued contributing to low productivity for both meat and eggs (Minga *et al.,* 2003). According to URT (2012), the weight of chicken ranges between 1.6 and 2.0 kg while annual eggs produced per hen per year are on average 36 eggs. In response to the low genetic potential of local chicken in Tanzania, the African Chicken Genetic Gains (ACGG) project introduced new chicken strains (Sasso and Kuroiler) which are deemed of having demonstrated to perform better in Ethiopia and India respectively and hence needed to be tested at village level in Tanzania. This study aimed to assess their economic viability relative to existing local chickens in different agro-ecological zones. The concept of on-farm testing adopted by the ACGG is in line with a shift in thinking away from looking at adoption as the delivery of an external, typically science-based innovation with farmers as potential end users. In this case, farmers are exposed to a more complex learning process involving a wide range of actors to allow them to become experts on their own farm and take decisions based on knowledgeable interference from observation and analysis through learning (Röling and Jiggins, 1998). Additionally, the ACGG project responds to the fact that the gateway to Africa's economic development hinges on innovation, diffusion and utilisation of agricultural technologies (Langat *et al*., 2013; Shaw, 2014). Therefore, in this case, the project tried to find a solution that support local chickens' keepers in Tanzania through increased chicken productivity. The introduced strains include Kuroiler strain that weighs about 1.8–1.9 kg (hen) and 2.3–2.4 kg (rooster), and a hen can produce about 150 eggs per year (World Society for the Protection of Animals, 2011). The second strain is Sasso that weighs 2.2–2.5 kg and 1.5–1.7 kg for cock and hen respectively and can produce about 150 eggs per hen per year (Rodelio and Silvino, 2013).

However, the economic viability of these birds in Tanzania's agro-ecological zones is not known. It is acknowledged that agro-ecological differences and socio-economic landscapes may play important role in determining the chickens' growth, productivity, and mortality rate, susceptibility to diseases and time to maturity (Francis *et al.*, 1995). Sunding and Zilberman (2000) argue that new innovations require assessment for their technical feasibility to provide the technical base for their adoption. In both economic and diffusion of innovations theories, farmers are presumed to be rational in making decisions based on available information, with a view to securing the optimum result possible (Simon, 1959). This study was therefore undertaken to determine economic viability of introduced chicken strains relative to the existing ones. The results are expected to help farmers and other development agencies whether to adopt the introduced chicken strains or retain keeping existing local chickens.

2.2 Methodology

2.2.1 Developmental research design

This article adopted developmental design to evaluate economic viability of introduced chicken strains. The design assumes a traditional model of skill in which the unit of analysis is taken to be the individual (AFNETA, 1992; Richey, 1994). According to Barrow and Röling (1989), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. The study design is in accordance to Thornton *et al.* (2017) that testing and dissemination of technology are at the core of development-oriented agricultural research. Selection of location for establishing on-farm testing sites was based on Tanzania's Agro Ecological Zones (AEZs) to present the general farming systems in Tanzania. The AEZs range from higher rainfall areas on the coast and highlands in the North, far West, South and Southwest, to arid and semi-arid areas in the interior of the country (URT, 2015). Accordingly, cropping patterns, climatic differences reflect biophysical characteristics for growth and stability of chickens. On-farm testing for introduced chicken strains across different AEZs was meant to facilitate farmers and other actors in poultry value chain evaluate the potential of the strains at farm level. Three assumptions underlie the design. First, selected farmers have had the experience in keeping chickens so that the design does not add any fixed cost such as chicken house, feeding facilities and drinkers. In other words, on-farm testing used already available facilities. Secondly, time and labour spent in keeping introduced chickens and available local chickens were presumed similar and hence zero opportunity cost. Third, small-scale local farmers in Tanzania operate relatively similar in keeping chickens. Thus, any of AEZs fit for on-farm testing. According to ACGG (2015), households recruited to receive the chickens met the following criteria:

i. Chicken keeping households that had kept local chickens for a continuous period of at least two years prior to the baseline survey;
ii. Keeping at least 15 adult chickens but no more than 50;
iii. Willingness to accept 25 birds of randomly selected strain;
iv. Commitment to provide some supplemental feeds and
v. Willingness to participate in the project for a minimum of 72 weeks.

Setting the basic criteria for selecting farmers to participate in on-farm testing, the baseline survey was conducted. Baseline survey was conducted to identify legible population in central semi-arid, Eastern sub-humid, Southern Highlands, Lake zone and Southern humid to represent different agro-ecologies in the country. Specifically, first step involved selection of three regions of Morogoro, Dodoma and Njombe to present AEZs. In each region, one district was selected purposely taking into account the availability of villages which had about 20 and above households that have least 15 adult chickens but no more than 50. Secondly, out of the qualified villages, four of them from each district were selected randomly from the long list of villages. Subsequent stage involved randomly selection of households from the long list of households that met the set criteria. After random selection of qualified farmers, it followed provision of six-week pre-brooded chicks to these households whereby each farmer received 25 chicks. At this stage, each farmer received either Kuroiler or Sasso. Chicks received the recommended vaccination against Mareks, Newcastle Disease, Infectious Bronchitis and fowl pox before being distributed to farmers. Farmers continued keeping these strains based on their practices with some additional supplementation using locally available feeds and providing treatment and shelter under a semi-scavenging system (ACGG, 2016).

2.2.2 Description of the study sites

The study was conducted in three regions namely Dodoma, Morogoro and Njombe where on farm testing were in Bahi, Ifakara and Wanging`ombe respectively. Dodoma Region is located in the Central part of the country on Latitude: -6° 00' 0.00' S and Longitude: 36° 00' 0.00' E. The region is bordered by Manyara region to the North, Singida region to the West, Iringa region to the South and Morogoro Region to the Southeast. It is primarily semi-arid and covers an area of 41 311 square kilometres. The region lies at altitude of 1 125 M above sea level. Annual rainfall is about 500 to 700 mm and annual average temperature of about 22.6°C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1°C (Climatic Data Org, 2016). Major crops include drought tolerant ones such as family of sorghum, groundnuts, sunflower, and some maize. Four villages namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa were purposively selected in case of Bahi district.

Morogoro region is administratively divided into six districts, namely Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo. The region lies between Latitudes 5°58' and 10°0' South of the Equator, and Longitude 35°25' and 35°30' to the East. It is bordered by seven other regions: Arusha and Tanga regions to the North, the Pwani region to the East, Dodoma and Iringa to the West and Ruvuma and Lindi to the South. Morogoro region lies at an altitude of about 525 M above sea level. The annual rainfall ranges from 600 to 1 200 mm with average annual temperature of about 25°C. The zone is characterized by an average annual rainfall of 1 160 mm with average temperature of 16°C. There are typically two distinct long and short rainy seasons of March–May and November–January/February, respectively, but this pattern is often interrupted(Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara district. The on farm test sites were located in four villages: Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe region lies between Latitude 08°40' and 10°32' South of the Equator and between Longitude 33°47' and 35°45' East of Greenwich and an altitude of about 2 000 M above sea level. The region borders Iringa region in the North, Morogoro region in the East and Ruvuma region in the South. It also borders the Republic of Malawi via Lake Nyasa and part of Mbeya region in the North-west and West. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1 160 mm with average temperature of 18.6°C (Climatic Data Org, 2016). On-farm testing sites were located in four villages namely Ujindile, Uhambule, Msimbazi and Ufwala.

2.2.3 Data sources

Data used in this study were mainly collected from farmers participated in the ACGG project in selected on-farm testing sites. A total of 202 participant beneficiaries from 12 villages were involved in the study. Out of the total famers, 111 farmers were Sasso strain keepers whereas 91 farmers were Kuroiler chicken keeping households. Data used were collected through: a) household survey, on-farm weekly data records, secondary data especially prices of inputs and discount rate and simulation exercises. Face-to-face interviews were conducted to household heads. The face to face interview questionnaire was structured into five main sections covering broad issues such as household characteristics and composition, household other animals keeping enterprise and main sources of income, chicken keeping enterprises and crop production.

On the other hand, weekly data from households under support from extension officers for 72 weeks was useful in collecting data on eggs production, chickens exit (sales, consumption, diseases, symptoms and other cause of death) and weight gain. Specifically, data collected included chicken production data: strains of chicken kept, number of chickens, number of eggs sold, hatched, ready for selling, number of chicks/chicken sold and ready for sale, chicken keeping inputs (amounts and prices of feeders, brooder, chicks, eggs, feeds, medicines, vaccines, labour and time spent), number of chicken/chicks mortalities, number of eggs not hatched and the cost of constructing a chicken house. The research reviewed various documents such as published data and research reports to gather necessary information in relation to trend of discount rate and exchange rate. Different sources of information, including historical data, can be used to establish a stochastic simulation of net economic returns (Richardson *et al.,* 2007a; Vorotnikova *et al.,* 2014). Discount rate used was an average discount rate of Bank of Tanzania for a period between 2009 and 2018 (BOT, 2014; BOT, 2018). In order to capture the approximate share of feeds from different sources in each site, the quantities of purchased and non-purchased (or on-farm) feeds were first adjusted with the average annual number of dry and wet months, respectively, in each district. Average feed prices were computed using prices reported by farmers, after validation with extension officers participating in the on-farm testing.

2.2.4 Variables measured

Two variables; chicken weight and feeds were measured by using digital weighing balance (HDB10K10N Hanging Scale). The farmers and the animal science field officers cooperated to weigh the live birds in interval of two weeks and the records were taken for about 72 weeks. Data on feeds were obtained by weight the quantity provided to chickens daily. The participatory approach was applied to enable farmers recall the quantities of feeds provided during different conditions. The conditions were classified as: harvesting, harsh months and intermediate condition. In each condition, farmers were asked to estimate the level and frequency of providing feeds to estimate total supplement provided per cycle. Table 2.1 below summaries the average supplementation level of both local chickens and introduced strains per chicken per 12 months.

Table 2.1: Descriptive Data of Chicken Feeding, Prices, Discount rate and Rate of return for off-farm investment

Variable						Value
Discount rate for NPV						0.10
Rate of return for off-farm investments						0.05
Current Exchange Rate to US Dollar-Tanzania shilling (US$)						2286
Quantities of variable inputs fed to chicken strains						
Statistics	**Maize bran (kg)**	**Rice bran (kg)**	**sunflower cake (kg)**	**Fishmeal (kg)**	**Minerals (kg)**	**Vegetables (bundle)**
Kuroiler strain						
Mean	7.49	6.58	1.83	0.65	0.55	2.27
SD	4.56	3.6	1.79	0.6	0.55	0.87
Minimum	1.01	1.69	0.11	0.1	0.02	0.85
Maximum	21	17.82	7.37	2.42	2.88	3.56
n	91	57	58	34	48	17
Sasso strain						
Mean	9.46	5.19	3.11	0.9	0.63	3.2
SD	5.03	2.12	2.23	0.68	0.59	3.02
Minimum	1.52	1.1	0.17	0.08	0.04	1.09
Maximum	26.54	8.78	11.53	2.43	2.21	16.33
n	105	17	54	16	32	25
Local chicken						
Mean	1.79	1.26	0.51	0.15	0.12	0.59
SD	1.03	0.67	0.44	0.13	0.12	0.51
Minimum	0.2	0.23	0.02	0.02	0	0.17
Maximum	5.69	3.5	2.47	0.52	0.57	3.5
n	163	71	110	50	77	43
Prices of inputs (US$)/Kg						
Statistics	**Maize bran**	**Rice bran**	**sunflower cake**	**Fishmeal**	**Minerals**	**Vegetables**
Mean	0.16	0.05	0.32	0.61	0.64	0.09
SD	0.05	0.02	0.17	0.21	0.32	0.01
Minimum	0.10	0.02	0.04	0.22	0.13	0.09
Maximum	0.31	0.15	0.66	0.87	1.09	0.11

Table 2.2: Chicken production, sales and production expenses

Variables/Chicken technologies (Scenarios)	Local Chicken	Kuroiler	Sasso	Local Chicken	Kuroiler	Sasso
	Hens			Pullets		
Mortality rate	0.06	0.30	0.30	0.47	0.56	0.57
Minimum Price	3.06	4.37	3.94	2.19	3.94	3.50
Average Price	4.37	5.25	6.12	3.94	6.12	6.56
Maximum Price	6.56	8.75	8.75	5.68	7.43	7.87
	Cockerels			Roosters		
Mortality rate	0.08	0.09	0.09	0.41	0.59	0.54
Minimum Price	3.06	4.37	3.50	3.06	4.37	3.50
Average Price	5.25	7.87	7.43	5.25	7.87	7.43
Maximum Price	8.75	13.12	15.30	6.56	7.87	8.31
Egg production and prices across				**Local chicken**	**Kuroiler**	**Sasso**
Minimum price of a dozen eggs (US$)				1.05	1.05	1.05
Average price of a dozen eggs(US$)				1.91	2.06	1.88
Maximum price of a dozen eggs(US$)				2.62	2.62	2.62
Egg production per hen -Minimum				28	19	20
Egg production per hen -Average				30	52	58
Egg production per hen -Maximum				42	95	109
Fraction of eggs for hatching				0.8	0.09	0.09
Average Annual expenses per chicken per annum				0.52	5.08	5.63

2.2.5 Data analysis and Monte Carlo simulations

Farm Level Economic and Nutrition Analysis (FARMSIM); a farm level Monte Carlo simulation model (Richardson *et al.,* 2016) was adopted to assess economic viability of introduced chicken strains in twelve villages from three regions. To analyse economic viability while using market prices, market/private prices of inputs and outputs were assumed to be equals to social prices. Simulation implies a different way of approaching scientific research (Mwinuka *et al.,* 2017). Simulation is an increasingly significant methodological approach to theory development in the literature focuses on strategy and organizations (Davis *et al.,* 2007). Consequently, economic models and micro-level simulations are in urgent need for informing decision-making (Fontana, 2005). To simulate by using FARMSIM, Simulation and Econometrics to Analyse Risk (Simetar©); an excel add-in is the simulating engine for the FARMSIM Model. The Monte Carlo simulation modelling approach is used because it is the best methodology for estimating the probability distribution of unknown variables such as rate of return on investment for a business (Richardson *et al.*, 2007a). The greatest benefit of a Monte Carlo simulation analysis is that the methodology explicitly incorporates risk faced by investors to develop realistic probabilistic forecast of KOVs (Richardson *et al*., 2007a).

FARMSIM is an extension of the Farm Level and Income Policy Simulation (FLIPSIM) model available in Microsoft Excel format which has been used extensively to simulate the impacts of alternative policies and farming systems on representative farms (Clarke *et al.*, 2017). The FLIPSIM is a FORTRAN simulation model that uses accounting equations, identities and probability distributions to simulate the annual economic activities of a representative or actual farm over a multiple year planning horizon. Richardson (2006) outlined the steps for developing a production based investment feasibility simulation model. First, probability distributions for all risky variables must be defined, parameterized, simulated and validated. Second, the stochastic values from the probability distributions are used in accounting equations to calculate production, receipts, costs, cash flows and balance sheet variables for the project. Stochastic values sampled from the probability distributions make the financial statement variables stochastic.

Third, the completed stochastic model is simulated many times using random values for the key risky variables. Results of the sample provide information used to estimate the empirical probability distribution for unobservable Key Outcome Variables (KOVs) (e.g. present value of ending worth, net present value, and annual cash flows) so that investors can evaluate the probability of success for a proposed project. Fourth, the analyst uses the stochastic simulation model to analyse alternative management scenarios and provides the results to decision makers in the form of probabilities and probabilistic forecast for the

KOVs. To estimate the differing economic viability indicators based on chicken farming system scenarios, the study compares the Net Present Values (NPV) and Net Cash Farm Income (NCFI) distributions of chicken technologies: keeping local chicken without supplementation, local chicken with supplementation, Sasso strain and Kuroiler strain (Table 2.1). The NPV was estimated by discounting the profits; a 10 per cent discount rate was used. To estimate profit/NCFI, revenue was first calculated by considering production as a product of eggs and live chicken sold multiplied by price. Next, total costs were estimated as a sum of both variable and fixed costs (farm expenses). These costs include the cost of buying feeds (maize and rice brans, fishmeal, sunflower cake, vegetables and proportion of cost of house construction. Thus, for the production season, profit/NCFI was calculated using Equation (2.7). The distributions of simulated NPV of net returns were generated using Monte Carlo simulations for 500 iterations (Equation (2.10). The economic viability indicators estimated are displayed graphically as a Cumulative Distribution Function (CDF) and the stoplight graph. Charts and probability portray more accurately the probable outcomes that a single point estimation (Richardson *et al.*, 2007a) for an investment. To simulate economic indicators by using private/market prices requires an assumption. Following description by Kray (2002), the present study assumes that private prices are essentially equal to social price because of the following reasons. First, Tanzania imports exotic chicken products and not chicken under assessment and local chickens, hence computation of social prices of chicken products cannot be weighed based on the Free On Board (FOB) prices. Second, farmers compare technologies at the same scale bring about relatively similar allocation of the factor inputs to the chosen technology. This holds since both introduced chicken strains and existing local chicken are fed inputs which are acquired in the market at the same prices.

Other output of FARMSIM is the stoplight graphs that depict the probabilities of each chicken technology being less than the lower cut-off value (the lowest mean) and greater than cut-off value (the highest mean). The probabilities of each technology exceeding the upper cut-off value are presented numerically and it is preconditioned to be coloured in green. The yellow segments represent the probability that values fall between the lower and upper cut-off values and the red segment presents the probability that values is below the lower cut-off (Clarke *et al.*, 2017; Bizimana and Richardson, 2019).

The present study used Gray-Richardson-Klose and Schuman (GRKS) distribution in simulation and estimation of economic viability indicators. The GRKS distribution is a continuous probability distribution which uses minimum, mean and maximum values of the key variables in analysis. With respect to present study, variables of interest were number of eggs, number of lived birds, prices of eggs and birds, proportions of birds/eggs consumed, morality rate and costs of inputs used. Traditionally, data for simulation of KOVs in for the FARMSIM (Richardson *et al.*, 2016) and any simulation model/engine has been done using experts' knowledge, and historical data (Clarke *et al.*, 2017) to empirically ascertaining the chances of an event occurring without actually incurring the risk and costs of a true business (Hasegawa *et al.*, 1990). However, this study advanced the approach by largely using data collected from on-farm testing and real market prices on farms inputs and outputs which in turn used to simulate the distribution of the farm economic returns.

FARMSIM model uses several equations to estimate and simulate the key outcome variables useful in comparing impact of technologies.

The following is the summary of equations:

$$\text{Estimate/Simulate it as} = \text{GKRS}(\text{Max}, \text{Mean}, \text{Min}) \qquad 2.1$$

$$Q_{it} = \beta_{jt} K_{jt} \qquad 2.2$$

Q_{it} is the total output of product for chicken j (eggs and live birds), β_{jt} is the number of chicken j (e.g. hen); K_{jt} is number of eggs and chicks per chicken in time t,

$$Qit \sim GRKS(Max, Mean, Min) \quad 2.3$$

$\sim$ implies the quantity of output, Q_{it} follows GKRS distribution

$$P \sim GKRS(Max, Mean, Min) \quad 2.4$$

P is the price of inputs and outputs, $\sim$ implies all prices follow GRKS distribution

$$TR_t = \sum_{i=1}^{i} Q_{it} * P_{it} + \sum_{j=1}^{j} Q_{lt} * P_{lt} \quad 2.5$$

TR_t is the total revenue from chicken sales i and eggs sales j in time t, Qc_{it} is the number of eggs and chicken for introduced ones in time t, P_{it} is the price of introduced chickens` products i, Q_{lt} and P_{lt} is the number of eggs and chicken and price respectively for local chicken in time t.

$$TC_t = FC_t + \sum_{i=1}^{i} VC_{it} + \sum_{j=1}^{j} VC_{lt} \quad 2.6$$

TC_t is total cost, FC_t is fixed cost, VCc_{it} is the variable costs for introduced chicken strain i and VC_{lt} is the variable cost of local chicken in time t.

$$NCFI_{ct} = TRc_t - TC_{ct} \quad 2.7$$

$NCFI_{ct}$ is the net cash farm income in time t for chicken outputs, TR_{ct} is the total revenue for chicken outputs and TC_{ct} is the variable total cost involved in chicken keeping.

$$CR_t = If(EC_t >= 0, EC_t, 0) \quad 2.8$$

CR_t is cash reserve and EC_t is the ending cash both in time t

$$CFD_t = If(ECB_t < 0, (-1 * ECB_t)) \quad 2.9$$

CFD_t is the cash flow deficit and ECB_t is the ending cash balance in time t

$$NPV_i = \sum_{t=1}^{5} {NR_{it}}/{(1+r)^t} + \sum_{t=1}^{5} {CNW_t}/{(1+r)^t} \qquad 2.10$$

NPV_i is the Net Present Value for chicken strain i, NR_{it} is the net return for strain i in time t, r is estimated interest rate, CWN_t is the change in net worth.

Further, risk is an inherent part of the production process and it plays an important role in farmers' decision to adopt new agricultural technology because of their attitude towards risk (Kumbhakar, 2002; Nalley and Barkley, 2007). The inclusion of risk measures in agricultural innovations assessment concretes right inferences on which innovation is the most preferable by which farmers based on farmers' behaviour towards risk. In other words, chances of bad versus good outcomes can only be evaluated and compared knowing the decision maker's relative preferences for such outcomes (Schumann *et al.*, 2004). This is very important since nearly all farmers are risk-averse, i.e. most of them will accept fewer dollars of return for fewer dollars of variability or loss (Fathelrahman *et al.*, 2011). Apparently, some indorsed innovations may be so risky to extent that added risk offsets the gain in income, leading to worsening the livelihoods of smallholder farmers. Richardson *et al.* (2008) summarise several numerical methods for ranking risky alternatives based on farmers' risk altitude, viz.; First degree Stochastic Dominance (FSD) and Second-degree Stochastic Dominance (SSD), Stochastic Dominance with Respect to a Function (SDRF) and Stochastic Efficiency with Respect to a Function (SERF). Others include Risk Premiums, Target Probabilities for Ranking Risky Alternatives and Target Quantiles for Ranking Risky Alternatives. The review of literature indicates that SERF is superior to others (Schumann *et al.*, 2004; Hardaker and Lien, 2010; Fathelrahman *et al.*, 2011; Asci *et al.*, 2014). SERF is a procedure for ranking risky alternatives based on their certainty equivalents (CE) for alternative Relative Risk Aversion Coefficient (RRACs).

A certainty equivalent (CE) is equal to the amount of certain payoff an individual would require to be indifferent between that payoff and a risky investment (Watkins *et al*., 2008). It can be applied for any utility function form based on the full range (i.e. from negative to positive) of a Relative Risk Aversion Coefficient (RRACs). Lastly, it is one of a few risk analysis techniques that can be used to easily visualise the stochastic frontier across the entire r range, where preferences for a particular alternative may be illustrated (Fathelrahman *et al*., 2011).

This study applied the Exponential Utility Function built in Simetar@ 2006 as shown hereunder:

$$u(w) = -\exp(ra, w) \qquad 2.11$$

where ra is the RRACs and w is maximum NCFI attained for keeping specific chicken strain.

2.3 Results and Discussions

2.3.1 Net Present Value (NPV) for Chicken Strains

The Cumulative Distribution Function (CDF) of NPV values for introduced chicken technologies are illustrated in Fig. 2.1. Overall, the NPV results indicate clearly that Sasso chicken is the most economic viable with the highest probability of gaining more income for improved livelihood. Local chicken production has the lowest mean (US$7.16) and the least risk (lowest standard deviation (US$20.47)). Keeping Sasso strain has the CDFs which indicate the possibility of getting NPV up to US$306.08 with a flock of 60 chickens. However, the application of input is very crucial for the economic potential of Sasso chicken strain. This is indicated by its NPV distribution, which lies mostly to the left with negative NPV of about US$153.04.

Kuroiler was the second strain with its CDF distribution lying between Sasso and local chicken strain along the positive NPV scale. However, the CDF distribution lies to the left of local chickens along the negative side of the NPV scale. This implies that the economic viability of Kuroiler strains is greater than that of local chicken but with higher probability of loss due to mortality rate than local chicken. The average cumulative mortality recorded at farmers' level, condition after 6 weeks old till the age of 68 weeks was 27.0% and 27.1% for Sasso and Kuroiler respectively. The mortality of Sasso strain was somehow higher than the mortality recorded Ethiopia whereby mortality at farmer level condition after 45-day old till the age of production was 25% (Getiso *et al*., 2017). The highest mortality was observed at the age between 26 and 42 weeks. Kuroiler and Sasso strains showed the highest mortality rate of 5% and 3.5% between 26 and 42-week age. Farmers and extension officers reported the signs of egg peritonitis and related infections as the plausible causes of mortality between that age intervals. Egg yolk peritonitis is the inflammatory reaction of peritoneum caused by the presence of yolk material in the coelomic cavity (Srinivasan *et al*., 2013). This is in line with Srinivasan *et al.* (2013) who reported that egg peritonitis was responsible for 15.39% of the reproductive tract abnormalities in commercial layers between 21 and 80 week of age. Other recorded causes of mortality included diarrhoea, cannibalism, coryza, fowl cholera, typhoid, toxic, accident and respiratory infections. Generally, the total mortality was found to be 27% and 27.1% for Sasso and Kuroiler respectively.

In three sites, local chickens were kept by both purely extensive and semi extensive (some with supplementation). Fig. 2.1 shows that the NPV ranges between negative US$55.58 and US$ 70.78 and between US $4.53 and US$130.89 for local chicken with supplementation and with no supplement, respectively. This indicates that supplementation is more costly, given the low genetic potential of local chicken. However, the variation for local chickens was lower which implies that the probability of getting higher profit or loss is low if the strain is kept under pure extensive system. The CDF graph in Fig. 2.1 indicates NPV for Sasso chicken lies to the right of others. However, the both Table 2.3 and Fig. 2.1 show the minimum NPV being negative in both introduced chicken strains and in local chicken with supplementations. The negative NPV for introduced strains was due to the high mortality, which was associated with diseases, cannibalism and unexpected low egg production whereas for local chicken, the negative NPV was mainly due to expenditure on feeds. For Sasso, the high prices of the live birds and many eggs positioned them with higher NPV. Based on the summary statistics in Table 2.3 supported by the CDF graph, it is plausible to conclude that keeping Sasso chicken is more economically viable, Kuroiler being the second most followed by local strain without supplementation and lastly local chicken with supplementation.

Table 2.3: Summary statistics for NPVs (US$) of chicken technologies

Statistics	NPV-Local Chicken extensive	NPV-Local semi-extensive	NPV-Kuroiler	NPV-Sasso
Mean (US$)	7.16	67.28	92.05	106.41
SD (US$)	20.47	21.39	63.55	74.08
Minimum (US$)	-55.58	4.53	-126.66	-144.05
Maximum (US$)	70.78	130.89	254.60	300.74

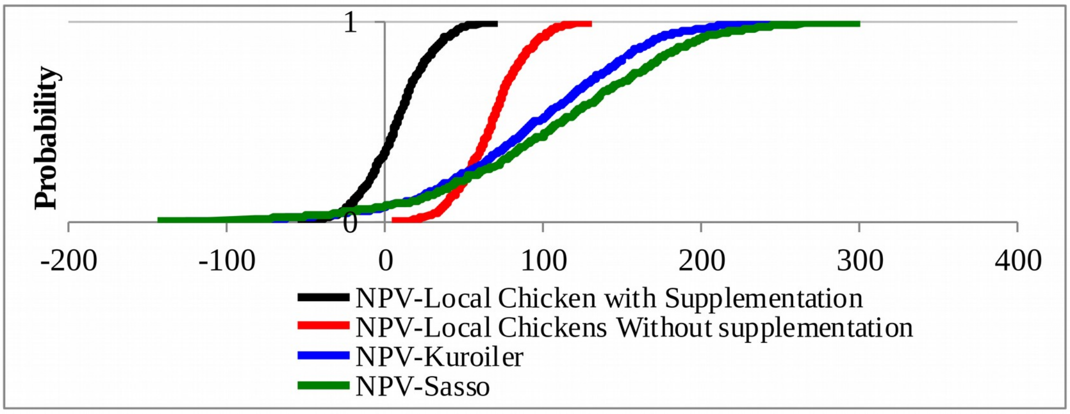


Figure 2.1: Cumulative Density Function of Net Present Value (NPV)

The stoplight chart (Fig. 2.2) presents the probabilities of NPV which is less than US$ 7.16 (red), greater than US$ 106.41 (green), and between the two target values (yellow) for the five-year planning horizon. The target values are the average of NPV for the lowest performing strain (local chicken with supplementation) for the lower bound; and the average of NPV for the best-performing strain (Sasso) for the upper bound. For the local chicken with supplement scenario, there was a 49% chance that NPV was<7.16% and 0% chance that NPV would exceed US$ 106.41. For the local chicken without supplementation, there was 96% probability of having NPV ranging between US$ 7.16 and 105.97 and only 03% probability to exceed US$ 106.41. For the Kuroiler and Sasso chicken keeping, there was 44% and 52% probability of generating NPV greater than US$ 106.41. These results suggest that investments in both Kuroiler and Sasso strains would increase productivity, offset the costs, and pay large dividends by increasing income.

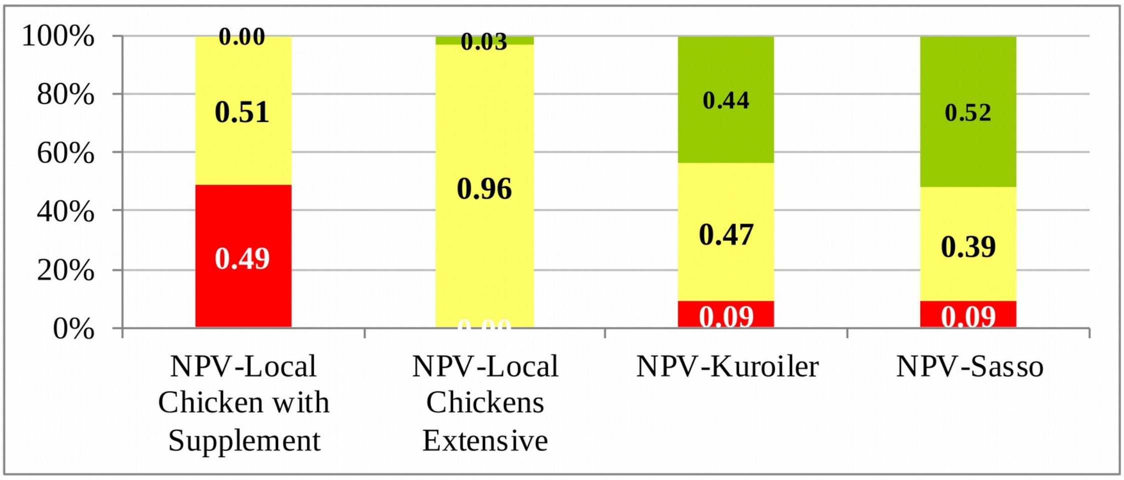


Figure 2.2: Stoplight chart for probabilities of NPV less than US$ 7.16 and greater than US$106.41

2.3.2 Net Cash Farm Income (NCFI)

Annual NCFI measures the amount of profit generated by the farm for each chicken technology. The summary results (Table 2.4) indicate that in terms of mean NCFI, Sasso chicken had the largest mean NCFI (US$ 29.41) followed by Kuroiler strain (US$ 23.50). Local chicken without supplementation performed thirdly with NCFI (US$ 22.79) whereas local chicken with supplementation generated the lowest mean NCFI (US$ 2.62). Further, CDF for NCFI (Fig. 2.3) shows that both Sasso and Kuroiler chicken strains generated higher NCFI than local chicken strain under different management systems. However, both the introduced strains had minimum NCFI with negative values. Farmers explained that main problems they faced in keeping the introduced chicken strains were mortality rate, delayed eggs production and high expenditure on feeding and medicines.

Table 2.4: Summary Statistics for NCFI for chicken strains

Summary Statistics	Local Chicken extensive	Local Chicken semi-intensive	Kuroiler	Sasso
Mean (US$)	22.79	2.62	23.50	29.41
Standard Deviation (US$)	9.41	8.54	37.55	46.11
Minimum (US$)	-4.04	24.21	199.34	245.89
Maximum (US$)	50.21	30.04	82.62	113.38

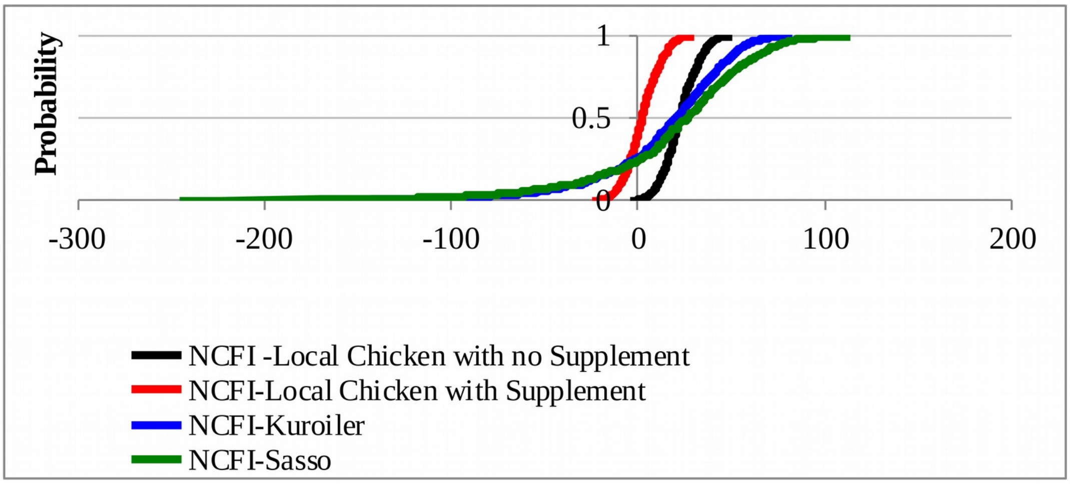


Figure 2.3: Cumulative Density Function of Net Cash Farm Income (NCFI)

The stoplight chart for NCFI shows that, keeping local chicken without supplementation, there was 06% probability that NCFI would be less than US$ 2.62 and 44% probability that NCFI would exceed US$ 29.41. In contrast, there was a 51% chance that annual NCFI was less for keeping local chicken with supplementation. For Sasso and Kuroiler chicken strains, there were 26% and 27% chances of getting NCFI less than US$ 2.62 respectively. Also, there were 53% and 47% respectively of probability of achieving NCFI greater than US$ 29.41. However, there was high variability in NCFI of Sasso and Kuroiler strains compared to NCFI for local chickens. The observed variability was due to high mortality rate, delayed egg production and high expenditure on feeding introduced strains. For example, in Sasso strain, farmers probably could get loss of US$ 250 (Fig. 2.3) for just keeping 60 chickens. These results suggest that keeping introduced chicken strains is riskier than keeping local ones.

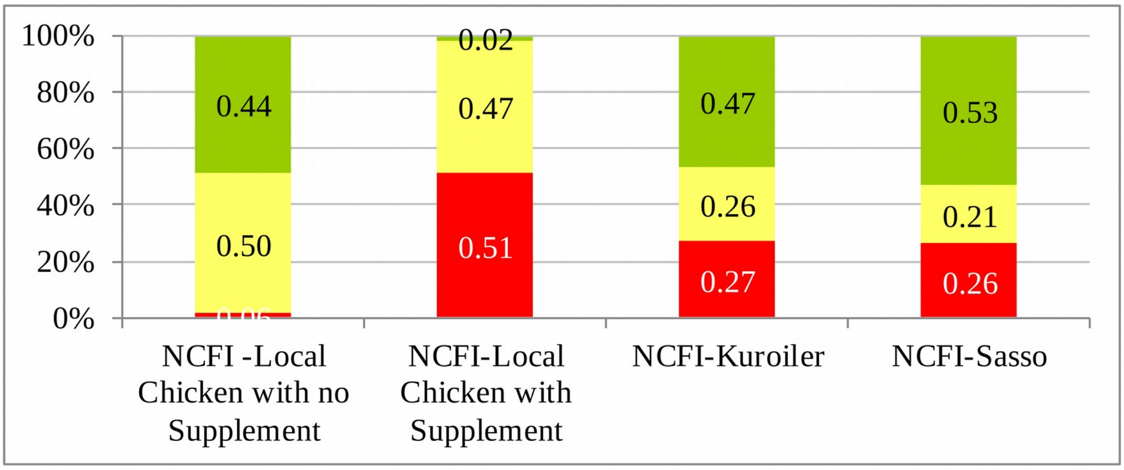


Figure 2.4: Stoplight chart for probabilities of NCFI less than US$ 2.62 and greater than US$ 29.41

2.3.3 Effect of agro-ecological differences on performance of introduced chicken strains

Kuroiler strain performed the best in Wanging'ombe (Tables 2.5 and 2.6, Figs. 2.5, 2.6 and 2.7) sites compared to Ifakara and Bahi sites. However, there is no performance gap (NPV and NCFI) between Bahi and Ifakara. This implies that the performances of Kuroiler in Bahi and Ifakara sites were similar. The stoplight chart for NCFI (Fig. 2.6) shows that, for

Kuroiler farming in Ifakara, the probability that NCFI would be less than US$ 16.60 is 36% and 7% probability that NCFI would exceed US$ 53.67. In Bahi District, there was 35% possibility that annual NCFI would be less than US$ 16.60 and just a 5% probability that NCFI would be greater than US$ 53.67. In Wanging'ombe sites, there was 18% probability that NCFI would be less than US$ 16.60 and 65% probability that annual NCFI would exceed US$ 53.67. With this regard, Kuroiler performed the best in Wanging`ombe sites.

Table 2.5: Summary statistics for NCFI (US$) Kuroiler chicken strain

Statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	106.62	240.20	112.80
SD (US$)	87.09	113.35	70.83
Minimum (US$)	-215.44	-184.80	-133.59
Maximum (US$)	304.64	490.56	283.77

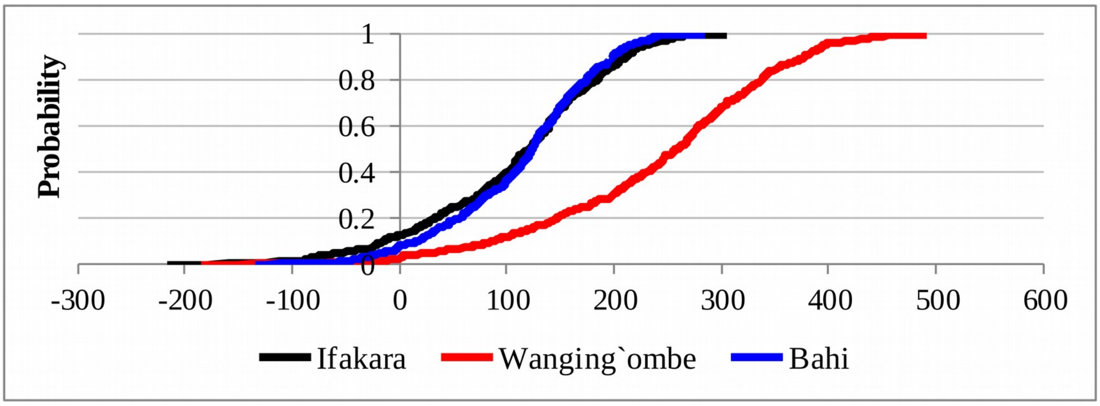


Figure 2.5: NPV for Kuroiler across three agro ecological zones

Table 2.6: Summary statistics for NCFI (US$) Kuroiler chicken strain

Statistics	Ifakara	Wanging`ombe	Bahi
Mean (US$)	16.54	53.51	18.44
SD (US$)	39.82	54.22	33.42
Minimum (US$)	-204.10	-257.46	-160.36
Maximum (US$)	72.62	129.33	68.74

Figure 2.6: NCFI for Kuroiler across three agro ecological zones

The stoplight chart for NCFI (Fig. 2.8) shows that, for Kuroiler farming in Ifakara, there is a 36% probability that NCFI will be less than US$ 16.60 and a 7% probability that NCFI will exceed US$ 53.67. In Bahi district, there is a 35% possibility that annual NCFI will be less than US$16.60 and just a 5% probability that NCFI will be greater than US$ 53.67. In Wanging`ombe sites, there is 18% probability that NCFI will be less than US$ 16.60 and a 65% probability that annual NCFI will exceed US$ 53.67. With this regard, Kuroiler performed the best in Wanging`ombe site.

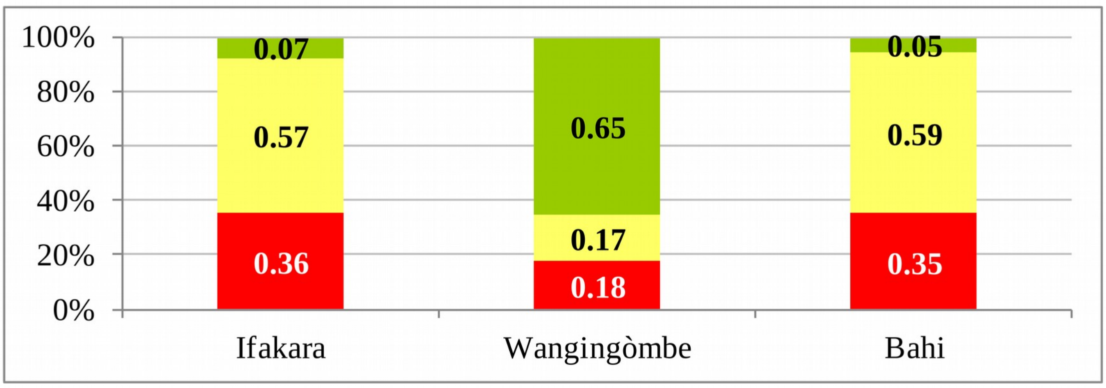


Figure 2.7: Stoplight chart for probabilities of NCFI less than US$ 16.60 and greater than US$ 53.67

On the other hand, the NPV for Sasso (Table 2.7 and Fig. 2.8) indicates that the strain performed well in Bahi sites followed by Wanging'ombe and Ifakara was the least. Keeping about 60 Sasso chickens, the enterprise can generate a mean of NPV about 88.87, 152.07 and US$ 77.73 (Table 2.6) in Bahi, Wanging'ombe and Ifakara respectively. Nevertheless, keeping Sasso strain in Wanging`ombe district has the highest possibility of generating loss with NPV 268.73 per a flock of 60 chickens. Table 8 and Fig. 2.9 detail the performance trends of Sasso strain across three agro ecological zones.

Table 2.7: Summary statistics for NPV (US$) for Sasso chicken strain

Summary statistics	Ifakara	Wanging'ombe	Bahi
Mean (US$)	77.69	88.83	152.01
SD(US$)	89.97	96.44	92.37
Minimum (US$)	-252.25	-268.62	-183.70
Maximum (US$)	285.09	295.05	372.79

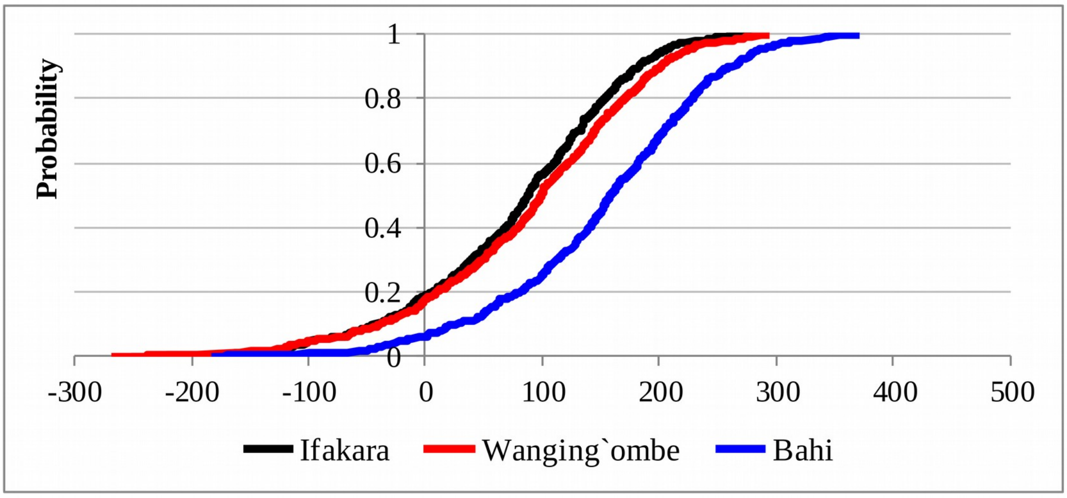


Figure 2.8: NPV for Sasso across three agro ecological zones

The NCFI results (Table 2.8 and Fig. 2.9) highlight the superior performance of Sasso in Bahi sites relative to Wanging'ombe and Ifakara sites. Keeping about 60 Sasso chickens, the enterprise can generate a mean NCFI 30.59, 16.23 and 10.15 US$ in Bahi, Wanging'ombe and Ifakara respectively.

Table 2.8: Summary statistics for NCFI for Sasso chicken strain

Summary Statistics	Ifakara	Wanging`ombe	Bahi
Mean (US$)	10.15	16.22	30.58
SD (US$)	46.70	49.81	45.66
Minimum (US$)	-255.42	-263.81	-215.81
Maximum (US$)	91.39	105.48	118.92

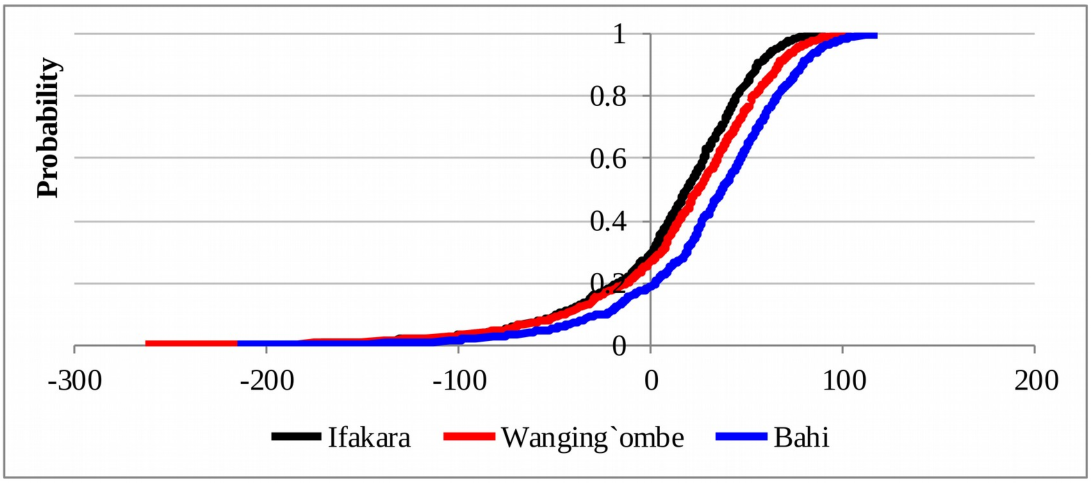


Figure 2.9: NCFI for Sasso across three agro ecological zones

The **stoplight chart** for NCFI (Fig. 2.10) shows that there was 25% probability that NCFI would be less than US$ 23 151 and the 58% probability that NCFI exceeds US$ 30.59 in Bahi sites. In contrast, in Wanging'ombe sites, the probability that annual NCFI would exceed US$ 30.59 is 44% and the probability that NCFI would fall between US$ 10.15 and 30.59 was 21%. In Ifakara sites, there was on average 36% probability that NCFI exceeds US$ 30.59 and a 24% probability that annual NCFI would fall between 10.15 and US$ 30.59. Overall, keeping Sasso strain was the most economically viable enterprise in Bahi District. Comparatively, Sasso strain is recommendable to all sites as the performance differences were found small (Table 2.7, Figs. 2.9 and 2.10) compared to performance differences of Kuroiler across three sites (Table 2.6, Figs. 2.7 and 2.8). Generally, higher economic returns of introduced chicken strains were noted fairly influenced by higher average eggs per hen and higher prices of the live birds compared to the existing local chickens. In addition, the current study noted that the economic return stability in the local chicken enterprise was due to low variation in egg production, output selling prices and low variation in mortality rate (Table 2.2).

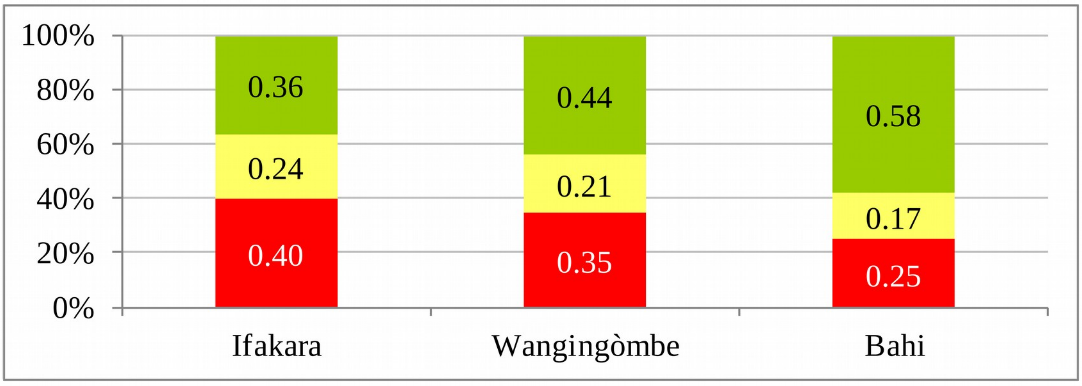


Figure 2.10: Stoplight chart for probabilities less than US$ 10.15 and greater than US$ 30.59

2.3.3 Chicken strains preference with respect to farmers' risk attitude

As a reminder, SERF is used to determine the preferred strain under various risk preferences. SERF analyses (Fig. 2.11) indicate that for the extremely risk-averse and moderate risk-averse farmers, local chicken without supplement was most preferred. Local chicken with supplement was the second most preferred followed by Kuroiler strain. Sasso strain was typically the least preferred system by the extremely risk-averse and moderate risk-averse farmers. Fig. 11 indicates that, the extremely risk-averse farmers would need to receive about US$ 170 and US$ 130 for keeping about 60 Sasso strain and Kuroiler strain respectively to be indifferent between keeping introduced strains and local chickens without supplement (highest ranked).

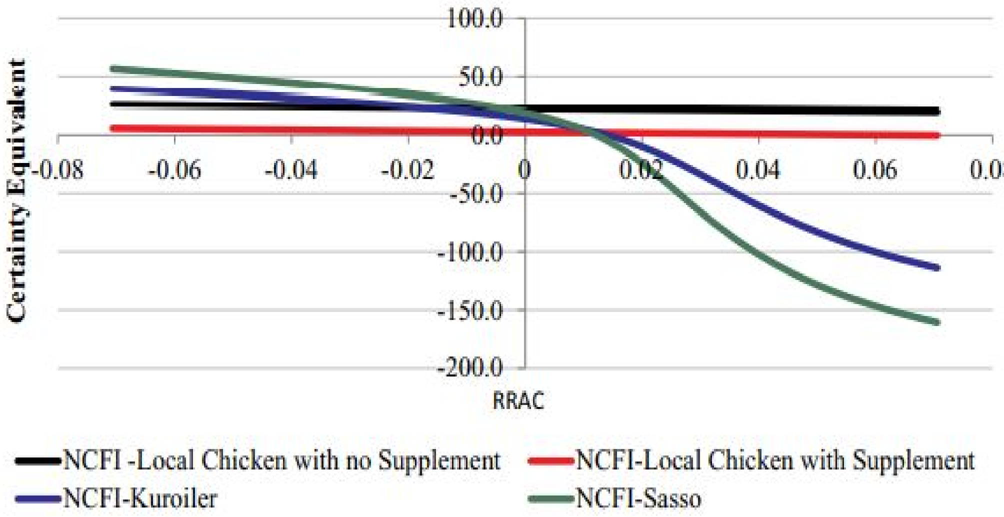


Figure 2.11: Stochastic Efficiency with Respect to a Function chart for net cash farm income for chicken strains

Normal slightly risk aversion and risk neutral farmers preferred the most, keeping local chicken without supplement. Sasso was the second followed by Kuroiler and local strain was the least preferred. Nearly risk neutral farmers at both extreme were likely indifferent between Sasso, Kuroiler and local chicken strain since the gaps between the lines is very narrow. Sasso strain was preferred the most by strongly risk loving individuals whereas Kuroiler strain was the second. Local chicken was the third preferred most whereas local chicken with supplement was the least. Using stoplight charts (Fig. 4), Sasso strain was found providing higher probability of gaining more income (53%) compared to local chicken without supplement (44%). In conjunction with risk behaviour of farmers towards these strains, only very extreme risk loving farmers would go for the Sasso strain whereas the rest would maintain their status quo. As detailed (Figs. 2.3 and 2.4), the performance of Sasso strain is so risky due to higher performance variability compared to local chicken without supplement. With this regard, efforts to reduce variability in performances for Sasso and Kuroiler strains is very important for harnessing the potential of the new strains to benefit the majority.

In summary, by comparing NPV, NCFI, Cumulative density function curves, sport light chart and graph for stochastic efficiency with respect to a function for introduced chicken strains from that of existing local chicken, it concluded that keeping introduced chicken strains is more economically viable economic activity.

2.4 Conclusions and Recommendations

This paper contributes to the production economics, adoption and poultry farming literature by integrating on-farm test and economic viability assessment based on the farm test data by establishing economic viability of introduced chicken strains relative to available local chickens in different agro-ecological zones. The article evaluated the economic viability of introduced chicken strains relative to the available local chickens in Ifakara, Wanging'ombe and Bahi districts. Local chicken strains were compared with two strains namely Kuroiler and Sasso. Overall, Keeping Sasso strain generated the most Net Present Value, Annual Net Farm Income and the highest probability of attaining more income from keeping chicken. Kuroiler is the second performer regardless of the agro-ecological zones. The results rank third local chicken without providing supplements whereas the provision of supplement scored the least. However, the results indicate that there is high variability in economic viability of Kuroiler and Sasso strains. The variability realised was due to mortality rate and delay and unexpected stop of egg laying of hens. The performance across agro-ecological zones depicts that Kuroiler performed the best in Wanging’ombe sites followed by Bahi sites and Ifakara site was the least. Sasso strain performed the best in Bahi followed by Wanging'ombe and Ifakara was the least. Inclusion of risk behaviour analyses revealed that extremely risk-averse farmers preferred most keeping local chickens without provision of supplements whereas extremely risk loving farmers preferred the most Sasso strain followed by Kuroiler. The present study recommends that the introduced chicken strains have to be promoted for adoption to increase household income for improved livelihood. However, scaling up of the introduced chicken strains must be integrated with education on technical know-how on good farming practices; feed formulations, medication and shelter for improved productivity.

Acknowledgements

Authors acknowledge Bill and Melinda Gates Foundation (BMGF) for financial support to the Africa Chicken Genetic Gains (ACGG) Project. Secondly the sincere thanks is extended Dr. Jean-Claude Bizimana and Prof. James W. Richardson (Agricultural and Food Policy Centre (AFPC), Texas A& M University) and Innovation Lab for Small Scale Irrigation (ILSSI) Project for developing FARMSIM Model followed by a series of training which enabled this study to adopt FARMSIM Model. Lastly, particular gratitude goes to the smallholder chicken keepers who agreed to participate in on the farm test of the introduced chicken strains and provided data for this study.

References

ACGG. (2015). Site Selection Framework. Project document. pp 6.

ACGG. (2016). African Chicken Genetic Gain project profile. pp 2.

AFNETA, (1992). Alley Farming Training Manual Volume 1 pg 196, November, 21. [http://biblio. iita. org/documents] site visited on 21/11/2016.

Asci, S., VanSickle, J. J. and Cantliffec, D. J. (2014). Risk in investment decision making andgreenhouse tomato production expansion in Florida. *International Food and Agribusiness Management Review* 17(4): 1–16. [https://www.ifama. org] site visited on 4/05/ 2019.

Barrows, R. and Röling, N. (1989). Extension Science: Information Systems in Agricultural Development. *American Journal of Agricultural Economics* 71(3): 833-834. [https://doi.org/10.2307/1242055] site visited 20/10/2020.

BOT. (2015). Annual Report 2014/15. pp264. [https://www.bot.go.tz/] site visited on 27/04/2019.

BOT. (2018). Annual Report 2018/19.pp 264 [https://www.bot.go.tz/] site visited on 27/04/2019.

Clarke, N., Bizimana, J. C., Dile, Y., Worqlul, A. W., Osorio, J., Herbst, B., Richardson, J. W., Srinivasan, R., Gerik, T. J., Williams, J., Jones, C. A. and Jeong, J. (2017). Evaluation of new farming technologies in Ethiopia using the Integrated Decision Support System (IDSS). *Journal of Agricultural Water Management* 180: 267–279. [https://doi.org/10.1016/j. agwat.2016.07.023] site visited on 02/02/2017.

Climatic Data Org. (2016). Tanzania Climatic Data. [https://en.climate-data.org] site visited on 12/03/2018.

Davis, P. J., Eisenhard, K. and Bingham, C. (2007). Developing Theory through Simulation Methods. *Academy of Management Review* 32(2): 480–499. [http://dx.doi. org/10.2307/20159312] site visited on 12/06/2016.

Fathelrahman, E. M., Ascough, J. C., Hoag, D. L., Malone, R. W., Heilman, P., Lori, J., Wiles, L. J. and Kanwar, R. S. (2011). Economic and stochastic efficiency comparison of experimental tillage systems in corn and soybean under risk. *Experimental Agriculture Journal* 47: 111–136. [https://doi.org/10.1017/ S0014479710000979] site visited on 8/12/2016.

Fontana, M. (2005). Computer simulations, mathematics and economics. Working Study06. Department of Economics, University of Turin, Italy. [http: //dx.doi.10.1007/BF0302985] site visited on 22/03/2018.

Francis, C., Mundy, V., Janke, R. and King, J. (1995). Alternative Approaches to On-Farm Research and Technology Exchange. [http:// digitalcommons. unl.Edu] site visited on 29/11 2016.

Getiso, A., Jim, A., Asrat, M., Giorgis, H. K., Zeleke, B. and Birhanu, T. (2017). Management practices and productive performances of Sasso chickens breed under village production system in SNNPR, Ethiopia. *Journal of Biology, Agriculture and Health Sciences* 7(7): 120–135. [http:// www.iiste.org/] site visited on 27/11/2018.

Hardaker, J. B. and Lien, G. (2010). Stochastic efficiency analysis with risk aversion bounds: a comment. *Australian Journal of Agricultural and Resource Economics* 54: 379–383. [https://doi.org/10.1111/j. 1467-8489.2010. 00498.x] site visited on 20/10/2018.

Hasegawa, A. C., Gempesaw, C. M., Daniels, W. H. and Petrosky, B. R. (1990). Simulating the Economic Viability of Crawfish Production: A Two-Stage Approach. Proceedings of the 1999 Winter Simulation Conference. November 13. [https://doi.org/10.1080/136573001093802 78] site visited on 12/03/2018.

Komwihangilo, D. M. (2015). The Role of Chicken in the Tanzanian Economy and Opportunities for Development: An Overview: First National Innovation Platform July 13th - 15th 2015 Blue Pearl Hotel, Dar es Salaam, Tanzania.

Kray, V. A. (2002). Agro-Food Policies in Slovakia and Bulgaria A Quantitative Analysis. [https://www.econbiz.de/] site visited on 21/11/2020.

Kumbhakar, S. C. (2002). Specification and estimation of production risk, risk preferences and technical efficiency. *American Journal of Agricultural Economics* 84(1): 8–22. [https://doi.org/10.1111/1467-8276.00239] site visited on 20/10/2018.

Langat, B. K., Ngéno, V. K., Nyangweso, P. M., Mutwol, M. J., Kipsat, M. J., Gohole, L. and Yaninek, S. Y. (2013). Drivers of Technology Adoption in a Subsistence

Economy: The Case of Tissue Culture Bananas in Western Kenya. A Study Presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013: Hammet, Tunisia. [http://ageconsearch.umn.edu/record] site visited on 14/06/2018.

Minga, U. M., Mtambo, M. M. A., Katule, A. M., Mutayoba, S. K., Mwalusanya, N. A., Lawrence, P., Mdegela, R. H. and Olsen, J. E. (2003). Improving the Health and Productivity of the Rural Chicken in Africa: Research and Development Efforts in Tanzania. *Journal of Livestock Research for Rural Development* 15(2): 134-139. [http://www.lrrd.org] site visited on 31/10/2016.

Mwinuka, L., Mutabazi, K. D., Sieber, S., Makindara, J. and Bizimana, J. C. (2017). An economic risk analysis of fertilizer microdosing and rainwater harvesting in a semi-arid farming system in Tanzania. *Journal of Agricultural Economics Research, Policy and Practice in Southern Africa.* [https:// www.Tandfonline.com /doi/ abs/ 10. 1080/ 03031853.2017.1343154] site visited on 18/05/2018.

Nalley, L. L. and Barkley, A. (2007). The Impact of the CIMMYT Wheat Breeding Program on Wheat Yields in Mexico's Yaqui Valley, 1990–2002: Implications for the Future of Public Wheat Breeding. Selected Study Prepared for Presentation at the American Agricultural Economics Association Annual Meeting, Portland. July 29–August 1.2007. [http://ageconsearch.umn.edu/] site visited on 8/12/2016.

Paikoff, R. L. (1996). Adapting Developmental Research to Intervention Design: Applying Developmental Psychology to an AIDS Prevention Model for Urban African American Youth. *Journal of Negro Education* 65(1): 44–59. [doi: 10.2307/2967367] site visited on 29/11/2016.

Peshin, R. (2013). Farmers' adoptability of integrated pest management of cotton revealed by a new methodology. *Journal of Agronomy for Sustainable Development, Springer* 33(3): 563-572. [https://hal.archives-ouvertes. fr/hal-01201370]. Site visited on 14/05/2018.

Richardson, J. W. and Bizimana, J. C. (2019). Agricultural Technology Assessment for Smallholder Farms in Developing Countries: An Analysis using a Farm Simulation Model (FARMSIM). Research Report 17-1.Agricultural and Food Policy Center, Texas A&M University.[https: //www. afpc.tamu. edu/research/ publications/ 683/ FARMSIM.pdf] site visited 14/02/ 2018.

Richardson, J. W. (2006). Simulation for applied risk management. Unnumbered staff report, Department of Agricultural Economics, Agricultural and Food Policy Centre, Texas A&M University, College Station, Texas. [www.researchgate.net › publication › 331946940_Econo.] site visited 14/02/ 2018.

Richardson, J. W., Herbst, B. K., Outlaw, J. L. and Gill, R. C. (2007a). Including Risk in Economic Feasibility Analysis: The Case of Ethanol Production in Texas. *Journal of Agribusiness* 25(2): 115-132, November 2. [econpapers. repec.org/RePEc:ags:jloagb:62291] site visited on 14/05/ 2018.

Richardson, J. W., Lemmer, W. J. and Outlaw, J. L. (2007b). Bio-ethanol Production from Wheat in the Winter Rainfall Region of South Africa: A Quantitative Risk Analysis. *International Food and Agribusiness Management Review* 10(2): 181-204. [https://www.afpc.tamu.edu] site visited on 14/11/2018.

Richardson, J. W., Schumann, K. and Feldman, P. (2016). *Simetar. Simulation and Econometrics to Analyze Risk*. Simetar, Inc. College Station, Texas. United State of America. pp103.

Richardson, J. W., Schumann, K. D. and Feldman, P. (2008). Simetar. Simulation and Econometrics to Analyze Risk. Simetar, Inc. User Manual, College Station, Texas. United State of America. pp145.

Richey, R. C. (1994). Developmental Research: The Definition and Scope in Proceedings of Selected Research and Development Presentations at the National Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (16th, Nashville, TN, February 16-20, 1994). [http://files.eric.ed.gov/ fulltext/ED373753.pdf] site visited on 18/08/2016.

Rodelio, B. C. and Silvino, Q. T. (2013). Sustainable Organic Farming in the Philippines: History and Success Stories. [http://www.afaci.org] site visited on 18/10/ 2016.

Röling, N. G. and Jiggins, J. (1998). *Facilitating Sustainable Agriculture: Participatory Learning and Adaptive Management in times of Environmental Uncertainty*. Cambridge: Cambridge University Press. pp283 –311.

Shaw, C. S. (2014). Agricultural Technology Adoption in West Africa. A Thesis for Award Degree of Master of Science of Texas A&M University. 131pp.

Simon, H. A. (1959). Theories of Decision-making in Economics and Behavioural Science. *American Economic Review* 49(3): 253-283. [http://pages. stern.nyu. edu/~dbackus] site visited on 20/01/ 2017.

Srinivasan, P., Balasubramaniam, A. G., Murthy, K. R. T. and Balachandran, P. (2013). Bacteriological and pathological studies of egg peritonitis in commercial layer chicken in Namakkal area. *Asian Pacific Journal of Tropical Biomedicine* 3(12): 988-994. [doi:10.1016/S2221-1691(13)60191-4] site visited on 11/05/2019.

Sunding, D. and Zilberman, D. (2000). *The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector*. pp105. [https://doi.org/ 10.016 /S1574-0072(01)10007-1] site visited on 24/10/2016.

Thornton, P. K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S. and Campbell, B. M. (2017). Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Journal of Agricultural Systems* 152: 145-153 [DOI: 10.1016/j.agsy.2017. 01.005] site visited on 06/05/2019.

United Republic of Tanzania (URT). (2012). National Sample Census of Agriculture Small Holder Agriculture. Volume III: Livestock Sector National Report. [http://www.kilimo.go.tz] site visited 09/05/2016.

URT, (2015). Tanzania Climate Smart Agriculture Programme: 2015-2025. [http://www.kilimo.go.tz] site visited on 19/10/2016.

Vorotnikova, E., Borisova, T. and VanSickle, J. J. (2014). Evaluation of the profitability of a new precision fungicide application system for strawberry production. *Agricultural Systems* 130: 77–88. [https:// doi: 10.1016/ j.agsy.2014.06.006] site visited on 14/05/ 2018.

World Society for the Protection of Animals. (2011). Enhancing rural livelihoods and nutrition through higher welfare poultry production in India. Case study. [http://www.Wspa-international.Org] site visited on 20/10/2016.

CHAPTER THREE

3.0 *EX-ANTE* ANALYSIS OF ADOPTION FOR INTRODUCED CHICKEN STRAINS AMONG SMALLHOLDER FARMERS IN SELECTED AREAS OF TANZANIA

Rogers Andrew[1], Jeremia Makindara[2], Mbaga S. H[3], Roselyne Alphonce[4]

1. Department of Policy, Planning and Management, Sokoine University of Agriculture, Morogoro, Tanzania
2. Department of Business Management, Sokoine University of Agriculture, Morogoro, Tanzania
3. Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania
4. Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania

Correspondence: Rogers Andrew, Email: randrew@sua.ac.tz

3.1 Abstract

Keeping local chickens is an integral part of Tanzania's rural economy although it suffers from low genetic potential. To address the problem, the Africa Chicken Genetic Gains (ACGG) project introduced and tested improved strains of chicken viz. Sasso and Kuroiler in Tanzania. The study aimed at predicting the rate of adoption of Sasso and Kuroiler chicken strains by using the Adoption and Diffusion Outcome Prediction Tool (ADOPT). Developmental research design involving provision of 25 six weeks old chicks to farmers was adopted. Data used were obtained from a questionnaire survey and Focus Group Discussion in 12 on-farm testing sites located in three regions of Tanzania. The results indicate that the peak for adoption is likely to be 34, 29 and 38% after 8, 7 and 9 years in Bahi, Ifakara and Wanging'ombe sites respectively. The sensitivity analysis indicates that the adoption rate may increase to reach 59, 49 and 57% and may decline to about 17, 16 and 21% in Bahi, Ifakara and Wanging'ombe respectively. Extension efforts to facilitate availability of the strains, feeds, treatment and reducing upfront and operating costs are main factors affecting change in the adoption rate to optimize the inherent genetic potential. It is recommended to facilitate extension efforts for adoption rate improvement by upgrading local chicken value chain to enable farmers to access the strains, feeds, medication and market.

Key words: *Ex –ante*, Adoption, ADOPT, Introduced Chicken strains, Tanzania

3.2 Introduction

Keeping local chickens is an integral part of Tanzania's rural economy whereby about 3.4 million households keep chickens. According to URT (2015), it is estimated that there are about 35.5 million local chickens and 24.5 million commercial chickens raised by individual households and small to medium commercial companies. The sector contributes about 1% of the national Gross Domestic Product (GDP). In 2013, the estimated monetary value of meat and eggs was TZS 874 billion and 364 billion respectively (Komwihangilo, 2015). However, local chicken rearing suffers from high mortality (over 50%) due to diseases, poor management, low input uses and inherent low genetic potential (URT, 2015). The low genetic potential of local chicken in Tanzania has multifaceted effects to increased contribution of the sector to the country's GDP and protein intake among rural dwellers. According to URT (2012), the weight of chicken ranges between 1.6 and 2.0 kg, while annual eggs produced per hen per year is 36 eggs on average.

In response to the low genetic potential of local chicken in Tanzania, the Africa Chicken Genetic Gains (ACGG) project introduced and tested tropically adapted and improved strains of chicken viz. Sasso and Kuroiler at village level in Tanzania. Kuroiler and Sasso are said to be fast growing and can produce about 150 eggs per year under moderate management (World Society for the Protection of Animals, 2011; Rodelio and Silvino, 2013). The concept of the on farm testing adopted by ACGG, is expected to provide empirical information for a better understanding of the diffusion, adoption, and impact of improved technologies to guide producer groups, researchers and policy makers in making prudent and informed decisions about allocating resources (Peshin, 2013; Milkias and Abdulahi, 2018). Further, ACGG project responds to the fact that the gateway to Africa's economic development hinges on innovation, diffusion and utilization of agricultural technologies (Langat *et al.*, 2013).

Adoption of new agricultural technologies leads not only, to increasing productivity and food security, but also enhances agricultural development while reducing poverty (Bizimana and Richardson, 2019). However, adoption of the introduced chicken strains may not be straightforward since farmers are economic agents who can only decide to adopt a new technology only if they are exposed to it (Foster and Rosenzweig, 2010), expected benefit exceeds the benefit of available related technology, and the technology is affordable (Pindiriri, 2016 and Loevinsohn *et al.*, 2013). According to Bizimana and Richardson (2018), the assumption is that farmers engage in adoption of new technology only if the benefits or perceived utility of using the new technology outweighs the benefits of the current or old technology.

3.3 Adoption Theories

Adoption is a process that involves a series of stages one undergoes first from hearing about a product to finally accepting or using it. Also, it includes the moment at which the decision maker acts to make the spread of the technology happen (USAID, 2015). Diffusion and adoption theories and frameworks seek to describe the dynamic process of the implementation and adoption of innovations (Miranda *et al.*, 2016). There are several diffusion and adoption theories and frameworks (Wisdom *et al.*, 2014). Nevertheless, USAID (2015) contends that, the Diffusion of Innovations theory by Rogers (Rogers, 2003) and Bass Diffusion Model (Bass, 1969) are classical theories that describe how, why, and at what rate new ideas and technology are spread. Rogers' model is applicable after adoption is complete while Bass' model estimates the probability that adoption will occur in response to exposure to the innovation (external influence) and the social interaction effect (internal influence), which is then applied to the total adoption at some point in time (Wright, 2011). In this study, a combination of these models was used to explain the likelihood of farmers adopt the introduced chicken strains since the strains have already on-farm and farmers have had an opportunity to make a comparison based on their merits and demerits relative to available strain.

3.4 Empirical Review

There is extensive literature on technology adoption in developing countries across a variety of topics (Shaw, 2014; Gupta *et al.*, 2018; Mottaleb, 2018). Kalaitzandonakes *et al.* (2018) provided evidence that; the rate and pattern of adoption of innovations vary according to the type of crop, the location and characteristic of the specific innovation. Adoption of new technologies contributes to poverty reduction in some African and Asian countries, but also instances in which they fail to benefit poor farmers (Gupta *et al*., 2018). In his review of the impact of agricultural technologies, Mottaleb (2018) revealed that, in reality, despite the visible benefits of many from the new agricultural technologies, including machinery and management practices, farmers either do not adopt them or it takes a long time to begin the adoption process and subsequent scaling up.

In Tanzania, several studies on adoption of agricultural technologies have been conducted (Kaliba *et al*., 1998; Namwata *et al*., 2010; Pedersen, 2012; Kahimba *et al*., 2014). All these studies used ex-post analyses mainly using Tobit or Probit regressions models. These analyses have been useful for increasing our understanding on why some individuals adopted and others did not adopt certain technologies. These studies used either Probit or Logit regression models both of which, according to Pindiriri (2016), fall short of proper methodological approaches for the exploration of the drivers of technology adoption in agriculture as they overlook non-exposure and selection biases. Further, the ex-post regression studies have contributed little to the problem of designing innovation adoption and scaling up pathways. The current study uses *ex-ante* approach to evaluate the likelihood of an innovation uptake at a large scale to guide producers, research institutions and policy makers in making prudent and informed decision regarding introduced chicken strains.

3.5 Factors Affecting Adoption of New Technologies

Adoption of technologies is a change in behaviour that ultimately leads to acceptance or rejection of that technology (Rogers, 2003). According to Loevinsohn *et al*. (2013), farmers' decisions about whether and how to adopt new technology are conditioned by dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances. Generally, the literature on adoption generalizes that the complexity of economic, social, environmental and psychological boundaries of farmers highly affect the adopting decision of the innovations (Francis *et al*., 1995; Yesuf *et al*., 2009; Hill, 2010; Holden, 2014; Emerick *et al*., 2015; USAID, 2015). Moreover, Rogers (2003), a renowned father of adoption theories, classifies factors into five major attributes of an innovation causing variance in the rate of adoption of a technology. These are: relative advantage, compatibility, complexity, trialability and observability. This study uses a tool which was built based on the scholarly accumulated 22 variables affecting the adoption of agricultural technologies to predict the adoption rate and time to reach adoption peak.

3.6 Methodology

3.6.1 Developmental research design

To evaluate the likelihood of adoption of the introduced chicken strains, developmental research design was applied. The design assumes a traditional model of skill in which the unit of analysis is taken to be the individual (AFNETA, 1992; Richey, 1994). According to Barrow and Röling (1989), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. The study design is in accordance to Thornton *et al*. (2017) that testing and dissemination of technology are at the core of development-oriented agricultural research. Selection of location for establishing on-farm testing sites was based on Tanzania's Agro Ecological Zones (AEZs) to present the general farming systems in Tanzania. The AEZs range from higher rainfall areas on the coast and highlands in the North, far West, South and Southwest, to arid and semi-arid areas in the interior of the country (URT, 2015). Accordingly, cropping patterns, climatic differences reflect biophysical characteristics for growth and stability of chickens. On-farm testing for introduced chicken strains across different AEZs was meant facilitating farmers and other actors in poultry value chain evaluate the potential of the strains at farm level. Three assumptions underlie the design. First, selected farmers have had experience in keeping chickens so that the design does not add any fixed cost such as chicken house, feeding facilities and drinkers. In other words, on-farm testing used already available facilities. Secondly, time and labour spent in keeping introduced chickens and available local chickens were presumed similar and hence zero opportunity cost. Third, small-scale local farmers in Tanzania operate relatively similar in keeping chickens. Thus, any of AEZs fit for on-farm testing. According to ACGG (2015), households recruited to receive the chickens met the following criteria:

i. Chicken keeping households that had kept local chickens for a continuous period of at least two years prior to the baseline survey;
ii. Keeping at least 15 adult chickens but no more than 50;
iii. Willingness to accept 25 birds of randomly selected strain;
iv. Commitment to provide some supplemental feeds and
v. Willingness to participate in the project for a minimum of 72 weeks.

Setting the basic criteria for selecting farmers to participate in on-farm testing, the baseline survey was conducted. Baseline survey was conducted to identify legible population in central semi-arid, eastern sub-humid, southern highlands, lake zone and southern humid to represent different agro-ecologies in the country. Specifically, first step involved selecting three regions of Morogoro, Dodoma and Njombe to present AEZs. In each region, one district was selected purposely taking into account the availability of villages which had about 20 and above farmers that have at least 15 adult chickens but not more than 50. Out of the qualified villages, four of them from each district were selected randomly from the long list of villages. Subsequent stage involved randomly selection of farmers from the long list of farmers that met the set criteria. After random selection of qualified farmers, it followed provision of six-week pre-brooded chicks to these households whereby each farmer received 25 chicks. At this stage, each farmer received either Kuroiler or Sasso. Chicks received the recommended vaccination against Mareks, Newcastle Disease, Infectious Bronchitis and fowl pox before being distributed to farmers. Farmers continued keeping these strains based on their practices with some additional supplementation using locally available feeds and providing treatment and shelter under a semi-scavenging system (ACGG, 2016).

3.6.2 Description of the study sites

The study was conducted in three regions namely Dodoma, Morogoro and Njombe where on farm testing were in Bahi, Ifakara and Wanging`ombe respectively. Dodoma Region is located in the Central part of the country on Latitude: -6° 00' 0.00' South and Longitude: 36° 00' 0.00' East. The region is bordered by Manyara region to the North, Singida region to the West, Iringa region to the South and Morogoro Region to the Southeast. It is primarily semi-arid and covers an area of 41 311 square kilometres. The region lies at altitude of 1 125 M above sea level. Annual rainfall is about 500 to 700 mm and annual average temperature of about 22.6°C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1°C (Climatic Data Org, 2016). Major crops include drought tolerant such as family of sorghum, groundnuts, sunflower, and some maize. Four villages namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa were purposively selected for setting on-farm testing.

Morogoro region is administratively divided into six districts, namely Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo. The region lies between Latitude 5º58' and 10º0' South of the Equator and Longitude 35º25' and 35º30' to the East. It is bordered by seven other regions: Arusha and Tanga regions to the North, Pwani region to the East, Dodoma and Iringa to the West and Ruvuma and Lindi to the South. Morogoro region lies at an altitude of about 525 M above sea level. The annual rainfall ranges from 600 to 1200 mm with average annual temperature of about 25ºC. The zone is characterized by an average annual rainfall of 1160 mm with average temperature of 16°C. There are typically two distinct long and short rainy seasons of March–May and November–January/February, respectively, but this pattern are often interrupted Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara district. The on-farm test sites were located in four villages: Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe region lies between Latitude 08º40' and 10º32' South of the Equator and between Longitude 33º47' and 35º45' East of Greenwich and an altitude of about 2 000 M above sea level. The region borders Iringa region in the North, Morogoro region in the East and Ruvuma region in the South. It also borders the Republic of Malawi via Lake Nyasa and part of Mbeya region in the North-west and West. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1160 mm with average temperature of 18.6°C (Climatic Data Org, 2016). On-farm, test sites were located in four villages namely Ujindile, Uhambule, Msimbazi and Ufwala.

3.6.3 Data collection

Data used in this study were mainly collected through household survey involving face- to-face interview and focus group discussion (FGD). A total of 202 participant households from 12 villages were involved in the study. Out of the total famers, 111 farmers were Sasso strain keepers whereas 91 farmers were Kuroiler chicken keeping farmers. In addition, in order to ascertain the likelihood of the adoption of the introduced chicken strains, in-depth interviews of extension officers at ward and district levels and focus group discussions (FGDs) with farmers were conducted. The use of participatory research methods such as FGDs is geared towards planning and conducting the research process with those people whose life-world and meaningful actions are under study (Bergold and Thomas, 2012). Twelve FGDs, each comprising a representatives of 12 ACGG participants and none participants across the three sites systems, were held between September and December 2017. The FGDs were conducted using a check-list guide (Appendix 2). The data collected were streamlined to 22 variables (Fig. 2.1) that are fundamental to adoption prediction functions as described in appendix 6. These include: profit orientation, risk orientation, enterprise scale, interested nonparticipant farmers,, production constraints, practice complexity, observability, advisory support, the relative upfront cost of the practice, time for profit and benefit to be realized in the future and ease and convenience of managing the introduced strains.

3.6.4 Estimation procedure

The Adoption and Diffusion Outcome Prediction Tool (ADOPT) (Figure 3.1) was applied to predict the likely peak level and proportional of the household that might adopt the introduced chicken strains and the probable time taken to reach that peak under prevailing environment. ADOPT is an MS Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a particular target population in mind (Dhehibi *et al.*, 2017; Kuehne *et al.*, 2017). As indicated (Fig. 3.1), ADOPT uses 22 parameters covering four areas that influence the rate and peak level of adoption: i) population specific influence, ii) relative advantage of the population, iii) actual advantage of using the technology/relative advantage of the practice and iv) learning of the actual advantage of the technology.

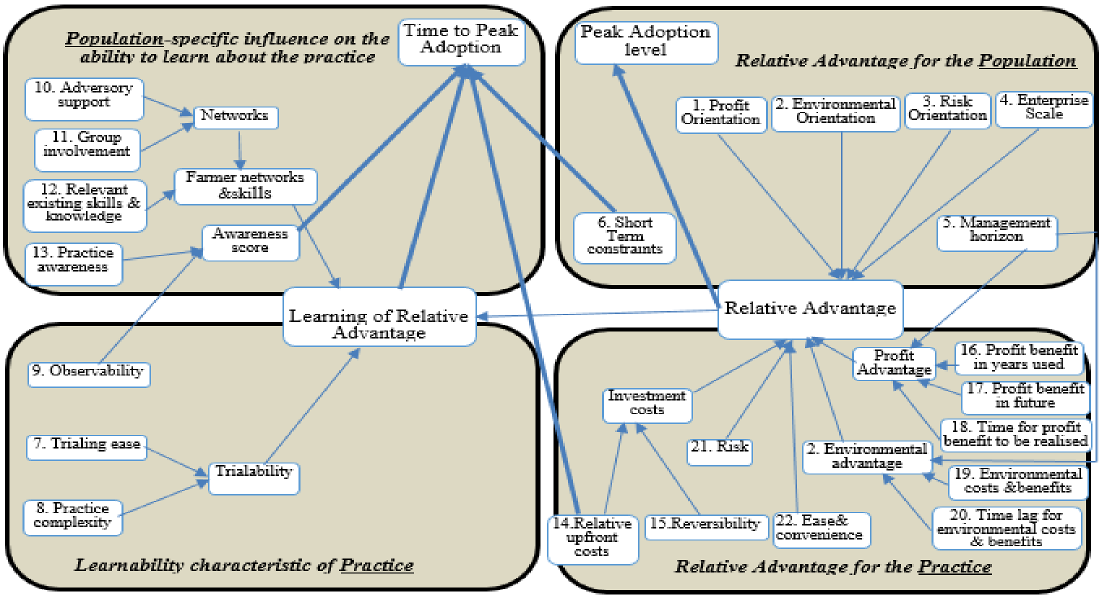


Figure 3.1: Adoption and diffusion outcome prediction tool framework (ADOPT)

Source: Kuehne *et al.*, 2017

While countless models of the adoption and diffusion of innovations exist, designing, calculating and interpreting results remains inaccessible for many people, ADOPT was created as a solution to this problem, and has three primary functions: (1) predicting an innovation‘s likely peak extent of adoption and likely time for reaching that peak, (2) encouraging users to consider the influence of a structured set of factors affecting adoption, and (3) engaging research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable (USAID, 2015). According to Kuehne *et al.* (2017), the tool operationalizes a framework that is based on well-established adoption theory and literature (Lindner, 1987; Pannell, *et al.*, 2006; Rogers, 2003).

Given that technology uptake is a complex and nonlinear process, influenced by multiple factors; it requires useful theories/tool to provide a full picture of the adoption process (Meijer *et al.*, 2015). ADOPT provides a comprehensive framework which takes into account the interaction of various factors that influence decision-making among farmers with regard to innovation uptake (Akroush and Dhehibi, 2015; USAID, 2015; Dhehibi *et al*., 2017; Kuehne *et al*., 2017).

ADOPT is configured with the following equations (Kuehne *et al*., 2017) useful in generating the outputs.

$$\pi \text{ advantage} = (\text{Profit benefit in years used} + \text{Profit benefit in future} * (1 + \text{Discount rate}^{-\text{Years to Future Profit Benefit}}))/2 \qquad 3.1$$

$$\text{Env. benefit} = \text{web} * \text{Environmental benefit} * \left(1 + \text{Discount rate}^{-\text{Years to environmental benefit}}\right) \qquad 3.2$$

$$\text{Relative advantage} = [(1 + \text{wp} * \text{Profit orientation}) * \pi \text{ advantage} + (1 + \text{wr} * \text{Risk orientation}) * \text{Risk} + \text{Ease and convenience} + (1 + \text{we} * \text{Environmental orientation}) * \text{Environmental advantage}] * (1 + \text{wes} * \text{Enterprise scale}) + \text{wic} * (\text{Investment cost} - \text{Max investment cost}) \qquad 3.3$$

$$\text{Peak adoption} = \text{Pmin} + (\text{Pmax} - \text{Pmin})/(1 + \text{EXP}(\text{cc} - \text{Relative advantage} * \text{cp}) \qquad 3.4$$

$$\text{Trialability of Practice} = (\text{Trialing ease} + \text{Practice complexity})/ \qquad 3.5$$

$$\text{Networks} = \text{Min}\,(\text{wgi} * \text{Group involvement} + \text{Advisory support}, 7) \qquad 3.6$$

$$\text{Learning of Relative Advantage} = \text{Trialability of practice} + \text{Farmer networks skills} + \text{wRA} * \text{Relative advantage} \quad 3.7$$

$$\text{Awareness Score} = A_{min} + \text{Practice awareness} + \text{Observability} - A_o * \text{Practice awareness} * \text{Observability} \quad 3.8$$

$$\text{Farmer networks and skills} = F_a + F_b * \text{Relevant existing skills \& } knowledge + F_c * \text{Networks} + F_d * \text{Relevant existing skills and knowledge} * \text{Networks} \quad 3.9$$

$$\text{Time to peak adoption} = \text{MAX}(T_{max} - \text{Learning of Relative Advantage} * L_m + \text{IF}(\text{UpfrontCosts} \geq 4, 0, T_{min} - \text{UpfrontCosts}) + (C_{max} - \text{ShortTermConstraints}) * \text{ShortTermConstraints} - \text{AwarenessScore}, 3) \quad 3.10$$

Whereby π is profit, Env. benefit is environmental benefit and for this analysis, its score is 100%; that environmental benefits are accrued equally to all farmers, Discount rate = 0.02 if Almost all have a long-term management horizon; 0.04 if A majority have a long term management horizon; 0.06 if About half have a long term management horizon; 0.08 if A Minority have a long-term management horizon; 0.1 if Almost none have a long-term management horizon.

In addition, key parameters configured in the ADOPT model detailed in Table 3.1 include: w_p=Profit orientation weight (0.4), w_r=Risk orientation weight (0.2), w_e =Environmental weight (0.4), w_{ic} =Enterprise scale weight (0.4), w_{ic}=Risk effect weight (0.6), T_{max} =Maximum time to adoption (50). The output of the tool is a value in years from time to peak adoption and a percentage value for peak adoption level.

Table 3.1: Parameters in the ADOPT model

Parameter	Definition	Parameter	Definition
$w_{p=}$	Profit orientation weight (0.4)	C_{max}	Maximum time added due to short-term constraints (4)

w_r	Risk orientation weight (0.2)	w_{ia}	Practice awareness weight (0.)
w_e	w_e=Environmental weight (0.4)	w_o	Observability weight (0.)
w_{ic}	Investment cost weight (0.33)	A_{min}	Minimum level for awareness score (-1.25)
w_{es}	Enterprise scale weight (0.4)	A_o	Weight on interaction between practice awareness and observability (0.15)
w_{re}	Risk effect weight (0.6)	w_{eb}	Environmental benefits weight (0.6)
T_{max}	Maximum time to adoption (50)	w_{RA}	Rescales RA score to have equal influence on learning as do Trialability and Farmer Networks & Skills
T_{min}	Minimum time to adoption (3)	w_{gi}*	Group involvement weight (0.7)
P_{min}	Minimum adoption rate (1)	c_c	Peak adoption curve parameter (3)
P_{max}	Maximum adoption rate (98)	c_p	Peak adoption curve parameter (0.3)
F_a	Intercept term for Farmer networks and skills (-0.63)	F_b	Weight on existing skills and knowledge (1.13)
F_c	Weight on networks (0.63)	F_d	Weight on interaction between networks and skills (−0.13)
L_m	Scalar of Learning of Relative Advantage Score (3.0)		

3.7 Results and Discussions

The general assessment of the introduced chicken strains indicates that farmers in selected sites consider the introduced strains useful and beneficial to them. The results indicate that the peak for adoption of the introduced chicken strains in Wanging’ombe, Bahi and Ifakara sites will be 38, 34and 29% after 9, 8 and 7 years respectively (Fig. 2.2). The predicted adoption peak level in Wanging’ombe is the highest because of market access for both inputs and poultry products. The district is located nearby Makambako Town centre, which is so potential for business activities. In Ifakara, it was noted that the predicted level of adoption was low in comparison with other sites. Contrary to expectation; Ifakara has the highest scavenging areas around homesteads and good environment which support production of crops to support chicken feeding. Bahi District is rather dry with limited food production, culminating in less feed available for chickens. The lower level of predicted adoptions is largely contributed by fact that either farmer in the area have many other options of income generating activities, or probably the strains are still new and it may take time to evaluate and make commitments to invest.

Moreover, the predicted adoption rates and the expected peaks present an impressive result given that in Sub Saharan Africa (SSA) new agricultural technology uptake has been reported to be rather low especially if the technology requires the use of a combination of inputs (Mukasa, 2016). For example, the uptake of tissue banana in Kenya was only about 10% after 12 years (Langat *et al.*, 2013). The findings are also consistent with other ex-post adoption studies of agricultural technologies in Africa. For example, in Tanzania, Kahimba *et al.* (2014) reported that in Arusha region, only 23.7% of farmers adopted minimum tillage practices (such as zero tillage, ripping and minimum tillage) while in the Dodoma region, 29.1% adopted pit technology as planting technique. However, Simtowe *et al.* (2011) observed that if all farmers had been exposed to improved varieties, potential adoption rate of improved pigeon pea in Northern Tanzania would be 62%. These findings imply that there is a potential for increasing adoption rate of the introduced chicken strains once all farmers become aware.

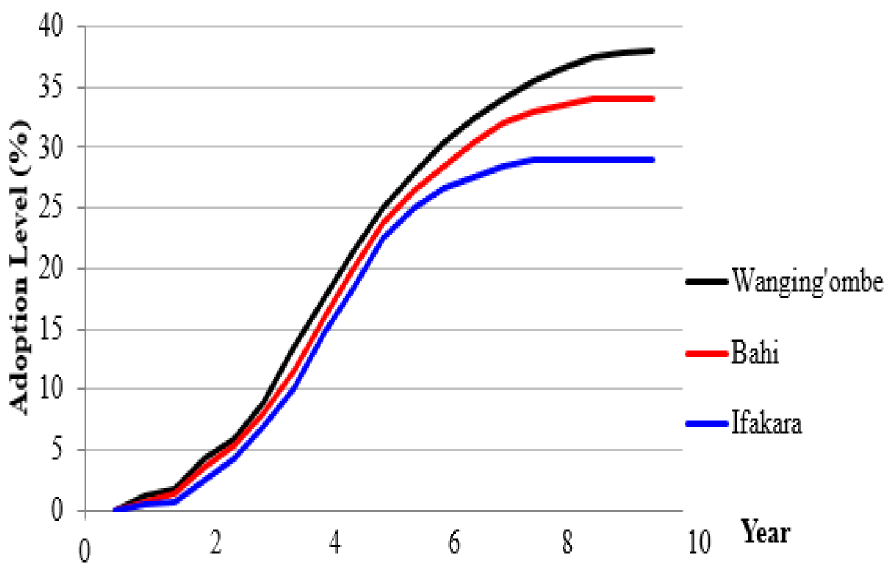


Figure 3.2: Predicted adoption level of introduced chicken strains

Sensitivity analysis and factors affecting changes in adoption rate

Sensitivity analysis of the likelihood of adoption (Fig. 3.3) indicates that the adoption peak level may change due to change in prediction parameters. Results indicate that there is likelihood of adoption peak to reach about 59, 49 and 57% in Bahi, Ifakara and Wanging'ombe respectively. However, the step down procedure indicates that the peak level may also decline to about 17, 16 and 21% in Bahi, Ifakara and Wanging'ombe respectively. A range of factors which may influence the rate adoption of introduced chicken strains include; scale of chicken keeping, relative upfront costs, profit accrued in the year of introduction, projected profit/benefit, risks and ease and convenience of keeping the introduced strains as detailed in subsequent paragraph.

Factors affecting the adoption of include the scale of chicken keeping, relative upfront costs, profit accrued in the year of introduction, projected profit/benefit, risks and ease and convenience of keeping introduced strains (Fig. 3.4, 3.5 and 3.6). In Bahi district (Fig. 3.4), an increase in the scale of operation may contribute to changes in the adoption rate by 17% up and by 14% down. With regard to Ifakara site, the sensitivity analysis (Fig.3.5) reveals that, if the introduced strains are promoted to large scale, they may contribute to increase adoption rates by 19% otherwise may contribute to decline in the adoption rate by 14%. While, in Wanging'ombe sites (Fig. 3.6), the changes in the scale of operation among those involved in keeping introduced strains may contribute to changes in adoption rate by 17% up and by 14% down. These results are consistent with the literature on the correlation between farm size and adoption of the innovation (Mignouna *et al.*, 2011; Lavison, 2013).

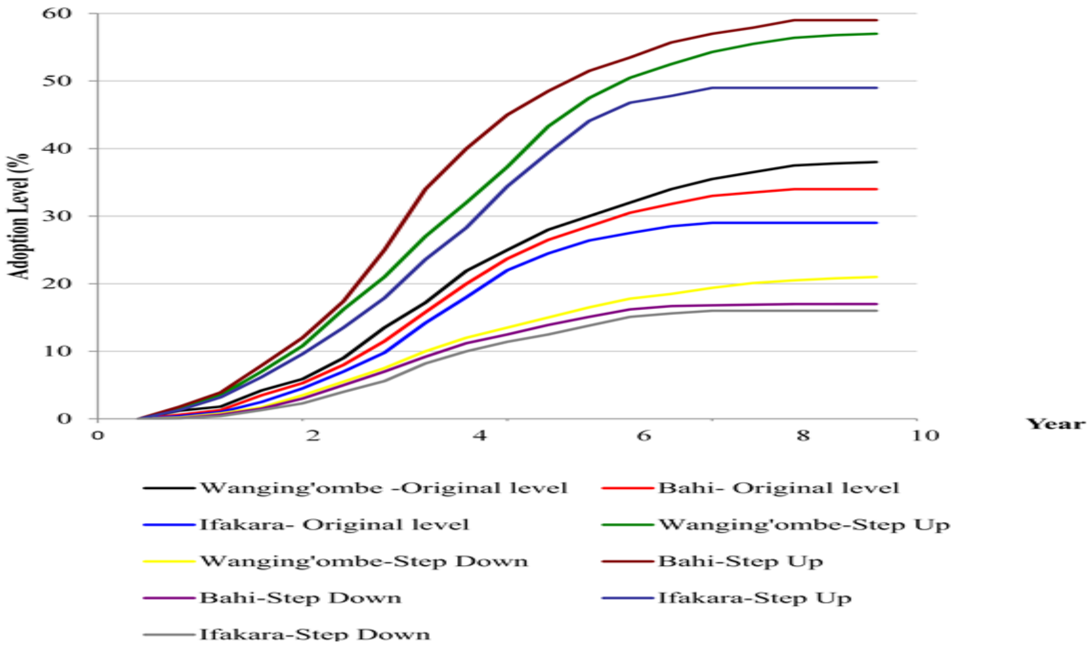


Figure 3.3: Sensitivity Curve for changes in adoption level of the introduced chicken strains

Likewise, a low upfront cost is critical to improved innovation uptake among small holder chicken keepers. Farmers observe that reduced upfront costs would contribute to increase adoption of the introduced strains by 18.5% (Fig. 3.4), 19% (Fig. 3.5) and 18% (Fig. 3.6) in Bahi, Ifakara and Wanging'ombe sites respectively. However, increased upfront costs may contribute to decline in adoption of introduced strains by 18, 14 and 13% in Bahi, Ifakara and Wanging'ombe sites respectively. The findings are consistent with rich literature that explains negative relationship between the upfront costs of adoption of the innovation (Makokha *et al.*, 2001; Wekesa *et al.*, 2003; Muzari *et al.*, 2013).

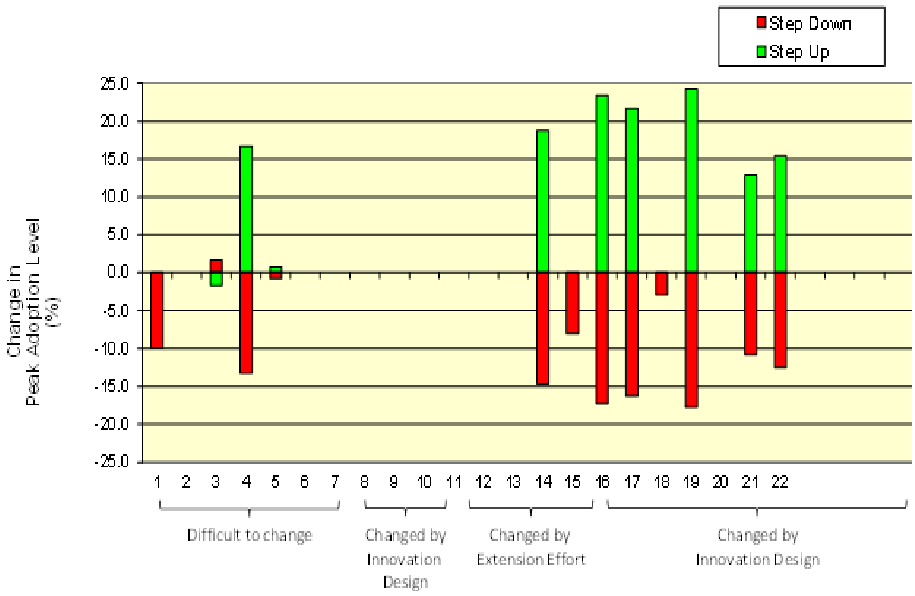


Figure 3.4: Factors affecting change in the peak level of adoption rate in Bahi sites

Farmers considered profit and future benefit in general to be critical in supporting increased adoption. Raised awareness that the introduced strains are beneficial may contribute to the increase in adoption as depicted in Fig.3.3, 3.4 and 3.5. However, farmers revealed that if profit and future benefit relative to available local chickens is not realized, the projected adoption may be reduced by 16, 15 and 10.5% in Bahi, Ifakara and Wanging'ombe sites respectively. According to Caswell *et al.* (2001), exposure to information about the profit of the new technologies as such significantly affects farmers' choices about it.

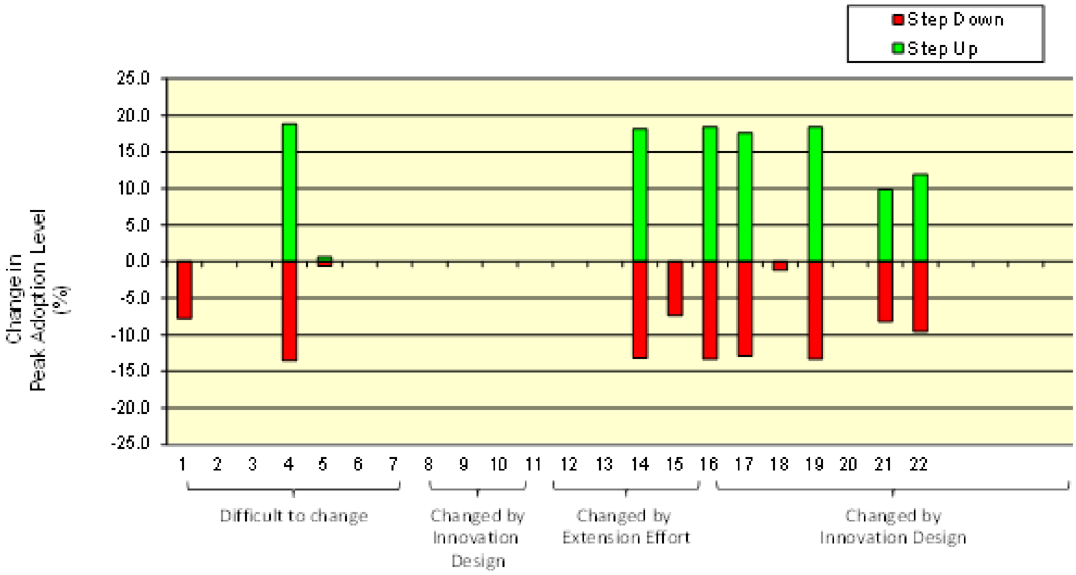


Figure 3.5: Factors affecting change in the peak level of adoption rate in Ifakara sites

Furthermore, sensitivity analysis indicates that risks (mortality, higher consumption of feeds and failure to brood) associated with keeping introduced strains play greater role in affecting farmers' decisions in adopting the technology. Taking into account on the risk associated with keeping introduced strains, adoption will be reduced by 11% in Bahi District (Fig. 3.3). However, if the observed risks are reduced, the adoption rate may be increased by 13%. In Ifakara site (Fig. 3.4), reduction of risks associated with keeping introduced strains increases uptake by 10%, otherwise there is possibility of contributing to reduced adoption rates by 8%. In Wanging'ombe sites (Fig. 3.5), farmers observe that reduced risks may contribute to increase adoption of the introduced strains by 11%, otherwise could lead to decline in adoption by 9%. The effect of risk on adoption revealed by this study is in line with the result by Salazar and Rand (2016) who observed that risk-averse farmers did not adopt improved seeds technology because they considered such technology to raise production risk by increasing yield variability significantly. In contrast, if the new technology has the potential to attenuate variability in economic outcomes, then it would be more rapidly adopted among risk-averse farmers.

Lastly, sensitivity analysis was meant to determine how easy and convenient in keeping introduced chicken strains adopting the keeping of introduced strains. The results indicate that ease and convenience are other potentially important contributing factors to the adoption decision among farmers. Other things being equal, ease and convenience of managing introduced chicken trains were found to contribute to increase in the adoption rate by 15, 12 and 13% in Bahi, Ifakara and Wanging'ombe sites respectively. Difficulties in keeping these strains especially the requirement for additional inputs was found to affect the increase in adoption of introduced strains by 13, 9.5 and 11% in Bahi, Ifakara and Wanging'ombe sites respectively. A degree at which a probable adopter can give a trial on a small scale first before accepting it from beginning to the end is a major determinant of technology adoption (Doss, 2003). The results is consistent with the results by Mignouna *et al.* (2011) who revealed that, the features of the technology were the reasons for adopting Imazapyr-Resistant maize (IRM) technology in Western Kenya. They argued that farmers who identify the technology being consistent with their needs as well as suitable were likely to adopt technology.

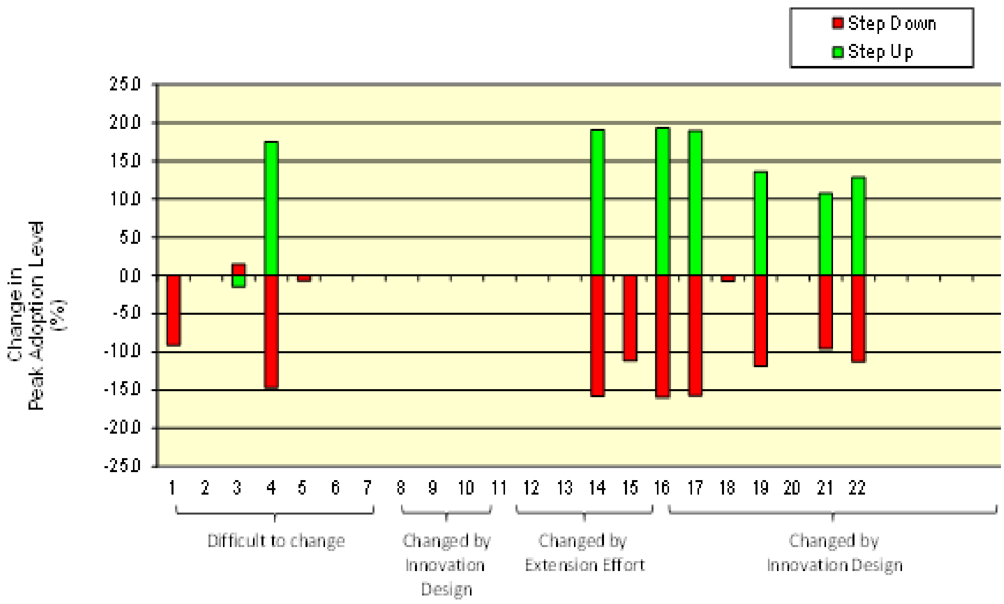


Figure 3.6: Factors affecting change in the peak level of adoption rate in Wanging'ombe sites

3.8 Conclusions and Recommendations

In a nutshell, this study had identified and categorized the factors preventing the adoption of agricultural technology, they are mainly economic, social, institutional and technology Factors.

Based on the findings it could be concluded that there is high possibility of adoption and diffusion of the introduced chicken strains, albeit at a different pace between selected districts where the on farm test was conducted. The difference in reaching the peak adoption is associated with the extent to which the farmers may be sensitized and the availability of these chickens. The sensitivity analysis identified scale of chicken keeping, relative upfront costs, and profit accrued in the year of introduction, projected profit/benefit, risks and ease and convenience of keeping introduced strains as the main determinant of peak adoption. It is recommended that to enhance adoption and diffusion rates of introduced chicken strains, more efforts should be directed at ensuring ready availability of the introduced strains, reduction of risks and promotion of innovative ways of reducing upfront costs.

Acknowledgements

The authors acknowledge Bill and Melinda Gates Foundation (BMGF) for financial support to the Africa Chicken Genetic Gains (ACGG) Project which supported this study. Secondly, sincerest thanks are extended to the Commonwealth Scientific and Industrial Research Organization (CSIRO) for granting authors the Adoption and Diffusion Outcome Prediction Tool (ADOPT) for analysis. Lastly, particular gratitude goes to the smallholder chicken keepers who agreed to participate in the on farm test of the introduced chicken strains and provided data for this study.

References

ACGG. (2015). Site Selection Framework. ACGG Project Document. pp 6.

ACGG. (2016). African Chicken Genetic Gain project profile.pp 2.

AFNETA. (1992). Alley Farming Training Manual Volume 1 pg 196. [http://biblio. iita. org/documents] site visited on 21/11/2016.

Akroush, S. and Dhehibi, B. (2015). Predicted Willingness of Farmers to Adopt Water Harvesting Technologies: A Case Study from the Jordanian Badia (Jordan). *American-Eurasian Journal of Agricultural and Environmental Sciences* 15(8): 1502-1513. [http:// dx.doi. org/10.5539/ sar.v6n1p80] site visited on 20/11/2018.

Barrows, R. and Röling, N. (1989). Extension Science: Information Systems in Agricultural Development. *American Journal of Agricultural Economics* 71(3): 833-834. [https://doi.org/10.2307/1242055] site visited 20/10/2020.

Bass, F. M. (1969). A New-Product Growth Model for Consumer Durables. *Management Science* 15: 215-227. [https://www.jstor.org/stable/ 2628128] site visited on 02/11/2017.

Bergold, J. and Thomas, S. (2012). Participatory Research Methods: A Methodological Approach in Motion. Qualitative Social Research. [http://www.qualitative-research.net/] site visited on 11/10/2018.

Biziman, J. C. and Richarson, J. W. (2018). Agricultural technology assessment for smallholder farms: An analysis using a farm simulation model (FARMSIM). *Computers and Electronics in Agriculture* 146: 406-425. [https://doi.org/ 10.1016/j. compag.2018.11.038] site visited on 20/11/2019.

Caswell, M., Fuglie, K., Ingram, C. and Kascak, S. (2001). Adoption of Agricultural production practices: Lessons learned from the US. Department of Agriculture area studies project. Washington, DC. US Department of Agriculture. Resource Economics Division, Economic Research service, Agriculture Economic Report No. 792.

Climatic Data Org. (2016). Tanzania Climatic Data. [https://en.climate-data.org] site visited on 12/03/2018.

Dhehibi, B., Nejatian, A., Wahaibi, H., Atroosh, K., Yafei, M.S., Otaibi, A., Hendi, M. and Belgacem, A. O. (2017). Adoption and Factors Affecting Farmer's Adoption of Technologies in Farming System: A Case Study of Improved Technologies in ICARDA's Arabian Peninsula Regional Program. *Journal of Sustainable Development* 10 (6): 1-13. [.http://www.ccsenet.org/] site visited on 20/11/2018.

Doss, C. R. (2003). Understanding farm level technology adoption: lessons learned from CIMMYT's microsurveys in Eastern Africa. Working Paper 03-07.pp. 20. [.cimmyt.org/bitstream/handle/] site visited on 20/11/2020.

De Janvry, A., Sadoulet, E and Dar, M. H. (2015). Technological innovations, downside risk, and the modernization of agriculture. [http://are.berkeley. edu/~esadoulet] site visited on 20/11/2018.

Foster, A. D. and Rosenzweig, M. R. (2010). Microeconomics of technology Adoption. Economic Growth Centre Discussion Article No. 984. Yale University: New York. [https://doi. org/ 10. 1146/annurev. economics. 102308.124433] site visited on 11/11/2016.

Francis, C., Mundy, V., Janke, R. and King, J. (1995). Alternative Approaches to On-Farm Research and Technology Exchange. [http://digitalcommons.unl.edu] site visited on 11/11/2016.

Gupta. A., Kagin, J., Taylor, J. E., Filipski, M., Hlanze, L. and Foster, J. (2018). Is technology change good for cotton farmers? A local-economy analysis from the Tanzania Lake Zone. *European Review of Agricultural Economics* 45(1): 27–56. [doi:10.1093/erae/jbx022] site visited on 12/05/2020.

Holden, T.S. (2014). Risky Choices of Poor People: Comparing Risk Preference Elicitation Approaches in Field Experiments. Centre for Land Tenure Studies Working Article 10/14. pp 46. [doi: 10.13140/2.1.4482.7200] site visited 21/11/2018.

Kahimba, F.C., Mutabazi, K.D., Tumbo, S.D., Masuki, K.F. and Mbungu, W.B. (2014). Adoption and scaling-up of conservation agriculture in Tanzania: Case of Arusha and Dodoma regions. *Journal of Natural Resources* 5: 161-1765. [http://dx.doi.org/10.4236/nr.2014.54016] site visited on 15/11/2018.

Kalaitzandonakes, N., Grigoroudis, E., Carayannis, E.G. and Rozakis, S. (2018). *Innovation and Technology Transfer in Agriculture*. In the book of From Agriscience to Agribusiness: Theories, Policies and Practices in Technology Transfer and Commercialization. pp 490. Springer ebook. [https://link.Springer.com/book/10.1007%2F978-3-319-67958-7] site visited on 29/04/2020.

Kaliba, A.R.M., Verkuijl, W., Mwangi, A.J.T., Mwilawa, P., Anandajayasekeram, H. and Moshi, A.J. (1998). Adoption of Maize Production Technologies in Central Tanzania. International Maize and Wheat Improvement Center (CIMMYT), the United Republic of Tanzania, and the Southern Africa Centre for Cooperation in Agricultural Research (SACCAR). [http://www.tanzaniagateway.org] site visited on 21/09/2018.

Komwihangilo, D.M. (2015). The Role of Chicken in the Tanzanian Economy and Opportunities for Development: An Overview: First National Innovation Platform July 13th- 15th 2015 Blue Pearl Hotel, Dar es Salaam, Tanzania.

Kuehne, G., Llewellyna, R., Pannell B., Wilkinsonc, R., Dollingd, P. J., Ouzmana, J. and Ewinge, M. (2017). Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. *Agricultural Systems* 156: 115–125. [https://doi.org/10.1016/j.agsy.2017.06.007] site visited on 11/11/2018.

Langat, B. K., Ngéno, V. K., Nyangweso, P. M., Mutwol, M. J., Kipsat, M. J., Gohole, L. and Yaninek, S. (2013). Drivers of Technology Adoption in a Subsistence Economy: The Case of Tissue Culture Bananas in Western Kenya. An Article Presented at the 4th International Conference of the African Association of Agricultural Economists, September 22-25, 2013: Hammet, Tunisia. [http://ageconsearch. umn.edu/bitstream/161444/2] site visited on 11/11/2017.

Lavison, R. (2013). Factors Influencing the Adoption of Organic Fertilizers in Vegetable Production in Accra, Msc Thesis, Accra Ghana. [http:// 197.255. 68.203/ handle/1 23456789 /5410] site visited on 21/08/2018.

Loevinsohn, M., Sumberg, J. and Diagne, A. (2012). Under what circumstances and conditions does adoption of technology result in increased agricultural productivity? Protocol. London: EPPI Centre, Social Science Research Unit, Institute of Education, University of London. [https://eppi.ioe.ac.uk] site visited on 01/05/2017.

Makokha, S., Kimani, S., Mwangi, W., Verkuijl, H. and Musembi, F. (2001). Determinants of Fertilizer and Manure Use for Maize Production in Kiambu District, Kenya. CIMMTY, Mexico. [https://repository. cimmyt.org/xmlui] site visited on 7/06/2017.

Meijer, S.S., Catacutan, D., Ajayi, O. C., Sileshi, G.W. and Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in Sub-Saharan Africa. *International Journal of Agricultural Sustainability* 13 (1): 40-54. [https://doi.org/10.1080/14735903.2014.912493] site visited on 11/11/2016.

Mignouna, B., Manyong, M., Rusike, J., Mutabazi, S. and Senkondo, M. (2011). Determinants of Adopting Imazapyr-Resistant Maize Technology and its Impact on Household Income in Western Kenya. *Journal of Agrobiotechnology Management and Economics* 14(3): 158-163. [https://mospa ce.umsystem.edu] site visited on 06/07/2018.

Milkias, D. and Abdulahi, A. (2018). Determinants of Agricultural Technology Adoption: The Case of Improved Highland Maize Varieties in Toke Kutaye District, Oromia Regional State, Ethiopia. *Journal of Investment and Management* 7(4): 125-132. [doi: 10.11648/j.jim.2018 0704.13] site visited on 13/11/2018.

Miranda, Q. M., Farias, S.J., Schwartz, A. and de Almeida, P.L.J. (2016). Technology adoption in diffusion of innovations perspective: introduction of an enterprise resource planning system in a non-profit organization. *Revista de Administração e Inovação (Journal of Technology Management and Innovation)* 13(1): 48-57. [https://doi.org/10.1016/j.rai.2016.02. 002] site visited on 11/11/2016.

Mottaleb, K.A. (2018). Perception and adoption of a new agricultural technology: Evidence from a developing country. *Technology in Society* 55: 126-135. [https://www.sciencedirect.com/] site visited on 05/05/2020.

Mukasa, A.N. (2016). Technology Adoption and Risk Exposure among Smallholder Farmers: Panel Data Evidence from Tanzania and Uganda. African Development

Bank Group Working Article No. 233 April 2016. Conference held on December 4-5, 2015 in Addis Ababa, Ethiopia. [https://www. afdb.org/] site visited on 09/08/2018.

Muzari, W., Gatsi, W. and Muvhunzi, S. (2012). The Impacts of Technology Adoption on Smallholder Agricultural Productivity in Sub-Saharan Africa: *A Review, Journal of Sustainable Development* 5(8): 69-77. [http://dx. doi.org/10 .5539/jsd.v5n8p69] site visited on 12/11/2016.

Namwata, B.M.L., Lwelamira, J. and Mzirai, O.B. (2011). Adoption of improved agricultural technologies for Irish potatoes (Solanum tuberosum) among farmers in Mbeya Rural district, Tanzania: A case of Ilungu ward. *Journal of Animal and Plant Sciences* 8(1): 927- 935. [http://www.m.elewa.org/ JAPS/2010/8.1/4.pdf] site visited on 19/08/2018.

Paikoff, R.L. (1996). Adapting Developmental Research to Intervention Design: Applying Developmental Psychology to an AIDS Prevention Model for Urban African American Youth. *Journal of Negro Education* 65: 44–59. [www.jstor. org/stable/2967367] site visited on 12/08/2016.

Pedersen, K.E. (2012). Factors affecting the adoption of improved banana technologies in Northern Tanzania. Published by Rockwool Foundation Research Unit. [https://www.rockwoolfonden.dk] site visited on 22/09/2017.

Peshin, R. (2013). Farmers' adoptability of integrated pest management of cotton revealed by a new methodology. *Journal of Agronomy for Sustainable Development* 33(3): 563-572. [DOI:10.1007/s13593-012-0127-4] site visited on 12/08/2016.

Pindiriri, C. (2016). Breaking the Tradition Trap: Assessing Drivers of Modern Technology Adoption by Smallholder Farmers in Hurungwe District, Zimbabwe. African

Economic Conference held in Abuja, Nigeria. 5-7 December 2016. [https://www.afdb.org/uploads/tx] site visited on 12/01/2018.

Richey, R.C. (1994). Developmental Research: The Definition and Scope in Proceedings of Selected Research and Development Presentations at the National Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (16th, Nashville, TN, February 16-20, 1994. [http://files.eric.ed.gov] site visited on 15/08/2016.

Rodelio, B.C. and Silvino, Q.T. (2013). Sustainable Organic Farming in the Philippines: History and Success Stories. [http://wwwafaci.org] site visited on 12/08/2016.

Rogers, E.M. (2003). *Diffusion of Innovations* (5th ed.). The Free Press, New York, USA. 551pp.

RÖling, N.G and Jiggins, J. (1998). *Facilitating sustainable agriculture: participatory learning and adaptive management in times of environmental uncertainty*. Cambridge: Cambridge University Press. pp283–311. [https://research.wur.nl/en/publications/] site visited on 22/06/2017.

Salazar, C and Rand, J. (2016). Production risk and adoption of irrigation technology: evidence from small-scale farmers in Chile. *Latin America Economic Review*, 25(2): 2-37. [https://doi.org/10.1007/s40503-016-0032-3] site visited on 12/08/2016

Shaw, C.S. (2014). Agricultural Technology Adoption in West Africa. A Thesis Submitted to the Office of Graduate and Professional Studies of Texas A&M University in partial fulfilment of the requirements for the degree of Master of Science. [https://oaktrust.library.tamu.edu/] site visited on 10/08/2018.

Simtowe, F., Kassie, M., Diagne, A., Silim, S., Muange, E., Asfaw, S. and Shiferaw, B. (2011). Determinants of Agricultural Technology Adoption: The Case of Improved

Pigeon Pea Varieties in Tanzania. *Quarterly Journal of International Agriculture* 50(4): 325–345. [https://www.researchgate] site visited on 10/08/2018.

Thornton, P.K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S and Campbell, B.M. (2017). Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Journal of Agricultural Systems* 152:145-153 [DOI: 10.1016/j.agsy. 2017. 01.005] site visited on 06/05/2019.

United Republic of Tanzania (URT). (2012). National Sample Census of Agriculture Small Holder Agriculture. Volume III: Livestock Sector National Report. [http://www.kilimo.go.tz] site visited on 09/05/2016.

URT. (2015). Tanzania Climate Smart Agriculture Programme: 2015-2025. [http://www.kilimo.go.tz] site visited on 19/10/2016.

USAID. (2015). Scaling Agricultural Technologies and Innovation Diffusion. pp 57. [http://pdf.usaid.gov/pdf_docs/PA00KFQG.pdf] site visited on 19/10/2016.

Wekesa, E., Mwangi,W., Verkuijl, H., Danda, K. and De Groote, H. (2003). Adoption of Maize Technologies in the Coastal Lowlands of Kenya. CIMMYT, Mexico, D.F. [https://ageconsearch.umn.edu/bitstream] site visited on 13/10/2018.

Wisdom, J.P., Chor, B.H.K., Hoagwood, E.K. and Horwitz, M.S. (2014). Innovation Adoption: A Review of Theories and Constructs. *Journal of Administration Policy Mental Health.* 41(4): 480–502. [doi:10.1007/s10488-013-0486-4] site visited on 12/08/2016.

Wright, V. (2011). Rates of Adoption: The Diffusion of Agricultural Innovations. Service Design Research Working Article 06-11. Published by the Victorian Government

Department of Primary Industries East Melbourne. [http:// geoffkain eresearch.Com] site visited on 15/10/2018.

World Society for the Protection of Animals. (2011). Enhancing rural livelihoods and nutrition through higher welfare poultry production in India. Case study. [http://www. Wspa -international. org] site visited on 19/10/2016.

Yesuf, M.; Kassie, M. and Köhlin, G. (2009). Risk Implications of Farm Technology Adoption in the Ethiopian Highlands. Discussion Article Series on Environment for Development. pp18. [http://www.efdinitiative.org] site visited on 17/10/2016.

CHAPTER FOUR

4.0 TECHNICAL, ALOCATIVE AND ECONOMIC EFFICIENCIES OF KEEPING NEWLY INTRODUCED CHICKEN STRAINS AMONG SMALLHOLDER FARMERS IN SELECTED AREAS OF TANZANIA: AN APPLICATION OF STOCHASTIC DATA ENVELOPMENT ANALYSIS APPROACH

Rogers Andrew[1], Jeremia Makindara[2], Said H. Mbaga[3], Roselyne Alphonce[4]

1. Department of Policy, Planning and Management, Sokoine University of Agriculture, Morogoro, Tanzania
2. Department of Business Management, Sokoine University of Agriculture, Morogoro, Tanzania
3. Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania
4. Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania

Correspondence: Rogers Andrew, Email: randrew@sua.ac.tz

4.1 Abstract

Efficient production is very essential for smallholder chicken farmers to get the maximum possible output for improving productivity and ultimately profit of the farm. The study was conducted to investigate the technical, allocative and economic efficiency of keeping introduced chicken strain; Kuroiler and Sasso at the farm level by using the input constrained Stochastic Data Envelopment Analysis. Data for this analysis were collected from farmers who were involved in the African Chicken Genetic Gain project. The study applied developmental research design which involved providing of pre-brooded chicks to farmers in selected sites. The on-farm test involved a total of 202 farmers who were provided with six weeks old chicks. The findings show that farmers in the study sites were technically, allocatively and economically inefficient. The mean technical, allocative and economic efficiency indices were 19.9%, 68.8% and 12.9% respectively. In this regards, the study confirms the hypothesis that on average, smallholder chicken farmers were economically inefficient and hence to conclude that there is considerable scope to improve chicken production and productivity through improving economic efficiency in input allocation and use. It is therefore, recommended that scaling up of the introduced chicken strains must be integrated with technical knowledge to ensure efficiency in keeping the introduced chicken strains. Moreover, actors in the poultry sub sector should create better market information systems for efficient input procurement and sale of outputs.

Key words: Economic Efficiency, Stochastic DEA, chicken strains, farm level

4.2 Introduction

Local chicken farming is a widely practised agricultural activity with a high potential for poverty reduction, enhancing food security especially for the poor and for enhancing women’s position in the household and society in Tanzania (Roy, 2017). In Tanzania, the economic value of chicken keeping is worth about TZS 874 billion and 364 billion for meat and eggs respectively (Match Maker Associates Limited (MMA) and Transcend Enterprises Limited, 2018). Despite accounting for over 60% of the total chicken population in Tanzania and supplying nearly all poultry meat and eggs consumed in rural areas and about 20% in urban areas, the potential of the local chicken farming remains largely untapped (MMA and Transcend Enterprises Limited, 2018). In addition, albeit the contribution of chicken farming to national Gross Domestic Product (GPD), income and food security, yet the sector faces several challenges. These challenges include low capital base, inefficient management, economic inefficiency, technical inefficiency, diseases and parasites and poor housing. According to Dinka *et al.* (2010), one of the constraints facing local chicken farming is minimal and inefficient use of inputs. Further, with little level of inputs supply among smallholder farmers, studies have shown that these households fail to harness the full potential of technological advancement because of input allocative errors (Shanmugam and Venkataramani, 2006).

There have been several initiatives aiming at improving local chicken productivity in Tanzania (URT, 2017). One of the recent initiatives was the introduction of and on farm testing of new and dual purpose chicken strains (Sasso and Kuroiler) by the African Chicken Genetic Gains (ACGG) project. Kuroiler and Sasso are claimed to be fast growing and can produce about 150 eggs per year under moderate management (World Society for the Protection of Animals, 2011; Rodelio and Silvino, 2013). It is postulated that technological improvement in any kind of production process aims at creating a new production function such that any given quantity of resources yields a larger output. This output should at least be above the threshold level of resource inputs thereby enhancing efficient resources allocation to produce a given output at least cost (Ghatak and Ingersent, 1984). Hence, key question to be addressed by the study is, given the little resources farmers have, are they producing at the optimum level to gain the optimum economic benefit possible of these strains? This question can be answered empirically by examining the economic efficiency of keeping these strains. This is very important since efficiency is an important factor of productivity especially to local chicken farmers since their disposable resources to enterprise are meagre.

4.3 Analytical Review

The seminal work of Farrell (1957) defines efficiency as the ability to produce a given level of output at the lowest cost. Further, Farrell (1957) classifies efficiency as Technical

Efficiency (TE), Allocative Efficiency (AE) and Economic Efficiency (EE). The TE measures the ability of a firm to produce maximum output from a given level of inputs, or achieve a certain output threshold using a minimum quantity of inputs, under a given technology. Meanwhile, AE is concerned with the use of inputs in optimal proportions to produce a given quantity of output at minimum cost, considering existing technology and input prices. Further, EE occurs when the cost of producing a given output is as low as possible and is a product of TE and AE.

Two separate branches are dominating the literature of efficiency analysis: the non-parametric; data envelopment analysis (DEA) (Farrell, 1957; Charnes *et al.*, 1978) and the parametric; stochastic frontier analysis (SFA) (Aigner *et al.*, 1977; Kuosmanen, 2006). The DEA is a non-parametric Linear Mathematical (LM) programming estimation (Coelli, 1996) which does not assume a particular functional form but is governed by the standard axioms of production theory: monotonicity, convexity, and homogeneity and is capable of handling multiple inputs and outputs (Farrell, 1957). The main strengths of the DEA include: its ability to accommodate multiple inputs and outputs; it does not require explicit a priori determination of a production function and it measures efficiency of each Decision Making Unit (DMU) relative to the highest observed performance of all other DMUs rather than against some average (Coelli *et al.*, 2005). Furthermore, by incorporating many inputs and outputs simultaneously in the estimation, DEA provides a straightforward way of computing efficiency gaps between each DMU and the efficient producers (Coelli *et al.*, 2005).

Stochastic Frontier Analysis, on the other hand is the stochastic treatment of residuals, decomposed into a non-negative inefficiency term and an idiosyncratic error term that accounts for measurement errors and other random noise (Kuosmanen, 2006). Further, SFA is capable of handling production analysis with single output and multiple inputs. However, SFA builds on the parametric regression techniques, which require a rigid ex-ante specification of the functional form. One of the challenges applied economists have encountered in estimating flexible functional forms in the production or consumer context is that the theoretical curvature conditions (monotonicity, concavity/convexity and homogeneity axioms) that are implied by economic theory are frequently not satisfied by the estimated production, costs, profit or indirect utility function (Diewert and Wales, 1987).

However, the conventional DEA suffers from some limitations: it requires the production process that is characterized by the observed input-output variables, which are free of errors. The model assumes that any deviations from optimal output levels are due to inefficiency, rather than errors. This is recognized as the most serious limitation of DEA (Farrell, 1957; Charnes *et al*., 1978; Kuosmanen, 2006; El-Demerdash *et al*., 2016). In this regard, DEA estimates tend to exhibit greater variability compared to stochastic frontiers, by either overestimating mean TE (Bravo-Ureta *et al.*, 2007) or underestimating the efficiency measures (Sharma *et al*., 1997). Further, DEA approach might erroneously categorise all DMUs operating with extreme input-output quantities as efficient, when there are insufficient comparable units (Charnes *et al*., 1995).

As the literature of DEA grew in both theory and application, researchers felt the need to incorporate stochastic considerations in order to effectively account for the presence of measurement and specification errors, and to consider the inherent variability in various business processes (Talluri *et al*., 2006). These efforts are meant to bridge the gap between SFA and DEA models by combining the strengths of both that automatically reduce the identified weakness. These efforts are viewed as stochastic extension of DEA in the same way as SFA extends the classic deterministic econometric frontier models (Kuosmanen, 2006) to have Stochastic Data Envelopment Analysis (SDEA). For example, Banker and Maindiratta (1992) proposed an amalgam of DEA and SFA that combines a DEA-style nonparametric, convex, piecewise linear frontier with a SFA-style parametric composite error term consisting of noise and inefficiency components. Kuosmanen (2006) introduced the stochastic nonparametric envelopment of data (StoNED) model, which is an additive variant of Banker and Maindiratta's model. Brazdik (2008) proposed the chance constrained problems for DEA analysis that accounts for stochastic noise in the analysed data. Subhash (2004) modified the standard DEA model to measure relative efficiency in the presence of random variation in the all outputs produced from given deterministic inputs. Land *et al*. (1993) extended DEA to include the case of stochastic inputs and outputs through the use of chance constrained programming to form the SDEA which is also known as a Land, Lovell and Thore (LLT) model. The main goal of a SDEA model is to handle random variations in both input and output variables (Land *et al.,* 1993; Bruni, 2013; El-Demerdash *et al*., 2016). The input constrained SDEA is applied to incorporate stochasticity in input measures into the decision-making process (Talluri *et al*., 2006). Given the shortfalls of SFA and DEA models, the input-oriented SDEA model was adopted for this study.

4.4 Methodology

4.4.1 Description of the study sites

The study was conducted in three regions namely Dodoma, Morogoro and Njombe where on farm testing were in Bahi, Ifakara and Wanging`ombe respectively. Dodoma Region is located in the central part of the country on Latitude: -6° 00' 0.00' South and Longitude: 36° 00' 0.00' East. The region is bordered by Manyara region to the North, Singida region to the West, Iringa region to the South and Morogoro Region to the Southeast. It is primarily semi-arid and covers an area of 41 311 square kilometres. The region lies at altitude of 1 125M above sea level. Annual rainfall varies from 500 to 700 mm and annual average temperature of about 22.6°C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1°C (Climatic Data Org, 2016). Major crops include drought tolerant ones such as family of sorghum, groundnuts and sunflower. Four villages namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa were purposively selected in case of Bahi district.

Morogoro region is administratively divided into six districts, namely Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo. The region lies between Latitude 5 º58' and 10º0' South of the Equator, and Longitude 35º25' and 35º30' East. It is bordered by seven other regions: Arusha and Tanga regions to the North, the Pwani region to the East, Dodoma and Iringa to the West and Ruvuma and Lindi to the South. Morogoro region lies at an altitude of about 525 M above sea level. The annual rainfall ranges from 600 to 1 200mm with average annual temperature of about 25ºC. The zone is characterized by an average annual rainfall of 1160 mm with average temperature of 16°C. There are typically two distinct long and short rainy seasons of March–May and November–January/February, respectively, but this pattern is often interrupted (Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara district. The on-farm test sites were located in four villages: Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe region lies between Latitude 08º40' and 10º32' South of the Equator and between Longitude 33º47' and 35º45' East of Greenwich and an altitude of about 2 000 M above sea level. The region borders Iringa region in the North, Morogoro region in the East and Ruvuma region in the South. It also borders the Republic of Malawi via Lake Nyasa and part of Mbeya region in the North-west and West. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1160 mm with average temperature of 18.6°C (Climatic Data Org, 2016). On-farm test sites were located in four villages namely Ujindile, Uhambule, Msimbazi and Ufwala. Maize, sunflower, pulses and horticultural production dominate farming system of the sites.

5.4.2 Development Research design

To evaluate the technical efficiency, allocative efficiency and economic efficiency of the introduced chicken strains, developmental research design was applied. The design assumes a traditional model of skill in which the unit of analysis is taken to be the individual (AFNETA, 1992; Richey, 1994). According to Barrow and Röling (1989), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. The study design is in accordance to Thornton *et al.* (2017) that testing and dissemination of technology are at the core of development-oriented agricultural research. Selection of location for establishing on-farm testing sites was based on Tanzania's Agro Ecological Zones (AEZs) to present the general farming systems in Tanzania. The AEZs range from higher rainfall areas on the coast and highlands in the north, far west, south and southwest, to arid and semi-arid areas in the interior of the country (URT, 2015). Accordingly, cropping patterns, climatic differences reflect biophysical characteristics for growth and stability of chickens. On-farm testing for introduced chicken strains across different AEZs was meant facilitating farmers and other actors in poultry value chain evaluate the potential of the strains at farm level. Three assumptions underlie the design. First, selected farmers have had experience in keeping chickens so that the design does not add any fixed cost such as chicken house, feeding facilities and drinkers. In other words, on-farm testing used already available facilities. Secondly, time and labour spent in keeping introduced chickens and available local chickens were presumed similar and hence zero opportunity cost. Third, small-scale local farmers in Tanzania operate relatively similar in keeping chickens. Thus, any of AEZs fit for on-farm testing. According to ACGG (2015), households recruited to receive the chickens met the following criteria:

i. Chicken keeping households that had kept local chickens for a continuous period of at least two years prior to the baseline survey;
ii. Keeping at least 15 adult chickens but no more than 50;
iii. Willingness to accept 25 birds of randomly selected strain;
iv. Commitment to provide some supplemental feeds and
v. Willingness to participate in the project for a minimum of 72 weeks.

For setting the basic criteria for selecting farmers to participate in on-farm testing, the baseline survey was conducted. Baseline survey was conducted to identify legible population in central semi-arid, eastern sub-humid, southern highlands, lake zone and southern humid to represent different agro-ecologies in the country. Specifically, first step involved selection three regions and the selected ones were Morogoro, Dodoma and Njombe regions to present AEZs. In each region, one district was selected purposely taking into account the availability of villages which had about 20 and above households that have least 15 adult chickens but no more than 50. Secondly, out of the qualified villages, four of them from each district were selected randomly from the long list of villages. Subsequent stage involved randomly selection of households from the long list of households that met the set criteria. After random selection of qualified farmers, it followed provision of six-week pre-brooded chicks to these households whereby each farmer received 25 chicks. At this stage, each farmer received either Kuroiler or Sasso. Chicks received the recommended vaccination against Mareks, Newcastle Disease, Infectious Bronchitis and fowl pox before being distributed to farmers. Farmers continued keeping these strains based on their practices with some additional supplementation using locally available feeds and providing treatment and shelter under a semi-scavenging system (ACGG, 2016).

4.4.3 Data collection

Data used in this study were mainly collected from farmers participated in the ACGG project in selected on-farm testing sites. A total of 202 participant households from 12 villages were involved in the study. Out of the total famers, 111 farmers were Sasso strain keepers whereas 91 farmers were Kuroiler chicken keeping households. Data were collected through household surveys involving face-to-face interviews, observation and direct measurement. Direct observation was applied to rank quality of chicken house and accessories. The survey questionnaire was structured covering broad issues related to chicken enterprise: strains of chicken kept, the number of chickens, number of eggs sold, number of eggs hatched, number of eggs ready for selling, number of chicks/chicken sold and ready for sale, chicken keeping inputs (amounts and prices of feeders, brooder, chicks, eggs, feeds, medicines, vaccines, labour and time spent), number of dead chicken/chicks and the number of eggs not hatched. Feeds were weighed to determine the general supplementation levels. The participatory approach was applied to enable farmers to recall different situations, which made them change the feeding pattern. The feeding patterns were classified as: harvesting, harsh months, intermediate and no supplementation at all. In each situation, farmers were asked to estimate the level and frequency of providing feeds (kg/bundle) and medication (frequency) provided per twelve months were used in analysis.

4.4.4 Data analysis

The present study applied the input oriented Stochastic DEA framework by using the Data Envelopment Analysis Program (DEAP V2.1) to analyse economic efficiency. Farmers participating in on-farm testing of the introduced chicken strains were the decision-making units (DMUs) under this analysis. Suppose there are n homogenous Decision-Making Units (DMUs), in order to produce r number of outputs (r=1,2,3,…k), s number of inputs are utilized (s=1,2,3,… m,) by each DMU i (i=1,2,3,…n). Assume also that the input and output vectors of i^{th} DMU are represented by x_i and y_i, respectively and data for all DMUs be denoted by the input matrix (X) m×n and output matrix (Y) k×n. The input minimization process to measure technical efficiency for each DMU can be expressed as:

$$TE = Min_{\theta\lambda}\theta$$

Subject to:

$$-y_i + Y\lambda \geq 0,$$

$$\theta X_i - Y\lambda \geq 0$$

$$N1' \leq 1$$

$$\lambda \geq 0 \qquad 4.1$$

where, in the restriction N1'λ=1, N1' is convexity constraint which is an N×1 vector of ones and λ is an N×1 vector of weights (constants) which defines the linear combination of the peers of the i^{th} DMU. $1 \leq \theta \leq \infty$ and θ-1 is the proportional increase in outputs that could be achieved by the i^{th} DMU with the input quantities held constant and $1/\theta$ defines a technical efficiency score which varies between zero and one. If θ =1 then the farm is said to be technically efficient and if $\theta < 1$ the farm lies below the frontier and is technically inefficient.

Similarly, to estimate economic efficiency (EE), a cost minimizing DEA is specified as equation:

$$EE = Min_{\lambda x_i^*} W_i' X_i^*$$

Subject to:

$$-y_i + Y\lambda \geq 0,$$

$$X_i^* - X\lambda \geq 0,$$

$$N1', \lambda = 1,$$

$$\lambda \geq 1 \qquad 4.2$$

Where, W_i' is a transpose vector of input prices for the i^{th} DMU and X_i^* is the cost-minimizing vector of input quantities for the i^{th} farm given the input prices W_i and total output level yi. Economic efficiency is measured as the ratio of potential minimum cost of production ($W_i' X_i^*$) to the actual cost of production ($W_i X_i^*$).

However, most data are stochastic and noisy with additive observation or measurement errors, which are often assumed to be normally distributed (Morita and Seiford, 1999) and are determined in term of standard variance. The variance of each input or output is estimated as:

$$\hat{\sigma}^2 = \frac{1}{N_j - 1} \sum_{k=1}^{N_j} (x_j^k - \bar{x}_j)^2 \qquad 4.3$$

Accordingly, Morita and Seiford (1999), in the presence of stochastic variation, there are two situations to utilize stochastic information of DMUs. The inputs and outputs stochastic variations are expressed as ($X_0 + \delta_x$) and ($Y_0 - \delta_y$) respectively (Morita and Seiford, 1999 and Huang and Li, 2001). Therefore Stochastic Data Envelopment Analysis (SDEA) for i[th] DMU is determined as following:

$TE = Min_{\theta\lambda}\theta$

Subject to:

$(-Y_i + Y\lambda) + \delta_{yi} \geq 0,$

$(\theta X_i + \delta_{xi}) - Y\lambda \geq 0$

$N1' \leq 1$

$\lambda \geq 0$ 4.4

and EE is determined as:

$Min_{\lambda xi^*} W_i' (X_i + \delta_{xi})^*$

Subject to:

$(-Y_i + Y\lambda) + \delta_{yi} \geq 0,$

$(X_I^* + \delta_{xi}) - (X + \delta_{xi})\lambda \geq 0$

$N1' = 1$ 4.5

Allocative efficiency can be estimated as the ratio of economic to technical efficiencies as:

$AE = EE/TE$ 4.6

4.5 Results and Discussions

Distribution of efficiency measures

A summary of the results as presented in Table 4.1 indicate that the mean TE was 19.9 and 18.2 for Sasso strain and Kuroiler strains respectively. The implication is that there exists about 80% potential for targeted farmers to increase their production as well as their income given the level of inputs supplied. Comparing Sasso strain household farmers and Kuroiler household farmers, generally, the difference in TE efficiency is not statistically different with Z calculated less than 0.65 (Critical Z value= 1.97). The maximum estimated TE is 1 in both strains, which means that some farmers were tangent to the frontier (Coelli *et al.,* 2005).

However, Fig. 4.1 shows that, about 81% of farmers were operating below 20% efficiency level while only 7% attained efficiency level of above 80% TE index. This implies that there was possibility of more output by using the same amount of inputs or applying small input mix to produce the same outputs. Comparing with other studies on technical efficiency of keeping chickens, the present results indicate lower efficiency score. For example, Ojo (2003) found the technical efficiencies of among Osun State of Nigeria farmers to vary widely between 0.24 and 0.93 with a mean of 0.76 and about seventy nine percent of the farmers had TE exceeding 0.70.Likely cause of lower efficiency indices is provision unstandardized supplements with high variation among farmers (Table 4.2). According to Muchadeyi *et al*. (2004), different birds are known to require different amounts of nutrients, depending on the production stage. For example, laying hens will require more for reproduction, whilst growers require more for tissue deposition.

Table 4.1: Summary statistics of technical, allocative and economic efficiency indices

Statistics	TE	AE	EE
		Sasso	
Mean	19.9	68.8	12.9
Standard Deviation	25.2	24.4	18.5
Minimum	2.2	13.8	0.9
Maximum	100.0	100.0	100.0
		Kuroiler	
Mean	18.2	59.6	11.8
Standard Deviation	23.8	24.6	22.0
Minimum	2.4	0.7	0.7
Maximum	100.0	100.0	100.0
z-value	0.65	0.01	0.07
Critical z value		1.97	

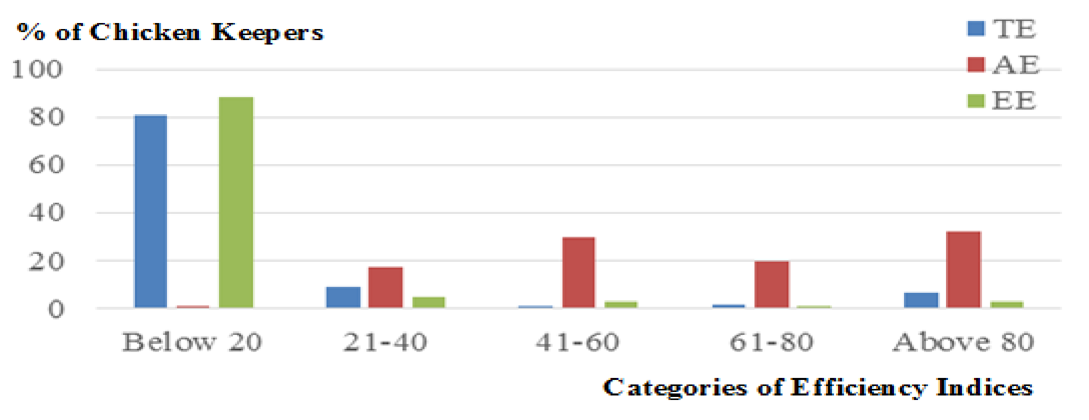


Figure 4.1: Distribution of technical, allocative and economic efficiency indices

Additionally, Table 4.2 indicates that farmers predominantly supplemented their chickens using energy-rich feeds (maize bran and rice bran) while protein rich ingredients and a mineral feeds were provided at lower level and by very few farmers. The revealed feeding situation is accordance to FAO (2019) that, village poultry sector, management is minimal and simply involves keeping the birds under free-range and scavenging conditions around the homesteads and rarely bestowing limited amounts of grain or bran. Accordingly, shortage of protein in the nutrition of chickens in rural areas is the major constraint in balancing diet for improved input output relationship (Pedersen, 2002).

It is acknowledged that diseases make poultry production a risky venture. Vaccination and treatment play great role in technical efficiency as they contribute much on mortality rate, eggs production and weight gain. Farmers and extension officers reported the signs of egg peritonitis and related infections as the plausible causes of mortality. Egg yolk peritonitis is the inflammatory reaction of peritoneum caused by the presence of yolk material in the coelomic cavity (Srinivasan *et al*., 2013).

The AE index varies across farmers from 13.8 to 100 and 0.7 to 100%, with a mean of 68.8% and 59.6% among Sasso and Kuroiler keeping farmers respectively. The result for mean allocative efficiency also suggests that the cost of production could be reduced by 31.2% and 40.4% in Sasso and Kuroiler keeping respectively. On one hand, these results relate to results by Daryanto (2014) who established that farmers were allocatively inefficient with a mean index of 70.0%.

Comparably, farmers who participated in on-farm testing of introduced chicken strains were more allocatively efficient that those from Kaduna state in Nigeria whereby the mean allocative efficiency index was 35% (Saliu *et al.*, 2015). However the results gave lower efficiency indices compared to other studies (Mahjoor, 2013; Omar, 2014). Singh *et al.* (2001) asserted that low and poor capital utilization in purchasing inputs is likely the cause of inefficiency in resources allocation, which leads to low economic efficiency scores.

Table 4.2: Summary statistics for feeds supplement per 12 months

Statistics	Maize bran (kg)	Rice bran (kg)	sunflower cake (kg)	Fishmeal (kg)	Minerals (kg)	Vegetables (bundle)
			Kuroiler strain			
Mean±SD	7.5±4.6	6.6±3.6	1.8±1.8	0.6±0.6	0.5±0.6	2.3±0.9
% of farmers	100	63	64	37	52	19
			Sasso strain			
Mean±SD	9.5±5.0	5.2±2.1	3.1±2.2	0.9±0.7	0.6±0.6	3.2±3.0
% of farmers	100	16	51	15	30	24

Lastly, farmers were also found to be economically inefficient with a mean EE index of 12.9% and 11.8% among Sasso and Kuroiler strains farmers respectively. This implies that farmers could reduce current average cost of production by 87.1 and 88.2% to achieve the minimum cost of production relative to the efficient farmers given the current output level. These results are similar of those of Heise *et al.* (2015) who undertook analysis of economic potential for investing in poultry sector in Nigeria. Their results show that, from an economic perspective, many producers manage their poultry farms inefficiently and therefore lose highly promising cost savings opportunities.

However, differences identified in efficiency indices between farmers provided with Sasso and those who received Kuroiler strain were not statistically significant at 5% significance level. Figure 4.1 shows distribution of EE whereby 88% of farmers were highly economically inefficient with EE indices of less than 20%. Meanwhile, Fig. 4.1 indicates that only 4% of target farmers had economic efficiency score greater ranging between 61% and 80%. The relatively low levels of economic efficiency indices imply that, farmers were in a better position to improve production and productivity just by reallocating inputs levels under market prices.

Moreover results of the current study are inconsistent with other poultry efficiency studies in terms of the low efficiency indices scores obtained. For example, results by Ohajianya *et* *al*. (2013) found that mean economic efficiency among local chicken farmers in Imo State Nigeria was 21%. This is probably due to lack of technical know-how to prepare feeds and supply them to chicken timely and at low cost. Accordingly, Dogan*et al.* (2018) put forth that, another possible explanation of the low economic efficiency scores may be the low capital utilization ratios of the farms.

4.5 Conclusions and Recommendations

It is concluded that farmers participated in on-farm testing of the introduced chicken strains were technically, allocatively and economically inefficient in keeping these chickens. The low mean technical, allocative and economic efficiency indices were suggests that there is considerable scope to improve chicken productivity in the study sites given the levels of inputs used. It is recommended that poultry stakeholders with intention to support the scaling up of the introduced chicken strains, have to develop strategies what will improve technical efficiency, allocative efficiency and economic efficiency to improve productivity.

Acknowledgements

Authors acknowledge Bill and Melinda Gates Foundation (BMGF)-Africa Chicken Genetic Gains (ACGG) Project and Sokoine University of Agriculture (SUA) which supported this study. The funding bodies had no role in the design of the study, data collection, analysis and interpretation of the results. Lastly, particular gratitude goes to the smallholder chicken keepers who agreed to participate in the on farm test of the introduced chicken strains and provided data for this study.

References

ACGG. (2015). Site Selection Framework. ACGG Project Document. pp 6.

ACGG. (2016). African Chicken Genetic Gain project profile. pp 2.

AFNETA. (1992). Alley Farming Training Manual Volume 1. [http://biblio. iita. org/documents.] site visited on 16/10/2016.

Aigner, DJ., Lovell, C.A.K. and Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Models. *Journal of Econometrics* 6: 21-37. [https://doi.org/10.1016/0304-4076(77)90052-5] site visited on 16/10/2016.

Banker, R.D. and Maindiratta, A. (1992).Maximum Likelihood Estimation of Monotone and Concave Production Frontiers. *Journal of Productivity Analysis* 3: 401-415. [https://www.jstor.org/stable/] site visited on 6/01/ 2017.

Barrows, R. and Röling, N. (1989). Extension Science: Information Systems in Agricultural Development. *American Journal of Agricultural Economics* 71(3), 833-834. [https://doi.org/10.2307/1242055] site visited on 20/10/2020.

Bravo-Ureta, B., Solis, D., Lopez, V.H.M., Maripani, J.F., Thiam, A. and Rivas, T. (2007). Technical efficiency in farming: A meta-regression analysis. *Journal of Productivity Analysis* 27(1):57-72. [doi: 10.1007/s11123-006-0025-3] site visited on 16/01/ 2017.

Brazdik, F. (2004). Stochastic Data Envelopment Analysis: Oriented and Linearized Models. World Bank working paper. [http://home.cerge-ei.cz/] site visited on 12/11/2018.

Bruni, M.E. (2013). Breast Cancer Screening: A Stochastic DEA Study. *American Journal of Operations Research* 3: 506-513. [http://dx.doi.org/ 10.4236/ ajor.2013.36049] site visited 12/11/ 2018.

Charnes, A., Cooper, W.W., Lewin, A.Y. and Seiford, L.M. (1995). Data Envelopment Analysts: Theory, Methodology and Applications, Kluwer. pp234.

Charnes, A., Cooper., W.W. and Rhodes, E. (1978). Measuring the Inefficiency of decision making units, European. *Journal of Operational Research* 2 (6):119-140. [https://www.utdallas.edu/] site visited on 23/11/2017.

Climatic Data Org. (2016). Tanzania Climatic Data. [https://en.climate-data.org] site visited on 03/12/ 2018.

Coelli, T.J. (1996). A Guide to DEAP Version 2.1. Data Envelopment Analysis (Computer) Program. Working Study96/08. [http:// une.edu. au/ econometrics /cepa.htm] site visited on 08/09/ 2016.

Coelli, T.J., Rao, D.S.P. and Battese, G.E. (2005). An Introduction to Efficiency and Productivity Analysis. (2ndedition). Kluwer Academic Publishers, Boston.

Daryanto, A. (2014). Technical, Allocative and Economic Efficiency of Pineapple Production in West Java Province, Indonesia: A DEA Approach. [DOI: 10.9790/2380-07631823] site visited on 21/03/ 2020.

Diewert, W.E. and Wales, T.J. (1987). Flexible Functional Forms and Global Curvature Conditions. *Econometrica* 55 (1): 43-68. [https://ideas.repec. org/a/ecm/ emetrp] site visited on 13/12/2018.

Dinka, H., Chala, R., Dawo, F., Leta, S. and Bekana, E. (2010). Socio-economic importance and management of village chicken production in rift valley of Oromia, Ethiopia. *Livestock Research for Rural Development* 22 (11): [http://www.lrrd.cipav.org.co/] site visited on 23/05/2019.

Dogan, N., Kaygisiz, F. and Altine, A. (2018). Technical and Economic Efficiency of Laying Hen Farms in Konya, Turkey. *Brazilian Journal of Poultry Science*.

20(2): 263-271. [https://doi.org/10. 1590/1806-9061-2017-0649] site visited on 11/04/2020.

El-Demerdash, B.E., El-Khodary, I.A. and Tharwat, A.A. (2016). A Stochastic Data Envelopment Analysis Model Considering Variation in Input and Output Variables. *International Journal of Data Envelopment Analysis and Operations Research* 2(1):1-6. [doi: 10.12691/ijdeaor-2-1-1] site visited on 12/05/ 2019.

Farrell, M.J. (1957). The Measurement of Productive Efficiency. *Journal of Royal Statistical Society, Series A (general)* 120(3): 253-281. [doi:10.2307/ 2343100] site visited on 19/11/ 2018.

Ghatak, S. and Ingerset, K. (1984). Agriculture and Economic Development. Johns Hopkins University Press, Baltimore. [http://econpapers. repec.org] site visited on 16/08/2016.

Heise, H., Crisan, A. and Theuvsen, L. (2015). The Poultry Market in Nigeria: Market Structures and Potential for Investment in the Market. *International Food and Agribusiness Management Review* 18(Special Issue A): 197-222. [https://www.ifama.org/resources/] site visited on 13/05/2020.

Huang, Z. and Li, S. (2001). Stochastic DEA Models With Different Types of Input-Output Disturbances. *Journal of Productivity Analysis, Springer* 15(2): 95-113. [https://doi.org/10.1023/A:1007 874 304 917] site visited on 24/03/2019.

Kuosmanen, T. (2006). Stochastic nonparametric envelopment of data: combining virtues of SFA and DEA in a unified framework, MTT Discussion Study No. 3/2006. [https://ideas.repec.org/p/ags/mt] site visited on 22/05/ 2019.

Land, K., Lovell, C. A. K. and Thore, S. (1994a). Chance-Constrained Data Envelopment Analysis. *Managerial and Decision Economics* 14: 541–554. [https://doi.org/ 10. 1002/mde.4090140607] site visited on 22/05/2019.

Mahjoor, A.A. (2013). Technical, Allocative and Economic Efficiencies of Broiler Farms in Fars Province, Iran: A Data Envelopment Analysis (DEA) Approach. [https://www.semanticscholar.org/] site visited on 21/03/2020.

Match Maker Associates Limited and Transcend Enterprises Limited. (2018). Poultry Subsector in Tanzania: A Quick Scan. pp 31. [www.agrob erichtenbuitenland.nl] site visited on 21/03/2020.

Mohamed, A.E. Omar, M.A.E. (2014). Technical and Economic Efficiency for Broiler Farms in Egypt. Application of Data Envelopment Analysis (DEA*). Global Veterinaria* 12 (5): 588-593. [https://www.idosi. org/gv/gv12(5)14/2.pdf] site visited on 21/03/2020.

Morita, H. and Seiford, M.L. (1999). Characteristics on Stochastic DEA Efficiency: Reliability and Probability Being Efficient. *Journal of the Operations Research Society of Japan* 42 (4):389-404. [https://doi.org/10.15807/ jorsj. 42.389] site visited on 22/05/2019.

Muchadeyi, F.C., Sibanda, S,. Kusina,N.T,. Kusina, J. and Makuza, S. (2004). The village chicken production system in Rushinga District of Zimbabwe. Livestock *Research for Rural Development Journal* 16 (6): 1-6. [http://www. lrrd. org/lrrd16] site visited on 11/04/2020.

Ohajianya, D.O., Mgbada, J.U., Onu, P.N., Enyia, C.O., Henri-Ukoha, A., Ben-Chendo, G.N. and Godson-Ibeji, C.C. (2013). Technical and Economic Efficiencies in Poultry Production in Imo State, Nigeria. *American Journal of Experimental*

Agriculture 3(4): 927-938. [www.sciencedomain.org] site visited on 29/10/2020.

Ojo, S. (2003). Productivity and Technical Efficiency of Poultry Egg Production in Nigeria. *International Journal of Poultry Science* 2: 459-464. [10.3923/ijps.2003.459.464] site visited 13/05/ 2020.

Pedersen, C.V. (2002). Production of semi-scavenging chickens in Zimbabwe. A PhD Thesis submitted to Royal Veterinary and Agricultural University, Copenhagen, Denmark in partial fulfilment of the requirements for the degree of Master of Science. 117pp.

Richey, R.C. (1994). Developmental Research: The Definition and Scope in Proceedings of Selected Research and Development Presentations at the National Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (16th, Nashville, TN, February 16-20, 1994. [http://files.eric.ed.gov] site visited 23/11/ 2016.

Rodelio, B.C. and Silvino, Q.T. (2013). Sustainable Organic Farming in the Philippines: History and Success Stories. [http://wwwafaci.org] site visited on 23/11/ 2016.

Roy, C.H. (2017). Local poultry market systems development in Tanzania; a myriad of hindrances leverage by stimulating private agribusiness investments. [https: //beamexchange.org/to_pdf/?url=/] site visited on 30/10/ 2018.

Saliu, L. A., Abdulrazaq, S. A. and Eleke, P. N. (2015). Production Efficiency of Poultry Egg (Layer) Production in Chikun and Igabi Local Government Areas of Kaduna State, Nigeria. *Nigerian Journal of Agricultural Economics* 6(1): 40-52. [DOI: 10.22004/ag.econ.267989] site visited on 19/03/2020.

Shanmugam, K.R. and Venkataramani, A. (2006). Technical Efficiency in Agriculture Promotion and Its Determinants: An Exploratory Study at the District Level, Indian. *Journal of Agricultural Economics* 61(2): 169-184. [https://ideas .repec.org/cgi-bin/refs.cgi] site visited on 19/03/ 2019.

Sharma, K.R., Leung, P.S. and Zaleski, H.M, (1997). Technical, Allocative and Economic Efficiencies in Swine Production in Hawaii: A comparison of parametric and nonparametric approaches. *Journal of Agricultural Economics* 20: 23-35. [https://tind-customer-agecon.s3.amazonaws. com] site visited on 18/03/ 2019.

Singh, S., Coelli, T. and Fleming, E. (2001). Performance of dairy plants in the cooperative and private sectors in India. *Annals of Public and Cooperative Economics* 72(4): 453-479. [DO-10.1111/1467-8292. 00178] site visited on 18/03/ 2018.

Srinivasan, P., Balasubramaniam, A.G., Murthy, K.R.T. and Balachandran, P. (2013). Bacteriological and pathological studies of egg peritonitis in commercial layer chicken in Namakkal area. *Asian Pacific Journal of Tropical Biomedicine.* 3(12): 988-994. [doi:10.1016/S2221-1691(13)60191-4] site visited on 11/05/2019.

Subhash, C.R. (2004). Data Envelopment Analysis: Theory and Techniques for Economics and Operations Research. Cambridge University Press. 2004. pp 364.

Talluria, S., Narasimhana, R. and Nair, A. (2006). Vendor performance with supply risk: A chance-constrained DEA approach. *International Journal of Production Economics* 100: 212–222. [100:212–222.DOI: 10.1016/j.ijpe.2004.11.012] site visited on 11/03/2018.

Thornton, P.K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S. and Campbell, B.M. (2017). Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Journal of Agricultural Systems* 152:145-153 [DOI: 10.1016/j.agsy. 2017. 01.005] site visited on 06/05/2019.

Tsadik, T. E., Tamir, B. and Sahile, Z. (2015). Husbandry practices of village poultry technology package and the nutritional quality of majorly used poultry feeds in the Central Oromia Region, Ethiopia. [http://www.lrrd.org] site visited on 22/05/ 2019.

URT (2014). Tanzania Agriculture Climate Resilience Plan, 2014-2019. Ministry of Agriculture, Food Security and Cooperatives, Dar es Salaam, Tanzania.83pp. [http://www.kilimo.go.tz] site visited on 25/03/2017.

URT. (2017). Tanzania Livestock Master Plan. Dar es Salaam. 2017/2018 – 2021/2022. 127 pp. [https://www.mifugouvuvi.go.tz/] site visited on 05/05/2020.

World Society for the Protection of Animals. (2011). Enhancing rural livelihoods and nutrition through higher welfare poultry production in India. In: Case Study. [http://www.Wspa-international. org/Images/Case] site visited on 20/10/2016.

CHAPTER FIVE

5.0 EFFECT OF INPUTS ON PRODUCTIONAND VARIABILITY OF INTRODUCED CHICKEN STRAINS AT FARM LEVEL IN SELECTED AREAS OF TANZANIA

Rogers Andrew[1], Jeremia Makindara[2], Said H. Mbaga[3], Roselyne Alphonce[4]

1. Department of Policy, Planning and Management, Sokoine University of Agriculture, Morogoro, Tanzania
2. Department of Business Management, Sokoine University of Agriculture, Morogoro, Tanzania
3. Department of Animal, Aquaculture and Range Sciences, Sokoine University of Agriculture, Morogoro, Tanzania
4. Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania

Correspondence: Rogers Andrew, Email: randrew@sua.ac.tz

5.1 Abstract

This study investigated the effect of inputs on the production and variability of introduced chicken strains. The study applied the developmental research design which involves provision of 25 six-week old chicks to 20 farmers in 12 on-farm testing sites. The study was carried out in Dodoma, Morogoro and Njombe regions to assess the effects of agro-ecological differences on production and production variability. Data used were gathered by using a structured questionnaire, direct measurement, farmers' and extension officers' records. A semi log multivariate regression model according to the Just and Pope

Framework was applied in this study. Results from the mean function revealed that maize bran, rice bran, sunflower cake, minerals, frequency of medication, vegetables and house condition had significant effects on production in both live chickens and eggs. Also, there is production variability attributable to inputs use and hence exposing farmers to risk. However, there was an inconsistent effect of input on production performance variability since some inputs were both variability increasing and reducing; that is, reducing in production of birds but, increasing in egg production for the same strain and vice versa. Therefore, it is likely that the full potential of the introduced strains requires standardized inputs and good management for reduced variability. It is important to design strategies that will lead to performance stability. Such strategies should include the design of trials at farm level to evaluate the input mix for chicken with minimum effect on output variability.

Keywords: production, variability, Just and Pope Function, Introduced Chicken Strains, On-farm testing

5.2 Introduction

In agricultural production, risk in terms of variability is an inherent part of the production process and plays an important role in both input use decisions and production of output (Asche and Tveteras, 1999; Kumbhakar, 2002; Nalley and Barkley, 2007). Agricultural production face risk surrounding the production and marketing processes which are related to unpredictable weather variation (drought, frost, flood, and wind storm), input quality, pest and disease attacks, price fluctuations, new technology failure, and changes in government policies. In addition, agricultural risk can be categorized into two main types namely, production risk which is characterized by high variability of production outcomes and price risk (Wanda, 2009; Bizimana and Richardson, 2017). With this regard, variability is among key the sources of risk in production process in Tanzania (Moshi *et al.*, 2017).

Hence, the performance of the introduced chicken strains is likely to suffer from the same and hence exposing farmers to risk. Additionally, agricultural performance variability also creates significant challenge in the design and implementation of technology (*De* Janvry, 1972; Chavas and Shi, 2015).

Recently, Tanzania established the Tanzania Livestock Master Plan (TLMP) 2017/2018-2021/2022 with overall target of raising annual chicken meat production almost eightfold; from about 60 800 to 465 600 tonnes and egg production from about 3.0 to 4.2 billion by year 2021/22(URT, 2017). The main pathways include: Improved Traditional Family Chicken (ITFC), Tropical Improved Chicken (TIC) and expanded Specialized/Commercial Chicken (SCC) with layers and broilers sub-systems. In addition, it considers interventions in the areas of animal health, genetics, marketing and processing being the cornerstone to increasing the contribution of the national poultry sector to gross national product by 182 percent to nearly USD 324 million over the 2017–2022 period. In supporting the established initiative, the ACGG project introduced two chicken strains for on-farm testing to evaluate their economic potential at farm level in different agro ecological zones. The introduced strains are Kuroiler and Sasso which have proven to be performing better in terms of growth rate and egg production than local strains in other countries. Kuroiler strain which is developed and marketed by Kegg farms, weighs about 1.8–1.9kg (hen) and 2.3–2.4 kg (cock) at 20 week age (cock) and a hen can produce about 150 eggs per year (World Society for the Protection of Animals, 2011). Sasso strain which originally was developed and marketed by Hendrix Genetics weighs 1.5-1.7 kg (hen) and 2.2-2.5kg (cock) at 20 week age and can produce about 150 eggs per hen per year (Rodelio and Silvino, 2013). However, the performance of the introduced strains may be unstable in terms of variability that emanates from input use, thus exposing farmers to production risk.

As noted by scholars (Simon, 1959; Hurd, 1994; Fufa and Hassan, 2003; Khayyat and Heshmati, 2014), the variability in agricultural production is one of the major sources of risk. In addition, some endorsed innovations may be so risky to the extent that added risk offsets the gain in income resulting into worsening the livelihood of the farmers (Richardson *et al.,* 2008). Facing variability in production, farmers will try to mitigate the risks through input choices (Tveteras *et al*., 2011), since such input choices play a great role in determining variability in performance (Antle, 1983).

The analysis intended to reveal the effect of controllable inputs on production and variability of the introduced chicken strains in selected areas in Tanzania. This is because ignoring effect of inputs on performance variability in assessing economic potential of agricultural technologies can lead to wrong inferences and recommendations (Koundouri and Nauges, 2005). The analysis is useful to farmers through increased knowledge on the effect of input choices on performance variability for improves production stability. Furthermore, it follows that the outcome of this study is important in the redesign and scaling up of the introduced chicken strains. The study is guided by the hypothesis that, input factors do not significantly influence the production and variability of introduced chicken strains.

5.3 Theoretical Framework

The study was based on the Just and Pope (1979) production function expressed as the summation of the mean and variance functions. It is widely recognized that agricultural products are stochastic and levels of inputs used influence variance of the output (*De* Janvry, 1972; Fufa and Hassan, 2003). To account for variability, the Just-Pope framework is used as a standard framework that can perform joint estimation of both the mean and variance functions (Just and Pope, 1979; Khayyat and Heshmati, 2014). The framework provides a method for estimating the effect of inputs on production and production variability. The production function is capable of evaluating; i) the effect of inputs on the mean level of output and ii) the effects of inputs on variability in yield (Just and Pope, 1979; Fufa and Hassan, 2003; IFPRI, 2006; Guttormsen and Roll, 2013).

The basic concept introduced by Just and Pope was to construct the production function as the sum of two components, one relating to the output level, and one relating to the variability of output to provide a convenient and flexible representation of the effects of inputs on means and variances (IFPRI, 2006). The model is also appropriate for analysing the risk effects of inputs on output distribution in cross sectional, time series and combination of time series and cross sectional production data (Fufa and Hassan, 2003).

In analysing the effects of inputs on production variability, it is a principle to start investigating whether there is any significant output variability (Asche and Tveteras, 1999). To test the presence of production variability one can be draw from the Just and Pope (1979) theoretical framework whereby it is determined in terms of heteroskedasticity (Asche and Tveteras, 1999; Fufa and Hassan, 2003; Guttormsen and Roll, 2013). The current study applied the Maximum Likelihood (ML) Breusch-Pagan test to test the existence of variability in both chicken and eggs production for Kuroiler and Sasso strains.

5.4 Methodology

5.4.1 Developmental research design

Developmental research design was applied for establishing on farm testing and then to analyse the technical, allocative and economic efficiency of keeping introduced chicken stains. The design assumes a traditional model of skill in which the unit of analysis is taken to be the individual (AFNETA, 1992; Richey, 1994). According to Barrow and Röling (1989), the development and transfer of appropriate technologies should be a function of the farmers' socio-economic and management practices at the field level. The study design is in accordance to Thornton *et al*. (2017) that testing and dissemination of technology are at the core of development-oriented agricultural research. Selection of location for establishing on-farm testing was based on Tanzania's Agro Ecological Zones (AEZs) to present the general farming systems in Tanzania.

The AEZs range from higher rainfall areas on the coast and highlands in the north, far west, south and southwest, to arid and semi-arid areas in the interior of the country (URT, 2015). Accordingly, cropping patterns, climatic differences reflect biophysical characteristics for growth and stability of chickens. On-farm testing for introduced chicken strains across different AEZs was meant facilitating farmers and other actors in poultry value chain evaluate the potential of the strains at farm level.

Three assumptions underlie the design. First, selected farmers had have experience in keeping chickens so that the design does not add any fixed cost such as chicken house, feeding facilities and drinkers. In other words, on-farm testing used already available facilities. Secondly, time and labour spent in keeping introduced chickens and available local chickens were presumed similar and hence zero opportunity cost. Third, small-scale local farmers in Tanzania operate relatively similar in keeping chickens. Thus, any of AEZs fit for on-farm testing. According to ACGG (2015), households recruited to receive the chickens met the following criteria:

i. Chicken keeping households that had kept local chickens for a continuous period of at least two years prior to the baseline survey;
ii. Keeping at least 15 adult chickens but no more than 50;

iii. Willingness to accept 25 birds of randomly selected strain;
iv. Commitment to provide some supplemental feeds and
v. Willingness to participate in the project for a minimum of 72 weeks.

Setting the basic criteria for selecting farmers to participate in on-farm testing, the baseline survey was conducted. Baseline survey was conducted to identify legible population in central semi-arid, eastern sub-humid, southern highlands, lake zone and southern humid to represent different agro-ecologies in the country. Specifically, first step involved selection three regions and the selected ones were Morogoro, Dodoma and Njombe regions to present AEZs.

In each region, one district was selected purposely taking into account the availability of villages which had about 20 and above households that have least 15 adult chickens but no more than 50. Secondly, out of the qualified villages, four of them from each district were selected randomly from the long list of villages. Subsequent stage involved randomly selection of households from the long list of households that met the set criteria. After random selection of qualified farmers, it followed provision of six-week pre-brooded chicks to these households whereby each farmer received 25 chicks. At this stage, each farmer received either Kuroiler or Sasso. Chicks received the recommended vaccination against Mareks, Newcastle Disease, Infectious Bronchitis and fowl pox before being distributed to farmers. Farmers continued keeping these strains based on their practices with some additional supplementation using locally available feeds and providing treatment and shelter under a semi-scavenging system (ACGG, 2016).

5.4.2 Description of study sites

The study was conducted in three regions namely Dodoma, Morogoro and Njombe where on farm testing were in Bahi, Ifakara and Wanging`ombe respectively. Dodoma Region is located in the central part of the country on Latitude: -6° 00' 0.00' South and Longitude: 36° 00' 0.00' East. The region is bordered by Manyara region to the North, Singida region to the West, Iringa region to the South and Morogoro Region to the Southeast. It is primarily semi-arid and covers an area of 41 311 square kilometres. The region lies at altitude of 1 125 M above sea level. Annual rainfall varies from 500 to 700 mm and annual average temperature of about 22.6°C. Between the driest and wettest months, the difference in precipitation is 129 mm and the average temperatures vary by 5.1°C (Climatic Data Org, 2016). Major crops include drought tolerant ones such as family of sorghum, groundnuts and sunflower. Four villages namely Mayamaya, Bahisokoni, Mudemu and Mpamatwa were purposively selected in case of Bahi district.

Morogoro region is administratively divided into six districts, namely Morogoro, Mvomero, Kilosa, Kilombero, Ulanga and Gairo. The region lies between Latitude 5 º58' and 10º0' to the South of the Equator and Longitude 35º25' and 35º30' to the East. It is bordered by seven other regions: Arusha and Tanga regions to the North, Pwani region to the East, Dodoma and Iringa to the West and Ruvuma and Lindi to the South. Morogoro region lies at an altitude of about 525 M above sea level. The annual rainfall ranges from 600 to 1200 mm with average annual temperature of about 25ºC. The zone is characterized by an average annual rainfall of 1160 mm with average temperature of 16°C. There are typically two distinct long and short rainy seasons of March–May and November–January/February, respectively, but this pattern is often interrupted (Climatic Data Org, 2016). Rice and maize production, horticultural produces and bananas dominate the production system in Ifakara district. The on-farm test sites were located in four villages: Kibaoni, Kikwelila, Lipangalala and Lumemo.

Njombe region lies between Latitude 08°40' and 10°32' South of the equator and between Longitude 33°47' and 35°45' East of Greenwich and an altitude of about 2 000 M above sea level. The region borders Iringa region in the North, Morogoro region in the East and Ruvuma region in the South. It also borders the Republic of Malawi via Lake Nyasa and part of Mbeya region in the North-west and West. Its climate is classified as warm and temperate. In winter, there is much less rainfall than in summer. The average annual rainfall is 1 160 mm with average temperature of 18.6°C (Climatic Data Org, 2016). On-farm test sites were located in four villages namely Ujindile, Uhambule, Msimbazi and Ufwala. Maize, sunflower, pulses and horticultural production dominate farming system of the sites.

5.4.3 Data collection

Data used in analyses for this study were collected from local chicken farmers participating in the ACGG project at the chosen sites. A total of 202 participant households from 12 villages were involved in the study. Out of the total famers, 111 farmers were Sasso strain keepers whereas 91 farmers were Kuroiler chicken keeping households. Data were collected through weekly recordings, survey and observation. Direct observation was applied to access the quality of the chicken house and accessories. The survey covered broad issues related to the chicken enterprise: viz. the number of chickens, number of eggs sold, ready for selling, number of chicks/chicken sold and ready for sale, amounts and prices of feeders, brooder, chicks, eggs, feeds, medication and labour), number of chicken/chicks which died and the cost of constructing the chicken house.

The following elements of improved poultry housing were used to assess housing structure of participating households: (i) ventilation status and orientation; (ii) spacing requirement of chicken; (iii) floor status; (vi) roof status (spillage); (v) presence of feeder and drinkers; (vi) presence of litter/bedding material; (vii) general hygiene status. The housing structure in this context was not necessarily built using expensive materials to be ranked high but rather to meets the basic requirements regardless of construction materials used (Pius and Mbaga, 2018). Thus, from the developed scale, poultry houses were ranked with three levels; a house scored between 1 and 3 as rated poor, between 4 and 5 and between 6 and 7 was rated normal/moderate and good house respectively.

5.4.4 Data analysis

Multivariate multiple regression model in the Just and Pope framework was applied to determine the effect of inputs on production and variability using Stata version 13 software. Multivariate multiple regression model is an extension of the standard multiple linear regression model. The model is used when a problem consists of two or more predictor variables and two or more response variables (Cassandra, 2013 and Dattalo, 2013). The multivariate regression model for each response on the ith observation, where i=1, 2,… n, is given as:

$$\begin{Bmatrix} Y_{i1} = \beta_{01} + \beta_{11}X_{i1} + \beta_{21}X_{i2} + \cdots + \beta_{r1}X_{ir}) + u_{i1} \\ Y_{i2} = \beta_{02} + \beta_{12}X_{i1} + \beta_{22}X_{i2} + \cdots + \beta_{r2}X_{ir}) + u_{i2} \end{Bmatrix} \quad 5.1$$

Where Y_1 is number of chickens sold, consumed and available, Y_2 is total number of eggs produced, X_i is inputs used in production process such as maize bran, rice bran, cakes, vegetable and fishmeal and u_{i1} and u_{i2} are random errors for chicken and eggs respectively.

Multivariate multiple regression in the Just and Pope stochastic production function can be represent as follows:

$$y = g(x, v) \qquad 5.2$$

where y is output, x is a vector of controllable inputs such as feeds, and medicines, v is a vector of non-controllable inputs such as weather conditions, and g(x, v) denotes the largest feasible output given x and v. The Just and Pope (1979) production framework can be expressed as follows:

$$g(x,v) = f(X,\beta) + [h(x,\theta)]^{1/2} e(v) \qquad 5.3$$

Where, *f*(.) is mean production function, *h*(.) is variance (or risk) function, x = vectors of inputs, β and θ are parameters for mean function and risk function respectively and e is the exogenous stochastic disturbance or production shock (error term). This specification allows differentiating the impact of inputs on output and risk, and has sufficient flexibility to accommodate both positive and negative marginal risks with respect to inputs. Further, the model allows first test for the presence of production risk and if production variability is found to be present, the mean and risk (variance) functions are estimated separately (Asche and Tveteras, 1999). Specifically, multivariate multiple regression can be specified as follows:

$$\begin{Bmatrix} g_1(x,v) = f_1(X,\beta) + h_1(x,\theta)e(v) \\ g_2(x,v) = f_2(X,\beta) + h_2(x,\theta)e(v) \end{Bmatrix} \qquad 5.4$$

Whereby 1 is J-P function for chicken and 2 is J-P egg production function.

It follows that, the decision as to which type of production function to be applied is made at two levels: first, at review of production functions and second at the empirical level. At the review level, the Just and Pope Framework requires that, heteroskedasticity (variability indicator) is non-linear, so its estimation must use a nonlinear function (Just and Pope, 1979). The later was done using a likelihood test of different models like Quadratic function, Square root functions, Translog and both Log and Semi log functions. In likelihood procedure, the semi log production function was found to be superior. The Semi log production functions for both mean and variance production functions are presented as follows:

$$\begin{Bmatrix} \text{In}Y_{i1} = \beta_{01} + \beta_{11}X_{i1} + \beta_{12}X_{i2} + \beta_{13}X_{i3} + \beta_{14}X_{i4} + \beta_{15}X_{i5} + \beta_{16}X_{i6} + \\ \beta_{17}X_{i7} + \beta_{18}X_{i8} + \beta_{19}X_{i9} + \beta_{110}X_{i10} + \beta_{111}X_{i11} + e_{i1} \\ \\ \text{In}Y_{i2} = \beta_{02} + \beta_{21}X_{i2} + \beta_{22}X_{i2} + \beta_{23}X_{i3} + \beta_{24}X_{i4} + \beta_{25}X_{i5} + \beta_{26}X_{i6} \\ +\beta_{27}X_{i7} + \beta_{28}X_{i8} + \beta_{29}X_{i9} + \beta_{210}X_{i10} + \beta_{211}X_{i21} + e_{i2} \end{Bmatrix} \qquad 5.5$$

and the risk function is given as follows:

$$\begin{Bmatrix} \ln\hat{u}_{i1}^2 = \theta_{01} + \theta_{11}X_{i1} + \theta_{12}X_{i2} + \theta_{13}X_{i3} + \theta_{14}X_{i4} + \theta_{15}X_{i5} + \theta_{16}X_{i6} \\ +\theta_{17}X_{i7} + \beta_{18}X_{i8} + \beta_{19}X_{i9} + \beta_{110}X_{i10} + \beta_{111}X_{i11} + v_{i1} \\ \\ \ln\hat{u}_{i2}^2 = \theta_{02} + \theta_{21}X_{i1} + \theta_{22}X_{i2} + \theta_{23}X_{i3} + \theta_{24}X_{i4} + \theta_{25}X_{i5} + \theta_{26}X_{i6} \\ +\theta_{27}X_{i7} + \beta_{28}X_{i8} + \beta_{29}X_{i9} + \beta_{210}X_{i10} + \beta_{211}X_{i11} + v_{i2} \end{Bmatrix} \qquad 5.6$$

Where Y_1=number of chickens (available, sold and consumed) for the i[th] farmer, Y_2 =number of eggs, β_0 and γ_0=Constants, β and θ =unknown estimates for production and variability respectively, e_{i1} and e_{i2} =random errors, X_1=amount of maize bran (kg)/annum, X_2= amount of rice bran(kg)/annum,X_3=amount of sunflower cake(kg)/annum, X_4=amount of fishmeal (kg)/annum, X_5=Minerals (kg), X_6=Number of bundles of vegetables, X_7=Frequency medication, X_9=House condition (defined as poor, normal, good), X_{10}=Labour (number of hours spent, X_{11}=Location, $\hat{u}_{i2}^2$ and $\hat{u}_{i2}^2$are variance (risk) for chicken and eggs respectively.

5.5 Results and Discussions

5.5.1 Mean yield function results

The estimated results for the mean response function for chicken production (live bird and egg) in study sites are given in Table 5.1. The factors affecting yield were quantity of maize bran, quantity of rice bran, quantity of sunflower cake, minerals, frequency of medication, vegetables and house condition. The results show that, for maize bran, the coefficient is positive for chicken production as well as in egg production. The elasticity of mean production for Sasso chicken and Kuroiler with respect to maize bran was 0.0007 and 0.0073respectively ($p<0.05$). This implied that maize bran has a positive effect on increasing production in both chicken strains. In addition, 1% increase in the use of maize bran by significantly ($p<0.05$) increased egg production by 0.0016% and 0.0009% for Sasso and Kuroiler respectively. Accordingly, maize bran is a main feed supplement in rural chickens keeping and greatly impacts production since its key in determining the nutrient intake levels (Mbajiorgu *et al.,* 2011).

The results also revealed that, rice bran had a significant positive effect on chicken production for both strains. Table 5.1 shows that, the elasticity of chicken production with respect to rice bran was positive (0.0009) and (0.0120) implying that a 1 percent increase in feeding rice bran supplement increase chicken production by 0.0009 and 0.0012% in Sasso strain and Kuroiler strain respectively. However, there was no significant difference (P<0.05) between Sasso and Kuroiler for the effect of rice bran on production. The results are consistent with the result by Samli *et al*. (2006). In their experimental research, they revealed that rice bran was very potential for chicken growth and egg production.

Sunflower cake supplement was found to influence chicken production (P<0.005) for Sasso strain. The results indicate that increase in provision of sunflower cake increased Sasso production by 0.0008%. However, in Kuroiler chicken and in both eggs production, the effect was not significant. Also minerals significantly influenced egg production in both introduced strains. As indicated in Table 5.1, 1% increases in sunflower provision significantly increase eggs production in Sasso strain by 0.01% (P<0.005) while in Kuroiler strain increased by 0.1089% (P<0.1).

The regression coefficients of medication in both chicken strains are positive implying that the increasing treating and vaccinating the introduced chicken strains contributed much on the rising production performance. The coefficients of medication for chicken production have positive sign, although not significant, which implies that there was likelihood of impacting on production. Further, the coefficients of medication on egg production had significant impact on egg production ($P<0.05$). As indicated in Table 5.1, 1% increases in frequent provision of medication increase egg production by 0.022% and 0.0315 in Sasso and Kuroiler respectively. The results are consistent with Verbeke *et al.* (2015). In their analysis, they concluded that the health of livestock is the critical determinant of the success of a livestock business. The addition of the cost of medication/vaccines makes the chickens in a healthy condition and be able to utilize feed consumed to support production optimally. Additionally, Thomsen (2005) indicated that farmers recognize vaccination as being the most effective means of combating disease for improving egg production.

Fishmeal is a high quality animal feed used to provide a good balance of essential amino acids, energy, vitamins, minerals and trace elements for poultry (Frempong *et al*., 2019). Contrary, fishmeal was found insignificant in effecting both live chicken and egg production. According to Cho and Kim (2011), researchers have demonstrated that including fish meal in chicken feeds result in better growth performance. However, limited availability, low rate use and timing are very crucial to realise its impact (Babu *et al*., 2005). Consistently, results in Table 5.2 indicate that very few farmers fed their chicken with fishmeal.

Table 5.1: Mean production function for chicken and eggs

Variable	Chicken Production		Egg production	
	Sasso	**Kuroiler**	**Sasso**	**Kuroiler**
Maize bran (kg)	0.0007***	0.0073***	0.0016**	0.0009**
Rice bran (kg)	0.0009**	0.0120**	0.0020**	0.0016*
Sunflower cake (kg)	0.0008**	0.0007*	0.0001	0.0001
Fishmeal	0.0020	0.0018	0.0030	0.0041
Minerals	0.0029	0.0029	0.0100**	0.1089*
Vegetables	0.0007	0.0008	0.0010*	0.00130
Frequency of medication	0.0057	0.0045	0.022***	0.0315***
Sites				
Ifakara	-0.0273	-0.0424	-0.574	-0.6341
Wanging'ombe	-0.0740	-0.0140	-0.159	-0.1875
House condition				
Good	0.099**	0.9332*	0.022**	0.6963*
Normal	0.0423	0.0413	0.045	0.1336
Labour	0.6120	-0.3216	0.1623	0.0916
Constant	1.2588***	1.6600***	2.411***	3.1638***
R^2	0.26	0.23	0.33	0.31

Significance levels are denoted by one asterisk (*) at the 10 percent level, two asterisks (**) at the 5 percent level, three asterisks (***) at the 1 percent level.

The coefficient of the chicken house condition (Table 5.1) is positive and statistically significant from zero in both Sasso and Kuroiler chicken production and in Sasso only in egg production. Chicken kept in a house rated good, performed better relative to poor house. Sasso strain kept in the good house performed better than the same strain kept in poor house with elasticity of 0.0990 while Kuroiler stain kept in good house performed better with elasticity of 0.0220 relative to the strain kept under poor condition house. The results are consistent with Oloyo and Ojerinde (2019) who asserted that, poultry housing condition is very crucial to protect the birds from the harsh environmental climatic conditions, which may have adverse effect on the chickens' performance and productivity. However, the results are inconsistent with that of Montero *et al.* (2011) who reported that there was no significant influence of house condition on chicken and egg differences.

Table 5.2: Summary statistics for feeds supplement for 12 months

Statistics	**Maize bran (kg)**	**Rice bran (kg)**	**sunflower cake (kg)**	**Fishmeal (kg)**	**Minerals (kg)**	**Vegetables (bundle)**
			Kuroiler strain			
Mean±SD	7.5±4.6	6.6±3.6	1.8±1.8	0.6±0.6	0.5±0.6	2.3±0.9
% of farmers	100	63	64	37	52	19
			Sasso strain			
Mean±SD	9.5±5.0	5.2±2.1	3.1±2.2	0.9±0.7	0.6±0.6	3.2±3.0
% of farmers	100	16	51	15	30	24

5.5.2 Testing for production variability

First, a hypothesis was carried out to test for the presence of input oriented performance variability (heteroskedasticity) in chickens and eggs production in the two strains. According to Moshi *et al*. (2017), a failure to detect heteroskedasticity is regarded as evidence that production risk does not exist, and the analysis should follow conventional deterministic framework approach. As indicated in Table 5.3, the χ^2 values in all four cases are statistically greater than the corresponding χ^2 Critical values, resulting in P values are less than 0.05 (critical value). Thus the hypotheses of homoskedasticity in chicken performances variability are rejected and hence confirming that there is existence of inputs caused variability in performance.

The finding on presence of performance variability conforms to that of Vaidyanathan (1992) who noted that agricultural technologies, even as they help to raise yield, also lead to great instability in output in terms of variability and hence creating risks to farmers. Further, Yang*et al.* (2016) who explained that variability in production is influenced by choice of input combinations.

Table 5.3: Testing for evidence of performance variability

Chicken	Hypothesis	χ^2 Critical Value	χ^2 Statistics	P-Value
Kuroiler- Birds	$e^2_{ikb} = \sigma^2_{kb}$	4.485	39.21	0.000***
Kuroiler-Eggs	$e^2_{ike} = \sigma^2_{ke}$	2.697	28.47	0.003***
Sasso –Birds	$e^2_{isb} = \sigma^2_{isb}$	8.08	55.21	0.000***
Sasso –Eggs	$e^2_{ise} = \sigma^2_{ise}$	2.25	23.98	0.014**

Notes: e^2-variance, kb-Kuroiler Bird, ke-Kuroiler eggs, sb-Sasso Birds, se-Sasso eggs

5.3 Effect of Inputs on Production Variability

Results of the specification of the J-P variance function shows both decreasing and increasing effects of inputs on chickens and eggs performance variability in the two strains (Table 5.3). Variability in performance of introduced chicken strains was not well explained by the controllable input factors under consideration as indicated by the low R^2 value (Table 5.3). The reason for this is that some of factors were beyond the researchers` control. These factors include scavenging for household scraps, rainfall, temperature and diseases incidences, which have strong influences on performance variability (Zaghari *et al*., 2011; Rust and Rust, 2013; Rekwot *et al.,* 2016).

Provision of maize bran was found to significantly ($p<0.05$) increase the variability of chicken and egg production in both chicken strains. A one percent increase in maize bran consumption increased chicken performance variability by 0.016 and 0.009 percent in Sasso and Kuroiler strains respectively. The results imply that increase in quantity of maize bran was more likely to increase production risk. This might be because these farmers depended heavily on the feed and hence over utilizing it relative to other feed ingredients.

However, egg production variability showed contradicting results; where maize bran feed ingredient increased variability with increasing input use in Sasso strains while variability decreased with increase in maize bran feeding in Kuroiler strains. Further, the results on egg production variability were insignificant, providing weak evidence that provision of maize bran leads to significantly influencing egg performance variability. Meanwhile, the use of rice bran did not significantly decreased performance variability for Sasso strains performance in both birds and eggs, but rice bran appears to have a significant ($p<0.05$) effect on the level of variability, with an elasticity of 0.009 percent for Kuroiler birds.

Sunflower cake was found to be a variability increasing input as the results show that a one percent increase in sunflower cake feeding, increases performance variability of Sasso birds by 0.0254 percent ($p<0.001$). However, sunflower cake did not affect performance variability of Sasso eggs, and Kuroiler eggs and birds. Though not significant, Fishmeal was found to be the only input factor with a sign of the variability decreasing effect in both live birds and egg production performances in both strains.

Vegetable supplementation indicates results (Table 5.4) whereby one percent changes in vegetable supplementation increased significantly performance variability by 0.035 percent in Kuroiler egg production while in rest cases the effect on production variability was not significant.

The results (Table 5.4) further showed that medication had a negative and significant effect on the production variability of egg production for both chicken strains. This implies that, farmers who treated their chickens timely increased egg production stability and hence reducing the risk that farmers in that area face. The coefficients for medication with respect to egg production were -0.1020 and -0.336 ($p<0.1$) and significantly different from zero, which means they had a risk reducing effect for Sasso and Kuroiler chicken strain respectively. This is consistent with Sodjinou (2011) and Thomsen (2005), who argued that good timing for vaccination and treatment reduced death rate amongst several birds and hence high contribution to variability decreasing. Nevertheless, frequency of medication showed the signs of variability increasing in Sasso and Kuroiler bird production.

House condition was found being variability decreasing significantly for Kuroiler chicken production but with a sign of variability decreasing in egg production in both strains while it showed the sign of variability increasing in Sasso bird production. The decreasing sign implies that house condition was important in reducing variability such that farmers with poorhouse conditions were more likely to have poorer production compared to those with good house.

Table 5.4: Effect of inputs on production variability of introduced chicken strains

	Chicken production		**Egg production**	
	Sasso	**Kuroiler**	**Sasso**	**Kuroiler**
Maize bran	0.0167***	0.009***	-0.0031	-0.007
Rice bran	-0.0069	0.009**	-0.0069	0.009
Sunflower cake	0.0254***	0.007	0.0031	0.021
Fishmeal	-0.0745*	-0.033	-0.0249	-0.038
Minerals	-0.0079	0.01***	0.0369*	-0.001
Vegetables	0.0004	-0.002	-0.0004	-0.035***
Frequency of medication	0.0494	0.015	-0.1020*	-0.336**
House condition				
Good	0.0496	-0.16***	-0.0037	-0.106**
Normal	-0.0413	0.054	0.0589	-0.170
Labour	0.832	-0.246	0.1237	-0.077
Agro-ecological zone (sites)				
Ifakara	0.7200	0.0933	-0.746	0.124
Wangingòmbe	0.5347	-0.1636	-0.0300	1.073
Constant	1.5821***	1.8710***	2.6120***	3.4713***
R^2	0.49	0.21	0.43	0.31

Notes: statistical significance levels: ***1%; **5%; *10%. Corresponding P value standard errors are shown in parentheses.

Labour spent in keeping introduced strains was found to have mixed effects on performance variability. In Kuroiler strain, time spend in feeding the chickens and cleaning house showed the sign of variability decreasing while in Sasso, it showed variability increasing. For variability decreasing, this study results are consistent with results by Fufa and Hassan (2003) who reported that labour was insignificant with positive and negative effect to production and variability respectively. Contrary, Wanda (2009) reported that labour was negatively related to yield variability of a crop production in Uganda.

Lastly, location had no effect on the production variability for both birds and eggs and in either strain. This implies that location specificity does not influence performance variability in both strains. On the contrary, study by Meon and Weill, (2005) found that geographical location contributed much on the performance and performance variability.

5.4 Conclusions and Recommendations

The results indicate that controllable inputs had effect on both performance and variability. Controllable factors having the effect included were quantity of maize bran, quantity of rice bran, quantity of sunflower cake, minerals, and frequency of medication, vegetables and house condition. Some inputs were both variability increasing and reducing; reducing in production of birds but increasing in egg production for the same strain and vice versa, although many inputs were not significant.

Overall, the study rejected the null hypothesis that input factors do not influence variability in production of the strains implying that they do have such influence. Nevertheless, it is likely that the full potential of the introduced strains requires inputs in the form of husbandry. It is important to design strategies that will lead to yield stability. Such strategies should include the design of trials at farm level to evaluate the input mix with minimum effect on output variability.

Acknowledgements

The authors acknowledge Africa Chicken Genetic Gains (ACGG) Project and Sokoine University of Agriculture (SUA) for their financial support in accomplishing this study. Lastly, particular gratitude goes to the smallholder chicken keepers who agreed to participate in the on-farm test of the introduced chicken strains and provided data for this study.

References

Adachi, N.; Suzuki, K.; Kasai, K.; Hiroki, M.; Kume, S.; Nonaka, I.; Abe, A., 2000: Effect of supplemental fish meal on milk yield and milk composition of Holstein cow during early lactation. Asian-Australian Journal of Animal Science 13, 329–333

ACGG . (2015). Site Selection Framework. ACGG Project Document. pp 6.

ACGG. (2016). African Chicken Genetic Gain project profile. pp 2.

AFNETA. (1992). Alley Farming Training Manual Volume 1 pg 196, November, 21. [http://biblio. iita. org/documents] site visited on 21/11/2016.

Antle, J.M. (1983). Testing the Stochastic Structure of Production: A flexible Moment based Approach. *Journal of Business and Economic Statistics* 1(3): 192-201. [doi:10.1080/07 350 015.1983.10509339] site visited on 21/11/2017.

Asche, F. and R. Tveteras, R. (1999). Modelling Production Risk with a Two-Step Procedure. *Journal of Agricultural and Resource Economics* 24(2): 424-439. [http://citeseerx.ist. psu.edu] site visited on 18/01/2017.

Babu, U. S., Wiesenfeld, P. L., Raybourne, R. B., Myers, M. J. and Gaines, D. (2005). Effect of dietary fish meal on cell mediated immune response of laying hens. *International Journal of Poultry Science* 4: 652–656. [DOI: 10.3923/ijps.2005.652.656] site visited on 03/11/2020.

Barrows, R. and Röling, N. (1989). Extension Science: Information Systems in Agricultural Development. *American Journal of Agricultural Economics* 71(3): 833-834. [https://doi.org/10.2307/1242055] site visited on 20/10/2020.

Bizimana, J. and Richardson, J.W. (2017). Agricultural Technology Assessment for Smallholder Farms in Developing Countries: An Analysis using a Farm Simulation Model (FARMSIM). Working Study February 2017. [DOI: 10.13140/RG.2.2.15949.23526] site visited on 24/10/2018.

Cassandra, Q. (2013). Multivariate Multiple Regression with Applications to Power lifting Data. [http://www.d.umn.edu/] site visited on 18/11/2016.

Chavas, J. and Shi, G. (2015). An Economic Analysis of Risk, Management and Agricultural Technology. *Journal of Agricultural and Resource Economics* 40(1): 63–79. [http:// www.waeaonline.org/] site visited on 13/11/2018.

Cho, J. H. and Kim, I.H. (2011). Fish meal–nutritive value. *Journal of Animal Physiology and Animal Nutrition*. 95:685–692. [DOI: 10.1111/j.1439-0396.2010.01109.x] site visited on 03/11/2020.

Climatic Data Org. (2016). Tanzania Climatic Data. [https://en.climate-data.org/tanzania]. site visited on 16/11/2016.

Dattalo, P. (2013). Analysis of Multiple Dependent Variables. [http://www. oxfordscho larship.com/] site visited on 18/11/2016.

De Janvry, A. (1972). Optimal levels of fertilization under risk: The potential for corn and wheat fertilization under alternative price policies in Argentina. *American Journal of Agricultural Economics* 54:1-10. [https://doi.org/10. 2307/123 7728] site visited on 27/06/2017.

Frempong, N.S., Thomas N.N.N., Paulk, C. and Charles, R.S. (2019). Evaluating the effect of replacing fish meal in broiler diets with either Soybean meal or poultry by-product Meal on Broiler Performance and total feed cost per kilogram of gain. *Journal of Applied Poultry Research* 28:912–918. [http://dx.doi.org/10.3382/ japr/pfz049] site visited on 03/11/2020.

Fufa, B. and Hassan, R.M. (2003). Stochastic Maize Production Technology and Production Risk Analysis in Dadar District, East Ethiopia. *Journal of Agricultural Economics Research, Policy and Practice in Southern Africa* 42 (2): 116-128. [http://ageconsearch.umn.edu/] site visited on 29/11/2016.

Guttormsen, A.G. and Roll, K.H. (2013). Production Risk in Subsistence Agriculture. *Journal of Agricultural Education and Extension* 20(1) 133-145: [http://dx.doi. org/10. 1080/138 9224X.20 13.775953] site visited on 13/11/2018.

Hurd, B.H. (1994). Yield Response and Production Risk: An Analysis of Integrated Pest Management in Cotton. *Journal of Agricultural and Resource Economics* 19(2): 313-326. [http://www.cpahq. org/cpahq/] site visited 03/12/2018.

IFPRI. (2006). Farmer Management of Production Risk on Degraded Lands: The Role of Wheat Genetic Diversity in Tigray Region, Ethiopia. Environment and Production Technology Discussion Study. [http://ageconsearch. tind.io//bit/] site visited on 03/11/2017.

Just, R.E. and Pope, R.D. (1979). Production Function Estimation and Related Risk Considerations. *American Journal of Agricultural Economics.* 61(2): 276-284. [http://www.jstor.org] site visited on 03/11/2016.

Khayyat, N.T. and Heshmati, A. (2014). Production Risk, Energy Use Efficiency and Productivity of Korean Industries. Discussion Study Series 8081, March 2014. Institute for the Study of Labour, Germany. [http://ftp.iza.org/ dp8081p df] site visited on 03/12/2016.

Koundouri, P. and Nauges, C. (2005). On Production Function Estimation with Selectivity and Risk Considerations. *Journal of Agricultural and Resource Economics* 30(3): 597-608. [https://core.ac.uk/] site visited on 3/04/2017.

Kumbhakar, S.C. (2002). Specification and Estimation of Production Risk, Risk Preferences and Technical Efficiency. *American Journal of Agricultural Economics* 84(1): 8-22. [https://doi.org/10.1111/1467-8276.00239] site visited on 19/04/2017.

Mbajiorgu, C.A., Ng`ambi, J.W. and Norris, D.D. (2011). Voluntary Feed Intake and Nutrient Composition in Chickens. *Asian Journal of Animal and Veterinary Advances* 6: 20-28. [10.3923/ajava.2011.20.28] site visited on 29/11/2020.

Montero, G.V., Franco, L.S., Ricalde, R.S. and Correa, J.S. (2011). Egg production and quality below three housing structures in the tropics. *Tropic Animal Health Production* 44(2): 201-204. [DOI: 10.1007/s11250-011-0006-z] site visited on 27/10/2020.

Moshi, A., Hella, J. and Isinika, A. (2017). Farm Technologies and Production Risk in the Face of Climate Change in Tanzania. *HURIA Journal of the Open University of Tanzania* 24(2): 1-18. [https://www.ajol.info/ index.php/ huria] site visited on 27/10/2020.

Nalley, L.L. and Barkley, A. (2007). The Impact of the CIMMYT Wheat Breeding Program on Wheat Yields in Mexico's Yaqui Valley, 1990-2002: Implications for the Future of Public Wheat Breeding. Selected Study prepared for presentation at the American Agricultural Economics Association Annual Meeting, Portland. July 29-August 1, 2007. [http:// ageconsearch.umn.edu/] site visited on 27/10/2017.

Oloyo, A. and Ojerinde, A. (2019). Poultry Housing and Management. Poultry - An Advanced Learning. [DOI: http://dx.doi.org/10.5772/intechopen.83811] site visited on 27/10/2020.

Pius, L.O. and Mbaga, S.H. (2018). Variations in village chicken management packages in two agro-ecological zones of Tanzania. *International Journal of Livestock Production* 9(3): 42-49. [DOI: 10.5897/IJLP2017.0422] site visited on 12/07/2019.

Rekwot, Z.G., Ugo, F.A. and Engo, B.O. (2016). Climate Variability and Livestock Production in Nigeria: Lessons for Sustainable Livestock Production. Agricultura Tropica et Subtropica (*the Journal of Agricultural Tropical and Subtropical*) 49 (1-4): 30-37. [doi: 10.1515/ats-2016-0004] site visited on 27/10/2017.

Richardson, J.W., Schumann, K.D. and Feldman, P. (2008). Simetar. Simulation and Econometrics to Analyse Risk. Simetar, Inc. User Manual, College Station, Texas. United State of America.

Richey, R.C. (1994). Developmental Research: The Definition and Scope in Proceedings of Selected Research and Development Presentations at the National Convention of the Association for Educational Communications and Technology Sponsored by the Research and Theory Division (16th, Nashville, TN, February 16-20, 1994). [http://files.eric.ed.gov/ fulltext/ED373753.pdf] site visited 18/08/2016.

Rodelio, B.C. and Silvio, Q.T. (2013). Sustainable Organic Farming in the Philippines: History and Success Stories. [http://wwwafaci.org/] site visited on 27/10/2017.

Rust, J.M. and Rust, T. (2013). Climate change and livestock production: A review with emphasis on Africa. *South African Journal of Animal Science* 43 (3): 255-267. [http://www.scielo.org.za] site visited on 19/04/2017.

Simon, H.A. (1959). Theories of Decision-making in Economics and Behavioural Science. *American Economic Review* 49 (3): 253-283. [http://pages.stern. nyu. edu/~dbackus/Exotic//] site visited on 18/01/2017.

Sodjinou, E. (2011). Poultry-based intervention as tool for poverty reduction and gender empowerment: empirical evidence from Benin. Institute of Food and Resource Economics, University of Copenhagen. [https://curis.ku.dk/ ws/files/33324451] site visited on 29/11/2020.

Thomsen, K.A. (2005). Poultry as development: an ethnography of smallholders and technical development assistance in Benin. MSc. thesis, Department of Anthropology, University of Copenhagen. pp104. [http://www.poultry. life.ku.dk/Information] site visited on 13/11/2019.

Thornton, P.K., Schuetz, T., Förch, W., Cramer, L., Abreu, D., Vermeulen, S and Campbell, B.M. (2017). Responding to global change: A theory of change approach to making agricultural research for development outcome-based. *Journal of Agricultural Systems* 152: 145-153 [DOI: 10.1016/j.agsy.2017. 01.005] site visited on 06/05/2019.

Traxler, G., Falck-Zepeda, J., Ortiz-Monasterio, J.I. and Sayre, K. (1995). Production Risk and the Evolution of Varietal Technology. *American Journal of Agricultural Economics* 77(1): 1–7. [http://link.springer.com/article/] site visited on 26/03/2017.

Tveteras, R., Flaten, O. and Lien, G. (2011). Production risk in multi-output industries: Estimates from Norwegian dairy farms. *Journal of Applied Economics* 43: 4403–4414. [https://doi.org/10.108 0/00036846.2010. 4914 61] site visited on 20/03/2017.

Vaidyanathan, A. (1992). Review: Instability in Agriculture: Extent, Causes and Consequences: *A Review Article Indian Economic Review* 27(2): 211-222. [https://www.jstor.org/stable/29793578] site visited on 20/03/2018.

Verbeke, W.T., Spranghers, P.D., Clercq, S.D., Smet, B.S. and Eeckhout, M. (2015). Insects in animal feed: Acceptance and its determinants among farmers, agriculture sector stakeholders and citizens. *Animal and Feed Science Technology* 204(1): 72-87. [https://doi.org/ 10.1016/j.anifeedsci. 2015.04.001] site visited on 02/11/2020.

Wanda, O. (2009). Production risks and Input use in Banana Production in Uganda. A Thesis Submitted as Partial fulfilment for the Award of MSc. Agricultural and Applied Economics, Makerere University. pp93. [https://docplayer. net/42771640] site visited on 18/04/2017.

World Society for the Protection of Animals. (2011). Enhancing rural livelihoods and nutrition through higher welfare poultry production in India. Case study. [http://www. Wspa-international. org/Images/ Case Study- Keggs-Final-sm_tcm25-21761.pdf/] site visited on 20/10/2016.

Yang, Z., Mugera, A.W. and Zhang, F. (2016). Investigating Yield Variability and Inefficiency in Rice Production: A Case Study in Central China. *Journal of Sustainability* 8(2): 1-11. [http://www.mdpicom] site visited on 18/04/2017.

Zaghari, M., Fazlali, F., Gerami, A., Eila, N. and Moradi, S. (2011). Effects of environmental factors on the performance of broiler breeder hens. *Journal of Applied Poultry Research* 20(3): 383–389. [doi.org/10.3382/japr.2009-00110] site visited on 09/05/2016.

CHAPTER SIX

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 Summary of Major Findings and Conclusions

Several principal findings emerged from the analyses conducted to test the hypotheses and answer research questions formulated to address objectives of the present study. The study began by analysing the economic viability of introduced chicken strains relative to existing local chicken. In addition, the present study assessed the adoption potential of the introduced chicken strains in selected agro-ecological zones. The present study also estimated the technical, allocative and economic efficiency among smallholder farmers who kept introduced chicken strains. Lastly, the study analysed the effect of controllable inputs on production and variability.

6.1.1 Economic viability of introduced chicken strains

The economic viability of introduced chicken strains relative to available local chicken was discussed in chapter two to address objective one. Keeping Sasso strain was the most economically viable activity with the highest Net Present Value, Net Cash Farm Income and the highest probability of attaining economic return. Kuroiler was the second, followed by keeping local chickens without supplement while local chicken with supplement was the least economically viable enterprise. The present study failed to accept the hypothesis which states that there is no statistically significant difference in economic viability between keeping introduced chicken strains and existing local chickens and hence concluding that introduced chicken strains are economically more viable than existing local chicken strains. However, inclusion of risk attitude toward risk revealed that extremely risk-averse farmers preferred mostly keeping local chickens without supplement whereas extremely risk loving farmers preferred the most Sasso strain.

6.1.2 *Ex ante* analysis of adoption of introduced chicken strains among smallholder farmers

The results indicate that the peak for adoption is likely to be 34%, 29% and 38% after 8, 7 and 9 years in Bahi, Ifakara and Wanging'ombe sites respectively. The sensitivity results indicate that the adoption rate may increase to reach 59%, 49% and 57% and may decline to about 17, 16 and 21% in Bahi, Ifakara and Wanging'ombe respectively. Extension efforts to facilitate availability of the strains, feeds, treatment and reducing upfront and operating costs are main factors affecting change in the adoption rate to optimize the inherent genetic potential.

6.1.3 Economic efficiency of keeping introduced chicken strains among smallholder farmers

The findings show that farmers in the study sites were technically, allocatively and economically inefficient in transforming inputs into outputs. The results indicate that the mean technical, allocative and economic efficiency indices were 19.9%, 68.8% and 12.9% respectively. This suggests that there is considerable scope to improve chicken productivity through increasing efficient us of inputs in the study sites. Furthermore, the input mix was not appropriate since very few farmers fed their chicken with sunflower cake, fishmeal and minerals which are potential for growth and egg production.

6.1.4 Effect of inputs and management practices on performance variability

The results indicate that there was performance variability attributed to controllable input factors; feed supplements, medication, labour and house condition. However, the effect of these inputs were inconsistent as some inputs were both variability increasing and reducing; reducing in production of birds but increasing in egg production for the same strain and vice versa. Further, agro-ecological differences had no significant effect on the performance variability. This implies that, on average these strains may be raised in any agro ecological zone with similar conditions to the studies zones. Hence the study results failed to accept its hypothesis that controllable inputs do not contribute to performance variability and conclude that inputs are key factors in determining performance variability. Nevertheless, it is likely that the full potential of the introduced strains requires inputs that reduce variability.

6.2 Recommendations

From the results generated in this study, it is recommended that:

i. The introduced chicken strains should be promoted to increase household income and improve people's livelihoods.

ii. The extension efforts should be devoted in order to ensure availability of these chickens, supporting farmers to formulate feed supplements at local levels, treatment and reducing upfront and operating costs to ensure adoption rate is improved.

iii. Scaling up of the introduced chicken strains must be integrated with education on optimal input use to increase economic efficiency. Moreover, actors in poultry sub-sector should create better market information systems for efficient input procurement and outputs disposal to improve allocative efficiency.

iv. Lastly, it is important to design trials at farm level to evaluate the input mix with minimum effect on production variability. Further, good management practices in keeping introduced strains should also be included in the extension package in order to reduce the risk of attack from diseases.

6.3 Implications of the Findings

6.3.1 Practical implications

Overall, the practical implications of this thesis are based on empirical findings that illustrate the economic potential of introduced chicken strains relative to available strains. This is important since new innovations require assessment for their technical feasibility to provide technical basis for their adoption. The thesis investigated the economic potential in terms of economic viability, effect of inputs on performance variability, likelihood of adoption and economic efficiency. Innovatively, risk issues from both the farmers and technology have been critically considered.

6.3.2 Economic analysis of new technology

Analysis of economic viability using simulation approach using farm based data coupled with probability distribution and farmers' attitude toward risk of adopting new technology is novel. Further, the use of FARMSIM and Stochastic Efficiency with Respect to Function (SERF) for this analysis constitutes a new empirical application of the method in analysing the economic potential of technologies.

Moreover, this analysis is a good reminder that, assessing a technology by just using descriptive statistics of key variables is not enough to provide substantive conclusions and recommendations. In this research, descriptive statistics of average NPV and NCFI for five years planning horizon and the probability distribution of gaining NPV and NCFI ranked the introduced chicken strains the best. However, when farmers' attitude toward risk was considered, it was established that very few farmers (extremely risky loving farmers) considered these new chicken strains as more beneficial relative to existing local chickens and hence they are likely to spend additional capital despite probable loses which may occur due to risks.

6.3.3 Prediction of adoption of new technology in farming systems

The second contribution of this study to knowledge is the use of real exploratory data from participant, non-participants and experts for the on-farm test to generate *ex ante* information for adoption of the introduced strains by using Adoption and Diffusion Outcome Prediction Tool (ADOPT). ADOPT is the first tool designed to allow those involved in agricultural systems research, development, extension and policy to make quantitative predictions about the adoption outcomes for new farming practices. Its application in this study will serve as a key reference to researchers wishing to quantitatively assess the likelihood of adoption of new technologies. In addition, the results of this show that the predicated curve of adoption are in line with existing adoption literature including that of Rogers' adoption of innovation curve and hence having explanatory power.

6.4 Area for Further Research

It is critical for feeds and animal nutrition experts to undertake further research on feed requirement of these strains at farm level to find the optimal and input mix that will increase the efficacy and reduce in based performance variability of these strains.

APPENDICES

Appendix 1: Questionnaire

Questionnaire number…………… Date of interview…………………

Region …………….District……………Ward……………….Village………………

A: Respondent's Characteristics and Household Composition

1. a)Sex of respondent__________ b) Age: ________years c) Education level_______4. Marital status:____

2. Position in the household (Tick one option): a) Household head _____b) Spouse________ c) Son____ d) Daughter_____ e) Other relative____ f) Farm manager ____g) Other farm employee____

3. Household composition

S/N	Age	Gender	Education level	Main Occupation	Hours spent for chicken

4. Please indicate the approximate average monthly household income from all sources ________________**TZS**

Section B: Household Animal keeping Enterprises and main source of income

1. What livestock types and numbers do you have on your farm?

Livestock type	Is it kept on the farm? **(Tick where applicable)**		Average number kept in **Livestock type** the last 12 months
	Yes	No	
Chicken			
Cattle			
Goats			
Sheep			
Pigs			
Other specify …			

2. Which activities does the household **mainly** depend on for livelihood, e.g., for provision of income, food, fees etc.?

Enterprise	Is it a source of livelihood? **(Tick where applicable)**		If **YES**, please indicate the **proportion of monthly income in an average year, from each enterprise** which is a source of livelihood **(***TICK one applicable range for each enterprise***)**			
	Yes	No	Less than quarter (<25%)	Between quarter and half (25-50%)	Between half and three quarters (50-75%)	More than three quarters (>75%)
Chicken keeping						
Cattle						
Crop (specify the main crop)______						
Off-farm employment						
Others						

C: Chicken Keeping Enterprise

C1: Chickens` keeping distribution

1. How many years have you been keeping chickens? (years)…………………………
2. Is there a specific person who takes care your chickens?__ (1 = Yes, 2 =No).
3. Please provide information on chicken production in your farm. (Fill responses in the empty space)

	C11: Chickens								
S/N	**Descriptions**	**Local ecotype**:___________________				**Introduced ecotype**:________________			
		Hens	Pullet	Cock erals	Rooste r	Hens	Pullet	cock erals	Roos ters

1. 1	How many do you have (did you have)								
2.	What is the average age (months)								
3. 2	How many currently available								
4.	How many bought								
5.	What was the average price								
6.	How many given								
7.	How many sold								
8.	How many consumed								
9. 3	How many died								
10.	How many gifted								

	C12: Eggs-Description	**Local eggs**	**Introduced eggs**
	At what age the pullet started laying eggs		
	How many do you have (did you have)		
11.	How many per hen per year?		
12.	How many eggs on average are incubated?		
13.	How many for hatching?		
14.	How many sold?		
15.	At what price?		
16.	How many eggs consumed?		
17.	How many eggs gifted?		

C2: Feeding, Medication and cost structure

1. How do you feed your chickens? (a) together________________(b) separated ____________________

2. If you feed separated, place explain how do you achieve it________________
____
____
____
____

3. If all chickens are given supplement together, on your opinion, which ecotype takes higher proportion?____

4. Can you estimate the average proportion does the heavy feeder takes?________

____

____

5. How often do you feed your chicken per day?______________

____

6. Please may you fill the table below on feed structure and medication per day

Feeds Medication

Type of feeds	**Quantity**	**Costs incurred**	**Sources**	**Type of medicine**	**Costs incurred**	**Sources**

C3: Labour structure

Please indicate cost of house construction and labour charge per week (fill in the blank where applicable)

	Costs	**Local chicken ecotypes**		**Introduced chicken ecotype**	
		Quantity	**Value**	**Quantity**	**Value**
	Labour charge per month				
	Hours laboured to chicken rearing/day				

C4: House structure

May you please indicate materials and cost structure for construction the chicken house

Specification of house	**Local ecotype**		**Introduced ecotype**	
	Materials	**Value**	**Materials**	**Value**
External walls				
Internal walls				
Flow				
Roof				
Windows				
Door				

C5: Cause of Chicken Losses

What have been the main causes of chickens' losses?, please indicate

Causes of losses	Number of losses	
	Local chicken ecotype	**Introduced ecotypes**
Diseases		
Prey of birds		
Cats and dogs		
Theft		
Automobile accidents		
Others, specify ________________________		

D: Crop Production

Please indicate how do you allocated resources on crop production, input and output uses of crop production

Crops/Parameter	Hectare planted	Yield harvested	Qntity sold	Qntity consumed kg	Qntity fed to chickens kg	Qntity paid to landlord	Qntity paid to workers
Maize							
Paddy							
Sorghum							
Irish							
Sweet							
Cassava							
Beans							
Peas							
Pulse							
Cowpeas							
Sesame(cake)							
Sunflower (cake)							
Irish							
Tomatoes							
Cabbage							
Onions							
Water melon							

E: ADOPT Questions on Farmers perceptions towards introduced ecotypes

Questions asked in ADOPT	SA	A	N	D	SD
Profit maximization is the strong motivation					
Risk minimization is the strong motivation					
Scale of operation has to remain small					
The plan of the enterprise is less than five years					
The enterprise is much constrained with short term financial constraints					
The introduced chicken are easily to keep and can be trialed on a limited basis before a decision is made to adopt it on a larger scale					
The complexity of keeping these ecotype allow the effects of its benefit not to be easily evaluated					
Farmers in neighbourhoods are able to observe and wish to keep the same					
Advisory support given (paid and not paid) were relevant to the practice					
Farmers around normally come, learn and discuss on how to keep these ecotypes					
Population need to develop substantial new skills and knowledge to keep these ecotypes					
Large proportion of the farmers in the village are aware of keeping or trialling of the ecotypes					
The size of the up-front cost/start up investment cost is relative high to the potential annual benefit					
To what extent is the adoption of the practice able to be reversed?					
The introduced ecotypes are likely to affect much the profitability of the farm business in the same year of introduction					
Farming introduced ecotypes are likely to have more effects on the future profitability of the farm business more than available chicken ecotypes					
It takes short time for effects on future profitability to be realized					
Introduced ecotypes are more risk in getting loss than available chicken ecotypes					
Farming management of the introduced ecotypes is ease and convenience					

THANK YOU FOR YOUR PARTICIPATION

Appendix 2: Checklist for Adoption and Diffusion Outcome Prediction Tool (ADOPT)

1. What proportion of the target population has maximising profit as a strong motivation?
2. What proportion of the target population has risk minimization as a strong motivation?
3. What proportion of the target farms is there a major enterprise that could benefit from the practice?
4. What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?
5. What proportion of the target population is under conditions of severe short-term financial constraints?
6. How easily can the practice (or significant components of it) be trialed on a limited basis before a decision is made to adopt it on a larger scale?
7. Does the complexity of the practice allow the effects of its use to be easily evaluated when it is used?
8. To what extent would the practice be observable to farmers who are yet to adopt it when it is used in their district?
9. What proportion of the target population uses paid advisors capable of providing advice relevant to the practice?
10. What proportion of the target population participates in farmers-based groups that discuss farming?
11. What proportion of the target population will need to develop substantial new skills and knowledge to use the practice?
12. What proportion of the target population would be aware of the use or trialing of the practice in their district?
13. What is the size of the up-front cost of the investment relative to the potential annual benefit from using the practice?
14. To what extent is the adoption of the practice able to be reversed?
15. To what extent is the use of the practice likely to affect the profitability of the farm business in the years that it is used?
16. To what extent is the use of the practice likely to have additional effects on the future profitability of the farm business?

17. How long after the practice is first adopted would it take for effects on future profitability to be realized?
18. To what extent would the use of the practice have net environmental benefits or costs?
19. How long after the practice is first adopted would it take for the expected benefits or costs to be realized?
20. Risk To what extent would the use of the practice affect the net exposure of the farm business to risk?
21. To what extent would the use of the practice affect the ease and convenience of the management of the farm in the years that it is used?

Household location and ID	Egg production_ day collection	Egg production_ egg number collected	Egg production _number of eggs weighed	Egg production _egg weight	Egg production_ introduced strain	Egg production_ local chicken strain	Egg production_ introduced eggs number	Egg production_ local strain eggs number	Egg production _comments

Appendix 3: Weekly eggs production data sheet for 72 weeks

Household location and ID_ key	**Reported_ bird exited**	**Bird exited_ tag**	**Bird exited reason**	**Bird exited symptoms**	**Bird exited_ Money**	**Bird exited comments**

Appendix 4: Weekly records for introduced chicken strains` exit; symptoms, disease, sales and other causes for 72weeks

Appendix 5: Weekly records for weight for introduced chicken strains

Household location and ID	Strain	Date of weight measuring	Male/ Female	Sample birds	Sample weight	Average weight	Comments

Appendix 6: Published paper: Economic Viability of introduced chicken strains at farm level in selected areas of Tanzania

Appendix 7: Published paper: *Ex-ante* analysis of adoption for introduced chicken strains among smallholder farmers in selected areas of Tanzania